Eco-Inclusive Opportunity

Operationalizing Environmental assets towards a resilient densification.

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Preface

The motivation for this research stems from a series of experiences gathered throughout the years. I was born in the country of Costa Rica and in my first seven years there I was taught the country's name, meaning rich coast in english, was based on Columbus' assumption that the verdant jungles would hold massive riches such as gold. Little did they know that the jungles, forests and rivers themselves would be the real riches. Not being a financially rich country, it has always been dependent on coexistence with nature for its development, whether it concerns ecotourism, hydropower or food production. This fact and the necessity to move beyond an exploitative relationship with the environment stayed with me throughout all these years.

Eventually it translated into an effort to include sustainability in my approach towards design problems in my years studying at TU Delft. This ambition was in fact one of the major reasons that lead me to choose to study at this University, with its focus on sustainability.
Spurred by my fascination for cities I started by researching the potential of density in both my courses and in the organization of the 2017 International Design Seminar "Crowded", and with the cooperative project "I am Dencity" (Kortman et al., 2018) being a research into potential densification of the Amsterdam Metropolitan Area.

It was during these projects and various study trips however, that I learned that sustainability tends to be considered a mere buzzword or luxury in practice. Whether it is in Brazil, the USA or China's burgeoning metropolises, the majority of development seems to have an alternative interpretation of sustainability, focused on short term financial returns.
During my interdisciplinary project, The Sponge City Project (Fong et al., 2018), in the Chinese city of Wuhan in particular, I experienced that ambition and reality can diverge greatly. While we are often taught to pursue Value based design at this institution, based on the people, planet, prosperity paradigm, most of the world operates on a different paradigm altogether. As profit-oriented strategies are leading there, all choices are measured against potential profits and costs, with a general focus on the short term.
The lack of valorisation of ecosystem services coupled with the absence of a strategic interdisciplinary approach seems to favor questionably sustainable solutions. This was, regrettably, even the case in the execution of the ambitious Sponge City Programme initiated by the government of China.

That led me to reconsider the position of the urbanist within the discussion of sustainability. The interdisciplinary field of Urbanism requires an understanding of the physical environment and its base and effects on socio-economic and environmental conditions. With the guidance of my supervisors Fransje Hooimeijer and Birgit Hausleitner I have conducted an exploratory research targeting the relationship between our ongoing socio-economic changes and our relationship to the natural environment. Within the City of the Future and the Urban Fabrics research groups my effort has been targeted towards creating a path towards resilience.

Manifest

We have praised technology

Our technological prowess has liberated humanity from nature’s grasp. At least that is what we thought. Considering ourselves apart from and superior to nature, we have unwittingly engaged in unsustainable patterns of urbanisation.

Throughout our emancipation, we’ve confused this vast land and resource consumption with progress, developing vulnerable environments reliant on the over exploitation of natural systems.

Now, as nature is reasserting its force in a world less hospitable, it is time for change. To ensure lasting liveability we need a reconciliation between the world of man and the planet we inhabit. We need metropolises that operate not despite their environmental conditions, but because of their ability to harness the potential of local ecosystem services.

This is no longer a choice. It is out of sheer necessity that we must adapt to thrive.
One may consider this idealistic, or even impossible, but we have adapted before. To quote Christiana Figueres, the Former UN High Commissioner responsible for the Paris Climate Agreement:
“Impossible isn’t a fact, it is an attitude”

This becomes even more apparent at this location. Are we not standing where peat marshes once dominated?
It is through perseverance and working with the local conditions that polder cities could develop. Technological innovation then enabled the creation of the current Randstad.

Now, amidst this period of rapid growth, we must pause and look back for a moment. Even now, with all this knowledge of potential climatic threats, we keep ignoring vulnerabilities, continually expanding our built environment into the open landscape while decrying densification as undesirable overcrowding.

The sheer scale of challenges we face, ranging from ageing and growing societies, resource depletion and environmental degradation to climatic and economic changes, require a shift that goes beyond a binary paradigm. Such paradigms not only ignore the vast range of approaches, but also seem more fit for absolutism and confrontation than for mutual comprehension and achieving common goals.

Starting with our living environments we need to answer several questions. What does density mean? And how do we define it? The same goes for liveability and ecosystem services. We need to develop an understanding of interrelations in the built environment in order to finally start developing an answer to the following question:

How can we develop resilient liveable environments?

This question in essence goes beyond an approach separately setting goals such as densification and a modal shift.

In this, we also need to harness our natural conditions, treating them as assets instead of waging this untenable and eternal war against them. This is not a capitulation, but an opportunity for meaningful collaboration.

Through the understanding of the various potentials this offers for natural and anthropomorphic development, we will then, finally be able to develop our cities into resilient environments. Environments capable of not only providing for our current, but also future needs in these swiftly changing conditions.

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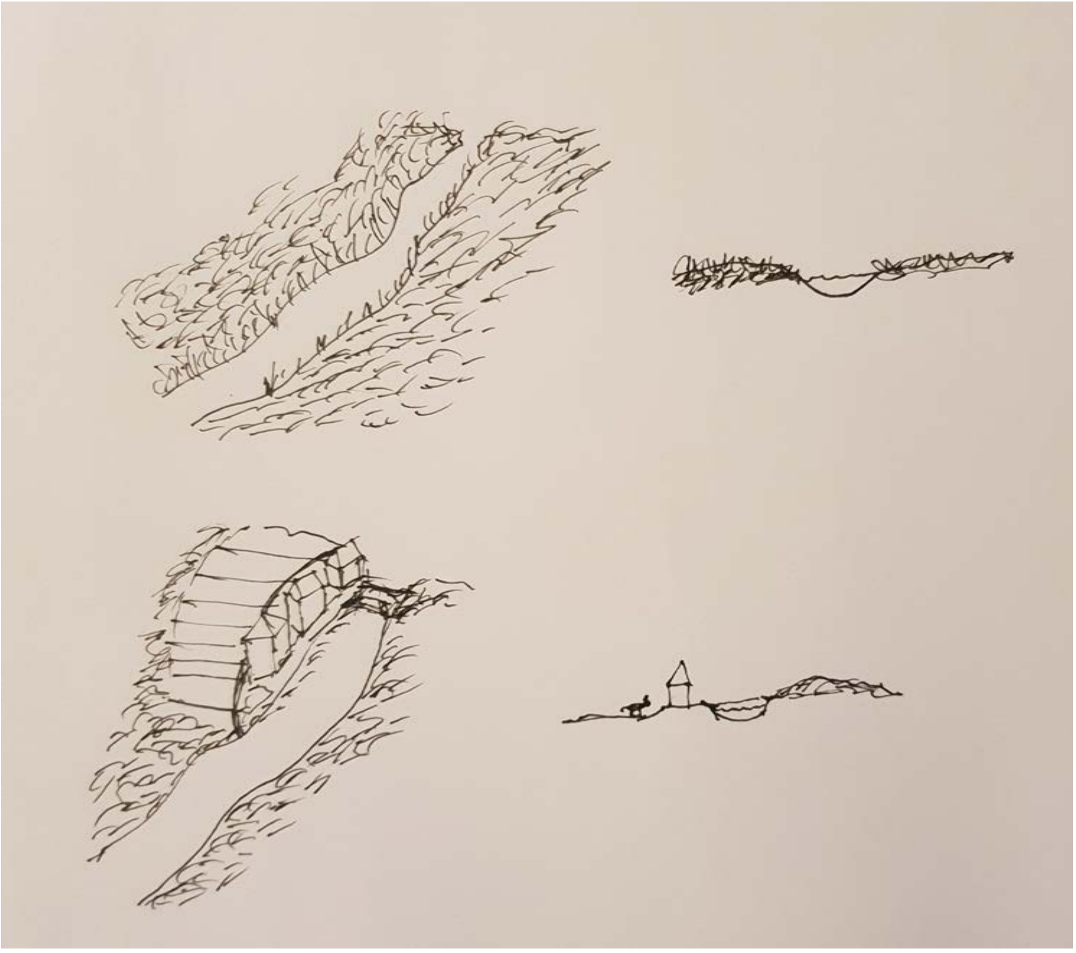


The landscape of the western Netherlands developed from peat marshes
that were slowly colonised through intricate interventions in the landscape

Introduction

The Dutch Metropolis. From peat marshes to polder cities to ?

Introduction

Our process of urbanization has long followed an unsustainable path. The current rate of space and resource consumption poses significant challenges to continued livability and stimulates the creation of vulnerable environments reliant on the overexploitation of natural systems (Harvey, 2012). In the face of climate change, this becomes a major hurdle towards making our cities more resilient. Not only is our current way of urbanization unsuitable for the present, but it is also unsuitable for the future, with the wellbeing of the most vulnerable being at stake (Shi et al., 2016).

Our growing populations, coupled with the increasing desire for resources have had profound effects on our planet as a whole. Where Hamilton describes our influence as a force of nature (2017), the spatial effects we've had cannot be ignored either. These go far beyond our cities, with our productive landscapes for food and feed production, resource extraction, infrastructure now exceeding 70% of the planet's land surface. (N. Katsis, personal communication, September 26, 2019)

When we consider how western resource consumption has been disproportional to the population size, exemplified by the Dutch resource footprint measuring over twice the available space per person on earth (Hackauf, Haikola, & Maas, 2014, p. 166), this path of development could be very problematic if widely adopted.

Adding financial institutions' expectation of a growing scarcity of resources (Smolders, 2011) and the need for adaptation to a changing climate, the question becomes whether proceeding with the subjugation of the natural environment is even financially feasible. The disproportional Dutch resource consumption, begs the question whether this approach is even ethical, as limiting the development of other regions to maintain our own consumption levels is unethical.
Therefor we must also change.

Looking at the widespread effects urban consumption has on the rest of the aforementioned 70% of the land surface, changing the urban could have far reaching effects. To explore this, this research focuses on the urban.

I believe this research can contribute to a shift away from this predatory urbanization by making the connection to the hybridization of functions, e.g. the combination of civil, logistics and environmental services with our living and interaction environments. This project operates within the paradigm of the Anthropocene, that is the epoch of mankind as sentient force of nature, as described by Clive Hamilton (2017)

The choice for a location in the Netherlands was informed by multiple factors, including data availability and proximity. One of the main reasons for choosing Amsterdam, though, is its long history of interaction with the environment. For most of its history, the city of Amsterdam had to find ways to thrive in an inhospitable environment, mostly consisting of peat marshes along the sea.

...there is a need for a return to an equitable balance with the natural environment, while still addressing the city's and its citizens' needs.

This process of urbanisation, led to the creation of specific typologies, of which the polder city is an example. However, affluence has relieved the city from the need to actively engage with the natural environment on equal footing. The city's and its citizens' needs and desires have reshaped the environment for the logic of the world of man. And major advancements in technology (Hooimeijer, 2014) and spatial planning allowed it. Now we are faced with a living environment in which the natural systems underlying the city are approached as a complication, a constraint to its development, instead of an asset or opportunity.

Therefore, there is a need for a return to an equitable balance with the natural environment, while still addressing the city's and its citizens' needs. Here spatial planning and urban design can play a vital role, targeting resource consumption related to building and mobility.

Within this, the development of the new district Haven-Stad offers opportunity, but also brings difficulties.

Problem

As the population of the Netherlands is growing and the household compositions are changing, the housing demand is changing. There is an increasing shortage of housing. (Lennartz, 2018) The decision to build 1 million additional dwellings in the Netherlands until 2030 to address this, has great spatial implications. It is even more relevant in the Randstad, where a large part of this housing is set to be built.

In response to the effects of vast horizontal expansion of the built area, several cities have decided to either limit or stop greenfield development, instead focusing on intensification. To avoid losing what remains of the so-called Green Heart ("Groene Hart"), to the development of the horizontal metropolis, the Dutch government decided to contain the cities and focus on densification of the existing environment (Cobouw, 2018).

While this enables a more efficient development and use of infrastructures and services (Bettencourt et al., 2007, p. 7301), it also brings up several challenges. While Bettencourt et al refer to these as "human adaptation to urban living" (2007, p.7301), this research focuses on the effects density has on liveability.

In the Western and European context, high density has long been considered a cause for low liveability. In the Netherlands in particular, large dense cities are often perceived as a blight rather than as an opportunity. (Hemel, 2016, p.12)
Acting on this assumption most urban expansion has been horizontal, leading to a high land consumption and requiring high investments in additional infrastructures.

This calls into question the relationship between density and liveability as well as the perception of density in the Western context. Especially since high densities are not a new phenomenon in the west. In his pamphlet, Unwin describes the context surrounding the high density, which he deems undesirable. (2013) It builds on the ideas for the Garden City, proposed by Ebenezer Howard, arguing against the, at the time, contemporary logic of profit maximisation through high land occupancy, instead focusing on what human values are lost due to such an approach. He praises the role of the original town in not only providing an identity, but also for its continued central function. This can be an explanation for the strong policies to develop garden cities internationally and the Dutch approach of developing so-called groeikernen during the 20th

The cities are now faced with the complex task of housing this increasing population in a way that increases the liveability of the cities on the long term.

century (Hemel, 2016, p.12), mirroring the garden city ideals.

Considering how this development has placed a strong emphasis on the importance of open and green space, it may be surprising that these areas are as, or maybe even more artificial and resource consuming in nature than the high-density cities they were developed in response to.

It could also be argued that contrary to the perception of high-density cities, many are no longer centres of squalor and instability, instead becoming

It is a question that requires a fundamental re-evaluation of the approach to space, mobility and the role of design towards resilience.

crucial for economic development and stability, while being vulnerable to climate change.
The cities are now faced with the complex task of housing their increasing populations in a way that increases the liveability of the cities on the long term.

Creating an additional 1 million dwellings within the current built areas undoubtedly brings up questions surrounding the spatial implications of this decision. Accommodating a high population density whilst maintaining or preferably increasing liveability presents several spatial challenges, ranging from the design of neighbourhoods to mobility and climate adaptations.

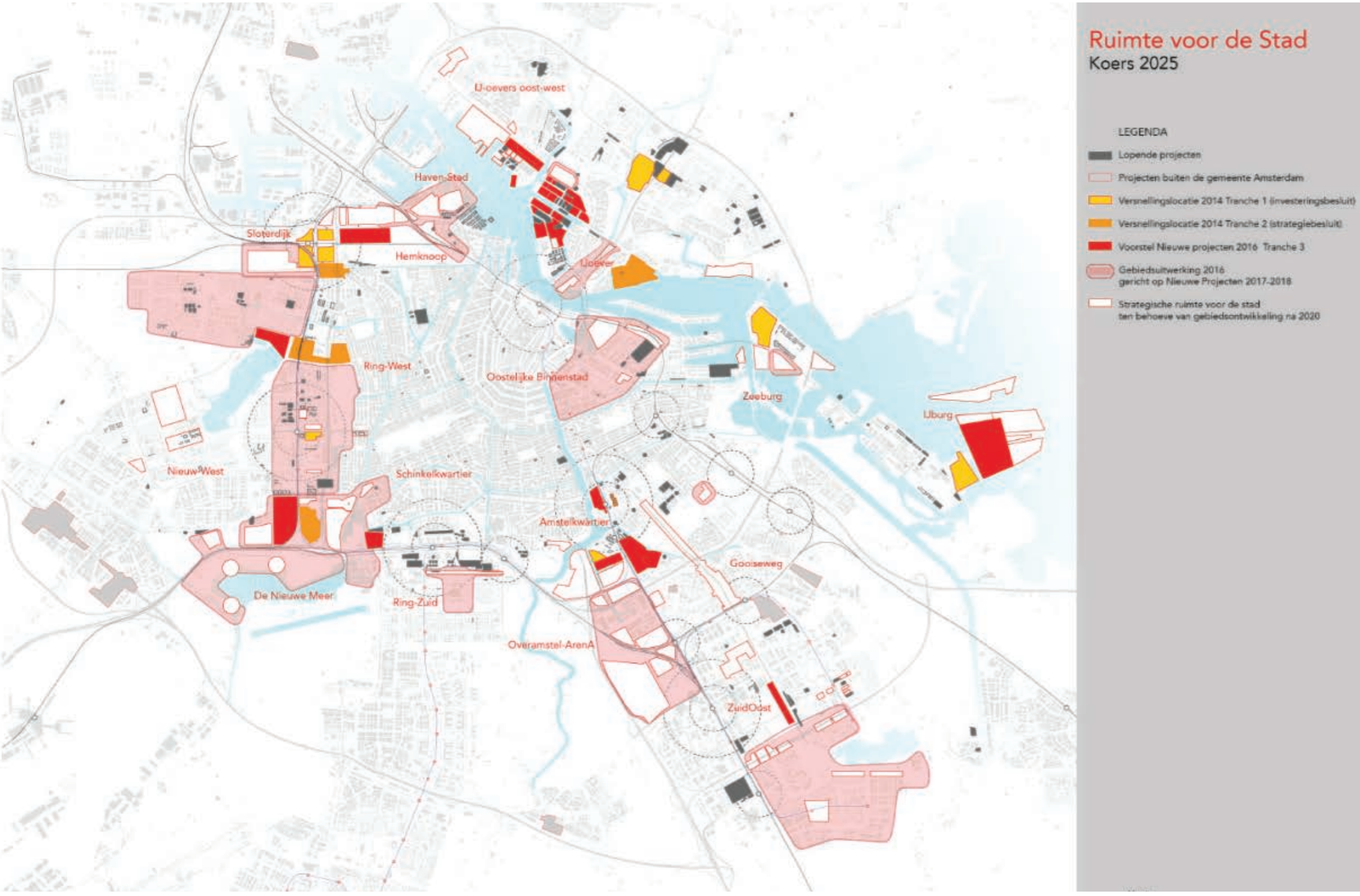
Due to our own actions as a species, the era of high predictability is behind us. There is no way back. (Sijmons, personal communication, 2018, December 07). A new, perhaps more pragmatic, approach, understanding of and including the natural systems rather than overpowering them is needed, for our built environment to be resilient.

The location for the design project is the city of Amsterdam. It is expected that the city will reach the demographic milestone of 1 million inhabitants before 2040 (Metropoolregio Amsterdam, 2017). This will add additional stresses due to the existing and the expected environmental conditions and occupation of space.

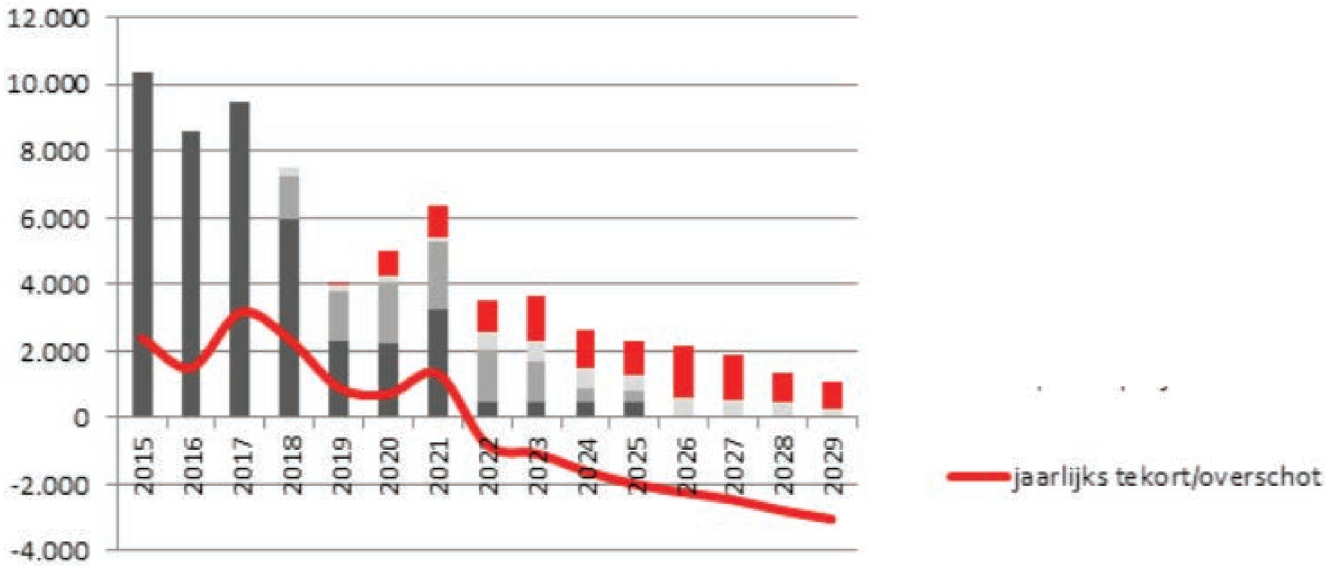
In this research the focus is on the planned district of Havenstad. The ambition to create a high-density environment in this area is a very interesting challenge due to the depth of the transformation required. Located between the city of Zaandam, the Amsterdam Harbour and the city centre of Amsterdam, Havenstad is an area containing a lot important infrastructure, connecting urban cores, industrial/logistics zones and office areas to the wider region.

Judging by the brief that calls for up to 70.000 dwellings and over 50.000 jobs (Gemeente Amsterdam, 2017) this transformation cannot just be considered a simple call to accommodate the city's current and growing population, and it should not be viewed in isolation. This is not limited to merely addressing the impending absolute housing shortage in the city.
It is a question that requires a fundamental re-evaluation of density in the Dutch context, in particular regarding the approach to space, mobility and the role of design towards resilience.
Although the fast growth and accompanying housing shortage already form a formidable challenge by themselves, the city's environmental conditions, with much of the land being reclaimed from peat marshes and the sea, have the potential to threaten the area. To make matters worse, the changing climate chips away at the predictability and robustness of the city's highly engineered systems.

The challenges to ensuring liveability in the high-density environment can then be classified in three main categories, being space, mobility and climate.



Development areas in various planning stages as assigned by the municipality of Amsterdam. Source: Gemeente Amsterdam (2016). Koers 2025. Ruimte Voor de Stad



Development of the yearly housing production and the potential absolute surplus/shortage of housing. The colors here correspond to the same legend as the map on the previous page. Source: Gemeente Amsterdam (2016). Koers 2025. Ruimte Voor de Stad

Challenges

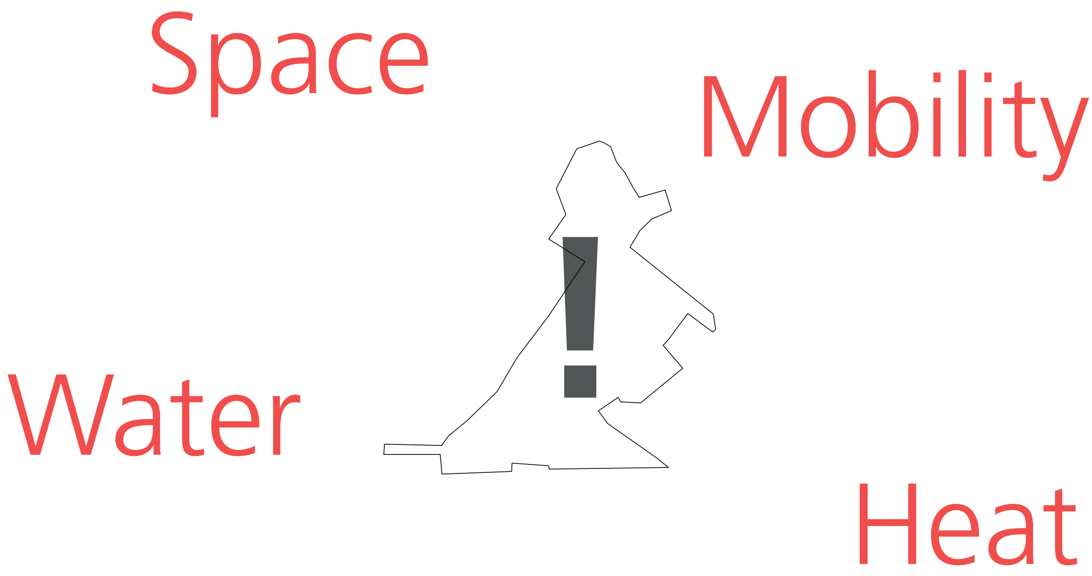
As mentioned in the previous paragraph, the city is faced with the challenge of housing a growing population along with additional functions within the current built area. Taking into account the negative perception of density, the major challenge in this research is to reconcile a high density with a high liveability. This requires an adequate response to the challenges this poses in regards to space and mobility, as well of an integrating climate resilience to this approach.

When considering the spatial consequences, the city's ambition regarding the projected population density is of particular interest. Amsterdam is planning for a population density that currently does not exist in the Netherlands, reaching a density of up to 35.000 inhabitants per square km (Gemeente Amsterdam, 2017). This requires new spatial solutions in order to allow for a high liveability in the area.

Realising this type of density not only affects the design of space and the correspondent buildings, but also calls accessibility and overall mobility into question. The mobility choices have a strong effect on space allocation and the resulting typologies. While the city aims for a strong modal shift towards active mobility and public transportation, the municipality's own research shows that this density cannot be achieved with the current modal split, due to spatial constraints and the effects it would have on the functioning of the rest of the city. (Gemeente Amsterdam, 2017)

This leaves the additional environmental challenges largely stemming from climate change. Not only has the yearly precipitation been increasing considerably over the years, but the incidence of high rainfall events has increased concurrently. (Klok L., personal communication [lecture notes], 2019, september 13) The city's current rain sewers with a capacity of 20mm per hour are increasingly insufficient, considering the future requirement to cope with 60mm per hour rains. (Gemeente Amsterdam, 2017) Confronting this problem requires a different approach to rainwater in both the public space and on private properties.

In addition to the water challenges presented by climate change, the city also has to cope with increasing heat during summer. It is expected that the incidence of extreme heat will vastly increase, while the decrease in cold periods will not be very significant (Pijpers-Van Esch, personal communication [lecture notes], 2019, 13 september). This requires novel solutions for the Dutch context.
The ambition of maintaining a high liveability therefor requires an integrated approach to space, mobility, water and heat in order to be successful.



City ~~of~~ for the Future

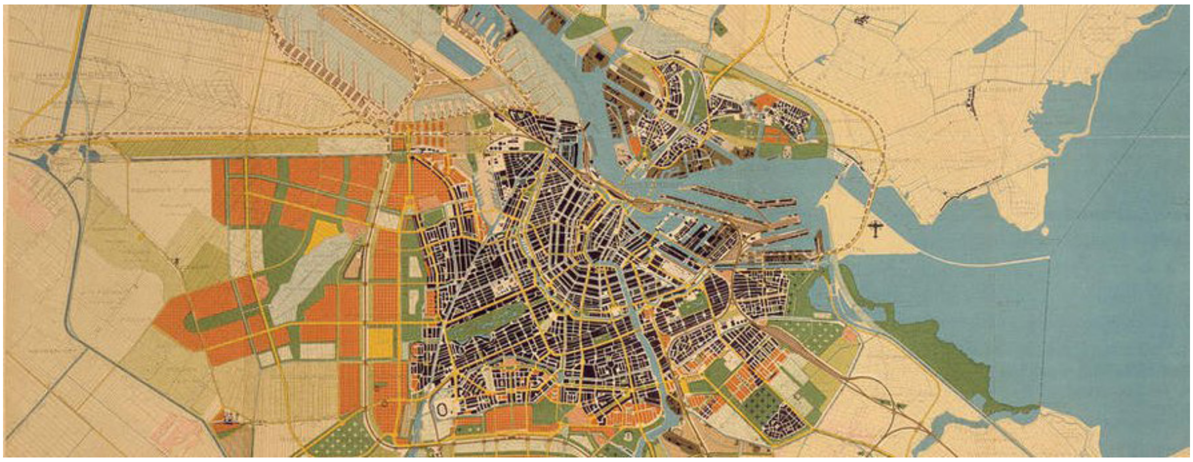
In a move showing the high ambition of the Havenstad project, the city envisions Havenstad as the city of the future. It is meant to be an area in which functions are highly mixed and flexible, an area that is prepared for future development. With this goal in mind it was Amsterdam's suggested location for the Stad van de Toekomst research project put forward by the BNA. (BNA, 2018)

However, such an ambition is not new to the city of Amsterdam.
In the twentieth century alone, there were three significant iterations of the idea of the city of the future, Berlage's Plan Zuid, the "Algemene Uitbreidings Plan" (AUP) and the Bijlmermeer. The three were developed in response to the past, with the goal of not just providing much needed housing but also tackling perceived social and spatial issues of the past.

As the city is once again embarking on such a large scale development, it is important to take into account the lessons of the previous iterations of the city of the future concept.

First Plan Zuid made use of the new powers granted to municipal governments in the "Woningwet" and the 1896 adoption of the land lease regulation to provide dignity to the working class and develop the city into a metropolis. Prior to the Woningwet and the land lease system the undesired effects of profit maximization without adequate services resulted in squalor and unhealthy conditions within the city, as new owners were able to ignore previous owners' agreements with the municipality (Heeling, Meyer, & Westrik, 2002, p. 43).

Plan Zuid by Hein Berlage - Gemeente Amsterdam, Public Domain, https://commons.wikimedia.org/w/index.php?curid=15479626



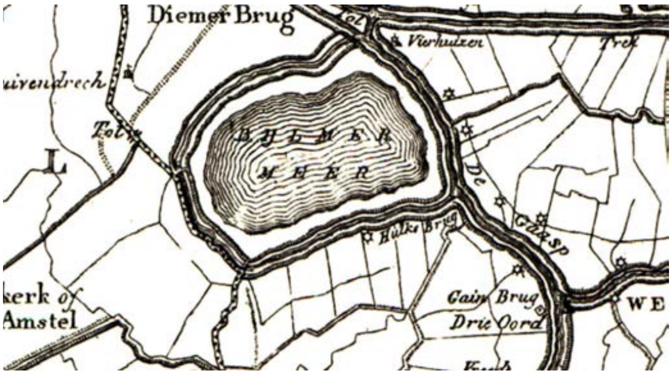
The "Algemeen Uitbreidingsplan van Amsterdam" (AUP) 1935 Source: Gebiedsontwikkeling.nu (2017) Leren van het Algemeen Uitbreidingsplan Amsterdam

Major changes in planning represented by this city of the future were the focus on the block rather than on the parcel, the shift from building for profit maximization to building to achieve ideals of collectivization and socialization and the inclusion of public services such as schools in the planning (Heeling et al., 2002, pp. 44-45). It aspired to a united image of the city (Van der Cammen & de Klerk, as cited in Berghauser Pont & Haupt, 2009, p. 52)

The following iteration, the AUP spearheaded by Van Eesteren, responded to what it perceived as the chaos of the metropolis, creating order through the separation of functions and a large-scale introduction of green space to the city. It continued with the ambitions of plan Zuid, while rejecting the spatial organization of the blocks in favour of free standing structures. (Heeling et al., 2002, p. 46) Here the city was no longer considered as a visual composition, but Engel and Van Velzen (as cited in Berghauser Pont & Haupt, 2009) describe it as a composition of functional relations.

In this new functionalist approach, residential areas would be largely separated from industrial and commercial areas, apart from small scale commerce and light industry being permitted in the residential areas. Most of the new development was to provide housing, while working was to be concentrated in the city centre and the new harbour area being developed (Part of what is to become Havenstad), with a green structure stretching into the city for recreation.

The planological research underpinning this functionalist approach, expanded on the stipulated requirements for public functions by adding a maximum distance to parks and minimal size of these parks to the planning. (Heeling et al., 2002,



1815

The Bijlmermeer is still a lake

1950

The Bijlmermeer is agricultural land

1970

The land has been altered for development

1990

The Bijlmermeer plan is complete

The Bijlmermeer in various years. Maps source: Topotijdreis. Retrieved on 29-04-2019 from https://www.topotijdreis.nl/

On the left: Aerial footage of Bijlmer Oost during its construction, part D and E, Karspeldreef. Photo Stadsarchief Amsterdam (1973)
On the right: Footage of then Dutch queen Juliana on a balcony in the new development, January 21 1971
Source: 99percentinvisible (2018) Bijlmer City of the Future Part 1. Retrieved on 05-08-2019 from https://99percentinvisible.org/episode/bijlmer-city-future-part-1/

p. 47) This inclusion of parks formed the base of the current green structure of the city. In this plan density had become a leading consideration (Berghauser Pont & Haupt, 2009, p. 36).
Where the AUP is considered to be a precursor to the Athens Charter, put forward by the architects party to CIAM(Hemel, 2016, p. 29), the next iteration of the city of the future was born from it.

The so-called Bijlmermeer expanded on the rejection of the perceived chaos and unhealthy conditions of the existing city through a wholesale rejection of the metropolis. The city was to be formalized and made efficient and equal. This functional city focused on mobility and equality with its spaces specifically meant to create a new society. Spatially this break was most apparent in the absence of a clear hierarchy of spaces. (Heeling et al., 2002, p. 49)

The ideal of not only controlling the city, but also the environment, is clearly visible in the transformation of the original landscape. Testament to man's technological prowess, a lake transformed to a polder was now covered in a thick layer of sand upon which a new landscape was to be created.

A strong separation of functions and types of mobility was central in the tightly planned new district. This district was to be the successful antithesis of the existing polluted and cluttered city. Here the ideals of "air, light and space" would finally be available for the common citizen. (99percentinvisible, 2018)

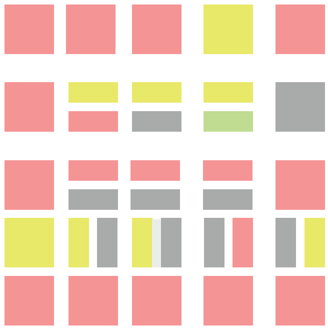
This strong egalitarian drive promised a vast park like environment where all the land was to be public. It did eventually succeed in the provision of extensive green space and high accessibility through various modes, but the development of neither the landscape nor the transport infrastructure was able to keep pace with the housing development, leading to a lower perceived liveability.

Following the Bijlmermeer the idea of the outright rejection of the city seemed to have stuck, with the garden cities continuing on a path of deconcentration and separation of functions.
The ongoing development of garden cities in and around Amsterdam further weakened the appeal of this district.

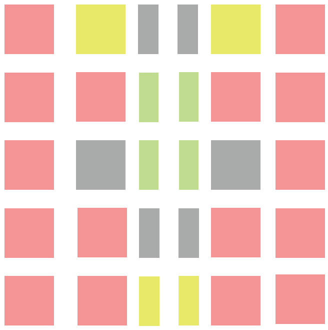
When looking at the current performance of these three cities of the future it is interesting to note that only the Plan Zuid Development managed to still be amongst the most desired areas in the city, evidenced by the concentration of high property values and incomes.
Despite ongoing developments, the areas of the AUP and the Bijlmermeer are amongst the poorest in the city.

The underperformance of the AUP could in part be attributed to unforeseen socioeconomical changes, especially the rapid decline of household sizes and the increased demand for recreation and non-recreational spaces. As the area never reached the expected population size and national government put a strong emphasis of the development of housing, these neighbourhoods have largely remained monofunctional.

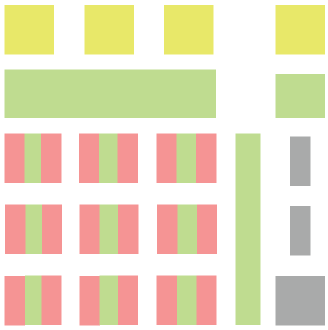
A challenge affecting the Bijlmermeer as well was



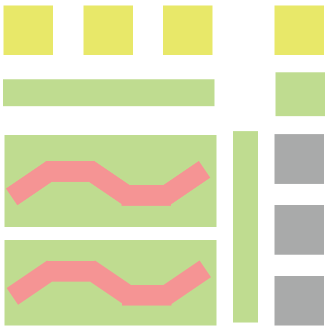
Mix of functions in the old city
The original city was perceived as disorganised. in particular in the Jordaan district.



Plan Zuid
Hierarchy and the spatial relations become important. The city as a visual composition.

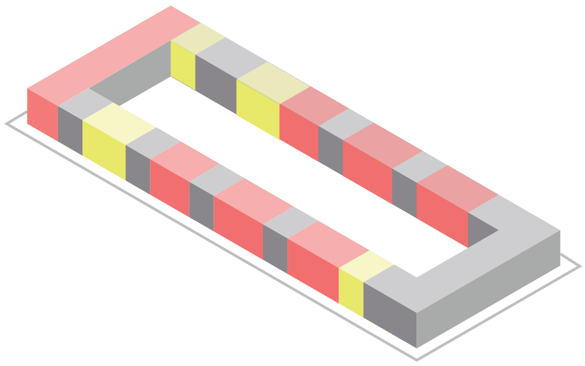


AUP
Separation of functions, introduction of large green spaces and the rejection of the closed building block. The city as a composition of functional relations.

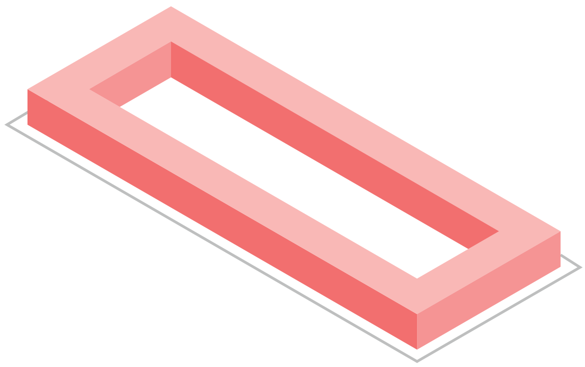


Bijlmermeer
Further separation of functions, increase of the green space and a vastly different relation between the built and the open.

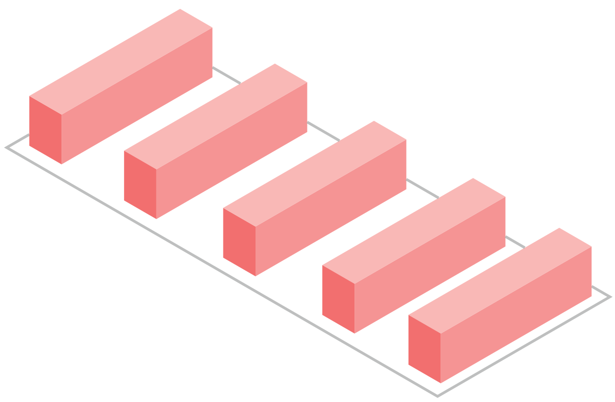
The Dutch Metropolis. From peat marshes to polder cities to ?



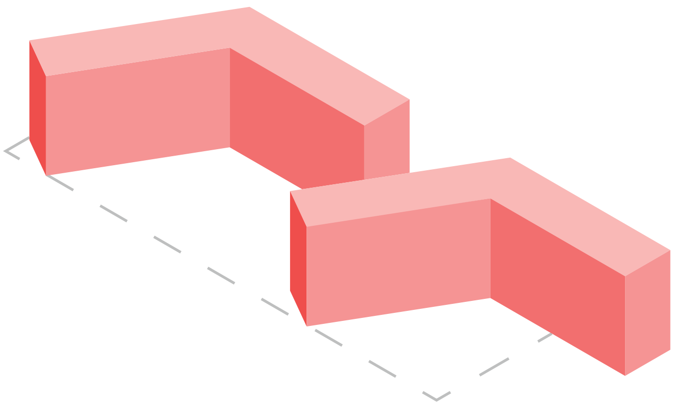
Parcel based development
A representation of the parcel based development



Plan Zuid
The building block becomes leading in the development.



AUP
Rejection of the closed building block in favour of the individual building, introducing large scale green and open space.



Bijlmermeer
Further development of new highrise typologies. The borders in the public domain become less clear.

The Dutch Metropolis. From peat marshes to polder cities to ?

the purposeful design of a green area for all with its strong separation of functions and mobility. This proved to be detrimental to social security, up to the point of it being one of the reasons crime started to thrive after being driven from the city centre, further decreasing security. (99percentinvisible, 2018)

Contrary to previous expectations, the projected egalitarian city for all was giving way to the city of no one, derided for its design, inhabitants and insecurity. The area designed for the middle class was not suited for its eventual use.
Spurred by the newfound attention for the area after the Bijlmer disaster, the area is undergoing transformation. This includes the mixing of functions and mobilities in an effort to improve the liveability of the area, while keeping some of the qualities specific to these areas, such as large green areas for its citizens and the high connectivity.

Here the existing city is no longer considered a cautionary tale to be avoided, but an example to be followed. However, as mentioned earlier, the AUP and the Bijlmer introduced large green and blue spaces that are scarce in the older parts of the city and less common in Plan Zuid. These spaces provide crucial ecosystem services to the city.

Now the city is positioning Havenstad as the "new" city of the future, it is important to understand what drove these vast differences in performance.
While Plan Zuid was intended as a metropolitan extension to the city, the AUP was intended as an improved and organized city. However, it had not anticipated the vast changes in household composition that were to take place. As a result of smaller household sizes and lower number of dwellings, the area did not reach the intended population density to support the planned commercial and public services in the area. The separation of functions therefor became stronger than intended, leading to a largely monofunctional area.

Interestingly, the area that is to become Havenstad, is actually a part of the AUP that was designated for industry, separated from the other areas by a green area. Its proposed transformation to a mixed environment fits within the development proposed for the other parts of the AUP.

However, the initial success and later underperformance of the previous attempts of the city to develop a city of the future put into question how much Havenstad can actually be designed, for our current needs, as future needs are not all yet known.

Instead, the city should be a city designed for the future, allowing for flexibility, while offering a framework for development. Here the existing conditions should not only be treated as threats, but as opportunities for the development of a desired new area.

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Havenstad
A city for the future, allowing for flexibility and offering a framework for development into a high intensity mixed area, optimising its environmental assets

Approach

Developing a city for the future, capable of incorporating changes within its fabric, requires a transition from planning based on current socioeconomic patterns. Havenstad must work to become a resilient high-density environment, as a high population density is integral to the city's ambitions.

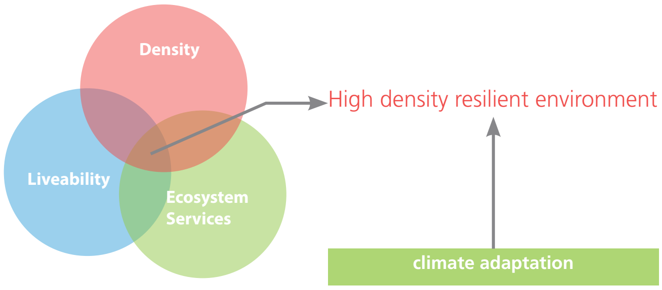
As mentioned earlier, density and liveability have been recurring themes, integral to the development of the various "cities of the future", with ecosystem services gaining a growing importance as the years progressed. However the blue/green spaces have in those iterations mostly been intended mostly with recreation purposes in mind. In Havenstad they will have to be able to fulfil multiple purposes in order to maintain a liveable environment.

The goal here is to allow for a high liveability that can be sustained over the long term. This is to be achieved for a great part through operationalising ecosystem services and integrating them spatially, taking into account the effects climate change may have on the area, while high density forms the context in which this is to take place.

In short this research revolves around the themes of density liveability and ecosystem services and their interrelations and spatial manifestations. The pictures to the right are intended to show schematically how the different themes manifest within the city. Here the Wan Chai district of Hong Kong has been taken as an example.

The first theme, density, is shown by highlighting the spatial component composed of buildings. The second, liveability is here shown correlating to the infrastructure and recreation facilities. Finally the ecosystem services are represented by the green spaces and the present vegetation.

To determine how liveability, density and ecosystem services relate to one another and how to assess the district performance, the theory that belies the three is explored in the next chapter.



Density

Liveability

Ecosystem Services

The research questions

To address the relationship between density, liveability and the integration of ecosystem services in a systematic and focused way, several research questions have been composed. The sub research questions are divided into groups in order to guide the research.

The main research question in this project becomes:

How can a resilient high-density environment be developed, utilizing the environmental conditions of Havenstad, to achieve a high liveability?

In order to answer this question, a number of sub questions have been formulated according to the various aspects that are touched upon in this project. These are divided by the following four types: The fundamental questions, the societal question, the analysis questions, the design questions and the question regarding the profession of the urbanist.

The fundamental questions are intended to build the foundation of the research and design strategy through the exploration of the theoretical framework. Starting from the fundamental question "What is a resilient high density environment?"

- How is resilience defined within this project?
- What is the relation between density and liveability?
- What determines high liveability in a high-density environment?
- How do ecosystem services affect liveability?
- What needs to be taken into account when combining density, liveability and ecosystem services?

The societal question relates to the ethics of the approach and the effects the design strategy will potentially have on the city. Here the socio-political decisions at the base of the design strategy are evaluated:

- Who should Havenstad be for?

Building on the foundation and the stated goals for the city for the future, the existing condition of the area is to be assessed. The analysis question then becomes: How does the area perform?
For this, the following analysis questions are formulated:

- What are the city plans for Havenstad?
- What are the present networks and environ mental conditions and how are they interre lated?
- What are the current functions and who are their stakeholders?
- What are the potential threats and opportu nities in the area?

This builds up to the design question of "How to operationalise the potential of the area?". This is answered through the design questions:

- How can the various networks, occupations and environmental conditions be integrated to create a resilient environment?
- How can the area develop on a course to acquire the desired modal shift?
- How can Havenstad contribute to the live ability of the surrounding neighbourhoods?

Lastly there's the reflection on the profession:

- What is the role of design and the designer in developing towards social and environ mental resilience?

Relevance

The relevance of this project can be subdivided in the scientific relevance and the societal relevance.

Scientific Relevance

This project intends to arrive to an evidence-based design. With this intention in mind, it includes a combination of the spacematrix approach by Haupt et al (2005), with ecosystem services and a technical profile. By doing so, it attempts including environmental opportunities to allow for a durable liveability. It further proposes to utilize the block approach developed by the Planbureau voor de Leefomgeving (Harbers et al, 2019) to not just determine the performance regarding spatial density, but also as a carrier for the environmental and spatial performance indicators. It is expected that doing this will not only allow an insight in the individual performances of the blocks, but also facilitate communication and serve as a base for the metrics of additional indicators. The aim throughout this project is to investigate how local environmental conditions can be utilized as an asset for the development of a resilient densification strategy. It will be a test to see whether an opportunistic approach (Ahern, 2007) to local conditions can be applied in a replicable, and quantifiable way.

Societal Relevance

This project intends to not just explore the opportunity to alleviate the housing shortage by incorporating a high density, but also challenge the notion that density is equated to low liveability and desirability (Hemel, 2016), and poverty. This notion has, apart from leading to the perpetuation of policies geared towards deconcentration, damaged the potential of the cities.

In this context where space is scarce, resulting in high prices, high densities could offer a solution to alleviate this shortage, while reducing additional resource consumption. Using ecosystem services to support a high liveability in high density environments can potentially alter the perception of density, while creating highly valued spaces and places. In addition, fulfilling the demand for housing with an ecosystem inclusive approach has the potential to create a more resilient urban environment, better equipped to weather the vast climatic challenges expected. Applying the block approach then can also facilitate communication to and with the public and the private sector.

When looking at both the scientific and the societal relevance, it becomes clear that the project aims to offer a way to combine various data to inform evidence based design, while also allowing for transparence and insight for citizens and private entities in the way their area could move towards resilience, while including the effects of spatial decisions on liveability.

This could eventually enable developers and citizens to use this as framework through which to argue for or against spatial changes.

Methodology

In order to answer the research question and develop a design strategy for a high-density environment in Havenstad, that allows for a high liveability through the use of the local environmental conditions, a year long study was conducted.

This study was divided into three main parts, taking part one after each other. Here a literature study forms the foundation of the research. During this study, the fundamental sub questions are explored in order to understand the relationship between density, liveability and ecosystem services, identify the important criteria, decide on relevant reference studies and draw conclusions based on the relations between the three themes.

These conclusions, the design guidelines and the block performance indicators, form the base of the Design Patterns and the Block Performance assessment that inform the design and are used for the optimization of said design for the area. The key is to develop a strong framework for density, liveability and ecosystem services.

After a first phase with a strong emphasis on research, the second phase is conducted through designerly research. Informed in part by the criteria from the foundation, the analysis phase applies a collection of design and analytical methods to further understand the area and develop the design. These consist of a spatial analysis, a network analysis and quantitative research utilizing the layer approach among others. The results of this phase are where the values for the block performance indicators are sourced.

The reference studies are selected based on their local conditions and ambitions/performances in regards to the integration of density, liveability and ecosystem services. The areas referenced all have a high density, but different approaches to increase liveability. Three of these locations have been visited in preparation for or during this project. They exploration of this areas is to inform the development of design patterns and allow for a reflection on the block performance indicators.

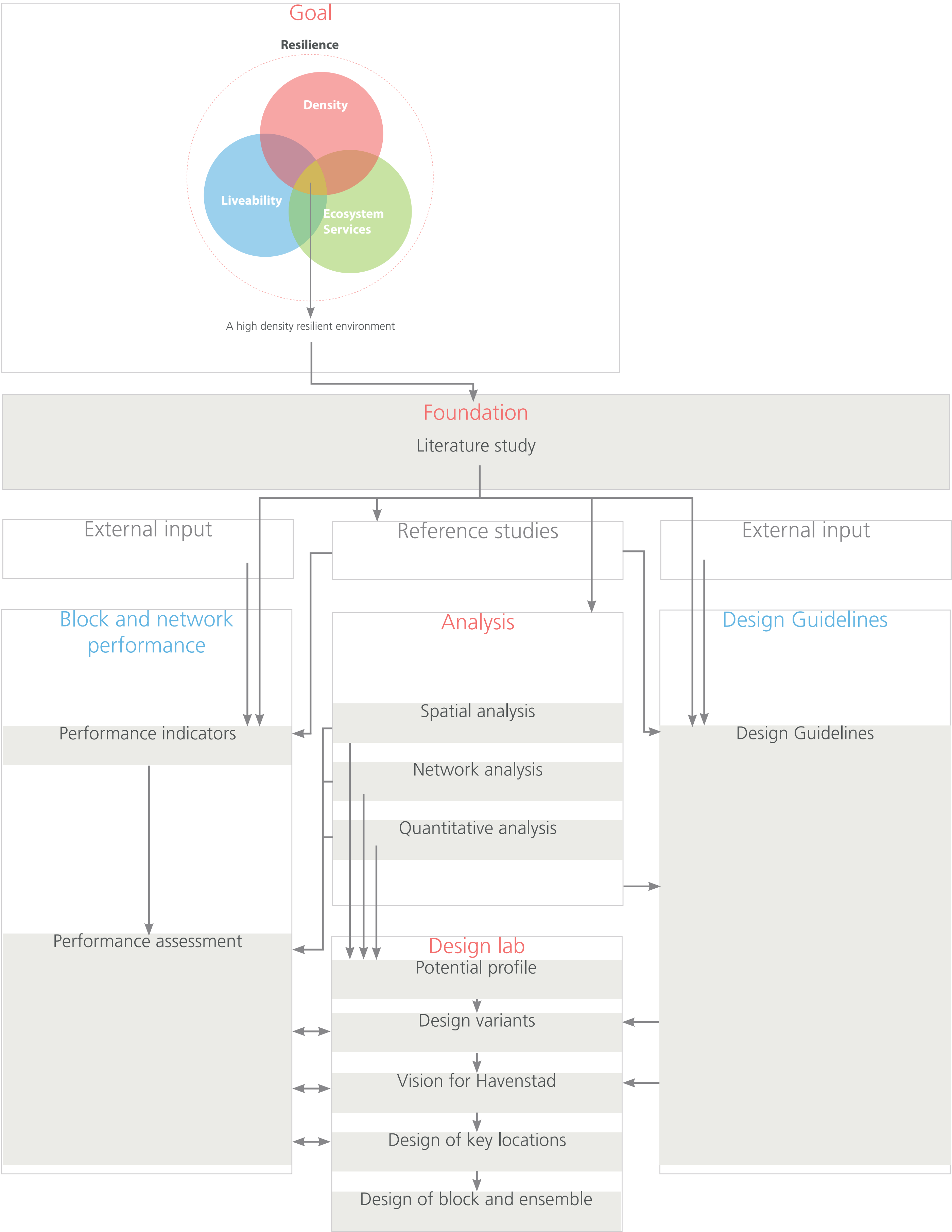
In this research the external input from practitioners, professionals and stakeholders is taken to inform the design patterns and block and network performance indicators.

The final phase consists of the Design lab. Here the input from the foundation, the analysis, the block performance and the design patterns is used to guide the design process.

The concrete aim is to explore how to achieve a high density in a transformation area while stimulating a high liveability. Here Havenstad, an existing commercial/industrial area envisioned as a high density resilient area, will be the testcase for the new approach integrating ecosystem services and high density.

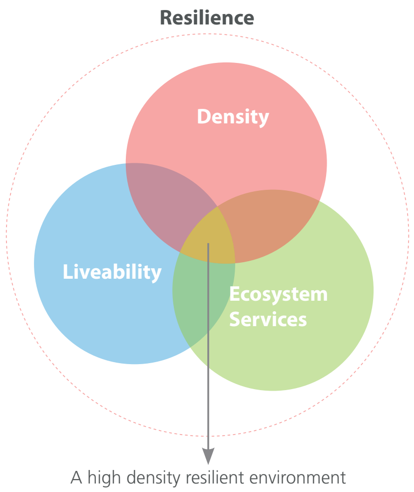
The scheme to the right illustrates the process that is followed. Here the arrows indicate how different elements inform one another.

A scheme showing the research objectives in shown in the next paragraph.


Goal
Resilience
Density
Liveability
Ecosystem Services
A high density resilient environment
Foundation
Literature study
External input
Reference studies
External input
Block and network performance
Analysis
Design Guidelines
Performance indicators
Spatial analysis
Network analysis
Quantitative analysis
Design Guidelines
Performance assessment
Design lab
Potential profile
Design variants
Vision for Havenstad
Design of key locations
Design of block and ensemble

Research objectives

Goal



Develop a strategy for the development of Havenstad into a city for the future.

Main Research question

How can a resilient high-density environment be developed, utilizing the environmental conditions of Havenstad, to achieve a high liveability?

Sub research questions

Foundation

What is a resilient high density environment?

- How is resilience defined in this project?
- What is the relation between density and liveability?
- What determines high liveability in a high-density environment?
- How do ecosystem services affect liveability?
- What needs to be taken into account when combining density, liveability and ecosystem services?

Sociopolitical decisions

Who should Havenstad be for?

Analysis

How does the area perform?

- What are the city plans for Havenstad?
- What are the present networks and environmental conditions and how are they interrelated?
- What are the current functions and who are their stakeholders?
- What are the potential threats and opportunities in the area?

Design

How to operationalise the potential of the area?

- How can the various networks, occupations and environmental conditions be integrated to create a resilient environment?
- How can the area develop on a course to acquire the desired modal shift?
- How can Havenstad contribute to the liveability of the surrounding neighbourhoods?

Reflection on the profession

What is the role of design and the designer in developing towards social and environmental resilience?

Methods	Outcomes	Results
Literature study Exploring the interrelations between density, liveability and ecosystem services and how to increase resilience.	Design guidelines The guidelines for succesful integration of Density, Liveability and Ecosystem services The Block performance indicators The key performance indicators for the block performance.	
Input from practice, professionals and stakeholders Talks of stakeholders and practice are considered, as well as documentation provided.	Design guidelines	
Spatial Analysis A synchronic analysis using the layer approach Network analysis The place syntax approach using GIS Quantitative Research place syntax, GSI, FSI, water retention and runoff	The Technical Profile An overview of the subsurface systems and the environmental conditions The Functional Profile An overview of the functions, relations and land ownership	
Reference study Explanatory reference study and field trips in Paris and Hong Kong	The Potential Profiles An overview of the spatial vulnerabilities and opportunities for the plan. Design variants Creating various design variants to test various performances.	The Vision for Havenstad Design for Havenstad Development timeline Based on the design considerations a possible timeline for the development of the area is suggested.

Ethical considerations

While the projection for Havenstad is to house a large number of new inhabitants for the city of Amsterdam, with the goal of easing the housing shortage experienced in the city, it will potentially be transformative for the city and its environment. Although the city aims for the inclusion of various socio-economical groups in the Havenstad area, the effects it will have on the direct vicinity requires a consideration of the surrounding neighbourhoods.

If the surroundings are taken into account, the development of a secondary city centre in Havenstad can not only help alleviate the pressures on the current centre, but also offer new opportunities for the narratives and identities of the current inhabitants, thereby also improving their quality of life.
Failure to recognise that, may deliver a highly functioning Havenstad that has little to no connection with its environment and fails to grab the opportunity to address the spatial inequality in the city, while radicallly transforming it. Such a development would risk to perpetuate the growing inequality in the city as a whole.

These considerations have been incorporated in the societal research question asking who the city and Havenstad are ultimately for. This question has been deliberately included to be reminded that this decision should be strongly argumented and not left to be overly affected by personal bias.

Limitations

As mentioned earlier, this process of research and design is to be conducted within the span of one single year. Due to this constraint a choice was made to focus on how to increase liveability while enabling high-density development by using ecosystem services, using high density as a given.

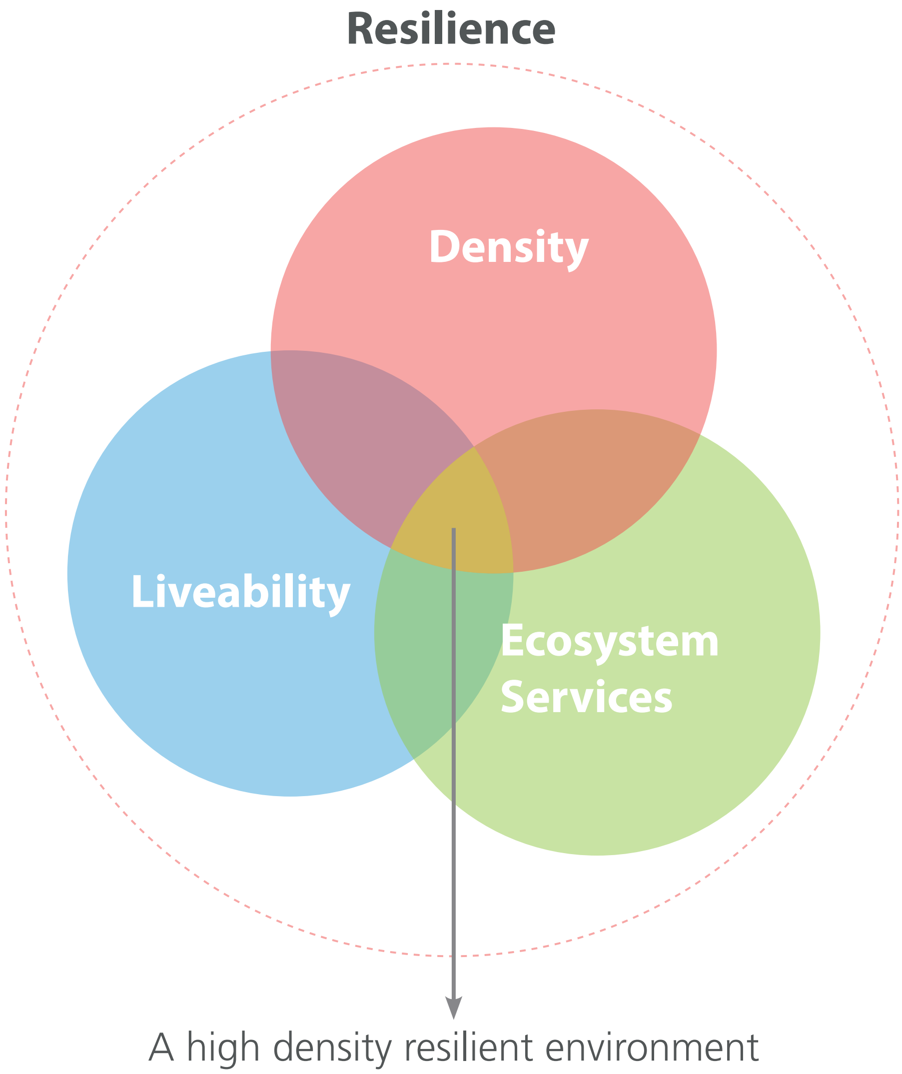
In the defining of the themes to be researched, the spatial definition for density is taken from the work of Haupt et al (2005) and that of Van den Hoek (2008), this is done as their definitions are being more widely used and they suit themselves to quantitative analysis. The definition for resilience as the capacity to overcome system failure after a calamity (100 Resilient Cities, 2018) is taken as the base for the ambition of a resilient environment.

Due to the sheer scale of the project, certain aspects such as financial feasibility and resource consumption will only briefly be mentioned, instead hinting at possible methods to increase the viability. It also affects the comparative studies. That is why the choice was made to opt for reference studies instead of a case study to explore the "how" of the various implementations.
In this, the extent of ecosystem services researched has also been limited for workability.

Further, the notion of the "just" or "fair" city is hinted at in the project, but the implementation, focuses more on the creation of economic and social opportunities through spatial interventions, instead of public and private incentives.

This is also the case for transportation and the input from practice and stakeholders. While this project acknowledges the upcoming changes in transportation, it continues to work with existing transport modes, while it focuses on walkability, cyclability and the limitation of car ownership proposed in the plans of the municipality. For longer range travel the car will still be taken into account, but more weight is given to the public transit system.

When it comes to the inclusion of stakeholders, this project is mostly limited to the input in provided by the stakeholders themselves, through informal discussions, documents authored by the stakeholders themselves and documents on the opinions of said stakeholders gathered by the municipality of Amsterdam.
In the case of ecosystem services this project has a focus on the potential for regulation of runoff and the potential to regulate high temperatures as these were considered the most important for supporting liveability in the area. Support of native flora and fauna is alluded to in the process, but not thoroughly elaborated, but more held as a collateral benefit of the strategy.


Resilience
Density
Liveability
Ecosystem Services
A high density resilient environment

?

Theory

This chapter lays the foundation for the research, especially regarding the prerequisites for integrating density, liveability and ecosystem services. At the end of each theory paragraph, the guidelines and performance indicators are shown.

Theoretical Framework

In this chapter the meaning of the resilient high-density environment Havenstad is intended to be, is further explored through a literature study. This forms the scientific base for the design strategy proposed in this project. Starting with the encompassing theme of resilience and its meaning for this project, the research proceeds to explore density as a context and its spatial implications. This is followed by the way liveability is understood in this project and the spatial factors that affect it, in particular in regards to a high density environment. Then the various types of ecosystem services are introduced, in particular those that are used in this project in order to increase the liveability. Throughout all paragraphs the way these affect the resilience of the area is explored.

The latter part of the chapter is reserved for the relations between the themes, followed by guidelines identified from the theoretical research and the way these inform the performance indicators for the assessment of the design.

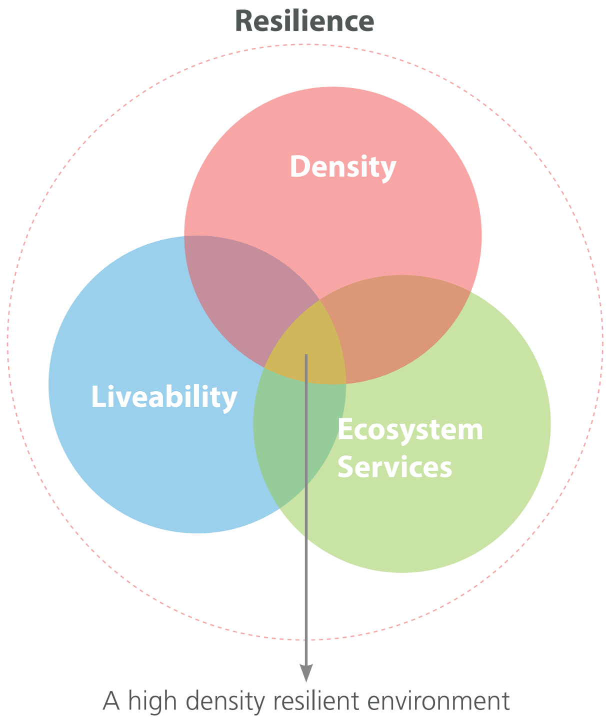
Through this chapter, several of the research questions will be addressed. These are the following conceptual questions:

What is the relation between density and liveability?
What determines high liveability in a high density environment?
How do ecosystem services affect liveability?
What needs to be taken into account when combining density, liveability and ecosystem services?

In addition one of the analysis questions is considered:
How can the various networks, occupations and environmental conditions be integrated to create a resilient environment?

Through this literature review, the guidelines for succesful integration are determined and the performance indicators that can be used for the assessment of the current area and of the design will become clear. The guidelines here are the start of the design patterns.

The image below shows the framework with Liveability, Density and ecosystem services within the definition of Resilience.

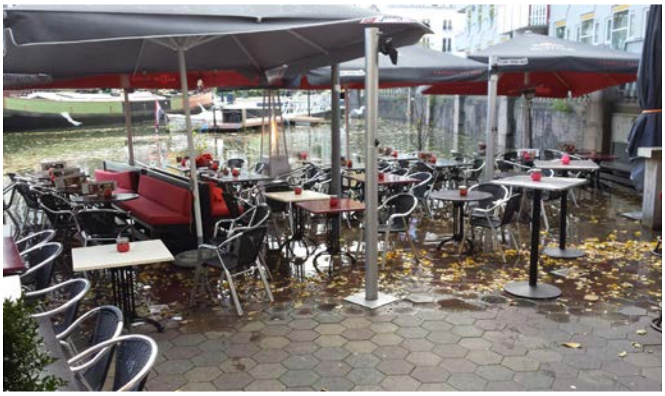


A visual representation of the theoretical framework on which this research and design project is founded.

Resilience

Resilience is the encompassing theme of the project. While at times the term resilience is misunderstood as a particular threshold that protective systems should be able to withstand, the resilience this project refers to is the coping capacity in the event of system failure.
This means that it is not about raising or broadening dikes to avoid failure, and consequent flooding, or installing air conditioning systems to avert heat, but rather the aftermath. The definition here originates from the 100 Resilient Cities effort initiated by the Rockefeller Foundation. Here the focus is on the impact of such an event, and the capacity of the system to recover after the systems fail (100 Resilient Cities, 2018). It is important to note the starting premise: such an event may take place.

Therefor much of the effort is guided towards not just resisting the calamity, but towards adapting to it and facilitating evacuation when necessary.



A terrace at Oudehaven in Rotterdam, during tidal flooding from the Maas in 2017. An example of manageable flooding.

Therefor much of the effort is guided towards not just resisting the calamity, but towards adapting to it and facilitating evacuation when necessary. A three-layer approach of resistance, adaptation and evacuation emphasises allowing for the continued functioning of the area, adding hierarchies of importance depending on the function. This approach has become more popularized after various hurricanes caused large scale damage in the cities of New Orleans (Hurricane Katrina) and New York City (Hurricane Sandy). In the Dutch context climate resilience mostly focuses on the changes in precipitation patterns and the rising sea levels, along with the increased incidence of high temperatures mentioned in the problem field. Therefor a coping strategy is required (Klok L., personal communication [lecture notes], 2019, september 13), for when circumstances exceed the system's capacity.

Diprose argues that shifting the responsibility from those causing the climate crisis to the communities to be affected by it is inherently unfair as it relieves the state from the responsibility of protecting and caring for the population, directing the focus towards personal coping capacity (2015). She further argues how resilience is used to defer fundamental changes to the existing system, while further cementing social and spatial inequalities. This being due to the fact that the choice between resistance, adaptation and evacuation correlates with the perceived value of the area.

In this the perceived need for resilience also affects the acceptance of an approach to create resilient communities. Ogunbode et al touch on this subject in their research on the resilience paradox (2019). Here the willingness to adapt or accept high investments to increase the community's protection seems negatively correlated to the perceived risk and

Bluntly said, the more resilient or protected the individual, the less likely they seems to consider community measures necessary.

Tourists in Venice during a flood. Photo Slavoj Žižek
An example of unmanaged flooding with normal activities are severely affected. Here the tourists present a form of individual resilience by going on through the situation.

the personal coping capacity.
Bluntly said, the more resilient or protected the individual, the less likely they seem to consider community measures necessary. Such suggests that additional efforts are required to increase the viability and effectivity of a resilience approach, with special attention to the potential external benefits.

Although the approach focuses on the response of the city to both long term stresses and sudden disruptions, the capacity to recover from crises and protect its inhabitants and environment seems connected to the economic opportunities for the city. (Batten, 2015)

It is not only important to focus on the coping capacity and recovery strategies, but to ensure the interventions are perceived as valuable when no such crisis take place, in the form of a resilience dividend (Rodin, 2017). Stimulating proactive interventions to prepare for such events and alleviate chronic stresses, then offers the opportunity to provide additional benefits for the area.

It is not only important to focus on the coping capacity and recovery strategies, but to ensure the interventions are perceived as valuable when no such crisis take place, in the form of a resilience dividend (Rodin, 2017).

Considering the effect of long-term stresses and sudden shocks on the city's resilience, this project identifies the environmental challenges as sudden shocks, while mobility and population growth are here considered long term stresses. This informs the principles of resilience that are guiding within this project.

In this Resilience is a process of constant adaptation, rather than a particular threshold, as stated by Batten (2015). The principles of the adaptation strategy towards resilience in the definition of the Rockefeller foundation (ARUP, 2014, p.5) are as follows:
Reflectiveness
Flexibility
Integration
Robustness
Resourcefulness
Redundancy
Inclusivity
Given the scope and the limitations of the project, the principles included in the research are resourcefulness, integration and a combination of robustness and flexibility. Resourcefulness is reflected in the opportunistic approach towards the area and the present systems and functions. What can be done with what is already present in the area? Integration is reflected in the approach through the different layers and corresponding stakeholders within the the project, reflected in the desire to combine functions. Robustness is reflected in the introduction of the block performance as a tool to gauge the effectiveness of interventions as well as allowing insight for the area's stakeholders, the flexibility herein lies in the fact that block performance allows for more flexibility than the normative functionalist approach showcased in the AUP and the Bijlmermeer.

In this project the approach to achieve the creation of a resilient urban environment is based on the integration of high density, high liveability and ecosystem services and the use of the t=2 years return period for precipitation (60mm in one hour) and heat as the threshold for the adaptation measures.

The return periods of flooding and heat events also determines the type of spatial intervention that will be applied.

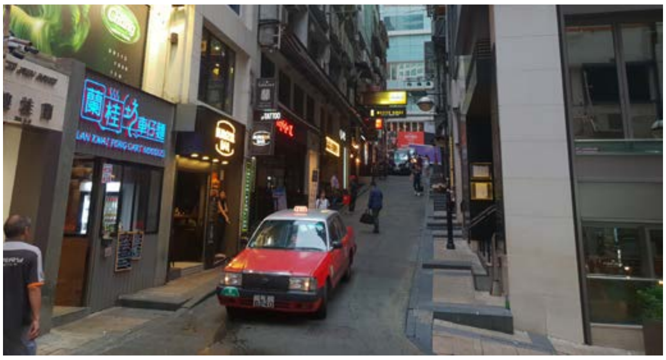
Guidelines for the design:

- Designate a hierarchy of protection, with the effects of failure spatially designed to improve the situation when there is no calamity.
- Be resourceful, by treating possible complications as assets for the development, rather than as impediments.
- Focus on the integration of different layers as an opportunity for new applications within the same space. Multifunctional solutions are the goal.
- Create robustness in the system by allowing insight in the performance while allowing for adaptability.

Density

Considering the location, in this case within the Netherlands, the local understanding and perception of density is one that needs to be taken into account. As mentioned in the introduction chapter, this perception tends to be more negative and new developments have generally been of a low density as a result.

The local perception ranges from high density being considered a non-Dutch phenomenon (Hemel, 2016) to describing it as a challenge to liveability (Cobouw, 2018). This is often accompanied by the impression that accommodating high density environments requires building skyscrapers. However, that is not necessarily true.



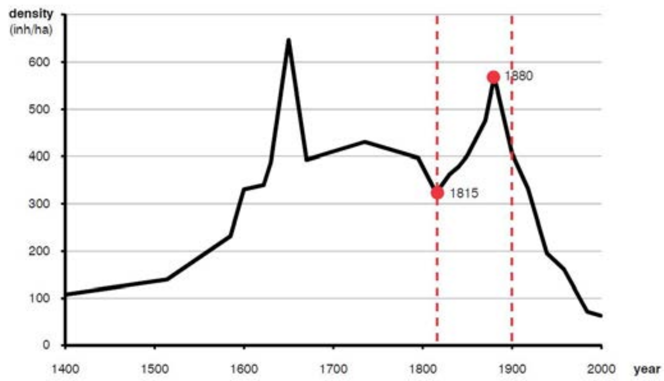
A street in the midlevels of the Central district in Hong Kong in 2018. An example of the perception of density being non-Dutch.

Perpetuating this misunderstanding is not without risk, considering the need to reduce resource consumption, with higher densities being strongly related to lower resource consumption (Owen, 2009), as well as accommodate an increase in the number of dwellings. To actually fulfill the desire of limiting greenfield development a shift is warranted.

To actually fulfill the desire of limiting greenfield development a shift is warranted.

First let's start with the perception that high-density are inherently alien to the Dutch context. When we look at the history in the city of Amsterdam, it is visible that the overall density has been considerably higher in the past, with the graph to the right showing the development of population density per hectare throughout the city.

This being particularly the case in the areas predating the Woningwet, or Housing act. This act, passed in response to the overcrowding in the



Population density in Amsterdam 1400-2000. *Space, Density and Urban Form* (p.33), by Berghauser Pont, M.Y.; Haupt, P. A., 2009, Delft, The Netherlands: TU Delft. Copyright 2009 by Berghauser Pont, M.Y.; Haupt, P.A

This graph shows the development of the population density in the city of Amsterdam, while highlighting several peaks (such as the golden age) and valleys (such as the Napoleonic wars and their aftermath). The last peak being the year the woningwet, or Housing Act was instated.

city and the deplorable housing conditions of the labour force, enabled cities to take an active role in the development of housing and their citizens living conditions. (Andere Tijden, 2000)
As low liveability was one of the reasons for passing this law, the rapid decrease in density seems to cement the perception that density limited liveability considerably.
However, this also raises questions regarding the continued validity of the perception that density negatively affects liveability. By assuming

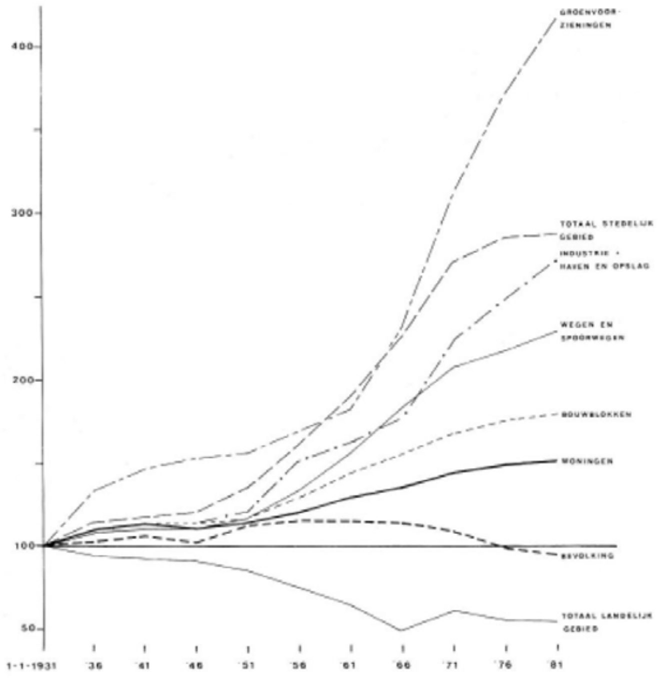
By assuming this is a strong negative correlation one neglects the influence that can be attributed to the vast improvements in hygiene, the changed land use patterns and increase in public amenities through the enactment of the Housing Act.

this is a strong negative correlation one neglects the influence that can be attributed to the vast improvements in hygiene, the changed land use patterns and increase in public amenities through the enactment of the Housing Act.
While the neighbourhood of the Pijp already had a considerable decrease in population density considered to the Jordaan neighbourhood, a

decrease from over 1000 inhabitant per hectare to an average of 700 inhabitants per hectare (Berghauser Pont & Haupt, 2009, p. 42), the population density in Berlage's Plan Zuyd was still high at 315 inhabitants per hectare. All of which wildly exceed Ebenezer Howard's garden cities with a proposed density of 75 inhabitants per hectare (Berghauser Pont & Haupt, 2009, p. 39).

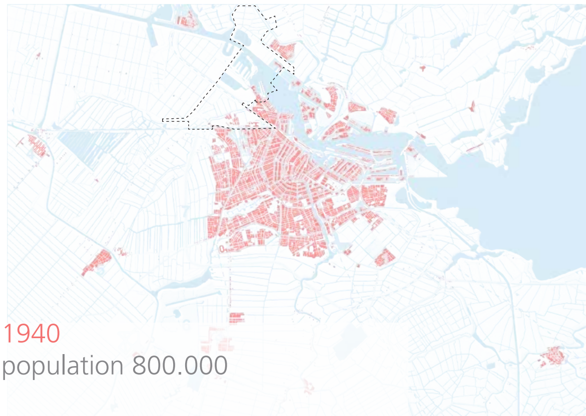
The cities' new mandate, together with changing lifestyles, triggered multiple changes in the ground use of the city. This new mandate had a strong spatial dimension, with the functions of public space and the building block being more strongly represented, each requiring their own share of the available space.

Interestingly, the various iterations of the city of the future, were designed to accommodate higher densities than what is currently the case, largely due to the aforementioned decline in household sizes. Berghauser Pont and Haupt argue that 70% of the increase is space consumption per capita can be attributed to this (2009, p. 47). In the drawings below this increase in built area, along with a decrease in population is visible.
The calculations supporting the AUP, were based on a household occupation exceeding 3 by the year 2000 and a dwelling density of 55 to 70 dwellings per hectare, resulting in a population density ranging between 181 and 231 inhabitants

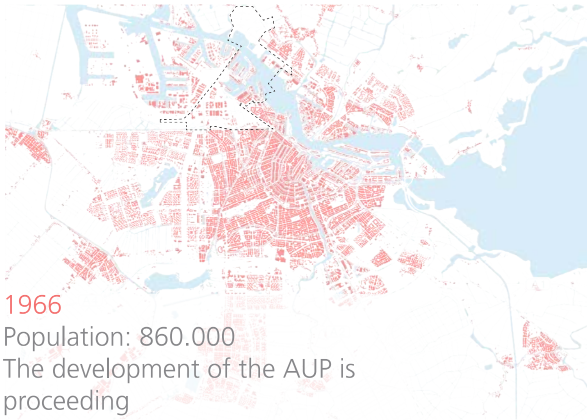


Relative growth of land use in Amsterdam 1931-1981 (1931=100) (Hellinga & de Ruijter 1985: 128). *Space, Density and Urban Form* (p.47), TU Delft, 2009, Delft, The Netherlands. Copyright 2009 by Berghauser Pont, M.Y.; Haupt, P.A

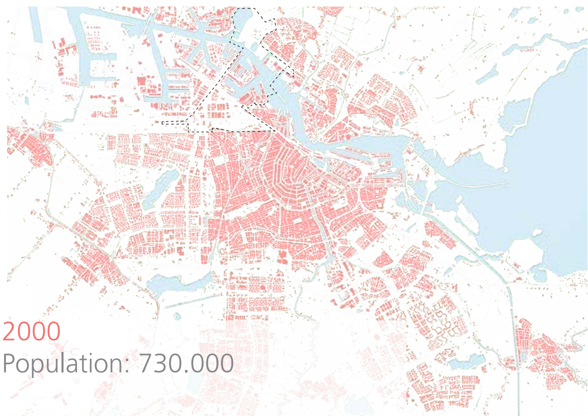
This graph shows how land use in the city has evolved, with functions like green space, industrial areas and road networks making up a growing proportion of the land area.



1940
population 800.000



1966
Population: 860.000
The development of the AUP is proceeding



2000
Population: 730.000

These maps are adapted from the Groeikaart van Amsterdam (Historisch Museum Amsterdam and Haartman, 2000). In these maps the outline of the plan area of Havenstad has been added.

per hectare. While this would have allowed for a capacity of over 900.000 inhabitants for the city, the population declined and the projected population density was never reached (Berghauser Pont & Haupt, 2009, p. 39). Instead, partly due to increasing home sizes as a consequence of economic growth, a dwelling density of 45 to 60 dwellings was reached, with an occupancy rate of 1,98 in the year 2000, allowing for a population density between 79 and 119 inhabitants per hectare.

The Bijlmer, on the other hand, was planned for a dwelling density of 44 dwellings per hectare with a resulting population density of 112 inhabitants per hectare. Both remain below the population densities in the Plan Zuid (over 200 inhabitants per hectare) and the Pijp (over 250 inhabitants per hectare).

Therefor population density or the density of dwellings seems to be a less useful metric for the performance of the area by themselves. This being as they can have widely different spatial manifestations.

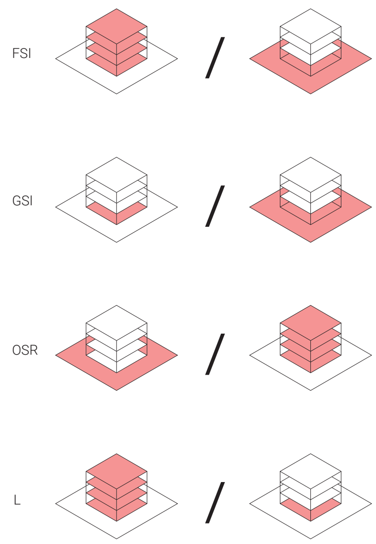
This means that to better understand density and it's poteTo better identify the spatial density of the built area, the floor space index (FSI), layer (L), ground space index (GSI) and open space ratio (OSR) as used by Berghauser Pont and Haupt (2009) are used in this research.

Here the FSI shows the amount of built space in relation to the footprint, GSI shows the share of the area that has been built upon, L the number of floors and OSR the ratio of the area that has remained unbuilt in proportion to the realized floor space.

In addition to the quantifiable spatial dimension, density also has a functional dimension. This can be seen in the more quantitative Mixed Use Index (MXI) developed by Van den Hoek to define the functional density (2008)

The perception that high density and high liveability are unreconcilable continues in the current debate about desirable densities in the Dutch context. Although Unwin argued against sprawl (2013), denouncing its effect on the identity of the city and the landscape, the perception of density is also one of the main arguments for horizontal expansion of the built area. (Cobouw, 2018)
These, however, are being challenged in publications such as Metro Mix (College van Rijksadviseurs, 2019) and Panorama Nederland (College van Rijksadviseurs, 2018).

With understanding density being the first step in dismantling the perception that density inevitably leads to a lower liveability, it is time to explore the ways these are connected.



How to calculate the various density indicators using the spacematrix approach by Berghauser Pont and Haupt (2009)

Guidelines for the design:

- Population density and amount of dwellings can be used when the spatial density and dwelling size has been determined.
- A higher adaptability may lead to a higher MXI.
- The spatial density is defined according to the indicators from the research of Berghauser Pont and Haupt.
- The functional density is defined using the MXI developed by Van den Hoek.

Performance indicators for the design:

- Population density
- FSI
- GSI
- OSR
- L
- MXI

Liveability

To better understand the relationship between density and liveability, it is first important to create a clear understanding of the meaning of liveability and the factors that influence it. Otherwise the effect of increasing of decreasing density can not be determined.

Considering the concept of liveability is given a high importance in planning and urban development, it is surprisingly ill defined. Among the widely used definitions, one can find the Economist's so-called Global Liveability Index (2018). This index uses several categories to determine liveability, being safety, stability, education, culture and environment, and infrastructure. As this research Is concerned with the spatial factors it could be argued that the spatial factors affecting liveability are mostly the latter two.

When moving towards a clearer understanding, the research of Ruth and Franklin offers a clear distinction into roughly two main dimensions. Here one is considered to be the demands of the population, or their needs and desires, while the other part is the environmental dimension. (2014) The environmental factor here refers to the influence of both the city's natural environment and the infrastructures. The needs and desires reflect the complexity of addressing both objective and subjective values in the city. The objective component being a definition like the ones

When looking at the spatial factors affecting density and liveability, it seems clear that an increase in spatial or population density will affect the liveability as infrastructures and the natural environment become more burdened, potentially lowering the liveability.

presented in the Economist's report, and for which clear spatial conditions apply.
That leaves the subjective component to be defined. There it seems to depend on various characteristics of the person interviewed. Socio-economic conditions come into play here as well as cultural expectations and experiences (Churchman, as referenced in Berghauser Pont & Haupt, 2009, p. 72).

Where Ruth and Franklin make a clear distinction between needs of the citizens and their desires, they also mention the difficulty in making a distinction between the two. There are two components, however, that seem present throughout the theory, being the environment and accessibility.

In a different research, Gough looks at the relationship between sustainability and liveability and also mentions the importance of affordable housing, transport options, economic competitiveness and support to existing communities (U.S. Environmental Protection Agency: cited in Gough 2015, p. 150). Due to the limitations of this project, the factors support to existing communities and affordable housing have not been included in the further research.

When looking at the spatial factors affecting density and liveability, it seems clear that an increase in spatial or population density will affect the liveability as infrastructures and the natural environment

Due to the subjective nature of the perception of liveability, the performance of the built space needs to be responsive to the existing and future users and inhabitants.

become more burdened, potentially lowering the liveability. Both accessibility and the quality of environment will then strongly be affected.
Where an increase in population density may translate into an increased pressure on open space, an increase in the spatial density inevitably leads to a lowering of the OSR, the indicator for the availability of open space, depending on the building land cover. By resorting to infill development, current and future liveability can be at risk due to the reduction of available public and open space. This is further argued by Pauleit et al as they discuss the effects of densification on the spatial composition (2005), among which an increased risk to the liveability.

To counter this, there is a need for a strong performance of the design. The success of the design relies on its performance, with objective performances being spatial configurations and the subjective performances being the values and affordances (A+T Research group, 2015, p. 137) Due to the subjective nature of the perception of liveability, the performance of the built space needs to be responsive to the existing and future users and inhabitants. This could potentially even allow for qualities like a specific identity for the neighbourhood to develop, addressing the lack of identity mentioned by Unwin. (2013)

The objective performances of different spatial configurations allow for different combinations of functions and therefor different levels of economic opportunity, hence affecting the potential densities further.

When it comes to the subjective performance, Gehl (2013) offers considerable information on the spatial conditions that allow for the perception of liveability. Here the types of interaction and overall use of public space seems strongly dependent on the perceived quality of the space.

In his book Cities for People (2013, p. 21), Gehl argues that the use of public space is strongly dependent on the physical quality. In doing so he divides outdoor activities into necessary activities, optional activities and social activities. Where necessary activities take place regardless of the physical quality, the presence of optional activities and/or social activities is strongly dependent on the quality of the space.

If we elaborate on this, a distinction between spaces and places becomes identifiable. Here the latter possess identities, histories and allow for various different behaviours, while the former can be designated non-places, deprived of said histories, identities and social value. (Hajer & Reijndorp, 2001, p. 48).
In their work Hajer and Reijndorp continue by stating that the meaning of the public domain lies

If we identify the potential for social and optional activities alongside that of necessary activities, a distinction can be made between spaces and places

with the connection of diverse groups to a space and the meaning it has to different identitities (2001, p. 42). This view aligns with how Nefs et al value a strong recognisable identity of growing importance to the attractiveness of the city (2016, p. 26).

When locating these so-called places Hajer and Reijndorp describe the areas where citizens still interact considerably with fellow citizens, although these are often areas not considered public spaces in the classical sense of the term, but rather commercial and transit infrastructures such as airports, train stations, shopping centres etc. (Hajer & Reijndorp, 2001). These spaces, designed for what Gehl refers to as necessary activity have become the places that transcend group identities.

A secondary shopping street in the city centre of Cologne in 2019. This is the example of a space that is designed to allow for social and optional activities such as strolling interacting with others and of course travel.

City redevelopment in the city of Shanghai in 2018. Here one form of spatial density, the lowrise neighbourhood, is removed to make place for a different typology, that of the commercial and/or residential tower. One could question what the effect on the use of public space will be.

Where Hajer and Reijndorp (2001) focus on the potential quality these places hold as places, Gehl (2013, p. 28) adds the argument that meeting people from different parts of society is considered key to crime prevention and De Hoog (2013) continues by adding the importance of clustering cultural and knowledge functions near such spaces to increase interaction between institutions, users, commerce and the public.

Here liveability seems to have a strong connection with accessibility as well as with a functional density and it alludes to particular requirements regarding population density. Illustrating this point, Berghauser Pont and Haupt compare the arguments of both Lozano and Jacobs for bandwidths of population density to allow for an acceptable liveability (2009, pp. 167-168). Here Lozano argument is for two different bandwidths, one being the bandwidth for community life (40-260 inhabitants or 20 to 130

So, the risk of a lowered liveability due to higher pressure on the open and public space requires a strong design to balance the loss in the OSR.

dwellings per hectare) and the other one allowing for more urbanity starting at 260 inhabitants per hectare. Jacobs' argument on the other hand starts at a higher threshold for urbanity, aiming for 350 to 700 inhabitants or 175 to 350 dwellings per hectare.
Interestingly their arguments for opposing even higher densities are directed towards different effects on liveability, with Jacobs citing a resulting lack of diversity and Lozano mentioning insuffient open space and mobility and privacy concerns (as referenced in Berghauser Pont & Haupt, 2009, pp. 167-168).

Coincidentally neither of the city of the future iterations currently reaches the density Jacobs' deems necessary for the development of urbanity, and all are located between the bandwidth Lozano describes for community life. The strong separation of functions in the latter two, one through circumstances and the other deliberately planned, did not help the situation either.

Hemel (2016, p. 37) adds to this by saying that a long lasting focus on order, limits, clarity, green space and transparency etc, at the expense of city attributes such as layering, complexity, density and spontaneity, is to blame for the severity and prolongation of the European economic crisis of the 1970's, as the urban qualities allow for greater resilience.
He mentions the activism of Jacobs' amongst others against what was perceived to be an attack on the intrinsic values of the city: density, diversity, complexity and centres of social and economic life, exactly what Gehl (2010) refers to as qualities required for optional and social activities. Hemel here mentions Jacobs' argument that a diverse

The aptly named tunnel/bridge Woestenij or Wasteland, near Eindhoven station in 2018.
Conceived as a solution to the conflict between active mobility and the automobile near Eindhoven train station. Although a the conflict has been resolved, the resulting spatial quality of the route discourages optional activities or social activities, resulting in a non-place.

"ecosystem of local businesses" is a prerequisite for sustained economic success in the city. The development of the city is then to be considered an effect of ongoing differentiation of the local economy, and controlling the growth would then be counterproductive(Jacobs as referenced in Hemel, 2016, pp. 79-81).
Meanwhile, the risk of a lowered liveability due to higher pressure on the open and public space requires a strong design to balance the loss in the OSR. Considering the value of space for the city increases, this may require a reconsideration of the allocation of public space, e. g. traffic versus recreation, and the functions it accommodates. Shifts such as pedestrianisation of areas and the creation of new parks and promenades on former roads then allows for more optional and social activities.

The way density and accessibility are related determines the type of living environments that can be realised, and the ways space can be allocated. This is especially the case considering functional density and spatial density as different functions have different mobility needs and the spatial density determines the available space. When high density is pursued without a high accessibility as well, the losses on the available open space per person might not be balanced by sufficient gains.

One of the elevated walkways at Pudong, Shanghai in 2018
Here the conflict between pedestrians automobiles has been used to create a totally new elevated infrastructure that functions as a place as it not only connects different buildings, but also allows for optional and social activities as part of the identity of the Pudong district.

Considering the need for social and optional activities in the city, one could then argue that higher densities, such as those argued by Lozano and Jacobs would be beneficial to the overall liveability, as long as the spatial design stimulates social activities and optional activities, as well as taking different mobility needs into account.

When looking at accessibility and level of infrastructure, the functional density needs to be combined with the spatial density and the performance of the infrastructure. Thankfully, a method to connect spatial density to accessibility through the existing infrastructure already exists. This so-called Space Syntax method (Al-Sayed et al., 2014) combines spatial density with the available transportation routes, e.g. the streets to produce an analysis of the accessible density and the expected use of infrastructure. Here the potential for economic opportunities becomes apparent, as the expected traffic increases in higher densities.
This tool was further used by Van Nes et al. in their research into Rotterdam South (2012), in which the combination with the MXI was used to determine the opportunities for densification in relation to liveability. Here people's access to amenities and commercial establishments is proven to be crucial to allow for additional densification. The amenities need a large enough customer or user base in order to be successful and they typically require access to a larger customer base than that in the direct environment (Berghauser Pont & Haupt, 2009, pp. 167-168).

An integrated approach of both infrastructure and density therefor allows for an increase in accessibility and economic opportunity, thereby raising liveability. Through this the potential for densification and the requirements for densifying an area become clear.

Here the subjective needs for a high-quality environment that invites walking and forms of interaction along the way, may seem at odds with the objective need for accessibility, leading to various conflicts in the planning of public space, most notably that between automobile space and pedestrian or cyclist space. The way this conflict plays out has profound effects on the resulting liveability in the area and affects the potential functional density, population and spatial density.

Looking back at the challenges the area is facing with regards to housing needs and a mobility as well as the responsibilities for the climatic challenges, a strong shift towards collective and active transport is preferable.

Not only does car mobility consume a large amount of space, limiting the potential space for recreation, interaction etc, it also is not the most efficient mode of transport within the city. Berghauser Pont and Haupt state that when the reachable ground area is considered, and we look at that within half an hour's reach of the pedestrian (20km2), the cyclist (175km2), public transit (150-400km2) and the car (700km2), it could be argued that the car is the best option. While doing this, however, they also point to the effects car dependence has on the potential

density of the area (it requires large amounts of space), showing that the amount of floor space that can potentially be reached is significantly higher in a high density transit and active mobility focused environment. (2009, p. 171)
Low density environments on the other hand may remain dependent on car mobility as the catchment is often insufficient for public transit and the reachable floor space by bike and by foot. Here the distance deemed acceptable once again depends on the spatial quality (Gehl, 2010, p.121)

If we take resource consumption and transport capacity into account, then pedestrians and cyclists yet again outperform car mobility. In terms of resource consumption for an equal distance cars consume 20 to 60 times more respectively. (Gehl, 2010, p.105) In terms of capacity of the space, the differences are even more pronounced. Where 7m of pedestrian space can accommodate 20.000 people an hour, 4 m of cycling lane can accommodate 10.000 people an hour, while the equivalent of roughly two car lanes is limited to 1000 to 2000 vehicles an hour.

Considering the need for social and optional activities in the city, one could then argue that higher densities, such as those argued by Lozano and Jacobs would be beneficial to the overall liveability, as long as the spatial design stimulates social activities and optional activities, as well as taking different mobility needs into account.

When it comes to how the spatial design could contribute to a high-quality environment that allows for a high liveability, we can take into account the arguments presented by Lozano and Jacobs (as referenced in Berghauser Pont and Haupt, 2009) considering the provision of amenities, green space, diversity, accessibility and privacy.

While green space can be measured as a part of the OSR, amenities can be determined through the MXI and the network performance in space syntax, the diversity can be determined in part through the FSI and the MXI and the accessibility can be determined using space syntax, the privacy is somewhat unclear still.

In this research this is taken to mean the transitions between public and private space, as they have a profound impact on the use and legibility of said space, as well as the behaviour there. Gehl (2013) here invokes the importance of what he refers to as "edge space", being the area between the private and the public, for the perception of the quality of the space, as well as for the amount of interaction in this zone. Here again density seems to be a threshold for the development of this interaction (Gehl, 2013, p. 83). The presence, or absence, of a soft edge space seems to have a strong influence on the perception of the area and the corresponding outdoor activities.

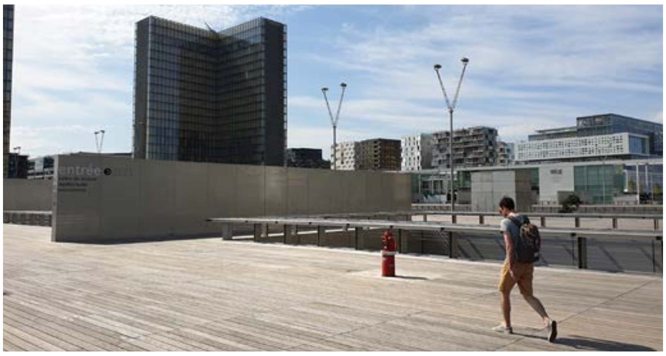
How edges are experienced and the type of interaction for which they allow is strongly connected to the senses. This has implications for the way this edge zone, and with it the spatial quality, can be perceived. In the vertical dimension the communication between the ground level and other levels seems to be limited to the fifth floor, with the first two floors allowing for a strong

The Bouwpub at TU Delft faculty of architecture in 2017. An example of an environment that allows for optional activities and social activities, due to the connection of functions and space design.

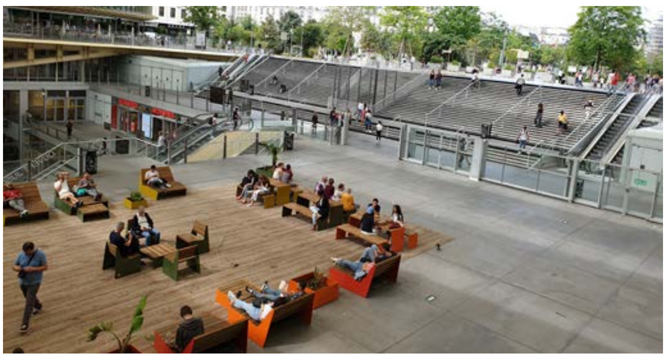
Vertical layering of the edge zone in Wuhan, China 2018. Through the layering of density in public space, the space remains legible and interaction with the lower floors of the buildings remains possible.

connection. (Gehl, 2010, p. 42) When it comes to elevated plazas or walkways he argues spatial quality has to be such to warrant the expense of moving vertically (2010,p.132)
In addition to this people also have certain requirements with regards to the amount of space that is available to them. For optional activity and social activities there must be the space to interact as well as the opportunity to avoid interaction by manoeuvring the distance between one another. (Gehl, 2010, p. 49)

The design of the edges seems comparable to the privacy zoning more clearly explored in the work of Van de Wal et al (2016), in which they explore the effect of architecture on the privacy zoning in residential buildings. The various steps in this research are that of the public, the communal, the collective and the private, representing the sequence of space in the building. Combining this definition with that of the proposed qualities for the "edge space" this research defines the privacy zoning as follows: public, semi public, semi private,



The National library of France, in Paris 2019. An example of how overdimensioning the public space creates a space with few social and optional activities.



Forum les Halles in Paris, 2019. Here it is clear how attempts have been made to break down the large space in the building in order to stimulate optional and social activities.

communal, collective, private. Here different degrees of overview are needed.
Designing quality space then not only relies on the variety of function, form and the edge space, but also requires attention to the human scale. Here the space should not be too small to not allow for a gradient in interaction, but the space should also definitely not be dimensioned too large, as that has a negative effect on the perceived suitability for social and optional activities.(Gehl, 2010)
Finally, connecting accessibility to density in an integrated way through Space Syntax and the MXI allows for a densification that also increases the liveability. Through connecting the spatial performance, the functional density and the infrastructure, it becomes possible to determine where an increase in density would be beneficial to the liveability and where it would require a change in the infrastructure.

Guidelines for the design:

- There are minimal densities for the presence of a number of amenities.
- The likelihood of optional and social activities is determined by the perceived quality of the space.
- To reach the potential liveability of a higher density, accessibility and spatial quality are paramount. This requires a reevaluation of space as car mobility can place a disproportionate burden on the city.
- The spatial quality relies for a great part on the possibility for interaction and therefor on the design of the edge zone.
- The vertical potential for social interaction is limited to 5 floors, with most of it limited to the first two floors.
- The scale of the space must align with its intended use. Do not overdimension space.
- There is a need for diversity of functions and therefor different spatial configurations.
- A higher population density may be better serviced via collective and active transport, although different functions have different mobility needs.

Performance indicators for the design:

- Privacy zoning
- legibility
- pedestrian accessibility
- public transit accessibility
- cyclist accessibility
- car accessibility
- differentiation of qualities
- green space accessibility

Ecosystem Services

> This project operates within the classifications applied by McPhearson, Kremer and Hamsted (2013). They classify ecosystem services in four categories, one being provisioning services, the next being regulating services, the third being support services and the last being cultural services.

In the previous two paragraphs the definition of density and its impact on liveability has been discussed. One of the recurring themes here has been the provision of green space within the city. From Unwin's garden city onward, green space has been considered of great importance for the liveability of the city. It was one of the reasons for the rejection of the closed block in the AUP and for the adoption of the CIAM towers in the park ideals in the Bijlmer. This was meant to be a new public domain, offering the citizenry a place for repose as well as an escape from city life.

It would, however, be too simple to merely see the value of this green space as one for repose, or an escape from city life as the village and later the city have had a profound interaction over the years. In their work De Jong and Moens state that human intervention (e.g. farming) might actually have increased the biodiversity in the Netherlands, as it led to a great variation in the landscape and soil compositions (1994, p. 6).

This reveals a co-dependency between humanity and natural systems. In his work Hemel argues that cities have always had to account for the nature based services such as provision of drinking water, food and sanitation, in addition to having to conceive of innovative ways to adapt to either unfavourable starting conditions, or had to conceive of ways to compensate for the difficulties density and population growth caused. (Hemel, 2016, p.66) The first is visible in the Dutch invention of the polder city (Hooimeijer, 2014), while the second tends to consist of systems for providing food, drinking water and sanitation. In the case of food and sanitation an economic system of exchange developed, with food being transported into the city and human and animal waste being traded to the farms and other lands (Hemel, 2016, p. 52), while local waste served as fertilizer for the local food production in cities like Paris.

The provision of drinking water from the dunes along the North Sea (Hemel, 2016, p. 99) still continues to this day. The dunes in question actually still bear the name "Waterleidingduinen", or water pipe dunes. One could argue that reaching the limits of the local capacity for providing sanitation and drinking water through on the one hand reducing the contamination (sanitation) and on the other hand acquiring it from an external location in a performative landscape (drinking water) is would count as an urban innovation.

A strong reliance on nature-based systems, these so-called ecosystem services has long played an important role in the development of cities, with the need for sufficient water and food strongly motivating followers of the garden city ideal. This was deemed necessary for the survival of the urban poor in particular(Hemel, 2016, p. 54). The main green structures in the AUP with their allotment gardens were a continuation of this line of thought, supplementing the supplies coming in from the countryside. The city that would be limited to a population of 1 million inhabitants (Hemel, 2016, p. 58).

Barthel et al state that cities are dependent on their hinterlands for the provision of their resources, while functioning ecosystems are crucial for the continuation of said services. (Barthel, 2013, p. 11) In this the research echoes Hemel's assertion that cities are the places where innovation towards solutions tends to occur (Hemel, p.66).

This project operates within the classifications

A neighbourhood acitivity in the Poptapark in Delft, 2017
An example of a park fulfilling cultural functions.

A pond in the Jardins Grand Moulin Abbé Pierre in Paris, 2019. This is an example of a park where runoff regulation has been integrated with provision of habitat for biodiversity as well as cultural services.

applied by McPhearson, Kremer and Hamsted (2013). They classify ecosystem services in four categories, one being provisioning services, the next being regulating services, the third being support services and the last being cultural services.

Here provisioning services pertain to food and other resource production, while regulating services largely include pollutant removal and carbon sequestration as well as local temperature regulation and runoff mitigation. Support services are considered the provision of habitat for biodiversity and cultural services are focused on recreation. (McPhearson et al., 2013)
Judging by the development of the city, the focus in development of the city and liveability has largely been on the first and the last of the four.

Considering the value these ecosystem services

Judging from the research to liveability and density, the fate of ecosystem services has mostly focused on preserving and defending landscape elements from development, as their value was not entirely understood or appreciated. At the same time our cities need to adapt to an increase of extreme climatic events, for which current environments are not built to cope.

present for the liveability in and the survival of the city, Barthel et al attempt to connect the value of said ecosystems to the development of the city in their research towards what they, similarly to McPhearson, Kremer and Hamsted term a social ecological approach. (Barthel et al., 2013)

They go on to argue for the creation of a so-called active ground, in conjunction with performative buildings. But would it be possible to expand this thought of performative buildings to the landscape, thereby creating a performative landscape?
Doing this aligns with the the argument Ahern makes, that the position of ecological processes, governing state of landscapes, makes them suitable to assess sustainability through different scales (Ahern, 2007, pp. 268-269).

Pointing to their applicability in urban landscapes, he mentions the lack of connectivity through man made barriers, which threatens the capacity to fulfil what he refers to as abiotic, biotic and cultural functions. (Ahern, 2007, p. 270)

If we try to place them within the categories McPhearson et al presented, we're able to identify to place the abiotic functions in the regulation category as well as part of the biotic category, the latter being part of the support services with their focus on biodiversity. Here Ahern expands on the understanding of the cultural services beyond merely recreation.

Here they add to the quality of space by allowing for different levels of interaction, be it with the ecosystems themselves (either observing the function of systems for education, inspiration or relaxation) or with other individuals.

Ahern then goes ahead to describe the spatial composition of the landscape patterns that allow for various functions, consisting of urban patches, urban corridors and the urban matrix. Here the patch is what is often referred to as the green area, with the corridors being the potential connectors between them and the urban matrix representing the dominant spatial configuration.(Ahern, 2007)
In this a collection of these patterns is considered a prerequisite for an overall strategy.

Judging from the research to liveability and density, the fate of ecosystem services has mostly focused on preserving and defending landscape elements from development, as their value was not entirely understood or appreciated. At the same time our cities need to adapt to an increase of extreme climatic events regarding heat and rainfall, for which current infrastructures are not built to cope, risking the liveability in the area. (Kleerekoper, 2016, p. 64)

This offers an opportunity to shift to a proactive and opportunistic strategy geared towards restoring ecosystem services and allowing for new ones in places where they previously didn't exist. (Ahern, 2007) An additional benefit is then that the available locations for ecosystem services include vertical and elevated systems.
Creating such green infrastructures then contributes to the objective and subjective liveability as it allows for continuation of necessary activities as well as contributing to quality of the space. Some argue that such infrastructure can even be realised at a comparable cost as engineered systems. (Boer F., personal communication [lecture notes], 2019, november 19)

Considering green/blue spaces as part of the performing landscape, offers new ways to organise the urban environment, while allowing for the perception of its function, contrary to common practice where it remains hidden from view, resulting in unexpected conflicts. (Bacchin, Ashley, Sijmons, Zevenbergen, & Van Timmeren, 2014, p. 2) Where Bacchin et al further argue the hydrological

The inner court of the National Library of France in Paris, 2019. Here a forest has been transplanted into the court. While it may provide several ecosystem services, the forest remains largely disconnected from other green spaces as it lacks corridors or clearly accessible stepping stones.

flows, soil type ground water level are important to the design quality (2014, p. 3), Kleerekooper mentions the potential of green and water to manage temperature through the effect on evaporation and heat absorption(2016, p. 96).

Defining the so called climatope (Lenzholzer, 2015) using the spatial density and the present ecosystem services may then help to inform the direction for the design as well as increasing the value of the large scale greenblue structures in the city.

The park around Annenborch elder care building in Rosmalen, 's-Hertogenbosch, 2019. Here the green space not only provides support and regulatory ecosystem services, but it is an important part of the privacy zoning.

Guidelines for the design:

- Embed ecosystem services into areas that currently do not possess them.
- Expand ecosystem services to innovative locations and combinations. This is particularly beneficial in high density environments.
- Embedding ecosystem services within the corridors has a potential to increase the spatial quality while reducing the pressure on engineered systems as well as making them visible.
- Allow for great diversity.

Performance indicators for the design:

- soil type
- soil quality
- soil carry capacity
- ground water table
- water system
- runoff
- retention capacity
- climatope
- vegetation
- ecostructure

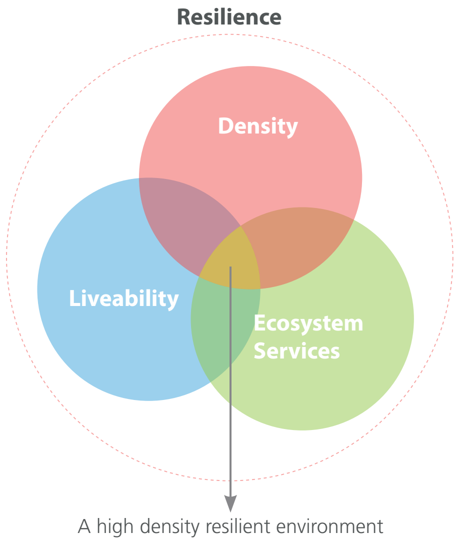
Integration

After investigating the relationship between Density, Liveability andEcosystem Services, the guidelines for a successful design were determined. After bringing them together in this paragraph, they were used to make the first design patterns. As density is rather the context than a design, with it's guidelines being mostly procedural and directed towards the indicators, the patterns that have to do with the effects of density have been assigned to liveability.

In preparation for the development of a pattern language these patterns have all been assigned a code based on the theme they are connected to, these being Resilience (R), Liveability (L) and Ecosystem Services (ES). The reason for this is to later be able to better determine the interdependencies between the patterns.

An example of this would be how a park with wadis and rain gardens includes Resilience dividend (R2), performative landscape (ES3) and runoff regulation (ES6).

The codes of these patterns, as well as the scales they affect has been made visible in the scheme on the following page. Here the degree of abstraction has also been included.



Guidelines for the design (Resilience):

- Designate a hierarchy of protection, with the effects of failure spatially designed to improve the situation when there is no calamity.
- Be resourceful, by treating possible complications as assets for the development, rather than as impediments.
- Focus on the integration of different layers as an opportunity for new applications within the same space. Multifunctional solutions are the goal.
- Create robustness in the system by allowing insight in the performance while allowing for adaptability.

Guidelines for the design (Density):

- Population density and amount of dwellings can be used when the spatial density and dwelling size has been determined.
- A higher adaptability may lead to a higher MXI.
- The spatial density is defined according to the indicators from the research of Berghauser Pont and Haupt.
- The functional density is defined using the MXI developed by Van den Hoek.

Guidelines for the design (ES):

- Embed ecosystem services into areas that currently do not possess them.
- Expand ecosystem services to innovative locations and combinations. This is particularly beneficial in high density environments.
- Embedding ecosystem services within the corridors has a potential to increase the spatial quality while reducing the pressure on engineered systems as well as making them visible.

Guidelines for the design (Liveability):

- There are minimal densities for the presence of a number of amenities.
- The likelihood of optional and social activities is determined by the perceived quality of the space.
- To reach the potential liveability of a higher density, accessibility and spatial quality are paramount. This requires a reevaluation of space as car mobility can place a disproportionate burden on the city.
- The spatial quality relies for a great part on the possibility for interaction and therefor on the design of the edge zone.
- The vertical potential for social interaction is limited to 5 floors, with most of it limited to the first two floors.
- The scale of the space must align with its intended use. Do not overdimension space.
- There is a need for diversity of functions and therefor different spatial configurations.
- A higher population density may be better serviced via collective and active transport, although different functions have different mobility needs.

Performance Indicators

Density performance indicators:

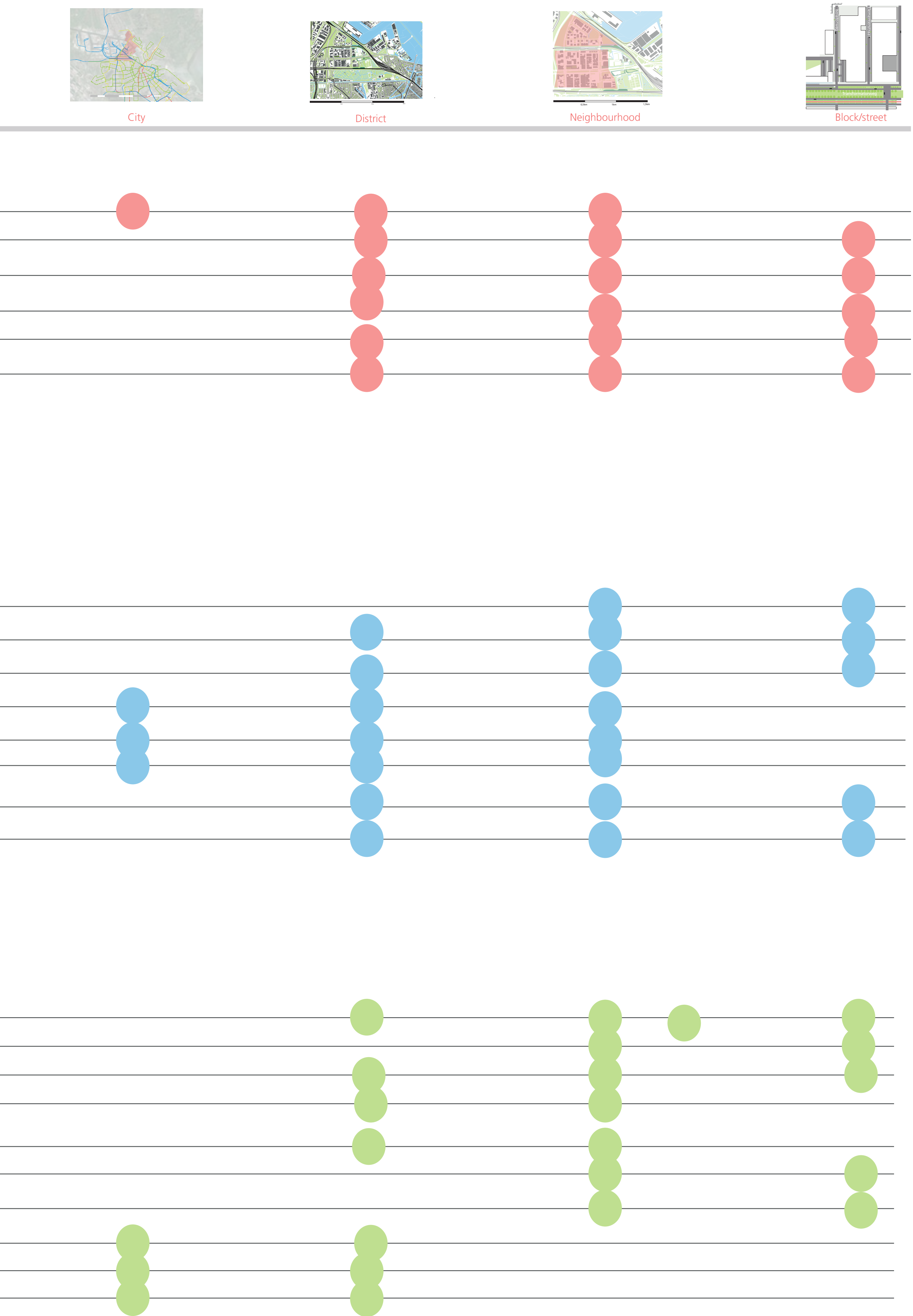
- Population density (quantitative)
- FSI (quantitative)
- GSI (quantitative)
- OSR (quantitative)
- L (quantitative)
- MXI (quantitative)

Density performance indicators:

- Privacy zoning (qualitative)
- legibility (qualitative)
- pedestrian accessibility (qualitative)
- public transit accessibility (quantitative*)
- cyclist accessibility (quantitative*)
- car accessibility (quantitative*)
- differentiation of qualities (qualitative)
- green space accessibility (quantitative*)

ES performance indicators

- soil type (qualitative)
- soil quality (qualitative)
- soil carry capacity (qualitative*)
- ground water table (quantitative)
- water system (qualitative)
- runoff (quantitative)
- retention capacity (quantitative)
- climatope (qualitative)
- vegetation (qualitative)
- ecostructure qualitative)


City
District
Neighbourhood
Block/street

“Impossible isn’t a fact, it’s an attitude.”

Christiana Figueres, Former Executive Secretary of the United Nations Framework Convention on Climate Change

Methods

In thhis short chapter the methods used and the scales at which they operate are shown.

Methods

External input

Over the couse of this research, additional input was gathered from a collection of sources connected to TU Delft and others. The connection to the BNA Stad van de Toekomst research was due to this project starting as part of the Stad van de toekomst Research and Design Studio.

In addition to this input was taken from the Architectuur van de Arbeid series in Het Nieuwe Instituut and the Stad x Klimaat series organised by the BNA.

The input was in the form of discussions, workshops and lectures. Here the Stad van de Toekomst was mostly focused on the integration of many different functions and technologies in a high density mixed urban area, Architectuur van de Arbeid on the interdependency of labour and living in the current city as well as the conflicting situations with regards to their combination.

Stad x Klimaat then focused on the climatic changes that will confront the city with conditions they have not developed for.

Spatial analysis

The spatial analysis of the city consists of a synchronic qualitative analysis to identify spatial qualities that could serve as assets, when using the "opportunistic approach" described by Ahern (2007), in which various natural elements and infrastructures are approached as an opportunity instead of an impediment. Depending on the scale of the analysis, the methods include either mapping, creating sections eventually creating a technical and a functional profile. The layer approach, showing the various layers of infrastructure relevant for the area and their correlation, allows for a better insight in the area, while facilitating determining threats and opportunities to be taken into consideration during the design.

network analysis

The spatial analysis is accompanied by quantitative spatial analysis following the space syntax methodology. Here the variables derived from the literature and the reference study are applied in GIS models of the Amsterdam metropolitan region. An example of this approach is pictured to the right. In this analysis the accessible FSI is shown. The variables taken for density are calculated according to the space matrix approach developed by Haupt et al.(2005) Here GIS models are used to combine various data, such as that concerning density and accessibility. Connecting these to the variables concerning liveability and ecosystem services using space syntax methodology (Al-Sayed et al., 2014) makes it possible to qualify the qualities of various areas.

These qualities are connected to the indicators that are developed in order to on the one hand determine where the highest impact can be achieved within the region and on the other calculating the influence of developments on their environment. The results of this analysis are shown in the functional profile. Further it is used to explore the effects of the interventions in the design proposal.

Reference study

The reference study ties in with the literature study through the exploration of different contexts where areas were realised that combine two or three of themes. The reason of this is to see how the literature research and the developed guidelines and patterns compare to the situation of realized areas. They serve as examples of how density, liveability and ecosystem services can be combined, along with their shortcomings or which pitfalls to avoid.

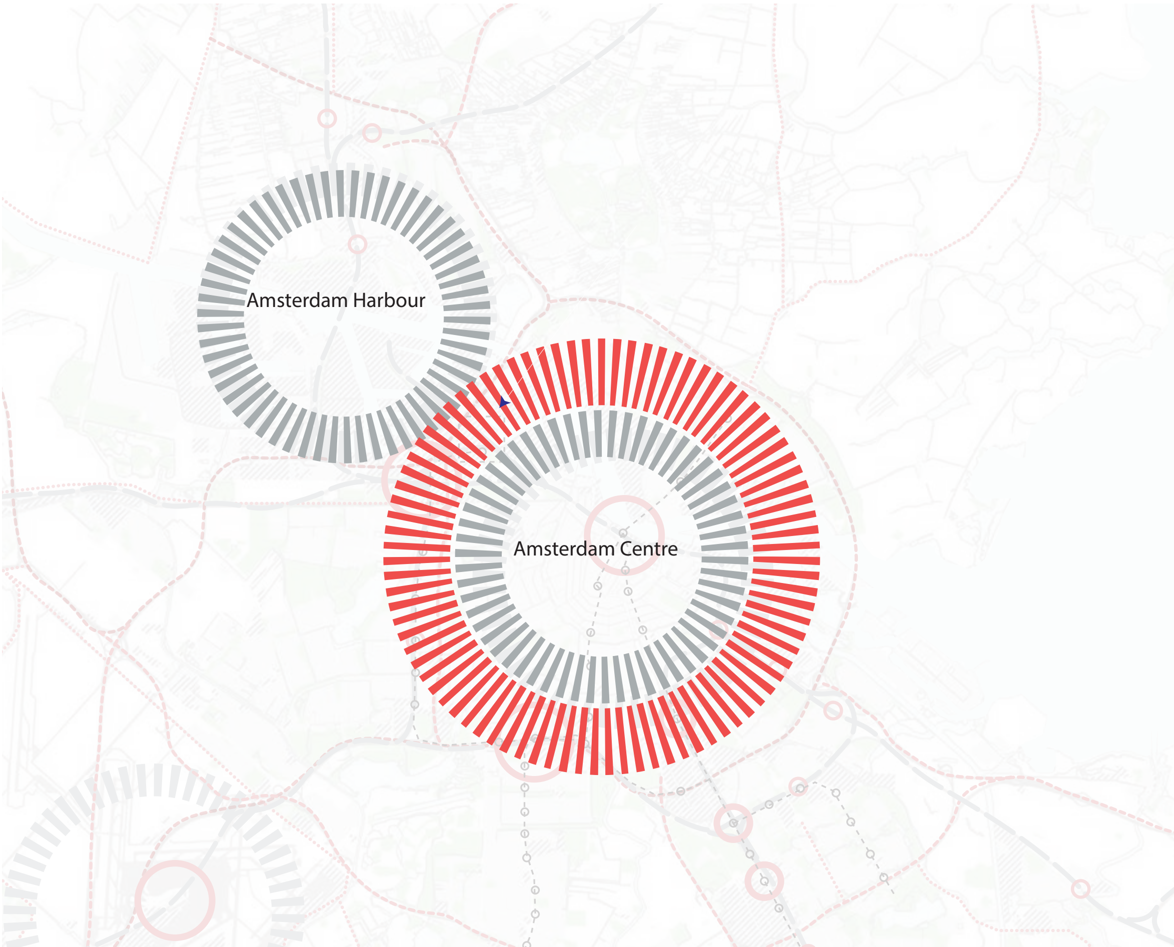
It uses an explanatory reference study to do this. This is based on the approach towards an explanatory case study mentioned by Yin.(2003) This is in order to identify which practices can be exported to the context of the Netherlands. Four cities were chosen for this reference study, one European city and three East Asian cities. The scales which were explored were the district scale, the Neighbourhood scale and the block scale. Each time the choices that were made for the realization of the areas and their effects on the result are shown.

The Asian cities were chosen as they have valuable experience regarding high density environments, of which there are considerably less in the western context. Here the result is to build on the innovation from these contexts, echoing Hemel's assertion that smaller cities often apply innovations conceived in large cities (2016, p.82). The European cities were similarly chosen due to their explicit choices regarding the chosen project that have strongly affected the They were further chosen due to their high performance on either liveability, density or the use of ecosystem services.

The cities explored at the scale of the district are Wuhan and Copenhagen, respectively the ErQi and Ørestad districts. The cities explored at the neighbourhood scale being Paris and Hong Kong, with a focus on quartier Masséna and Central. Finally the cities explored at the block level are Singapore and Vienna, here the Landscape in Urban Spaces and Highrises and the Gemeindebau are explored.

Of these cities, the areas in the cities of Wuhan, Hong Kong and Paris were visited either as part of, or prior to this project.

Together with the literature study, this will allow for the development of design patterns and assemblages that could be tested in the Havenstad area.


Amsterdam Harbour
Amsterdam Centre

Analysis

In this chapter the current situation of Havenstad is explored from several angles. first the position within the city and the plans of the city regarding the development of the district are explored, after which the area is analysed through a combination of spatial analysis and GIS research.

The socioeconomic context

This paragraph serves to understand the current state of the city. It mostly consists of a socioeconomic context of the city through graphs, tables and maps picturing the statistical data of the city.

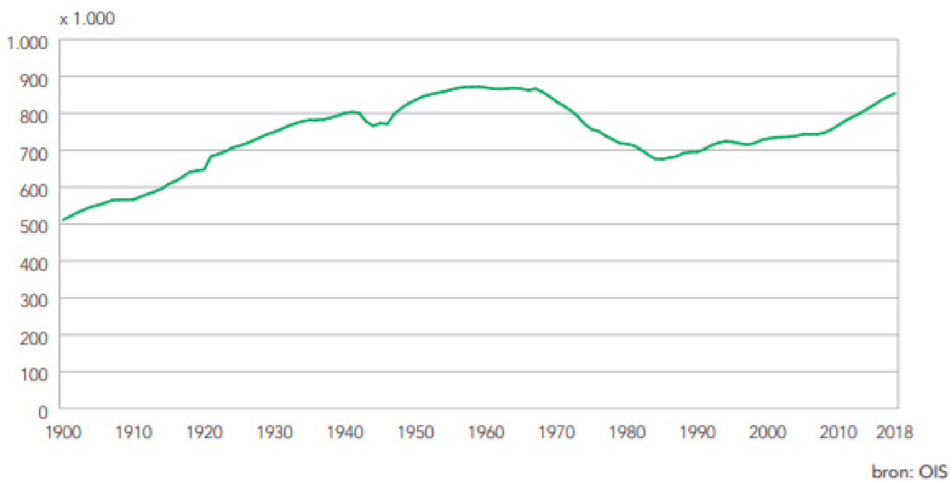
The graph below shows the population size since 1900. It is clear that the city did not continue its population decrease, instead turning it into an average growth averaging 11.000 a year. Soon the city will not only surpass its previous record high population of 879.000 in 1959, but the city is expected to surpass the 1 million mark by 2034. (Metropoolregio Amsterdam, 2017)

The table on the following page shows that the city is not expecting large changes in the composition of the city, even though the population is expected to grow considerably.

The mapped data can be found in Appendix I. When

		prognose		
	1 januari 2018	2025	2030	2035
geslacht				
mannen	423292	458764	474273	485171
vrouwen	431024	464373	481565	494479
totaal	854316	923137	955838	979650
leeftijd (%)				
0- 4 jaar	5,5	5,4	5,6	5,6
5-19 jaar	14,0	13,0	12,4	12,3
20-34 jaar	29,3	30,0	29,5	28,7
35-49 jaar	21,3	20,5	20,9	21,1
50-64 jaar	17,6	17,3	16,4	15,7
65 jaar e.o.	12,4	13,8	15,3	16,6
migratieachtergrond (%)				
Surinaams	7,6	6,6	6,1	5,6
Antilliaans	1,4	1,3	1,3	1,2
Turks	5,1	4,7	4,7	4,6
Marokkaans	8,9	8,9	8,8	8,7
overig niet-westers	12,4	14,5	15,5	16,6
westers	18,0	19,1	19,7	20,5
Nederlands	46,6	44,8	43,9	42,8
huishoudens (%)				
alleenstaand	53,3	53,0	53,5	53,9
samenwonend zonder kinderen	20,7	20,8	20,6	20,4
samenwonend met kinderen	15,9	15,9	15,4	15,2
eenoudergezin	8,8	8,8	8,9	9,0
overig	1,3	1,5	1,5	1,5
totaal %	100	100	100	100
abs.	462584	493134	509348	523941

Demographics prognosis for the municipality of Amsterdam. Source: Gemeente Amsterdam (2018). Amsterdam in cijfers 2018

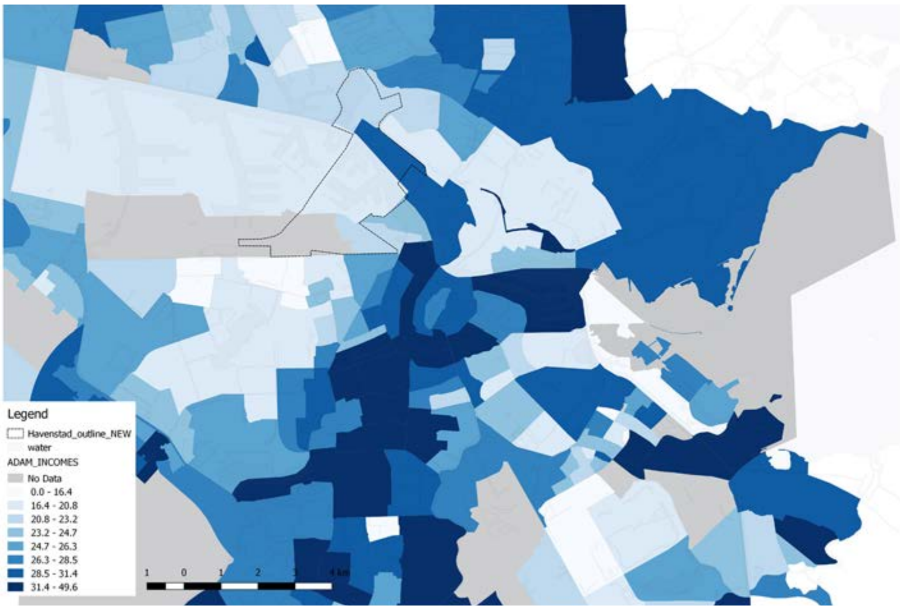


Development of the population size. Source: Gemeente Amsterdam (2018,). Amsterdam in cijfers 2018 mapping this data it becomes clear that the city consists mostly of a working age population, with the percentage of dependents being higher outside the city centre. Also the distribution of density becomes visible, with the highest densities being adjacent to the city centre.

The expected modal split for transportation seems to favour active and collective mobility over private automobility as ownership is low.

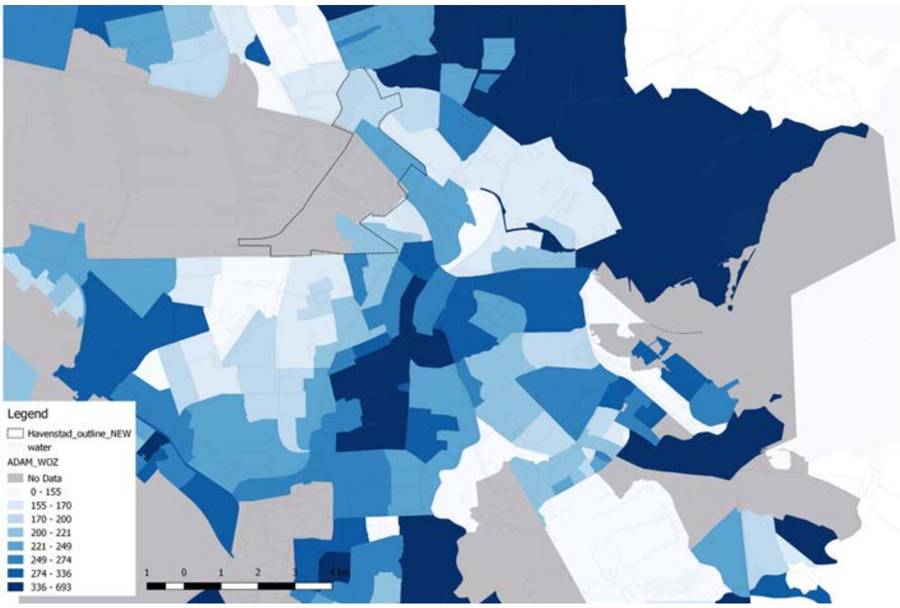
For housing it is important to note that the vast majority of the city's population lives in rental housing. Considering higher property values generally cause higher rents, it comes as no surprise that highest concentrations of the affluent population coincide with the higher real estate values as shown below.

Incidentally many of those neighbourhoods were built either during the industrialisation period.



Average income level per inhabitant in the city
(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

This map clearly shows the division of wealth in the city. Here the areas surrounding Havenstad are shown to have lower incomes.



WOZ- value in thousands of euros
(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

The division in wealth becomes particularly clear through this map, as home values largely correlate to the income levels. Currently the average Dutch WOZ value sits at 230 thousand euros (CBS, 2018), a value already exceeded in large parts of Amsterdam in 2014.

The current citywide level is 340 thousand euros. According to the CBS this is an increase of nearly 48 percent (CBS, 2018).

Havenstad ambitions: Space challenge

The location of Havenstad in the city of Amsterdam. Adaptation of Bing maps.

The development of Havenstad is strongly motivated by the shortage of housing within the municipality of Amsterdam.
The aerial image shown above illustrates that this is not a greenfield development, but consists of adding of an entirely new population of over 100.000 residents to an area that currently serves as a business area.

The proposed construction of the district of Havenstad in this industrial and commercial area implies a large-scale transformation with the potential to displace many businesses.

Following displacement of industrial functions in favour of other functions at Houthavens and NDSM warf, an administrative agreement between various parties was signed, delineating an area within which housing development would be severely limited. A fear for displacement of the businesses led to this so-called 'pas op de plaats convenant' in the harbour area. (Provincie Noord Holland, 2009) This agreement, signed in 2009, would effectively bar redevelopment of most of the area until 2029. In order to allow for a development of the area the

Havenstad with the Pas op de plaats convenant. Source: Gemeente Amsterdam. Pas-op-de-plaatsgebied Amsterdam Retrieved on 03-04-2019 from https://www.amsterdam.nl/projecten/haven-stad/pas-op-de-plaats/

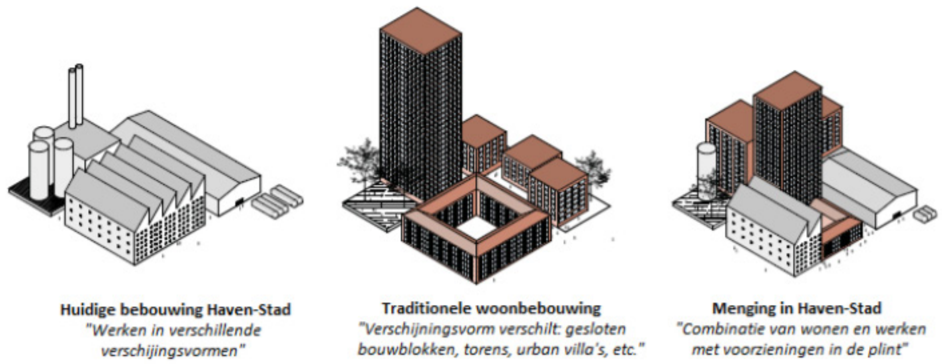
development should allow for coexistence of businesses and dwellings.

The city's wishes to create a mixed environment, thereby transforming the area from a nearly 100% working area as shown by the statistical data in appendix A1, to an area where 20% of the space is dedicated to work places and 80% has a residential function (Gemeente Amsterdam, 2017), could then potentially help towards developing this coexistence.

As for the desired work/residential balance for the district of Havenstad it is interesting to see how the city as a whole compares in the region and the district in the city. Below it becomes clear that Amsterdam provides a lot of employment for the region.

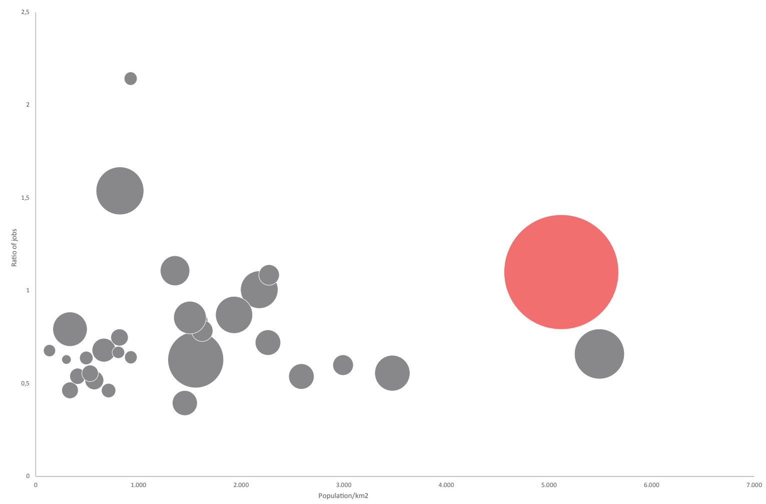
The complete dataset can be found in appendix A2.

When looking at where these jobs are located, it is visible that the new Havenstad development is expected to perform the same as an average district, albeit on a smaller surface.



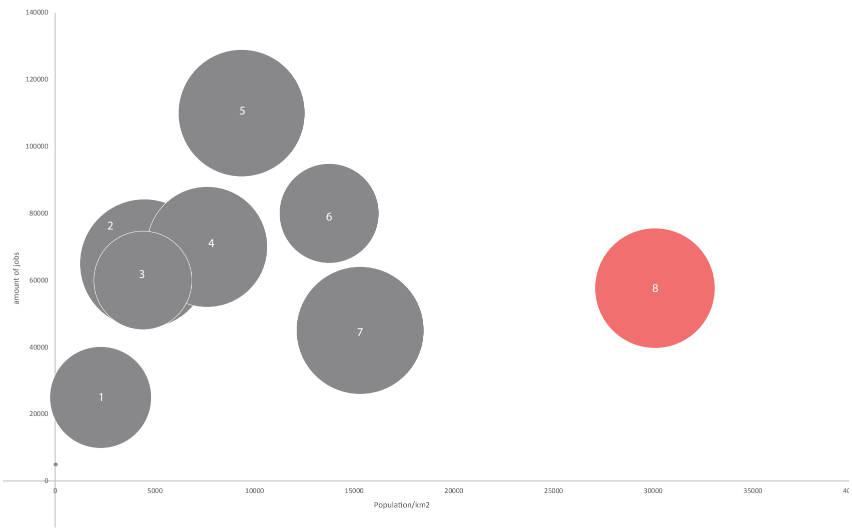
Vision for mixing functions.
Source: Gemeente Amsterdam (2017, p.40). MER Haven-Stad

This vision consists of the creation of a hybrid urban environment where business and living functions are combined.



Jobs vs population density in the AMA
Adapted from "Job ratio" (Kortman et al., 2018, p.28)

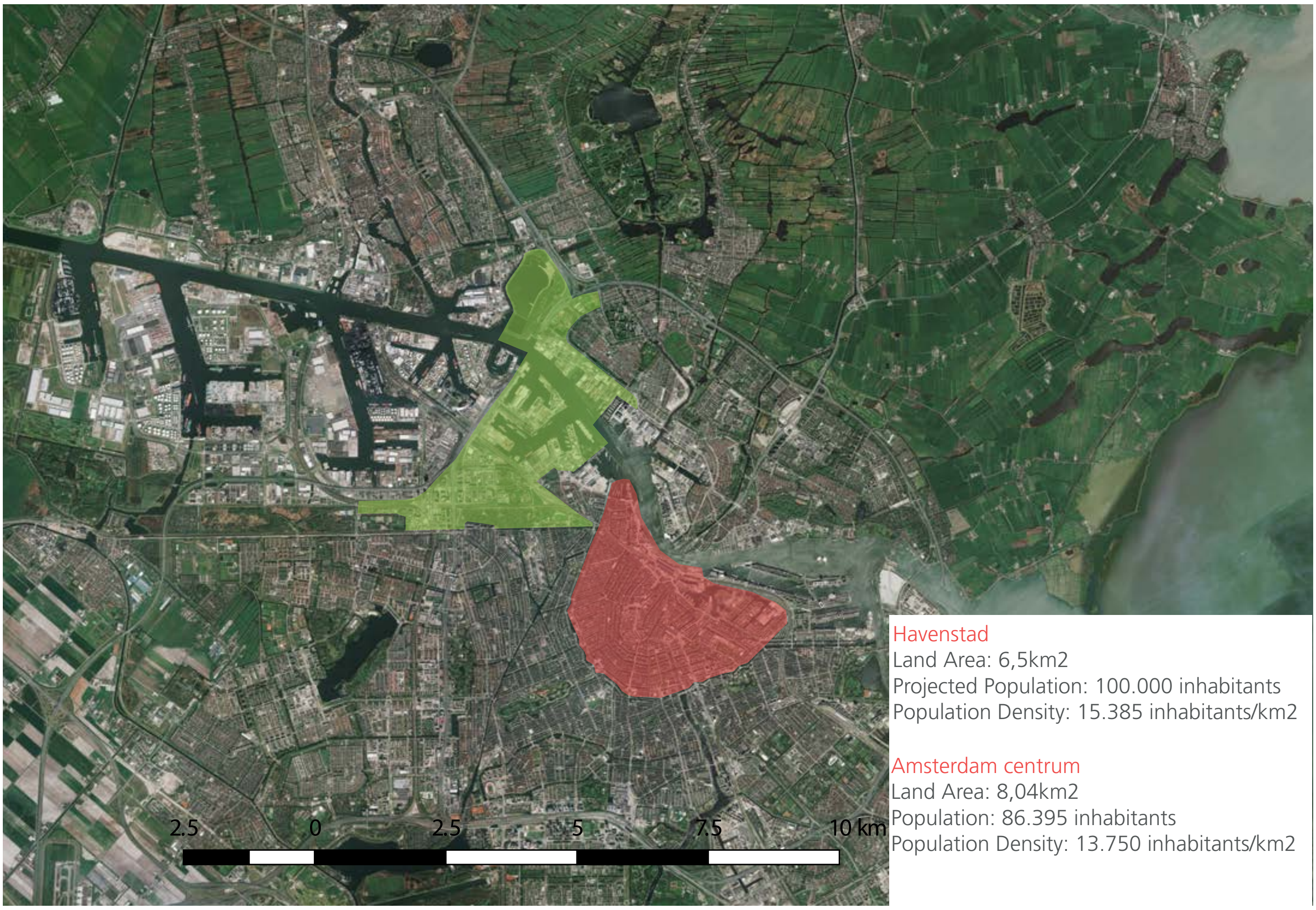
In this the size of the circle represents the population size. The municipality of Amsterdam has a ratio of 1,10 jobs per working age individual (19-65 years old)



Jobs per district vs population density
Data compiled using data from the city (Gemeente Amsterdam, 2017).

The size of the bubbles correlates to the population size in the districts.

1 Noord
2 Nieuw West
3 Zuid Oost
4 Oost
5 West
6 Centrum
7 Zuid
8 Havenstad



The location of Havenstad and the city centre, including data. Adaptation of Bing maps.

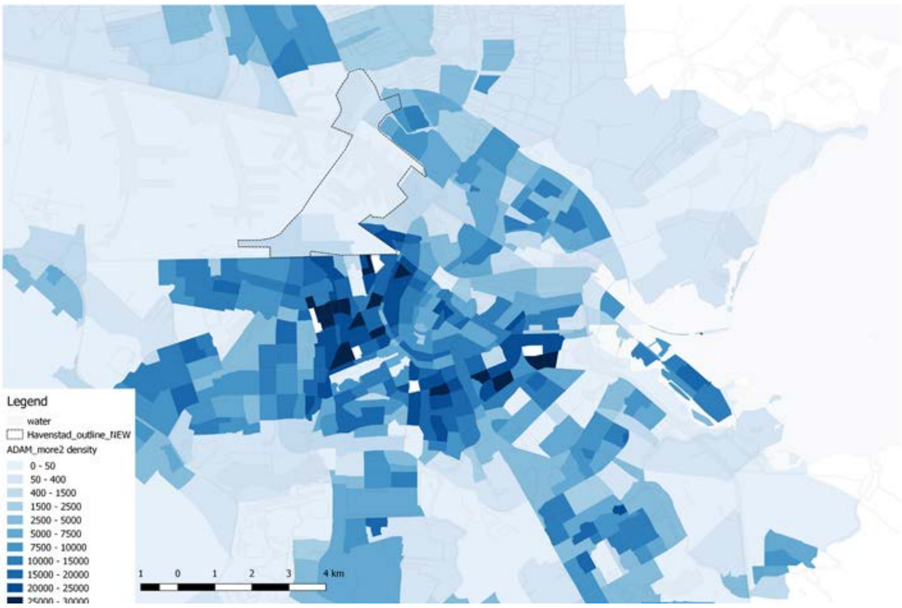
Havenstad is expected to be a new centre for the city of Amsterdam, connecting the urban tissue of Amsterdam with that of Zaandam. When we compare it to the existing city centre it is clear that Havenstad consists of approximately 6,5 km2, with a planned population of up to 100.000 inhabitants. This contrasts with the figures for the city centre, which is at the same time larger (8,04km2) and has a lower population at 86.000 inhabitants.

Translated to the population densities, this implies an average density of 15.385 inh/km2 for Havenstad as a whole, compared to the density of 13.750 inh/km2 for the current city centre.
Given the ambition to include large amounts of open space within Havenstad for recreation and nature the area is expected to hold many buildings of greater height to accommodate the expected population.

The district will have the highest population density of all districts, averaging around 30.000 inhabitants/km2, as the Westerpark is to be excluded from this development. This is a higher population density than any current neighbourhood in the city has.
On the next page the neighbourhoods comprising Havenstad are shown together with the projected population densities shown within the city.

The projected population densities for the neighbourhoods will result in Havenstad being a large population centre, exceeding the densities in all the other parts of the city.

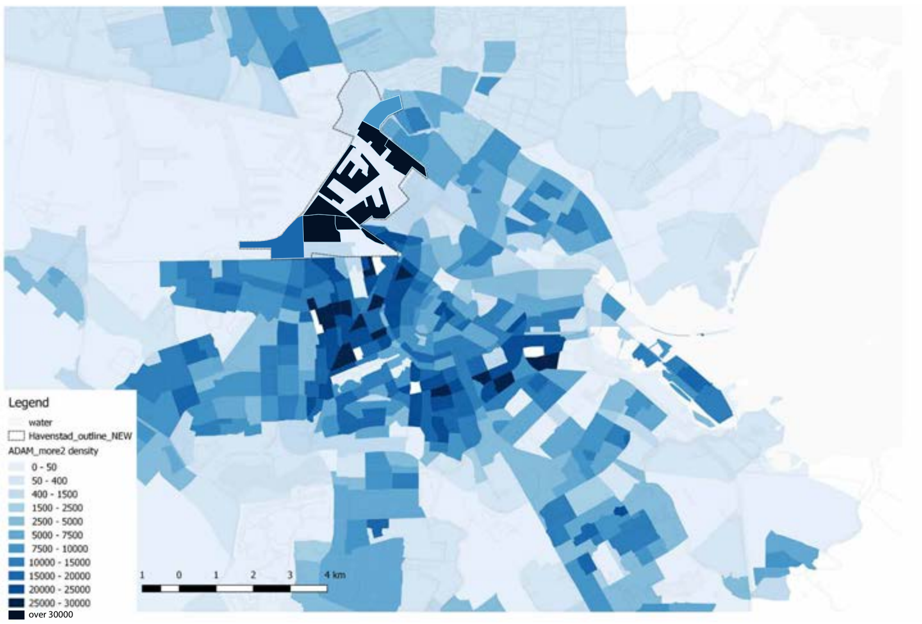
Several key data of the district are shown in the following page, with the full dataset being available in appendix A3.
When the data taken from the MER (Gemeente Amsterdam, 2017) is analysed, it becomes clear that the city prepares for a population of over 125.000 inhabitants.



Population density per km2 current situation

Created using dataset CBS wijk en buurtkaart 2018

In this map the density of the population per km2 for the neighbourhoods has been shown. This map illustrates that the highest densities of population are present in the areas developed between 1903 and 1940.



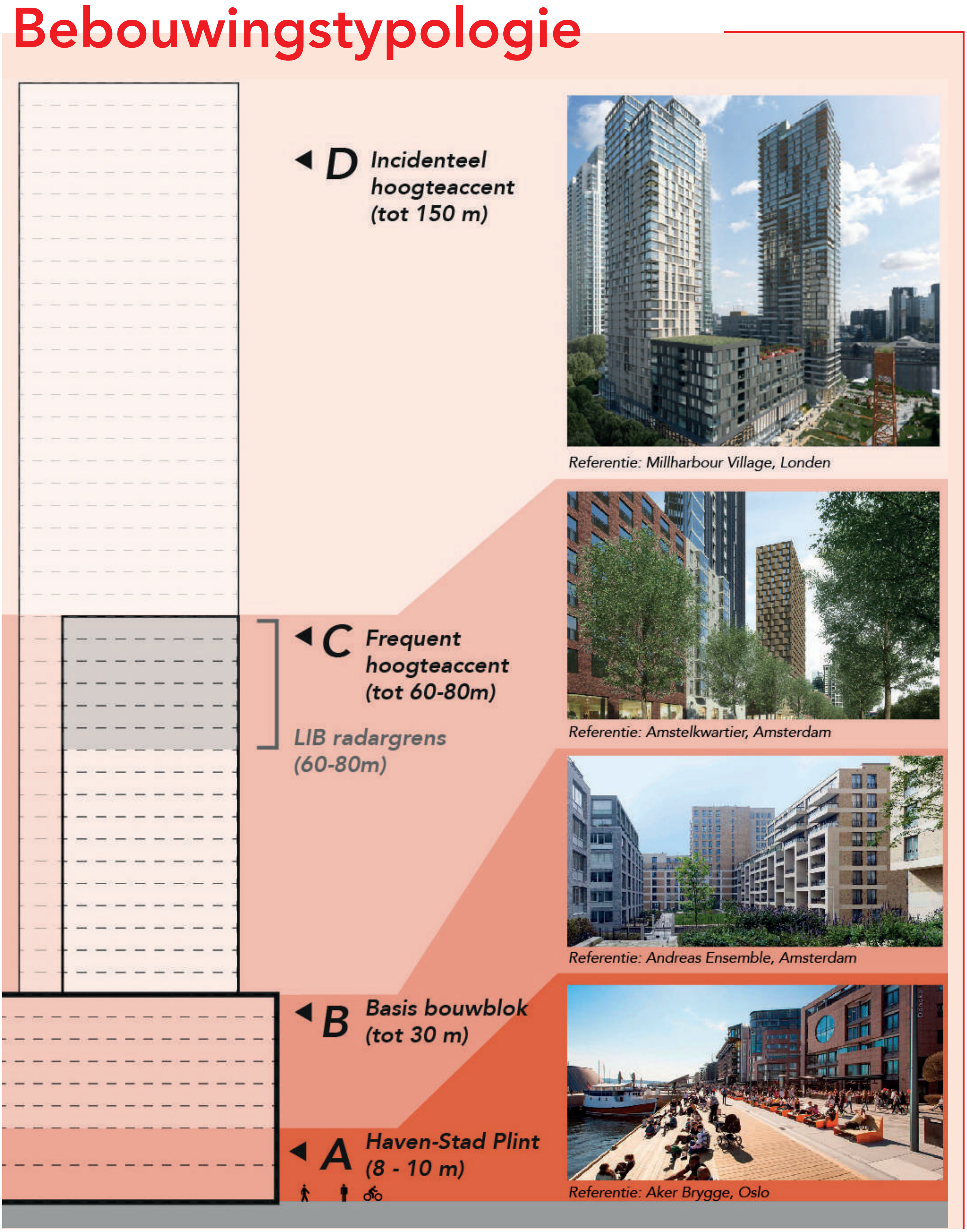
Population density per km2 projection with Havenstad

Created using dataset CBS wijk en buurtkaart 2018 and MER Havenstad (2017)

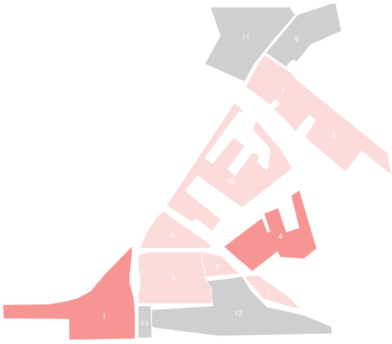
This map illustrates how the projected population density in the new neighbourhoods of the Havenstad district would compare to the rest of the city. With most of the neighbourhoods projected with a density of 35000 inhabitants/km2 this area would be truly unique in the city.

	neighbourhood	population	GFA change (%)	jobs change (%)	current FSI	future FSI
1	Sloterdijk Centrum	12967	103	7,1	0,79	1,6
2	Sloterdijk I	19635	211	58,1	0,64	2
3	Zaanstraat emplacement	3185	1450	2932	0,12	2
4	Minervahaven	20335	407	4,5	0,39	2
5	Sportpark Transformatorweg	3290	3358	6165	0,06	2
6	Alfadriehoek	9100	386	98,3	0,41	2
7	Cornelis Douwes 0-1	12075	586	252,2	0,29	2
8	Cornelis Douwes 2-3	16800	435	189,6	0,37	2
9	Melkweg Oostzanerwerf	2800				0,47
10	Coen en Vlothaven	26950	652	1081,5	0,27	2
total*		127137	340	78,3	0,41	1,82

Some of the most significant changes proyected for Havenstad. Data taken from MER Haven stad (Gemeente Amsterdam, 2017)



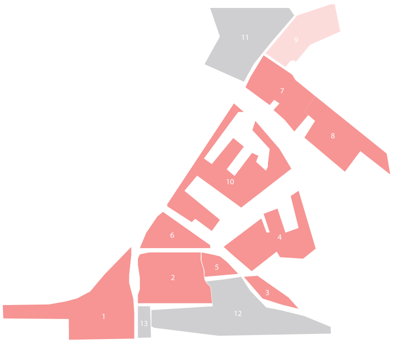
Vision for the spatial make up in Havenstad. Source: Gemeente Amsterdam (2017, p.56). Ontwikkelstrategie Haven-Stad



Current type of labour

The current types of labour classified in extensive of intensive labour(Gemeente Amsterdam, 2017, p.106 -148).

light red: extensive labour, over 70m2 per job
darker red: The new Havenstad average, around 30m2 per job
gray: no data



Future type of labour

The current types of labour classified in extensive of intensive labour(Gemeente Amsterdam, 2017, p.106 -148).

light red: extensive labour, over 70m2 per job
darker red: The new Havenstad average, around 30m2 per job
gray: no data

While the gross floor area, the GFA, is projected to increase by 339 percent, the GFA dedicated to work is expected to decrease by 12 percent. Meanwhile the amount of jobs will increase by 78 percent. This amounts to a profound change in the nature of the jobs in the area. The new Havenstad average falls between the 15m2 per job classified as intensive labour by the municipality and 70m2 classified as extensive labour (Gemeente Amsterdam, 2017, p 148).

While considering the prospect of a new form of density for Amsterdam, the quality of space for the inhabitants and visitors remains to be seen.

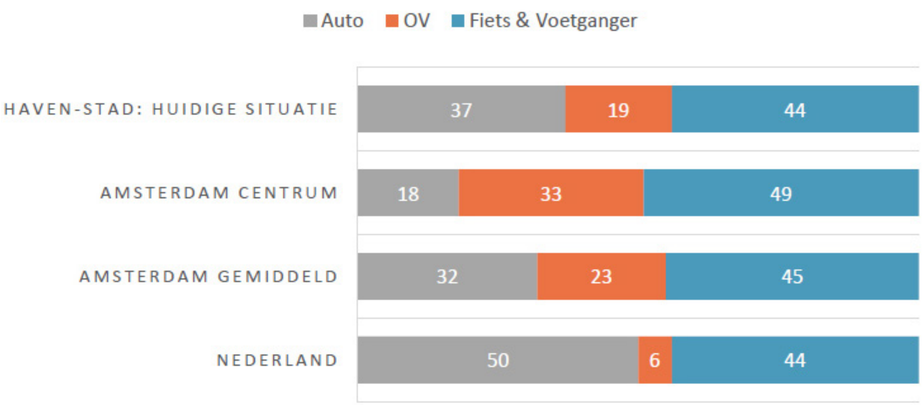
Havenstad ambitions: Mobility challenge

To allow for a non disruptive development, the city is committed to developing a district where active and collective transport comprise the majority of trips. The ultimate goal is to have Havenstad outperform the current city centre's modal share of active mobility and public transport.

Although the city intends to limit the parking norm to 0,2 for residences (Gemeente Amsterdam, 2017), the sheer amount of dwellings could lead to the addition of 14530 additional cars on the road network of the city. If the parking space for these cars were to be added on the ground, an additional 8% of the area would have to be reserved for parking. However, this norm does not allow for street parking.

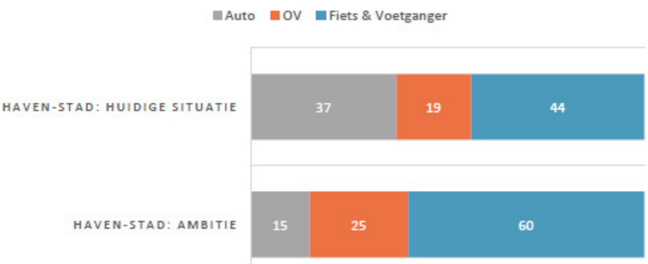
This means that all these additional parking spaces have to be realised within the GFA of the residences, taking around 6% and limiting the usable floor area, UFA, to 55m2 per residence, below the 60m2 average for the city(Gemeente Amsterdam, 2017). Doing this would also have the effect of increasing the housing price in the area, potentially either lowering the potential amount of housing or requiring an exception from the Woonvisie.

Considering the major change to the current work areas going from primarily extensive labour to a mix of intensive and extensive labour, the permitted car space for businesses would be 1 per 250m2 GFA (Gemeente Amsterdam **bestemmingsplan**, 2018, p.27). Adhering to this would further imply a need for 7325 parking spaces on the plots themselves, most probably located in garages.



Current modal split.
Source: Gemeente Amsterdam (2017, p.12). Bijlage 3 Achtergrondrapport Mobiliteit MER Haven-Stad

It is visible that Havenstad currently has a comparable share of active mobility as the rest of the Netherlands, but a higher share for cars.



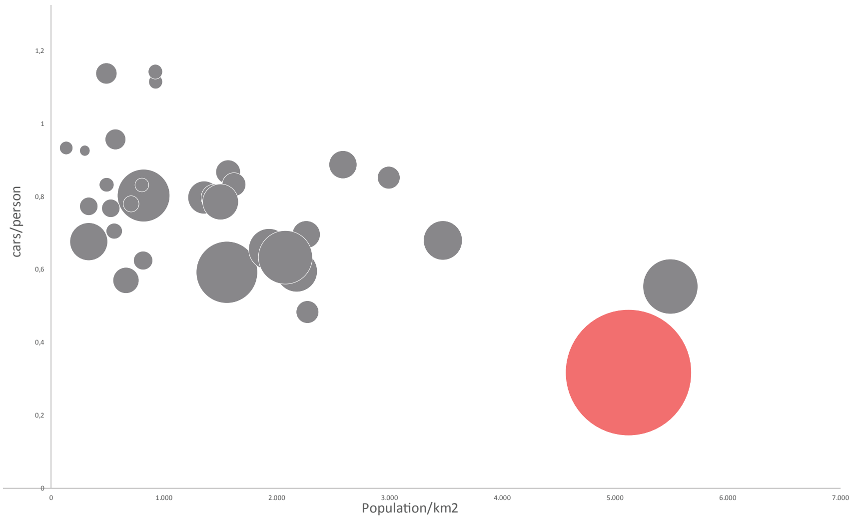
Ambition modal shift
Source: Gemeente Amsterdam (2017, p.12). Bijlage 3 Achtergrondrapport Mobiliteit MER Haven-Stad

It is visible that the Havenstad development is not only slated to vastly decrease the share of personal private transport in the form of cars, but also reach a higher share for active mobility than the city centre.

The effects can be seen clearly in the scatterplots below. They show the correlations between density and amount of cars and density and number of cars per km2.

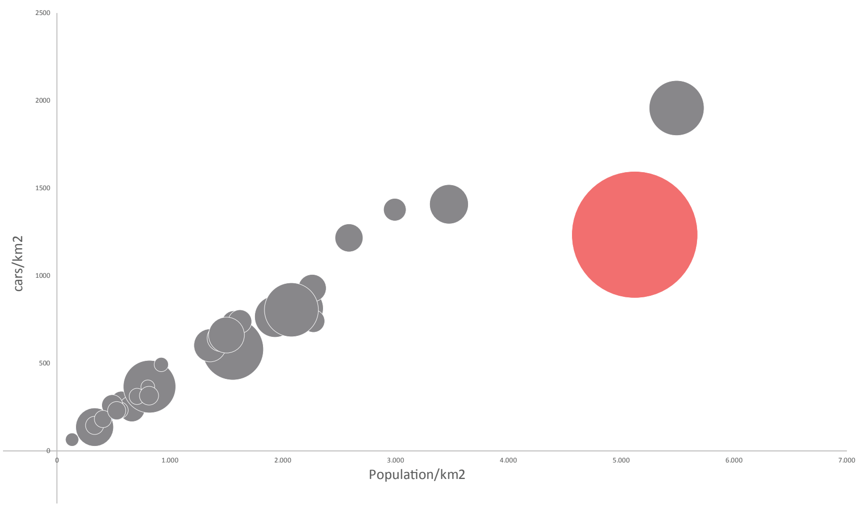
When comparing the rate of car ownership, the municipality of Amsterdam seems to perform quite well, as the lowest amount of people own a car. When looking at the resulting amount of cars per km2 the impact of even a low level of car ownership becomes clear.
With many of the current businesses being heavily car dependent for their employees and clients coming from the rest of the AMA (Gemeente Amsterdam **MER verkeer**, 2017), a further increase in locally owned vehicles could lead to an increased congestion within the city, while an approach to aggressively ban automobiles could have a strong negative impact on the businesses.

Considering the currently strong connection of the area to road networks, having three connections to the A10 ring highway, a strong development towards car dependency can hardly be a surprise. This is further compounded by the current connection to the public transit system.



Cars/inhabitants in the AMA
Adapted from "Car ownership" (Kortman et al., 2018, p.30)

The size of the circles represents the population size. The data shows a significant positive correlation of 0,95 (Kortman et al., 2018,).



Cars/m2 in the AMA
Adapted from "Density of cars" (Kortman et al., 2018, p.30)

The size of the circles represents the population size. The municipality of Amsterdam has a ratio of 1,10 jobs per working age individual (19-65 years old)

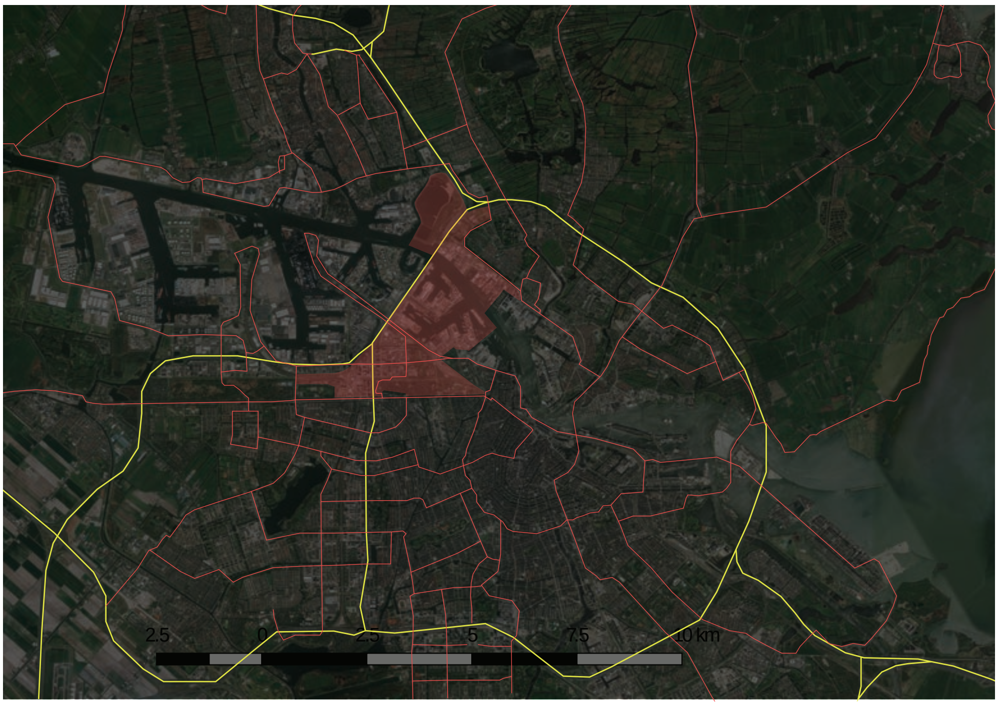
When looking at the current situation of the city, it becomes clear that Havenstad is a lot less connected to the high intensity transit options. While the area hosts the Sloterdijk intercity train station, the access to tram and metro connections is significantly lower than that in the rest of the city. Two metro stops and two tram stops in the far south of the area(one of the metro and one of the tram stops being located at Sloterdijk station) is all.

Officials have argued that the city should invest in rapid buses (Verlaan, 2018), but the current so called "plusnet" network has a lower capacity than trams or metros would have.

The challenge this poses to the desired modal shift has been recognised by the city and several solutions, such as the change of the road network and the construction of additional subway lines have

Public transit connectivity
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

The image to the left shows that while the city of Amsterdam as a whole is strongly connected to through an extensive HOV public transit network consisting of metros and trams, Havenstad is not.



Main road network
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

As is visible in the picture to the left, Havenstad has a strong connection to the A10 highway and the main/regional road network been proposed, however, the proposed construction of additional metro lines is not expected to be complete prior to 2040. (Gemeente Amsterdam, 2017)

That could pose a major problem as the redevelopment of the area is supposed to be well on its way by that time, risking either limiting the potential density of the development or creating a car dependent environment.

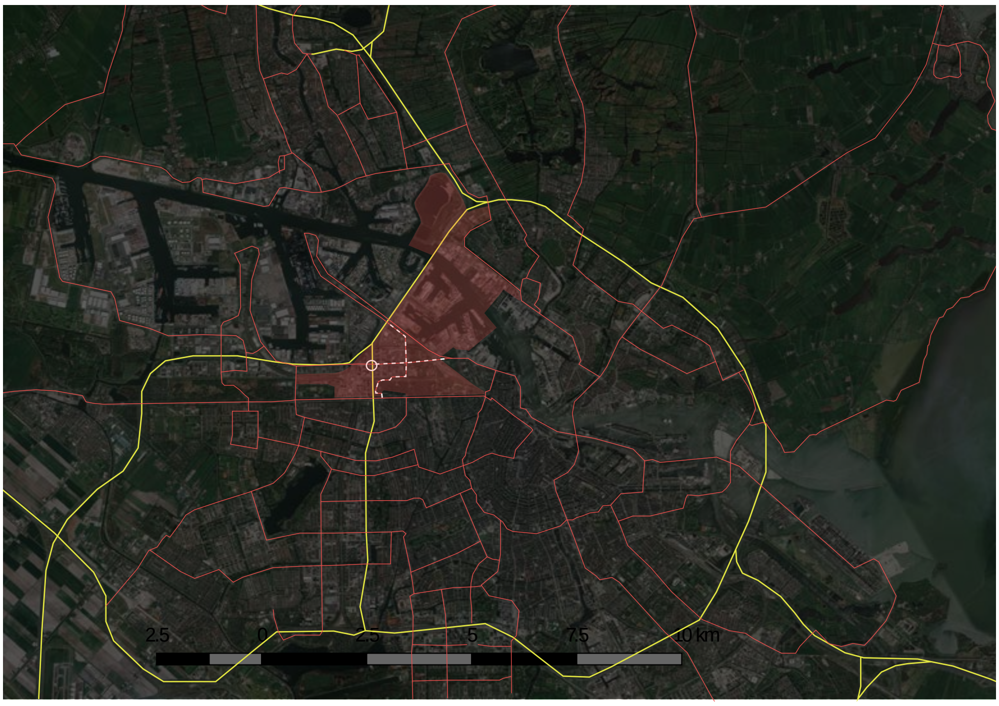
For now, the city is focused on increasing cycling and collective mobility via buses (Gemeente Amsterdam MER, 2017). However a true reduction in car use within the area also requires better alternatives to travel to the area from the region and a smart use of the current possibilities.

Connectivity proposals
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

The image to the right shows proposed extensions to the metro system. The precise route of these extensions is yet to be determined.

Road mobility proposals
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

The image to the right shows the roads whose status the city intends to change in the Havenstad development in addition to a potential location for a mobility hub.

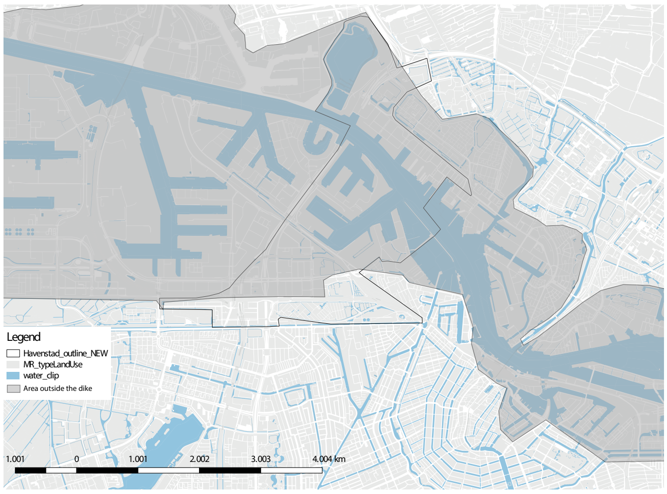


Havenstad ambitions: Climate challenges

A combination of pre-existing conditions, compounded by land occupation and a changing climate, create a set of environmental challenges for the development of Havenstad. In addition to mobility, several challenges pertaining to potential urban flooding, heat stress, remain.

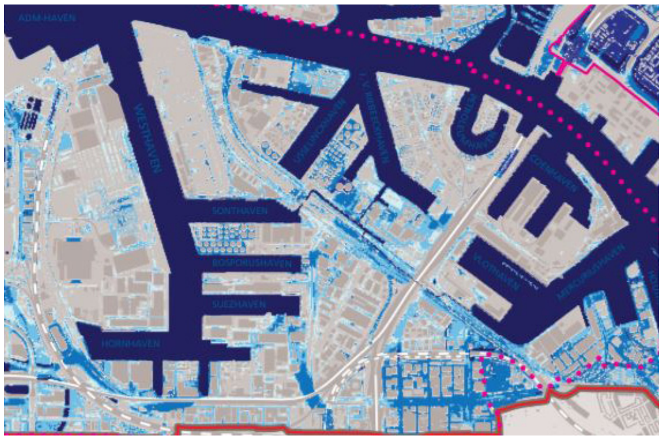
One of the consequences of our impact as a force of nature, has been the change of climate. (Hamilton, 2017) For the Netherlands this means an increase in precipitation, high intensity rainfall and storm events, drought and extreme heat. (Klok L., personal communication [lecture notes], 2019, september 13)

The area is currently located outside the Amsterdam dike protection, with much of the area is potentially at risk of fluvial flooding through the IJ and



The area located outside the primary dike
Map drawn using data from Waternet and the city of Amsterdam.

Scenario 1, flooding of the Lek at the current safety level:
Water level in the Noordzeekanaal under current conditions at 0,4m - 0,9m NAP,
Return period: now, 1/250

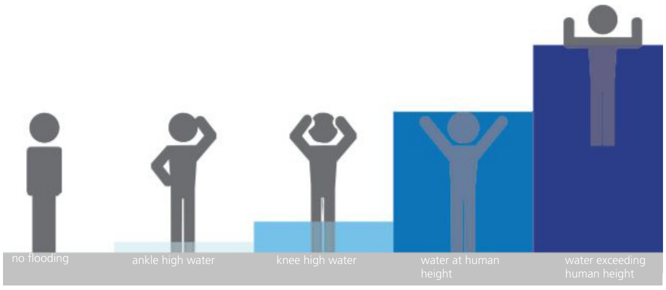


Scenario 2, flooding of the Lek at the 2050 safety level:
Water level in the Noordzeekanaal under current conditions 0,8m - 1,3m NAP
Return period: now, 1/10.000, in 2050 1/10.000

Scenario 3, breach at IJmuiden under the current safety level:
Water level in the Noordzeekanaal under current conditions 0,9m - 1,4m NAP
Return period: now, 1/10.000

Scenario 4, breach at IJmuiden at the 2050 safety level:
Water level in the Noordzeekanaal under current conditions: 1,5m - 2,0m NAP
Return period: now, 1/100.000, in 2050 1/100.000

The four scenarios for fluvial flooding in the area. Adapted from Kroeze et al, "Overstromingscenario's oorzaak en aankomsttijd"(2017, p.22) Adaptatiestrategie Waterbestendig Westpoort. The dashed line represents the boundaries of Westpoort. The red line shows the dike.



Flooding heights.
Adapted from Kroeze et al, "Overstromingscenario's oorzaak en aankomsttijd"(2017, p.22) Adaptatiestrategie Waterbestendig Westpoort

Noordzeekanaal in the event of a breach of the river defenses in the Lek river or a failure of the sea defences (Kroeze et al., 2017).

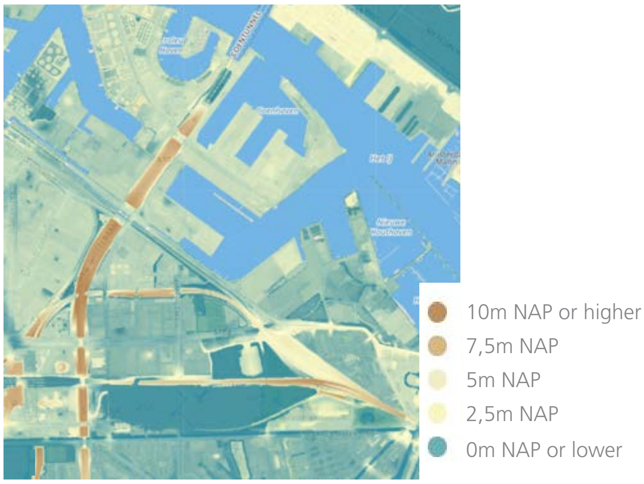
In the image below the four scenarios that the harbour operates with in the "adaptatie strategie" by Kroeze et al is shown (2017).

The images on the next page show the severity of flooding during the various scenarios set against the potential height of the water during such an event. This water height may not always pose a direct threat to life, but the flooding of vital infrastructure and industries located in the harbour can have far reaching consequences.

Support systems like power networks, pump systems, district heating and transport could be severely impaired.

While these events constitute a mild to catastrophic failure of the flood defenses, the impacts vary strongly in time and return period. To the left the various scenarios are shown with their corresponding flooding height. The return period for a +1,15m NAP event is extremely high. (Kroeze et al., 2017)

Although fluvial flooding constitutes a high risk, its return period is very high. It also carries many unknowns with it. What is increasingly difficult to determine for example, is the water level resulting from such an event.
As high intensity rainfall events increase, the Dutch cities are struggling to cope with this once rare phenomenon. The infrastructures are struggling to operate through this new reality.



The ground height
Map based on the Algemene Hoogtekaart Nederland, third edition (AHN3). Source: Waterschap Amstel Gooi en Vecht. Retrieved on 05-07-2019 from https:// https://agv.klimaatatlas.net/

The water labels of the buildings.
Source: Waterlabel. Retrieved on 13-09-2019 from https://waterlabel-v1.lizard.net/

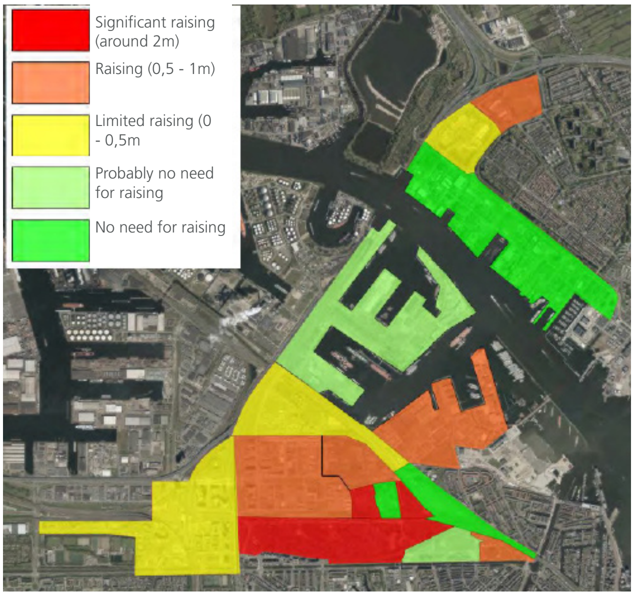
The effect of these events is further compounded by the local topography and the low retention rate of the buildings that occupy much of the pluvial flood risk area. As most buildings have a water label of E or worse, meaning that they can store less than 7mm.

The capacity of the current separate rain sewer system is about 20mm/h. Not only does this mean that the public space becomes flooded, but it also strongly affects mobility. It is clear that this is not enough for the increasing high rainfall events and the need maintain a capacity for an event with a two year return period of 60mm (Gemeente Amsterdam **MER water**, 2017, p.16-28)

While 60mm/h is the new norm, the image at the below is an example of shows the effects of a potential 100mm/h downpour.
This means that a mere capacity of 60mm/h through 20mm/h rainwater sewer capacity and 40mm/h (Gemeente Amsterdam **MER water**, 2017, p.33-34) retention is not enough.

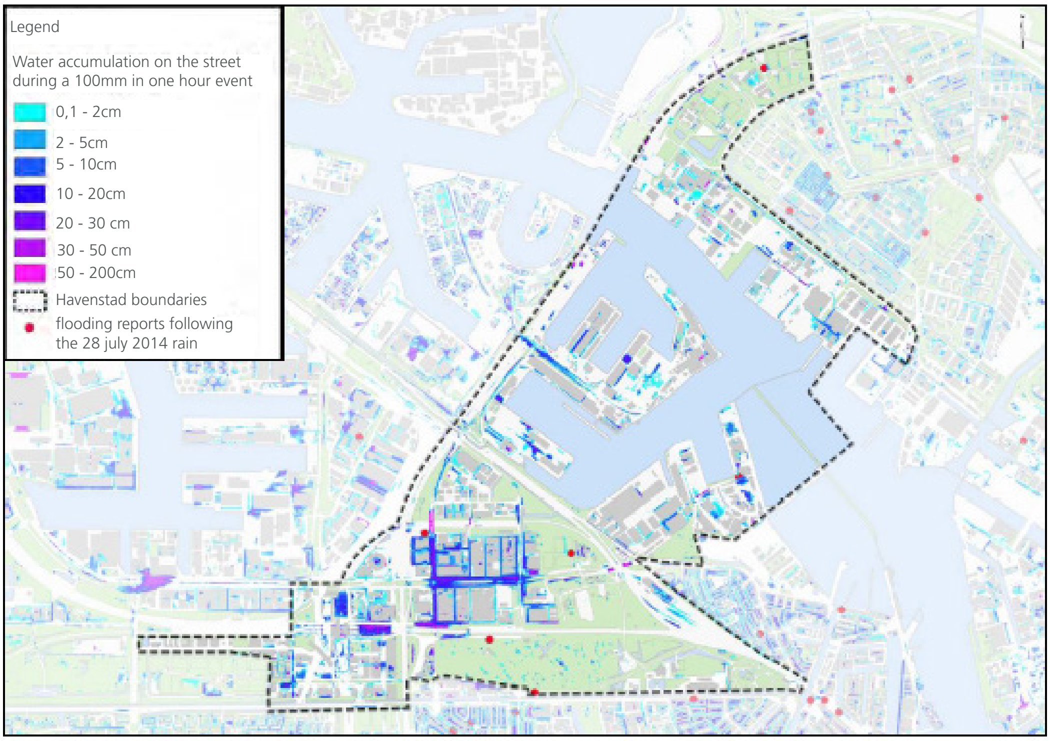
With the norm for the return period for flooding once per 100 years, additional measures are necessary to achieve it.

The map above shows the level that the ground level would need to be raised in order to avoid flooding



Expected need for raising of the surface level.
Adapted from Gemeente Amsterdam (2017, p.41). Bijlage 10 Achtergrondrapport Water MER Haven-Stad

The colours indicate the expected need to raise the ground surface level in order to mitigate the flood risk.



Pluvial flooding risk at 100mm/h.
Source: Gemeente Amsterdam **MER water** (2017, p.17). Bijlage 10 Achtergrondrapport Water MER Haven-Stad
Simulation of amount of rainwater on the street during a simulated 100mm in an hour event. This includes the locations where a water nuisance was reported during a rainfall event of 50 - 80mm in the span of three hours. A combination of a high groundwater table, adding to the low level of infiltration of the soil and a mostly impermeable surface causes the rainwater to accumulate.

altogether. Considering the scale of such an undertaking and its environmental and financial effects, a different approach, oriented towards resilience may be preferable.

Such a multilayered approach (Gemeente Amsterdam **MER water**, 2017, p.19) would be a departure from a solely defensive tactic, instead shifting the focus to adaptation and calamity preparations and management.

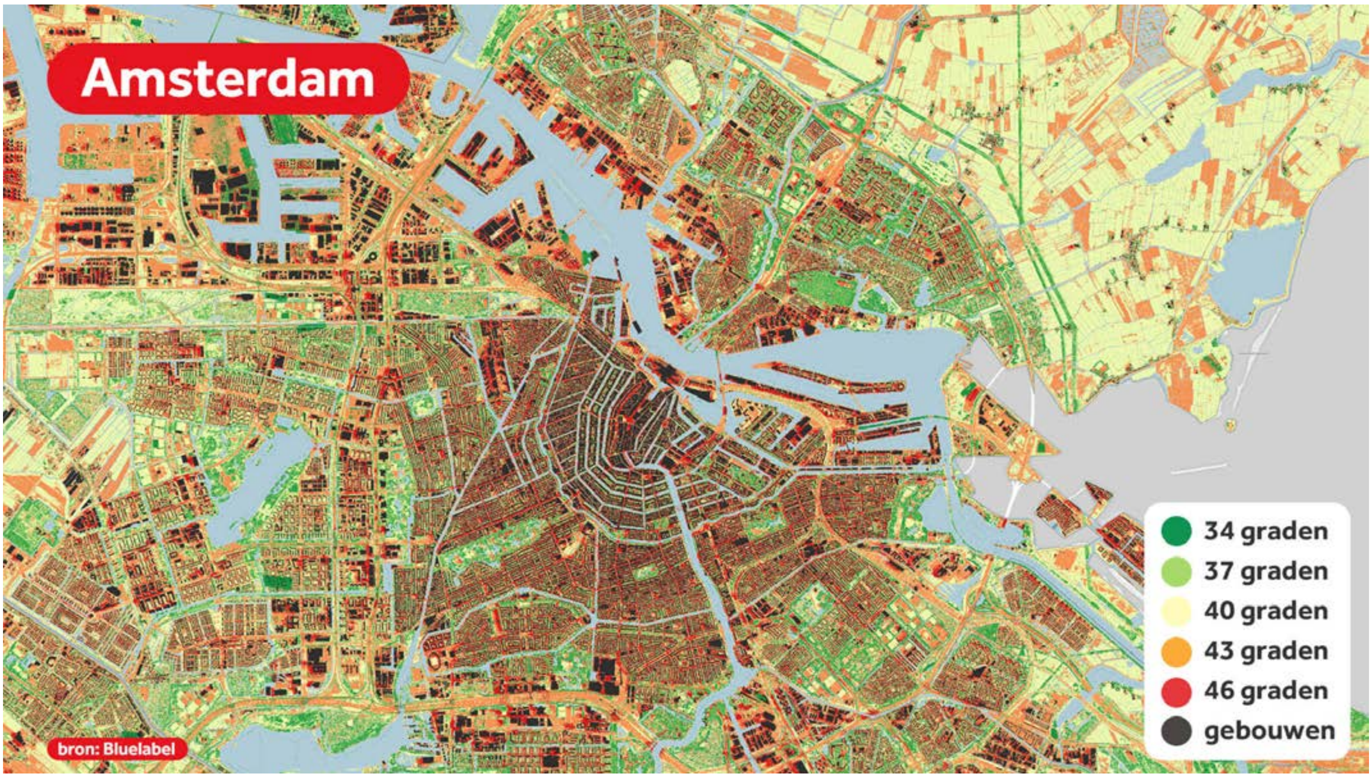
The final environmental challenge that will be taken into account is that of heat stress.

While many are primarily focused on the reduction of cold during winter due to the warming climate, the incidence of extreme heat is expected to increase considerably. And with it an increase in lethality for older people in particular (Pijpers-Van Esch, personal communication [lecture notes], 2019, 13 september)

As cities create their own climatic conditions due to the accumulation of built mass, heat generation and their influence on humidity and wind. (Lenzholzer, 2015)

Extreme heat conditions, however, are detrimental to the city and its inhabitants. With the spatial design having such a strong impact on the perceived heat, far more so than on the absolute temperature (Klok, personal communication, 2019, september 13), designing with and for heat conditions becomes necessary.

In short the main factors influencing the urban temperatures are radiation, energy consumption(and consequent heat production), thermal capacity, evaporation, heat storage and heat transport (e.g. through ventilation). Depending on the local conditions, different approaches can be suitable to create more pleasant conditions in the new development of Havenstad than the current heat island.



The perceived temperature on a hot summer day.
Source: Bluelabel, "De gevoelstemperatuur op een hete zomerdag". Retrieved on 14-09-2019 from https://nos.nl/artikel/2290680-overal-een-warme-zomerdag-toch-grote-verschillen-in-gevoelstemperatuur.html
It is visible that the perceived temperature can differ depending on the typology and the design of public space.

The project area

The limitation of the project area. Adapted from Google Maps.

The project area consists of a built area with a lot of infrastructure and a green area containing the current Westerpark.

Businesses with their own landscaping. 2018

The Mosque. 2018

The A10. 2018

Hotel and parking in the area. 2018

Creative industries. 2018

Businesses. 2018

The freight rail line beneath the A10. 2018

The soon to be decommisioned coal plant. 2018

Large industrial and hydraulic infrastructure. 2018

New cafes and restaurants. 2018

Soberly designed outdoor space. 2019

Renmants of the preindustrial landscape. 2019

A remaining section of the former rail dike. 2019

Landscaping of the allotment gardens. 2019

Educational garden. 2019

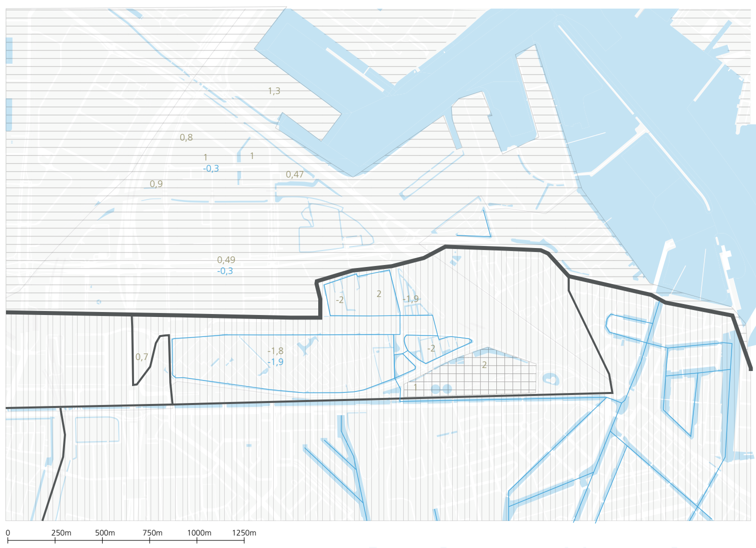
Subtle height differences. 2019

Recreation in the park. 2019

Part of the polder water system. 2019

Technical profile

infrastructures



water system

Green structure and geology

Legend
background
power plant
transformer station
data centre
surface water
rail
district cooling ducts
district heating ducts
water main line
high pressure sewer
drainage pipes
main gas pipe
high voltage cables
MR_typeLandUse
Havenstad_outline_NEW
surface water
0,49 ground level
-0,3 ground water level
primary flood barrier
secondary flood barrier
hydrovak
drainage towards the IJ
polder water system
isolated water system
secondary green structure
secondary green structure
primeval trench
water

Infrastructures

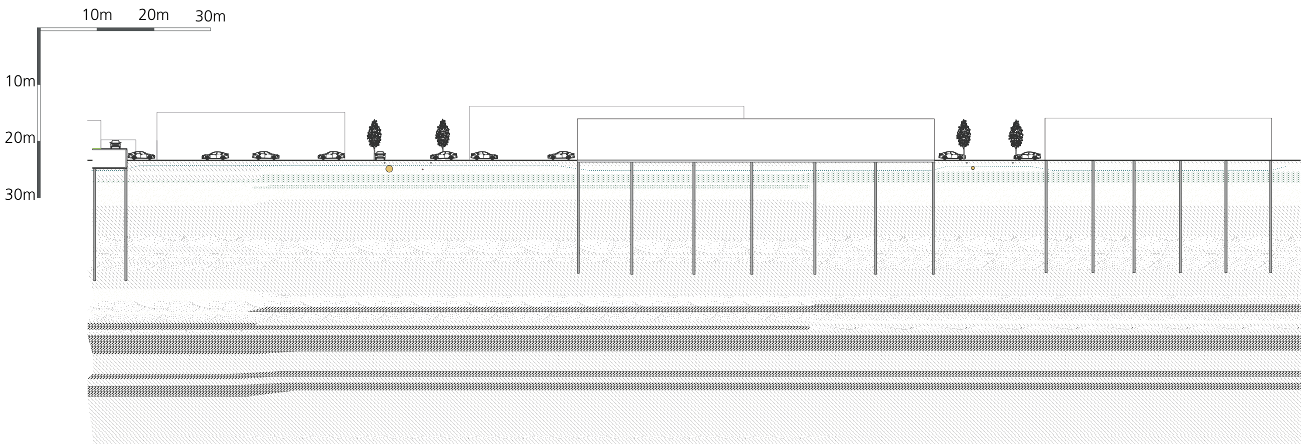
The area contains a high concentration of supporting infrastructures, in particular within the Transformatorweg. Here a gas main, running through the middle of the road, is an important factor to take into account.

water system

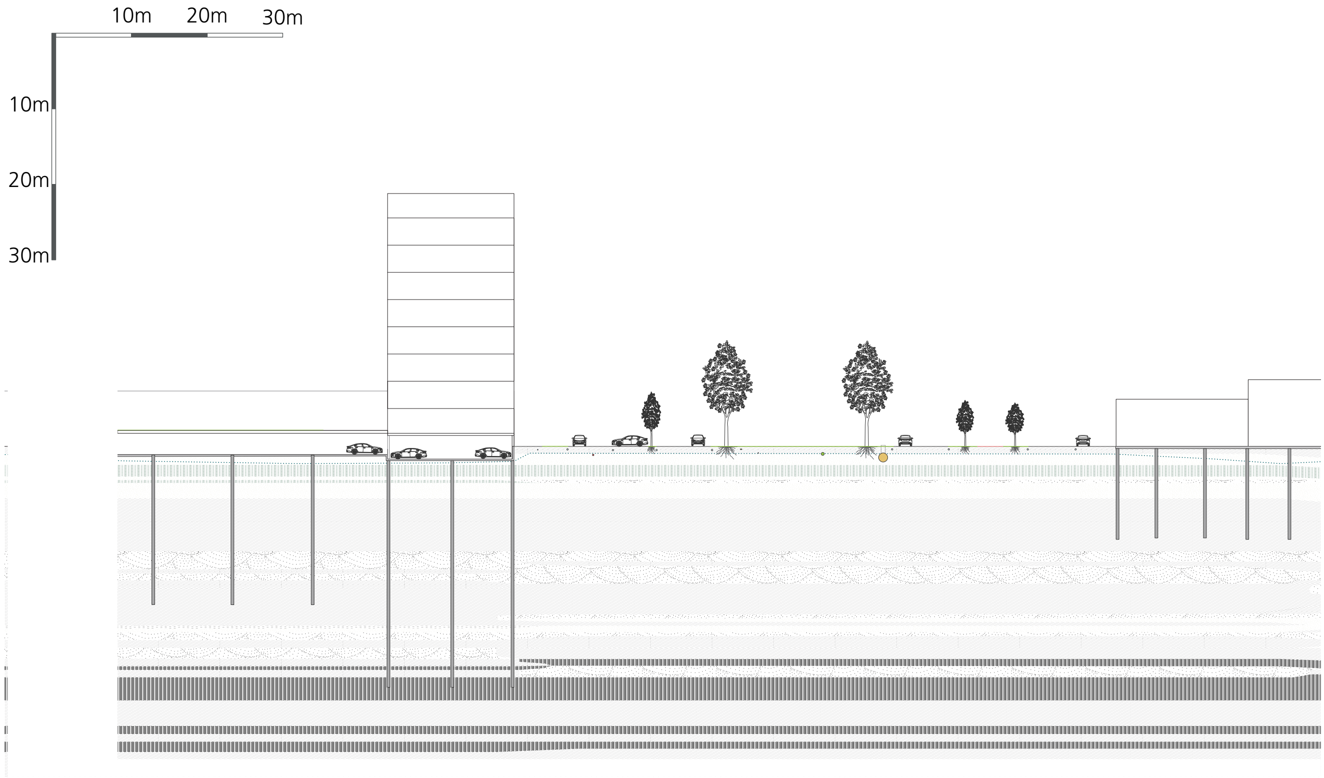
The area contains two different water system types. One is the open system that discharges into the IJ and one is the closed polder system, dependent on the pump capacity for the discharge of excess water. Considering the increase in high volume rainfall events, this should be included in the design strategy.

Green structure and geology

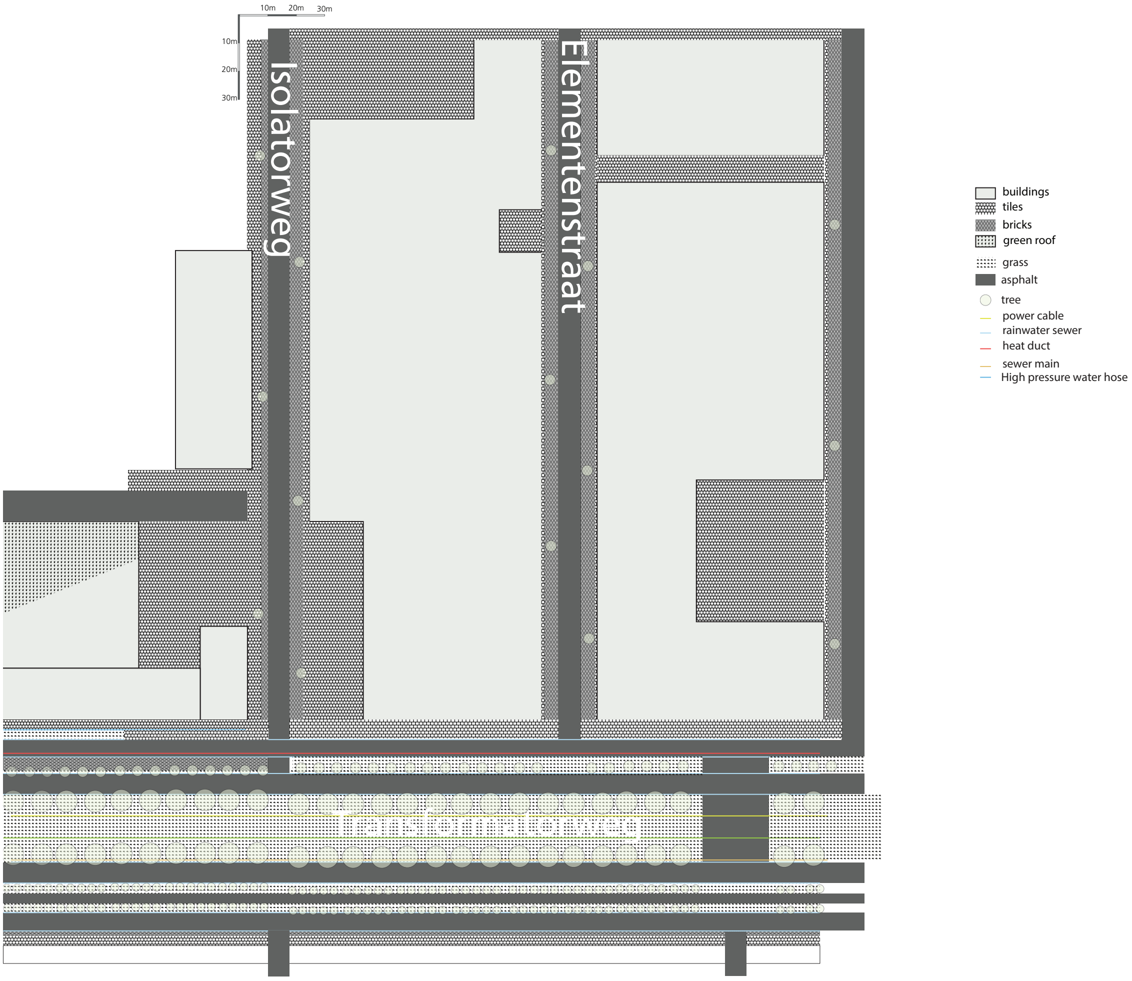
It becomes clear that the green structure follows the primeval trench for an important part. Here the trench is a result of glacial and fluvial erosion around the last ice age, forming a trench that was filled in with peat and clay, resulting in weak soil.



Section elementenstraat



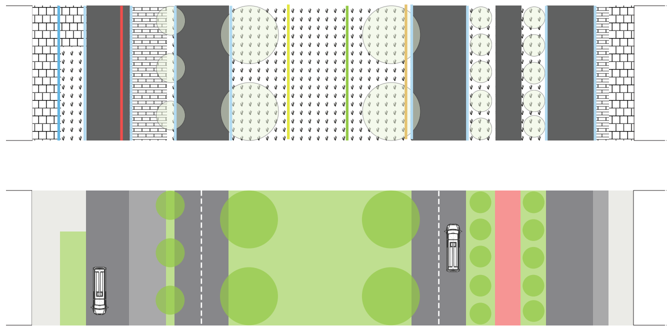
Section Transformatorweg



Land cover map of Elementenstraat and transformatorweg.

This has been used to conduct several sample calculations for a rain situation.

Transformatorweg current 30mm



BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m²**

explanation: is to make meters in the formula

is the amount of rainwater in m³ falling per hour

is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m²	x 30 mm water in 1 hour = m³ water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *	remarks:
UNPAVED									
private									
Garden open soil (private)	0	0	15	50	0.1 m3/m2	15	0	0	
public									
Surface water	0	0	0	0	0.5 m3/m2	0	0	0	* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives are
Rain garden, infiltration field	0	0	25	75	0.1 m3/m2	60	0	0	
Lawn, green belt, shrub (public)	618,5	18,555	15	50	0.1 m3/m2	15	-52,5725	0	
Playground, footpath	0	0	5	5	0.1 m3/m2	5	0	0	
Vegetated swales	0	0	10	10	0.5 m3/m2	30	0	0	
PAVED									
private									
Roofs – sloping	0	0	1	0	0	0	0	0	
Roofs – flat, tar	0	0	5	0	0.05 m3/m2	10	0	0	
Green roofs – extensive	0	0	10	0	0.1 m3/m2	15	0	0	
Green roofs – intensive	0	0	25	0	0.2 m3/m2	15	0	0	Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?
Garden tiled	0	0	3	8	0.05 m3/m2	5	0	0	
public									
Roads, car parks – asphalt	518,5	15,555	1	0	0.05 m3/m2	5	15,0365	15,0365	
Roads, car parks – porous asphalt	0	0	1	40	0.05 m3/m2	5	0	0	
Roads, car parks – brick	123,5	3,705	3	10	0.05 m3/m2	5	0,8645	0,8645	
Roads, car parks – porous pavement	0	0	3	40	0.05 m3/m2	5	0	0	
Sidewalk, terraces –tiles	176,5	5,295	3	8	0.05 m3/m2	5	1,9415	1,9415	

total private area in m²	0	0	total of water
total public area in m²	1437	43,11	total of water
Total area in m² and total m3 water	**1437**	**43,11**	

sewer capacity: 20 mm per day

1,7 mm in 2 hours		17,8425	m³ directly to sewer
mm of water going to the sewer in 2 hours:	**21,7990226**	0	m³ delayed to the sewer
		99	m³ to natural system
		-34,73	total amount of water m3 that enters your area
		17,8425	**total of surplus in m³**

% open water: **0**

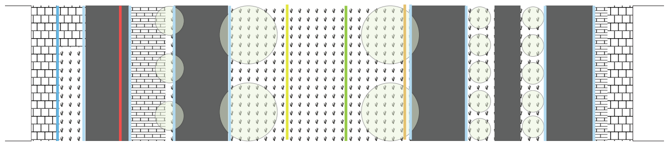
NB. when there is open water, you can store 0,5 m³ per m² open water; when there is not, you have to find another solution

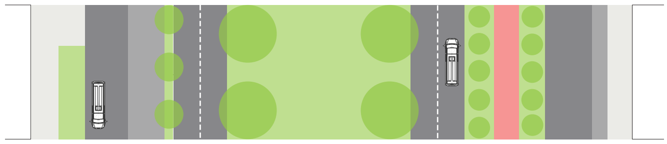
Water Excel

(Van De Ven, Hooijmeijer, Aalbers,personal communication, 2018)

This calculation has been used to understand the effects of the land use on the potential coping capacity of the area with regards to rain. Here it is clearly visisble that there is no problem under the current conditions with a 30mm rain treshold.

Transformatorweg current 60mm





BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m²**

explanation: is to make meters in the formula

is the amount of rainwater in m³ falling per hour

is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m²	x 30 mm water in 1 hour = m³ water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *
UNPAVED								
private								
Garden open soil (private)	0	0	15	50	0.1 m3/m2	15	0	0
public								
Surface water	0	0	0	0	0.5 m3/m2	0	0	0
Rain garden, infiltration field	0	0	25	75	0.1 m3/m2	60	0	0
Lawn, green belt, shrub (public)	618,5	37,11	15	50	0.1 m3/m2	15	-34,0175	0
Playground, footpath	0	0	5	5	0.1 m3/m2	5	0	0
Vegetated swales	0	0	10	10	0.5 m3/m2	30	0	0
PAVED								
private								
Roofs – sloping	0	0	1	0	0	0	0	0
Roofs – flat, tar	0	0	5	0	0.05 m3/m2	10	0	0
Green roofs – extensive	0	0	10	0	0.1 m3/m2	15	0	0
Green roofs – intensive	0	0	25	0	0.2 m3/m2	15	0	0
Garden tiled	0	0	3	8	0.05 m3/m2	5	0	0
public								
Roads, car parks – asphalt	518,5	15,555	1	0	0.05 m3/m2	5	30,5915	30,5915
Roads, car parks – porous asphalt	0	0	1	40	0.05 m3/m2	5	0	0
Roads, car parks – brick	123,5	3,705	3	10	0.05 m3/m2	5	4,5695	4,5695
Roads, car parks – porous pavement	0	0	3	40	0.05 m3/m2	5	0	0
Sidewalk, terraces –tiles	176,5	5,295	3	8	0.05 m3/m2	5	7,2365	7,2365
total private area in m²	0	0	total of water					
total public area in m²	1437	43,11	total of water					
Total area in m² and total m3 water	**1437**	**61,665**						

remarks:

* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives are

Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?

sewer capacity: 20 mm per day

1,7 mm in 2 hours

mm of water going to the sewer in 2 hours: **51,7990226**

42,3975	m³ directly to sewer
0	m³ delayed to the sewer
99	m³ to natural system
8,38	= total amount of water m3 that enters your area
42,3975	= **total of surplus in m³**

% open water: **0**

NB. when there is open water, you can store 0,5 m³ per m² open water; when there is not, you have to find another solution

Water Excel
(Van De Ven, Hooijmeijer, Aalbers,personal communication, 2018)

Here it is visible that while the area can still cope with the rain, there is a significant decrease of available capacity for rainwater. Considering this is one of the areas with the most vegetated unpaved land, this doesn't bode well for the rest.

Test block current 30mm

BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m^2**

explanation: is to make meters in the formula

is the amount of rainwater in m^3 falling per hour

is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m^2	x 30 mm water in 1 hour = m^3 water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *
UNPAVED								
private								
Garden open soil (private)		0	15	50	0.1 m3/m2	15	0	0
public								
Surface water		0	0	0	0.5 m3/m2	0	0	0
Rain garden, infiltration field		0	25	75	0.1 m3/m2	60	0	0
Lawn, green belt, shrub (public)		0	15	50	0.1 m3/m2	15	0	0
Playground, footpath		0	5	5	0.1 m3/m2	5	0	0
Vegetated swales		0	10	10	0.5 m3/m2	30	0	0
PAVED								
private								
Roofs – sloping		0	1	0	0	0	0	0
Roofs – flat, tar	16501	495,03	5	0	0.05 m3/m2	10	412,525	412,525
Green roofs – extensive		0	10	0	0.1 m3/m2	15	0	0
Green roofs – intensive		0	25	0	0.2 m3/m2	15	0	0
Garden tiled		0	3	8	0.05 m3/m2	5	0	0
public								
Roads, car parks – asphalt		0	1	0	0.05 m3/m2	5	0	0
Roads, car parks – porous asphalt		0	1	40	0.05 m3/m2	5	0	0
Roads, car parks – brick		0	3	10	0.05 m3/m2	5	0	0
Roads, car parks – porous pavement		0	3	40	0.05 m3/m2	5	0	0
Sidewalk, terraces –tiles	3179	95,37	3	8	0.05 m3/m2	5	34,969	34,969

remarks:

* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives

Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?

total private area in m^2	16501	495,03	total of water
total public area in m^2	3179	95,37	total of water
Total area in m^2 and total m3 water	**19680**	**590,4**	

sewer capacity:	20 mm per day		
	1,7 mm in 2 hours	447,494	m^3 directly to sewer
mm of water going to the sewer in 2 hours:	**22,73851626**	0	m^3 delayed to the sewer
		99	m^3 to natural system

447,494 = total amount of water m3 that enters your area

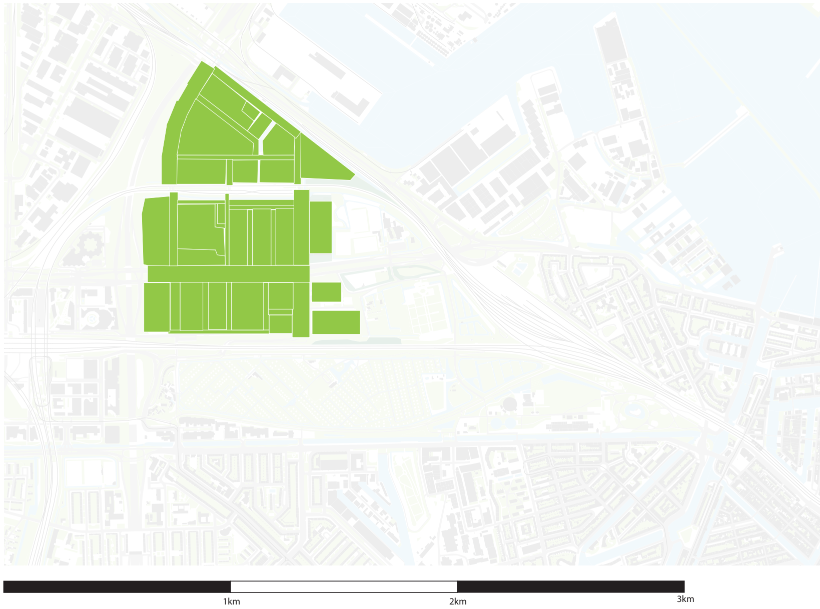
447,494 = **total of surplus in m^3**

% open water: 0

NB. when there is open water, you can store 0,5 m^3 per m^2 open water; when there is not, you have to find another solution

Water Excel
(Van De Ven, Hooijmeijer, Aalbers,personal communication, 2018)

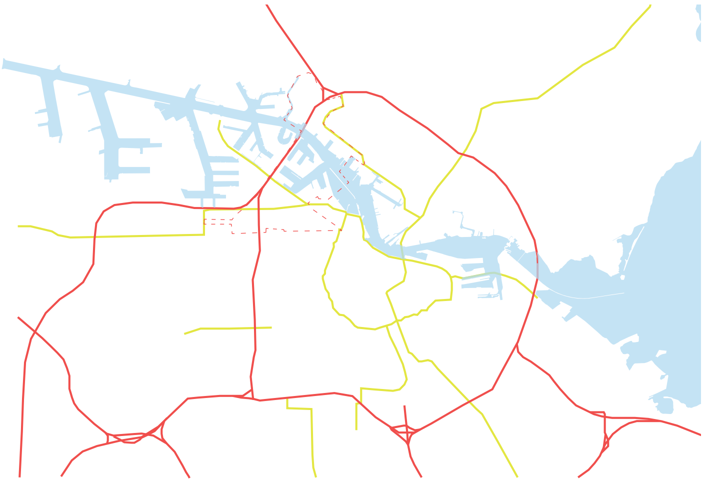
Here it is visible that for one of the base blocks even a regular rain is more than it can handle.



Rainfall within the capacity of the system

Here in green it is visible how the rainfall of up to 30mm is within the system's coping capacity. However this is not the case when it comes to the new standard of 60mm or extremes such as 90mm per hour. (see added table in the last appendix for details)

Functional profile



Map of the highways and the main roads in Amsterdam.

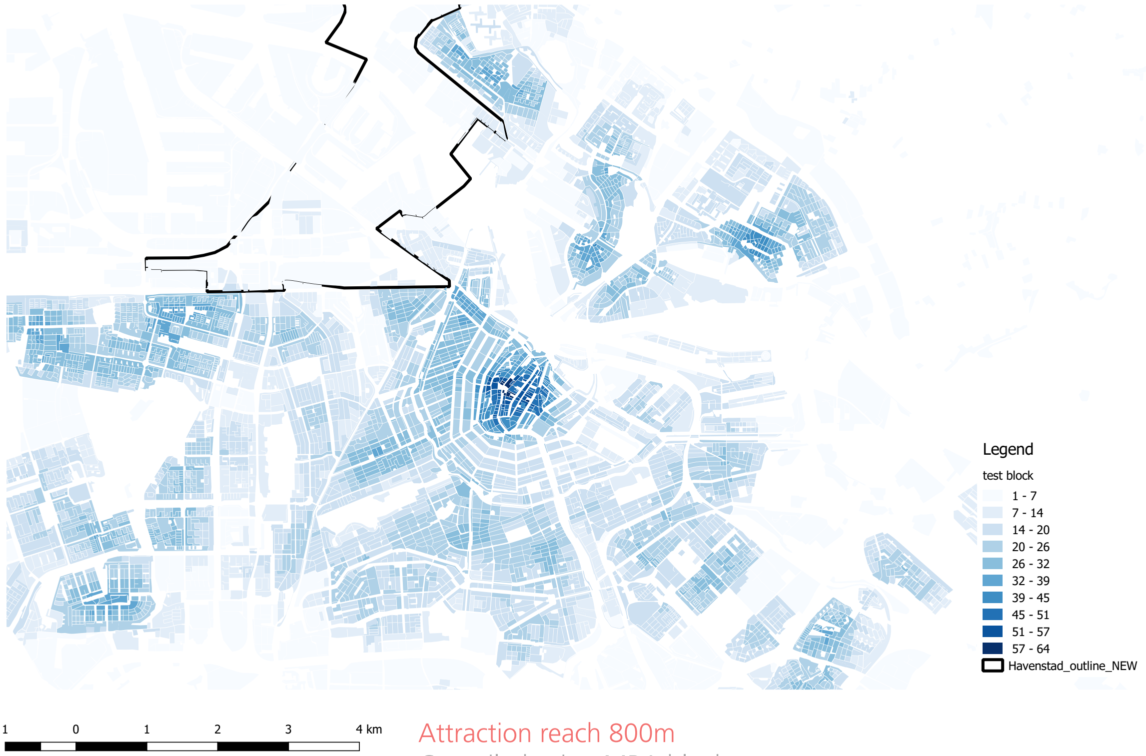
Red: Highways

Yellow: Main roads
It is clearly visible that the Havenstad area is very well connected to the main road network.

Map of the railways and high capacity public transit (trams and metros)

grey: railways
pink: tramways
purple: metro

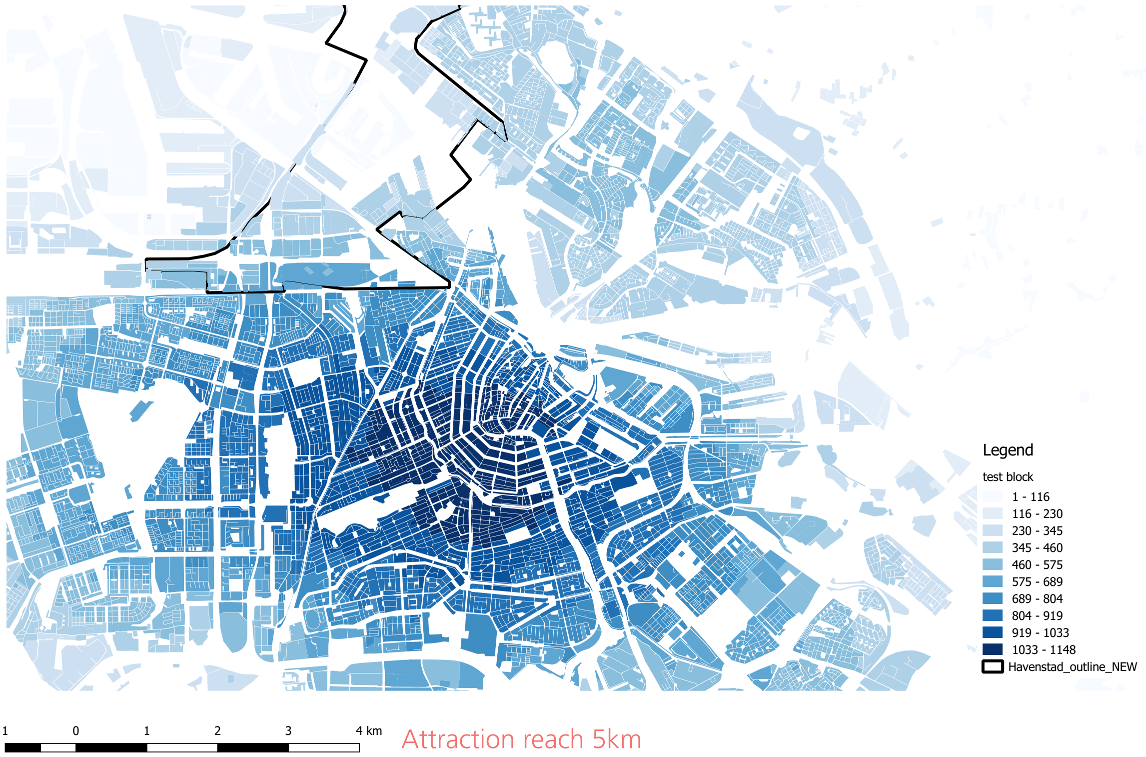
In contrast to the connection to the main road network, Havenstad is largely disconnected from the public transit network.



Attraction reach 800m

Compiled using MRA blocks

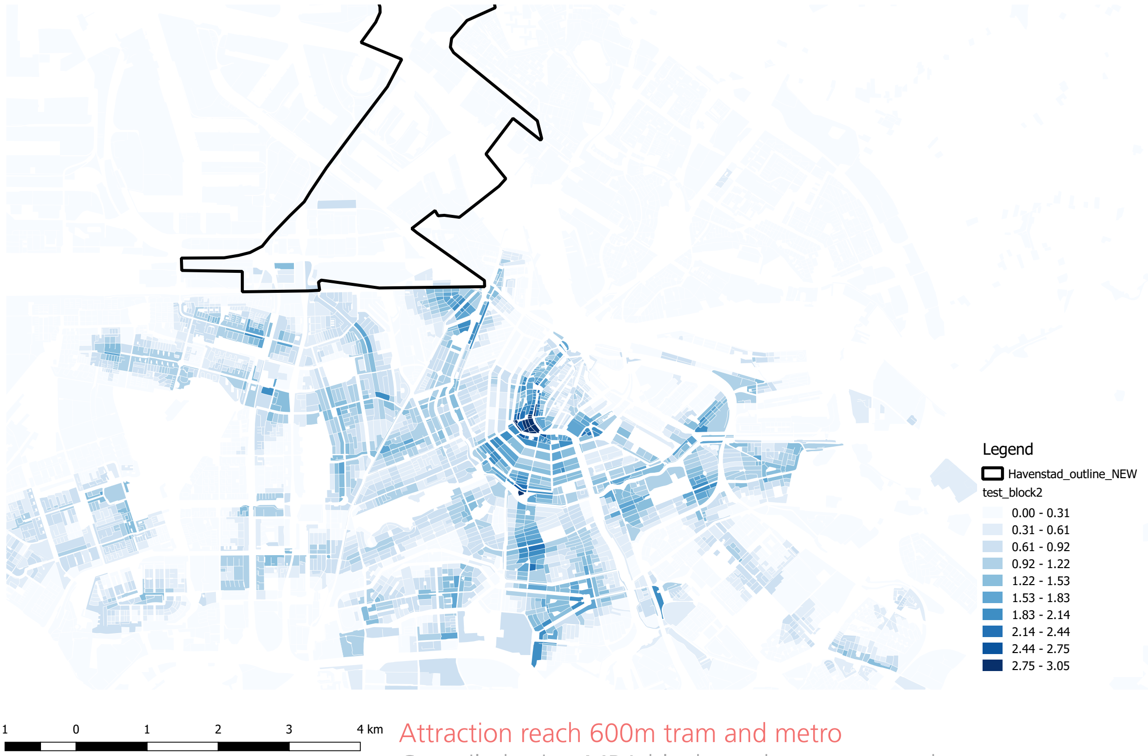
It is clear that Havenstad lies outside of the areas that are most connected for pedestrians.



Attraction reach 5km

Compiled using MRA blocks

When looking at the situation from the cyclist's perspective the area is still located peripherally compared to the centre, but the short distance to said centre has positive effect.



Attraction reach 600m tram and metro

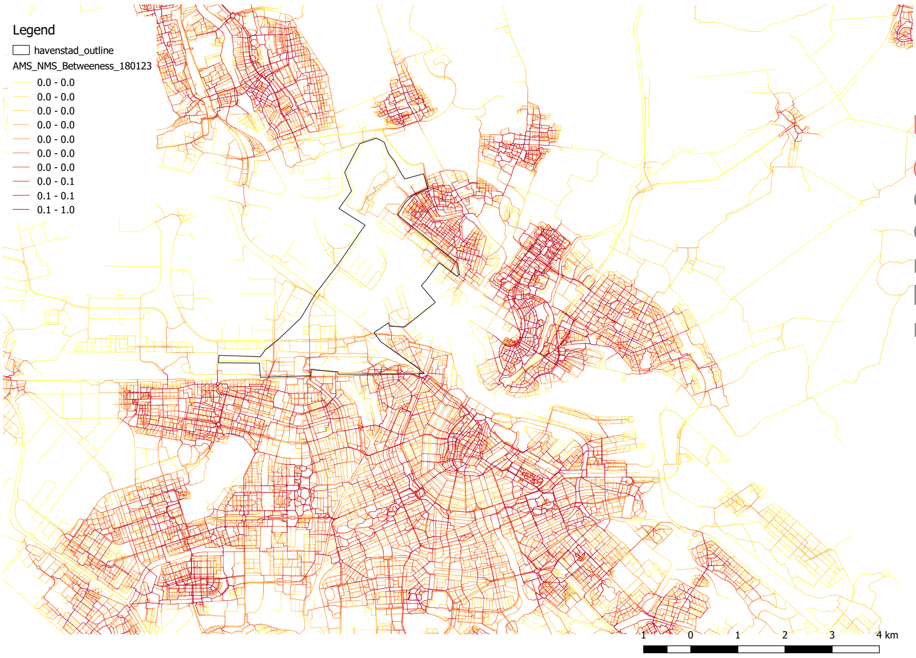
Compiled using MRA blocks and maps.amsterdam

While the disconnection from the public transit network was mentioned earlier, here, it can be clearly seen that the area has but weak connections to the rest of the city via transit.

Attraction reach 900m train and metro

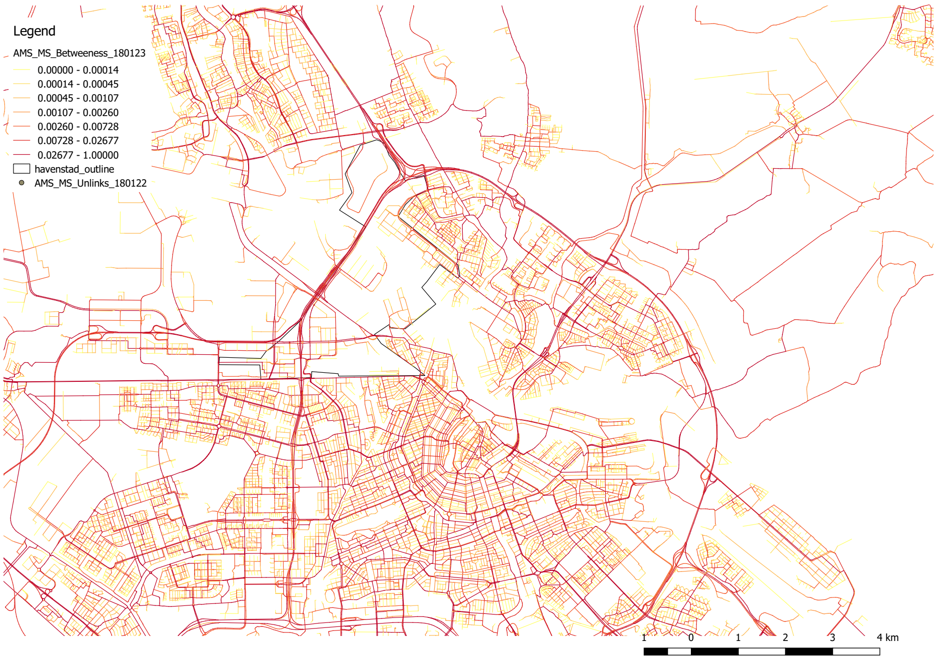
Compiled using MRA blocks and maps.amsterdam

Here the situation is more accentuated, although here the short distance to Sloterdijk station proves beneficial.



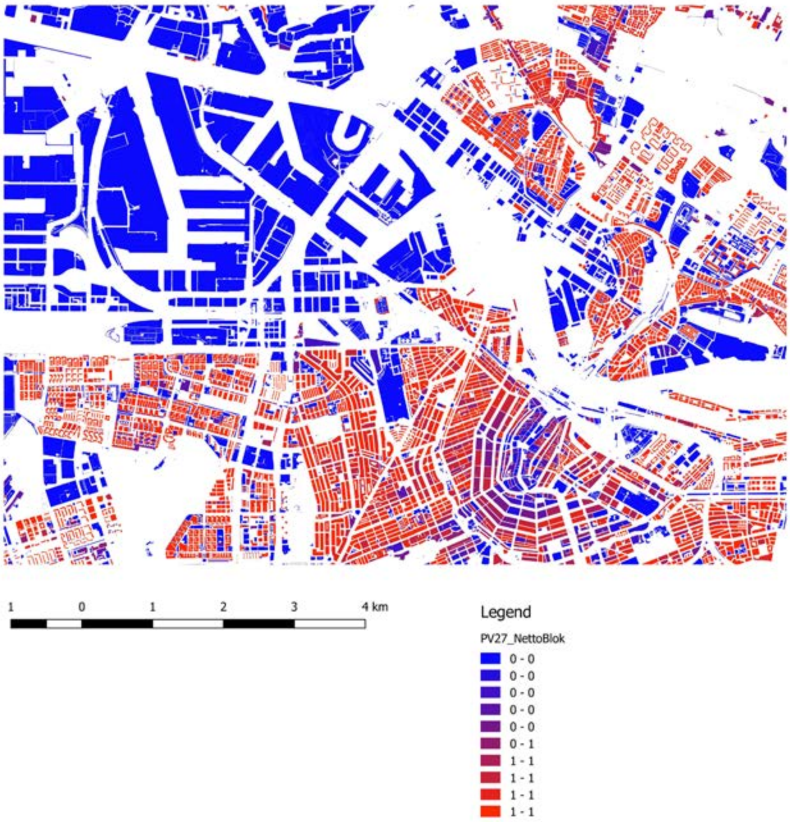
Network betweenness for pedestrians (up to 800m)

Calculated using the PST tool in QGIS. Calculated using “AMS_nms_betweenness” and AMS_nms_unlinks” provided by Birgit Hausleitner (personal communication, 2018)



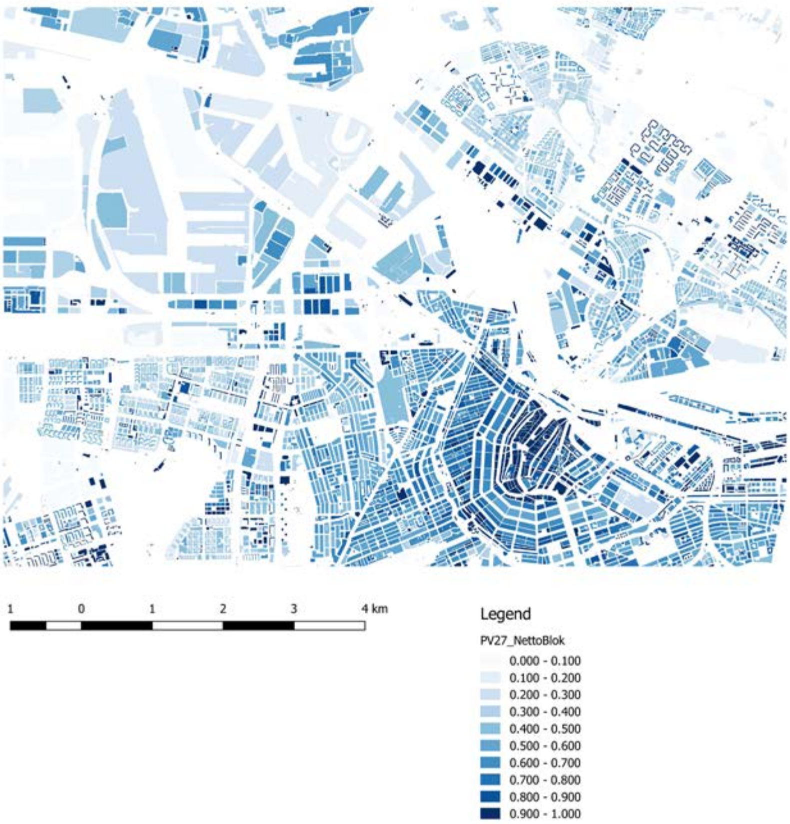
Network betweenness for automobility (up to 20km)

Calculated using the PST tool in QGIS. Calculated using “AMS_ms_betweenness” and AMS_ms_unlinks” provided by Birgit Hausleitner (personal communication, 2018)



MXI in Amsterdam

Created using dataset RUDIFUN by PBL

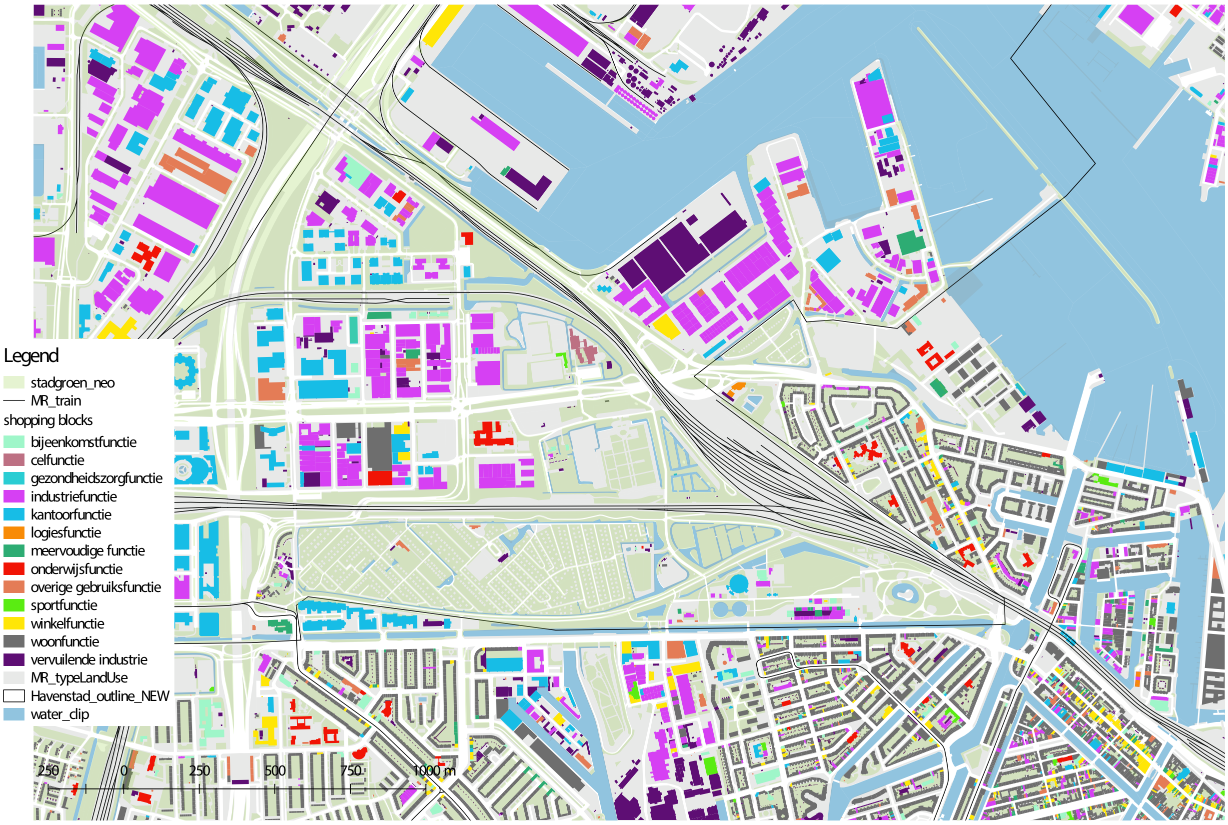


GSI in Amsterdam

Created using dataset RUDIFUN by PBL

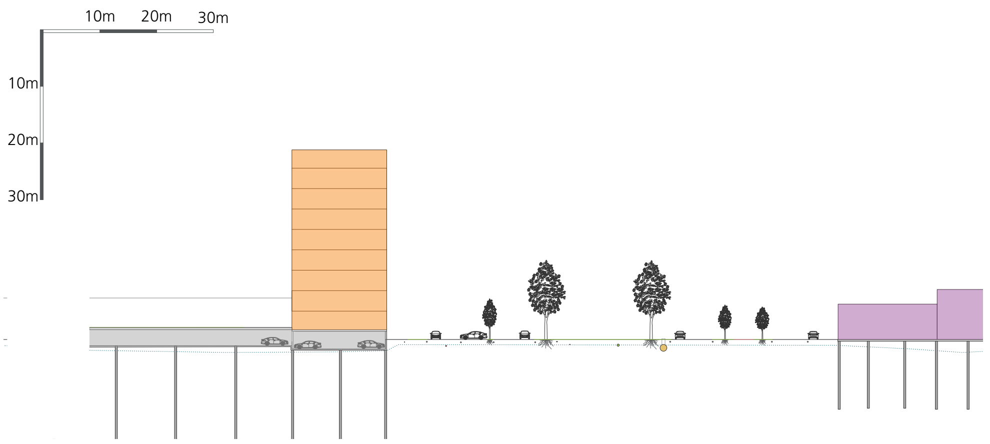
Green structure of the area

Adaptation Gemeente Amsterdam data. Retrieved on 02-05-2019 from https://data.amsterdam.nl/data/?modus=kaart&center=52.364597%2C4.8858121&lagen=egnp%3A1%7Cegnnp%3A1%7Cegsp%3A1%7Cegve%3A1%7Cegwo%3A1%7Cegwa%3A1%7Cegpr%3A1%7Cegst%3A1%7Cegog%3A1%7Cegga%3A1&legenda=true&zoom=8

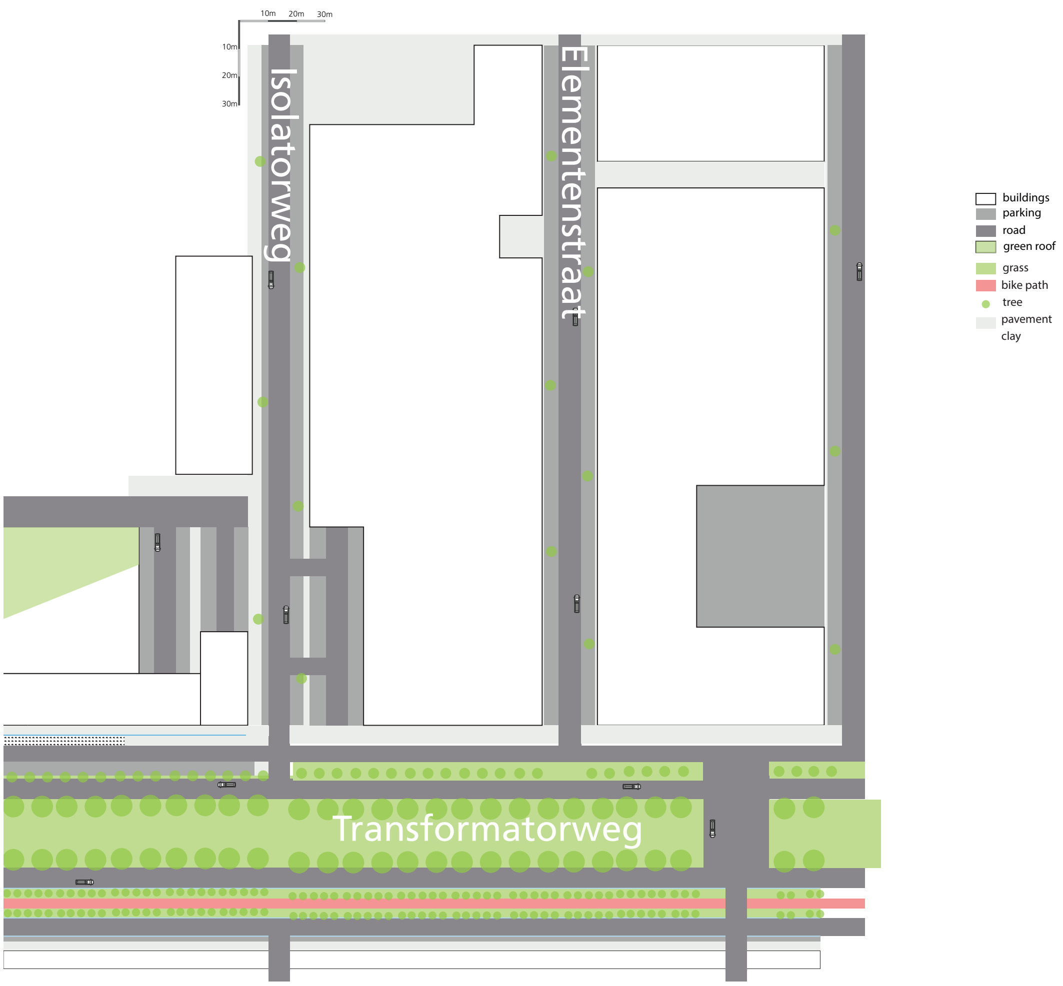


Functions in the area

Adaptation BAG GIS data.

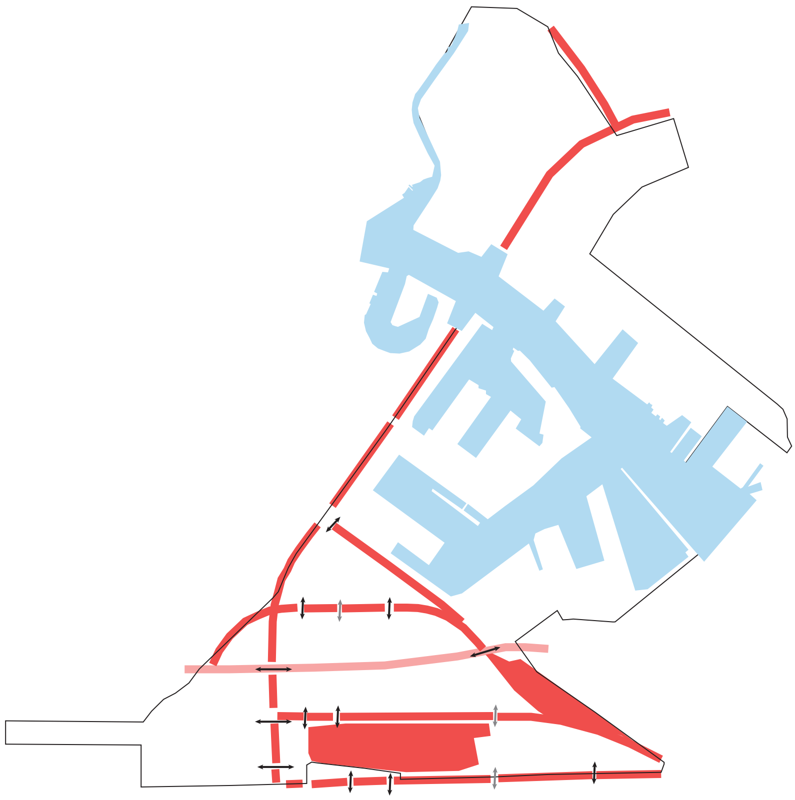


Seciton Transformatorweg



Threats and opportunities

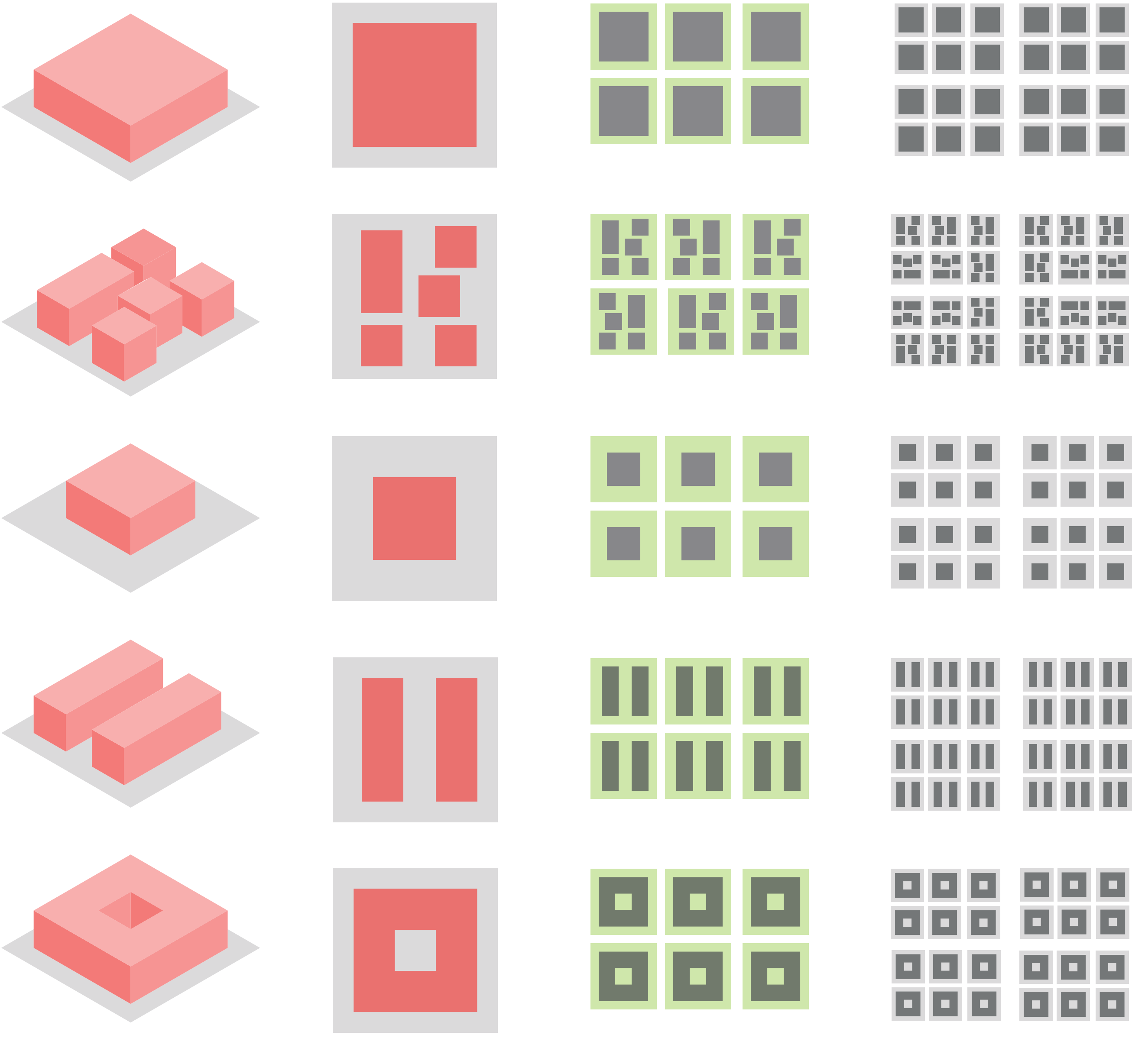
When looking at the different layers it is clear that some threats have a direct influence on the potential of the other layers. The limited amount of space dedicated to surface water in the area affects the subsurface layer as the groundwater levels can rise. Similarly the high degree of impermeable ground cover limits the potential for the ground to fulfill an ecosystem service.



Guidelines from external input

In the research conducted for the Milieueffectrapportage Haven-Stad (MER) (Gemeente Amsterdam, Antea Group, 2017) and the Ontwikkelstrategie Haven-Stad several points for the development into the high quality urban working and living environment are mentioned:

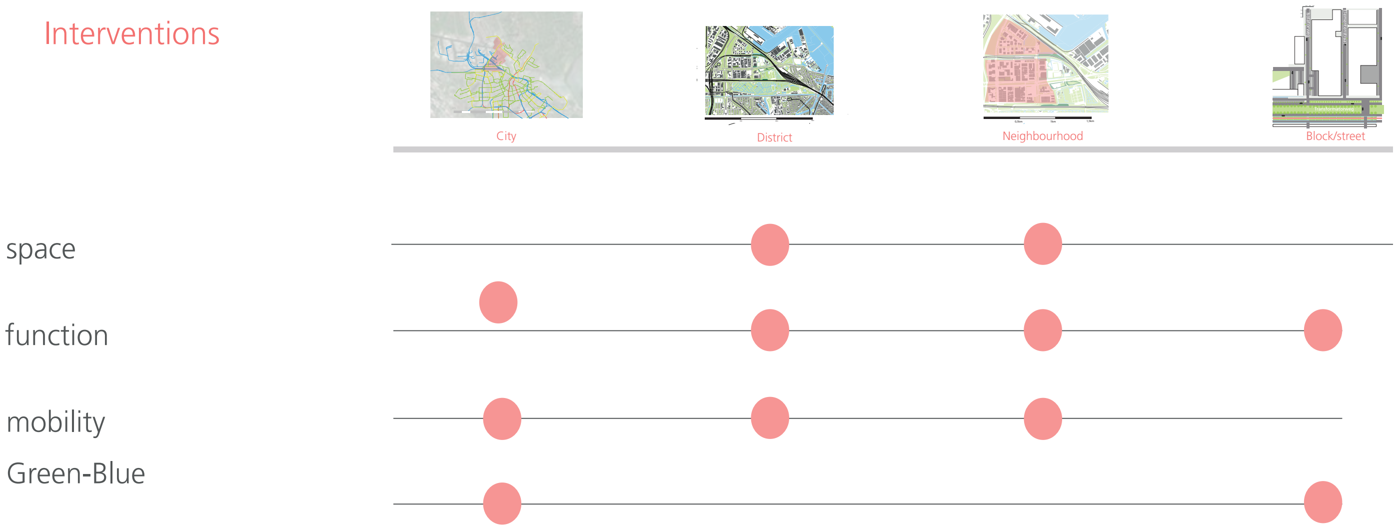
- Facilitating active mobility such as cycling and walking through the introduction of a small grained network.
- Uphold a maximum of 0,2 parking spaces per dwelling.
- Introduce high quality bus connections to the city centre and Noord.
- Change the main routes for car traffic.
- Limit street parking and stimulate car and ride sharing.
- Introduce collective parking connected to transit along the A10 ring.
- Expand the existing metro network and introduce high impact public transit.
- Do not connect any developments to gaslines.
- Address the issue of sound within the area.
- Connect green areas and improve the quality of said green.
- Create 8-10m high plinths for the buildings.
- The institution of a surface water replacement mechanism and rain water retention in the blocks.



Synthesis

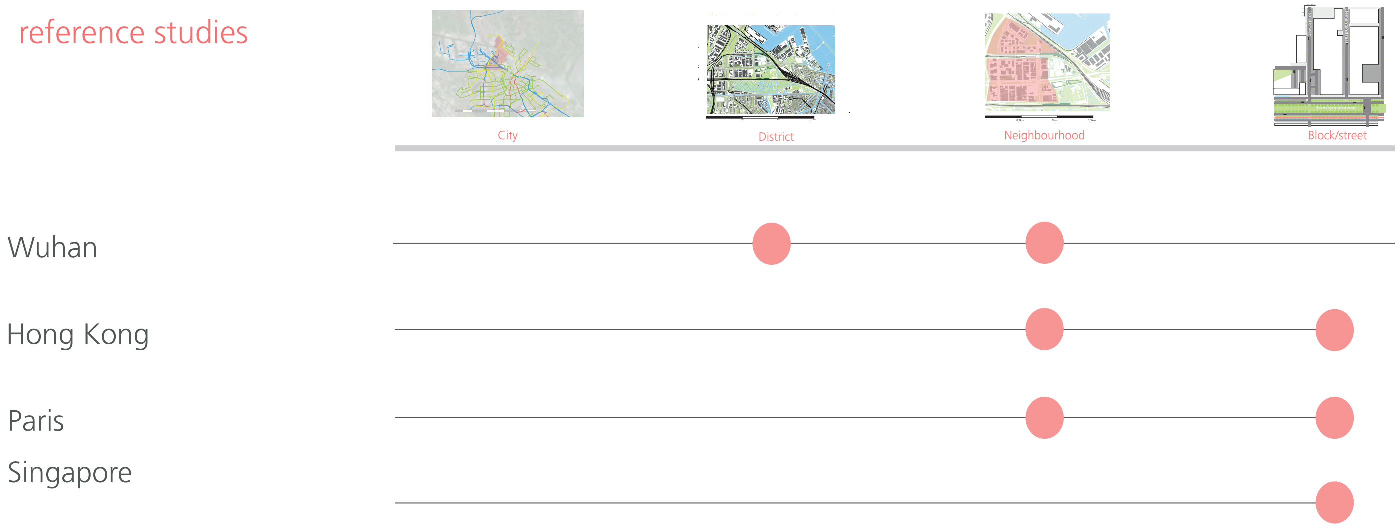
This chapter is where the design approach comes together with the problems in an experimenting fashion. What performs well within the area and what could, should definitely be improved? To inspire this process, several reference studies have been undertaken. All leading up to the design vision.

Interventions



Both the

Reference studies



The research includes several reference studies from 6 different cities, from which a specific type of environment has chosen to understand how this environment functions in relation to the theory framework that is established. In doing so, the aim is to inform the design process. The chosen cities are divided between Europe and East Asia, so the applicability of the different guidelines and patterns may differ according to the location.

On the district scale city of Wuhan has been chosen:

- Wuhan. The reason this city has been chosen is the adoption of the Sponge City Programme by the Chinese government in response to challenges regarding urban flooding and drought. The insights on this city and the relation to resilience has been informed by an interdisciplinary project undertaken in this area in China.
-

On the neighbourhood scale the cities of Paris and Hong Kong were chosen:

- Paris. Here the development of the Massena quarter after a masterplan by Pontzamparc is taken as an example of how the theory and patterns can be applied in the design strategy. Paris for the development of Quartier Massena. This has been informed through a field visit to the area.
- Hong Kong. This city was chosen due to the high density and the high accessibility in the city. While the amount of buildable land has been limited both legally and as a result of the mountaineous landscape, the population of the city has continued to increase. The liveability in the city is strongly connected to the connectivity and the design of the new public domain that operates independently from the ground has been explored during a field visit in preparation for the project.

On the scale of the street/block the cities of Vienna and Singapore were chosen:

- Singapore. The city state has been chosen based on the strategic approach to densification that incorporates ecosystem services in new developments. This so-called Landscaping for Urban spaces and Highrises (LUSH) programme is a evolving guideline to which new developments must comply in order to receive greenlighting.

Wuhan

The ErQi International Business District under development, with an approximate FSI of 3,8 (or 5,6 including the garages) for the district.

In response to recurring urban flooding, often exacerbated by the rapid construction development of the cities, the Chinese government launched the so-called Sponge City Programme(SCP) in 2014 (Dai et al., 2018). As the name suggests, the aim of said programme is to increase the water retention capacity of the city to reduce the incidence of urban flooding and store it for a later use (Arcadis, 2017; Yang, 2016). The city of Wuhan is amongst the selected Sponge Cities, requiring compliance for new projects. This has a profound effect on the development of new areas, such as the ErQi International Business District under development to capitalize on the opportunities afforded by its function in the One Belt, One Road initiative, connecting China, and connecting the world to China.

This is evidenced by the proactive development of infrastructure, such as the metro system.

In this development the pressures of development led to difficulties regarding the compliance with the, now mandatory, SCP. Through personal experience as part of the Sponge City Project Multidisciplinary team working on the water management for this area with Arcadis.

Here the seeming conflict between development and resilience arose as the proposed occupation and the natural conditions of the area did not allow for traditional implementation of green blue solutions. More so, the strict adherence to the SCP guidelines such as permeable pavement and depressed green, was proven to be less effective than desired without a strategy on a larger scale, taking into account the interaction of the local conditions.

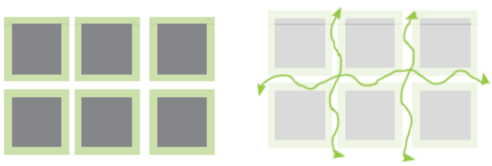
An additional challenge here is what happens during a stronger rain event.

Guidelines for the project:

- The resilience structure is central in the design. pushing it to a later phase of the project requires difficult and costlier solutions to achieve the desired outcome. A proactive approach is key.
- The T=2 event is the base design. To ensure continued function, the design should take larger events into account.
- Make sure to have an overall strategy for the resilient design, including local conditions.

As the ErQi neighbourhood is still under development a similar situation has been pictured above. The neighbourhood typology near Houhu station in Wuhan, 2018. Here the area consists of towers with private parks atop parking structures. Here the use of permeable pavement and depressed green as called for in the SCP requires additional drainage as infiltration to the soil is not possible.

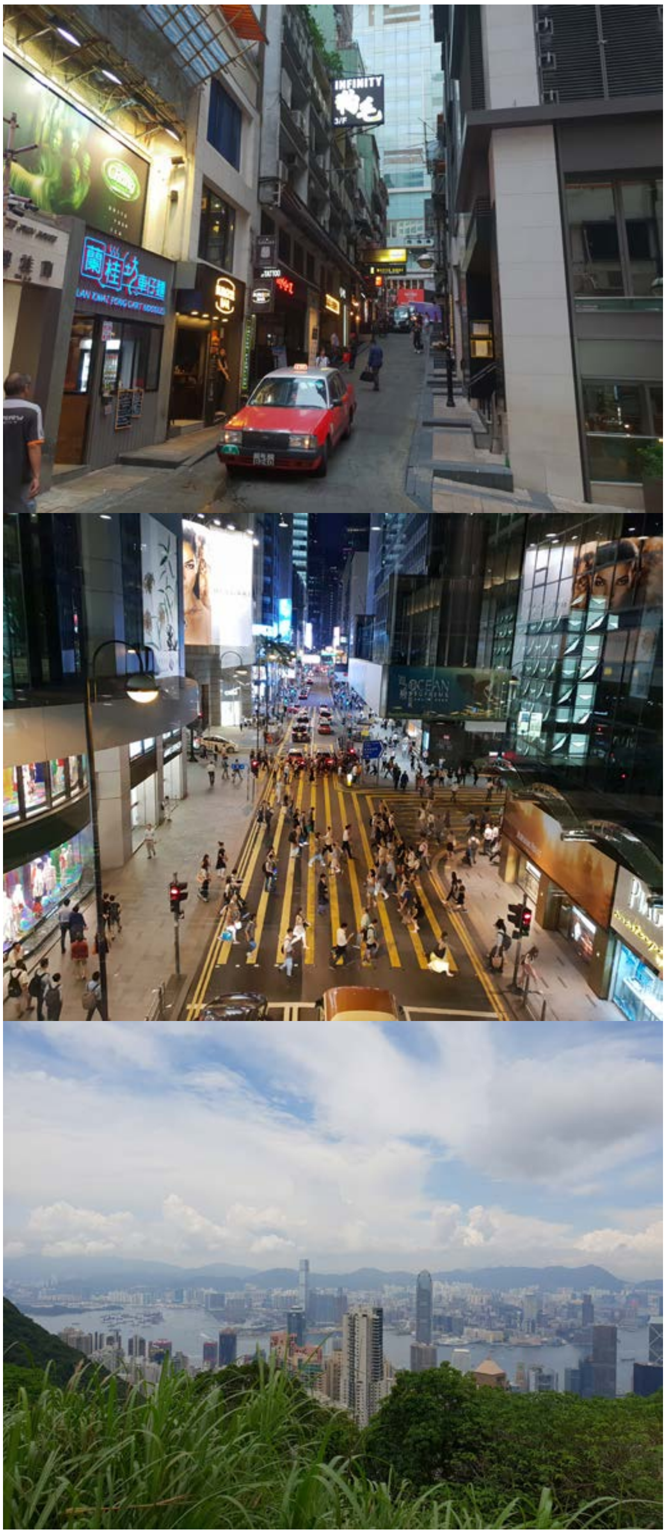
Various ground level uses during different times of the day.



The closed block

Regarding the function for ecosystem services the chinese towerblock functions as a closed block.

Hong Kong



The pressure on the ground is very high in the built area of Hong Kong. On much of Hong Kong island the FSI ranges from 6 to 10.

While most of the Special Administration region of Hong Kong consists of non built environment, legislation has for a long time mostly limited development to the areas within the city's limits. (Hwang, personal communication, May 2017)

This purposeful policy of limiting the land use, coupled with a consistent increase in population has resulted in the highest population densities in the developed world, with neighbourhoods reaching densities of up to 54000 inhabitants per square kilometre.

Such high population densities have required a vastly different approach to space alltogether. As space, both public and private, is extremely limited in this city, a public domain has developed that extends over multiple layers.

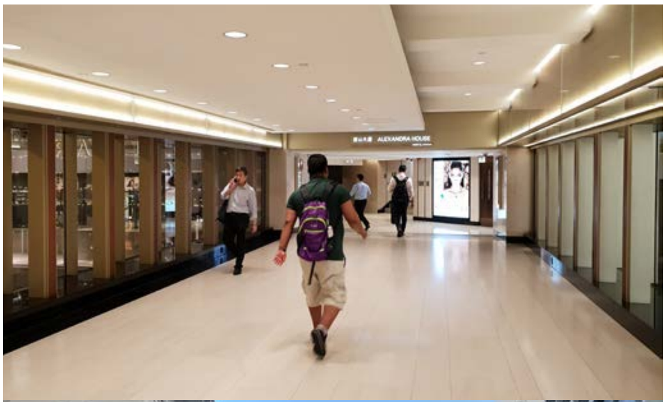
In the neighbourhood of Central that has been pictured on these pages it is clear that transit oriented design has been taken to a whole new level altogether. Here public transit is a vital and central component of the network. From here the pedestrian multilevel connections reach much of the area.

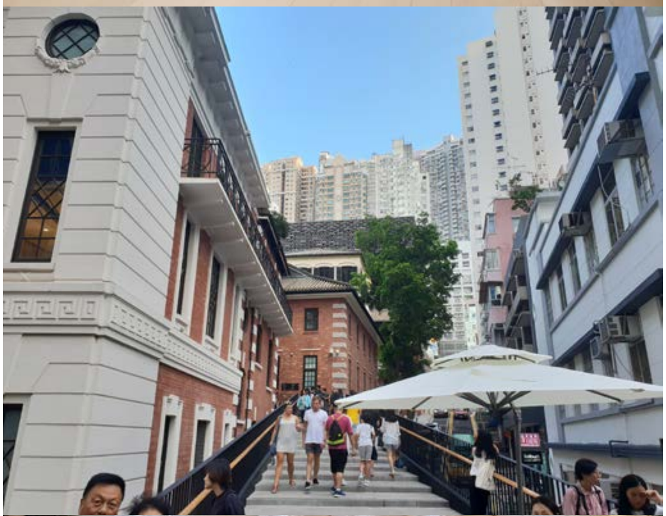
It is particularly interesting to see how the design quality of these essentially privately owned areas is strongly maintained and has become the main network businesses are connected to instead of the street level. (Frompton, Solomon & Wong, 2012)

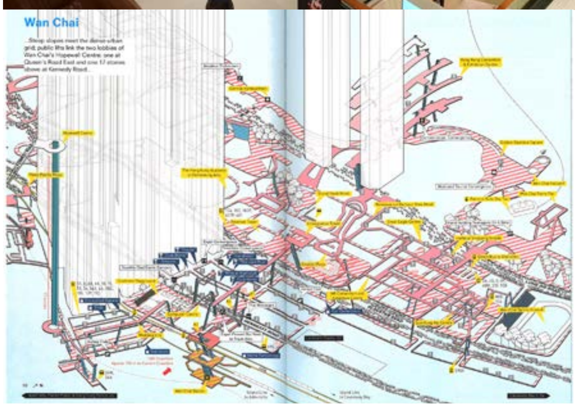
This multilevel approach extends to green spaces

Guidelines for the project:

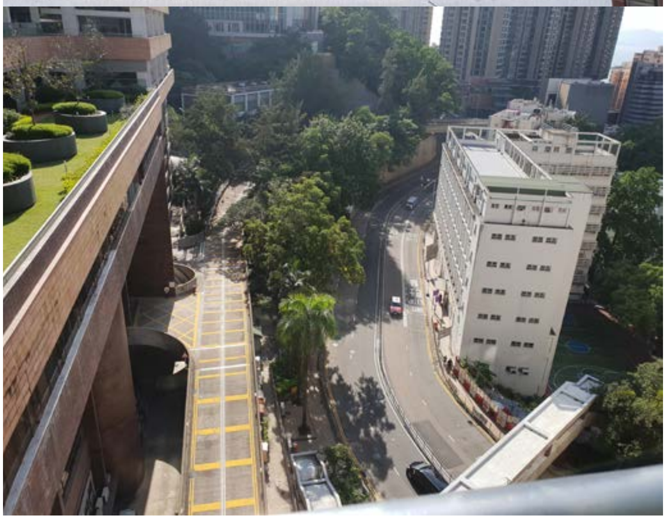
- A high accessibility is crucial for the liveability in environments of such a high spatial density.
- Extreme space constraints can inspire the development of a different type of public domain, like what Hajer and Reijndorp suggested would be the case (2001, p. 48)
- Space constraints apply to everyone. The T=2 event is the base design. To ensure continued function, the design should take larger events into account.







What started out as a footbridge connecting two warehouses, has developed into a vast system of multilayered spaces connecting entire neighbourhoods. The image below is the scheme for Wan Chai by Frampton, Solomon and Wong (2012)

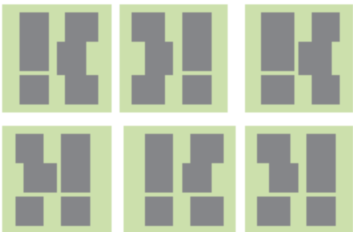


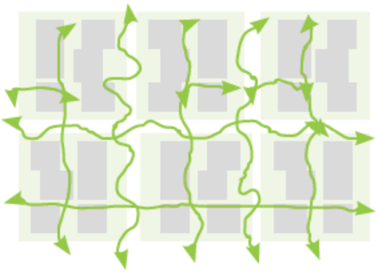
Blending rooftop green areas with the mountainside works as an illusion of the ground.

By using the ground level as well as going underground, even large scale commerce, such as IKEA could be accommodated.

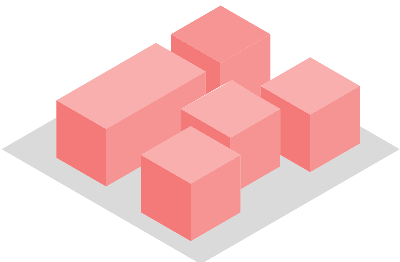
Paris

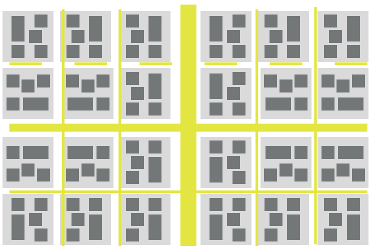
In the city of Paris the Massena district designed by Pontzamparc. The way it is special is that ist is a different iteration of the urban block that is neither open nor closed. I essentially consists of an assortment of buildings grouped and designed in such a way that the city maintains a cohesive legible structure, while it offers space for leisure and for ecosystem services.





The Massena block





Regarding the function for ecosystem services the chinese towerblock functions as a closed block. The Massena block type offers a host of opportunities regarding space and potential hierarchies.

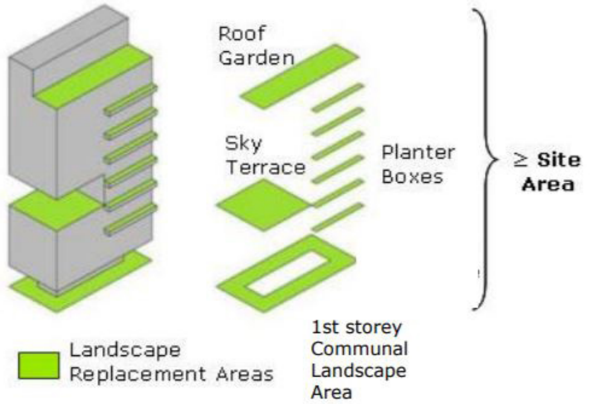
Singapore

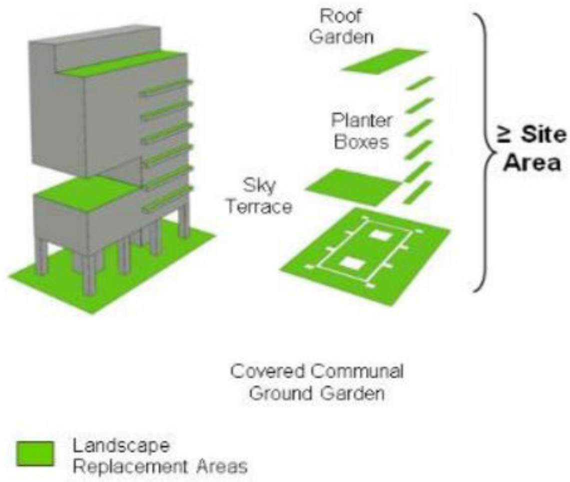
Singapore has been selected for the seeming paradox arising from the city's desire to be a garden city, while the area is strongly being developed.

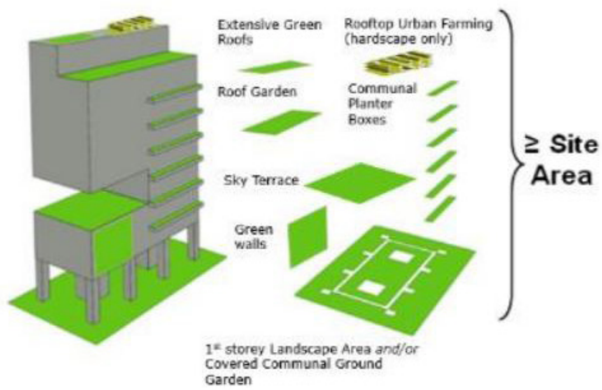
The institution responsible for land management and development, the Urban Redevelopment Authority, developed

beig committed to being a Garden City. In response to the inevitability of a loss of open space the city has developed the LUSH policy in order to be able to provide its growing population with additional housing opportunities while maintaining and in places increasing green spaces and ecosystem services.

Comparable due to the city's lack of space for expansion and the historical vertical development.







LUSH 1,2 and the current policy, LUSH 3"Diagram of various types of Landscape Replacement Areas that could be incorporated within a development" 09 11 2017. Urban Redevelopment Authority. Retrieved on 20 Nov 2018 from https://www.ura.gov.sg/-/media/User%20Defined/URA%20Online/media-room/2017/Nov/pr17-77a.pdf

Kampung Admiralty. Image by K. Kopter “Kampung Admiralty / WOHA” 25 Oct 2018. ArchDaily. Accessed 23 Sep 2019. <https://www.archdaily.com/904646/kampung-admiralty-woha/> ISSN 0719-8884

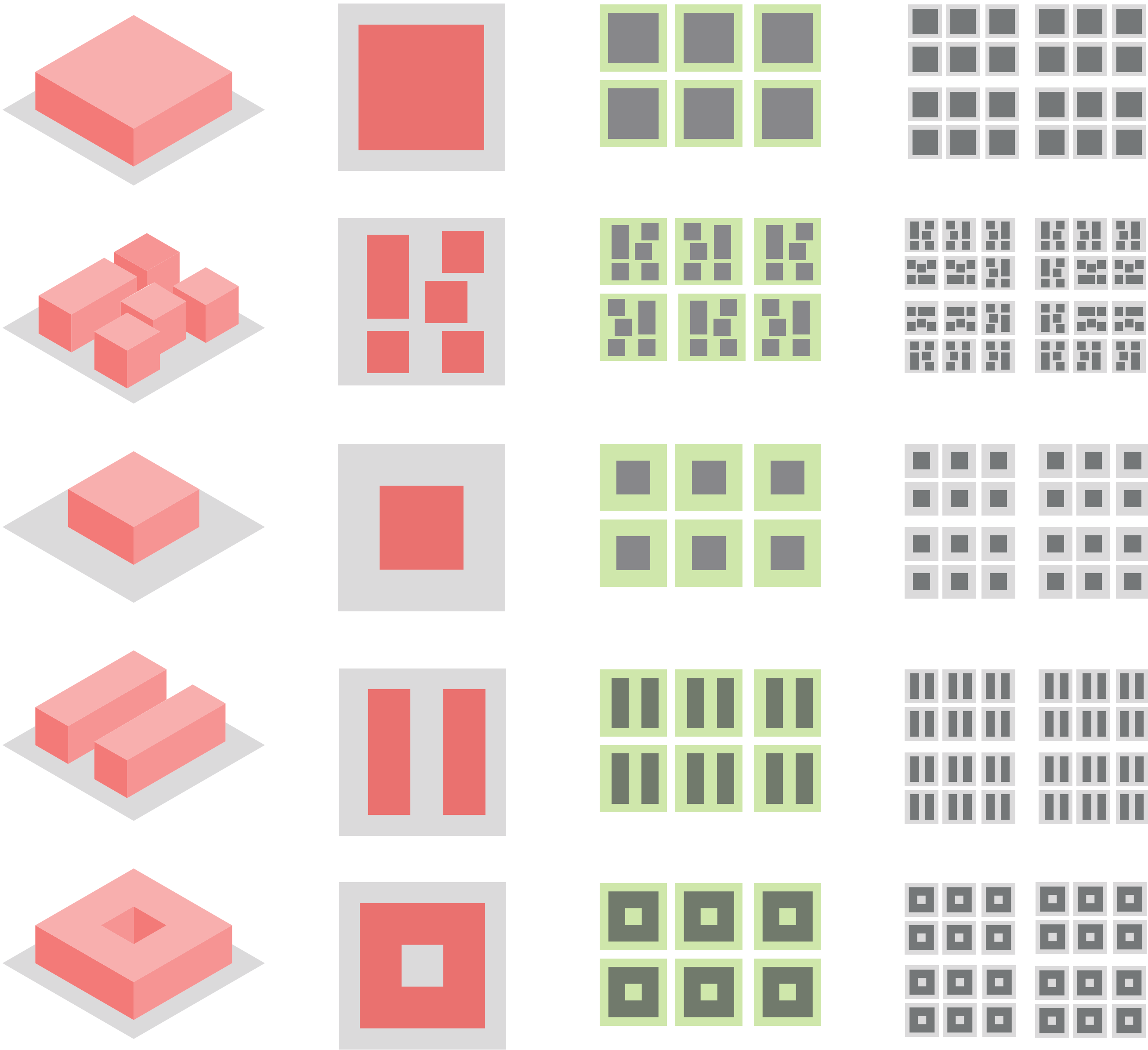
Kampung Admiralty. Image by K. Kopter “Kampung Admiralty / WOHA” 25 Oct 2018. ArchDaily. Accessed 23 Sep 2019. <https://www.archdaily.com/904646/kampung-admiralty-woha/> ISSN 0719-8884

Kampung Admiralty. Image by K. Kopter “Kampung Admiralty / WOHA” 25 Oct 2018. ArchDaily. Accessed 23 Sep 2019. <https://www.archdaily.com/904646/kampung-admiralty-woha/> ISSN 0719-8884

PLACEHOLDER Sources

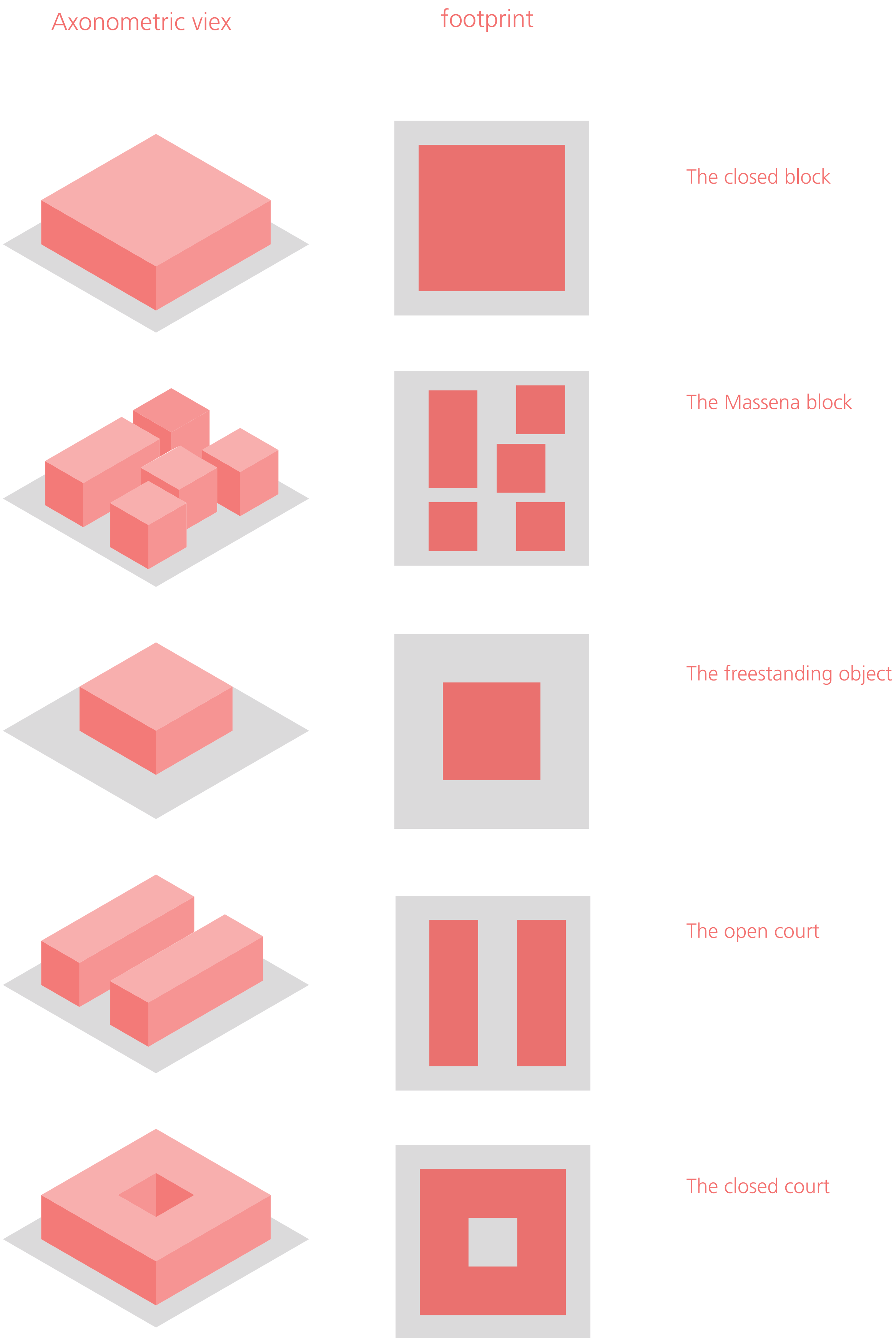
An example of ecosystem services being realised on top of buildings.

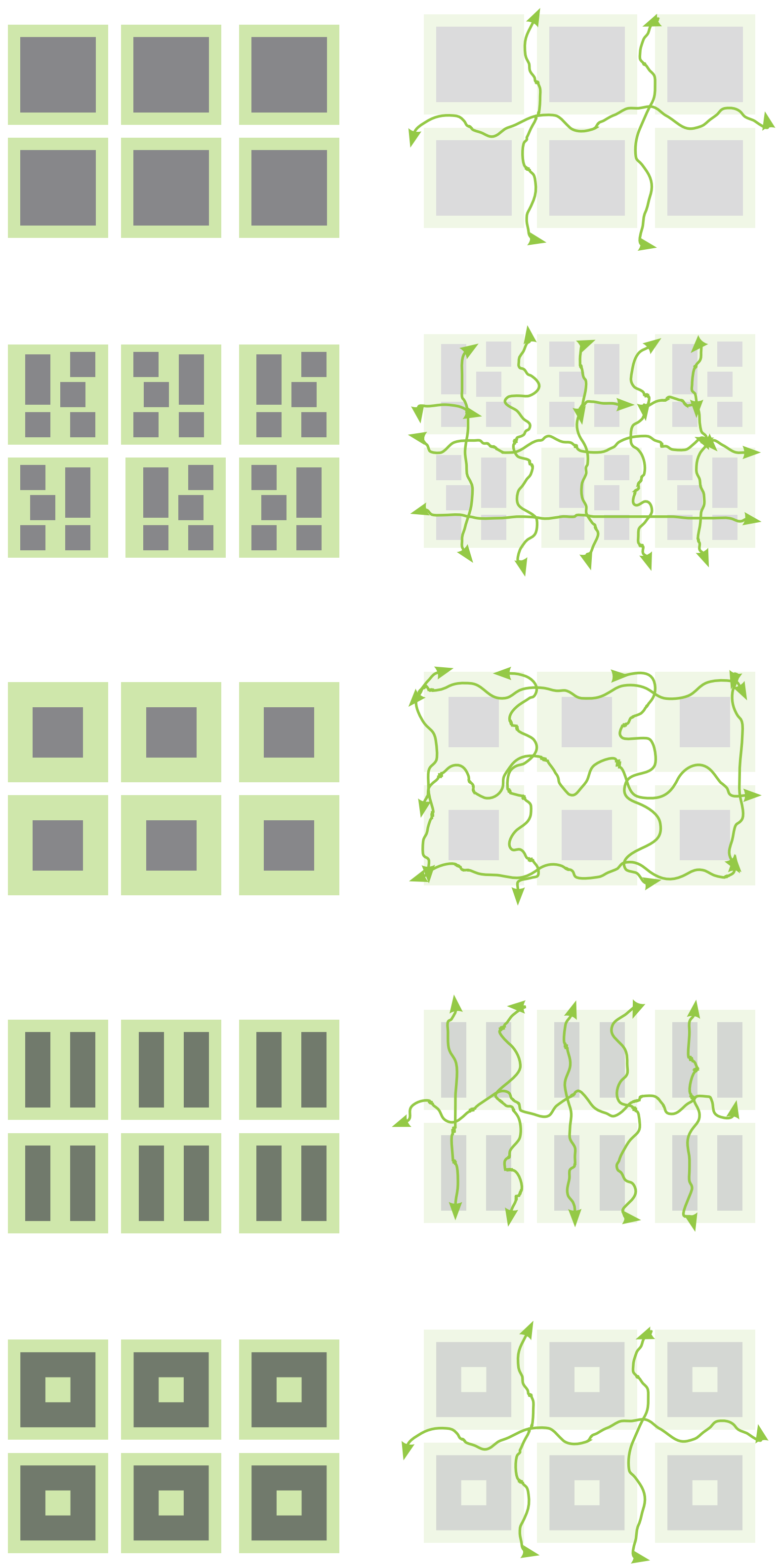
Testing



Looking at the current city of Amsterdam and the reference studies 5 base builting block typologies have been identified, the closed block, the Massena block, the freestanding object, the open court and the closed court.

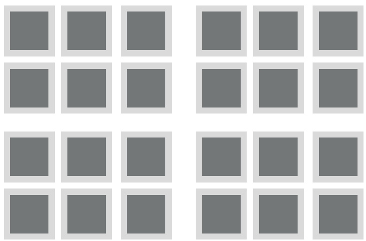
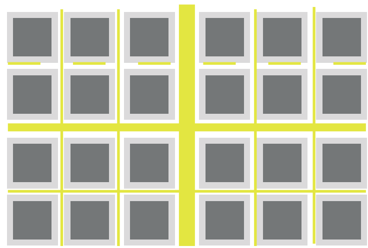
They have been tested according to their capacity to shape the space and resulting qualities.


Axonometric viex
footprint
The closed block
The Massena block
The freestanding object
The open court
The closed court

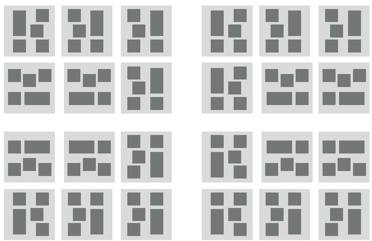
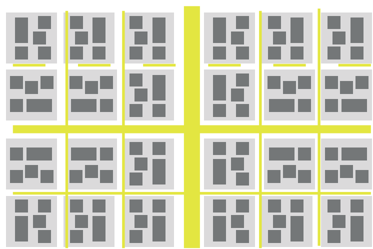

Free ground level space
potential green connectivity
The closed block
The Massena block
The freestanding object
The open court
The closed court

neighbourhood composition

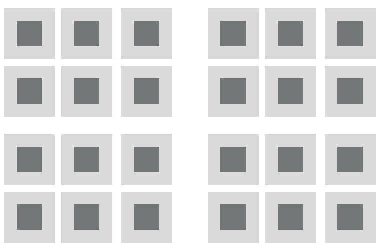
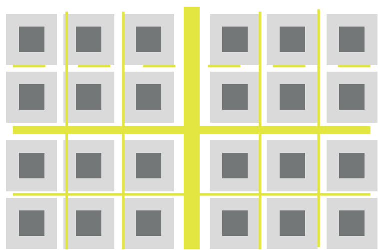
hierarchy of space

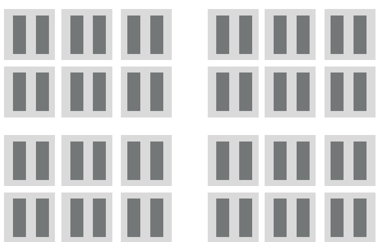
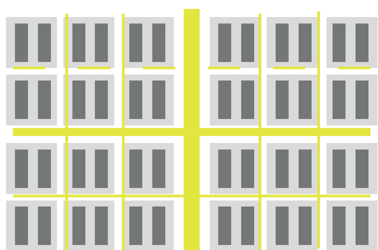
The closed block

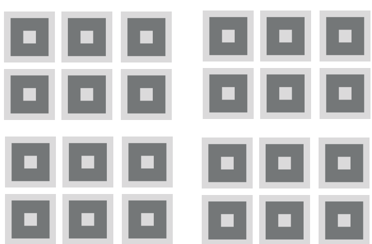
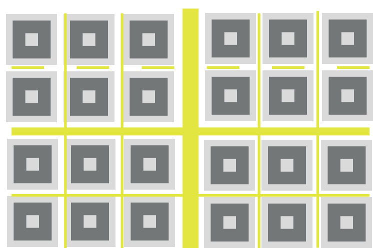
The Massena block

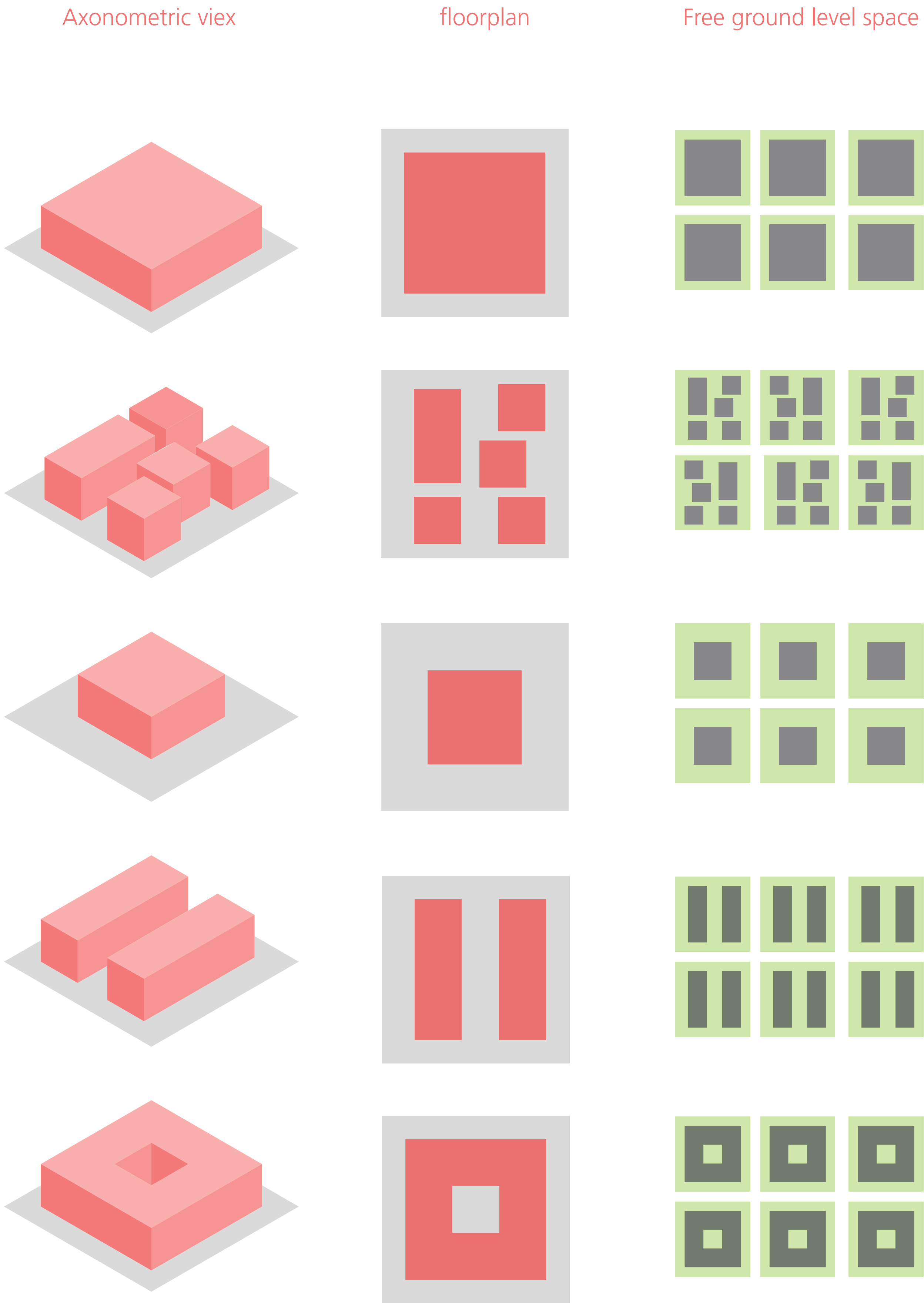
The freestanding object

The open court

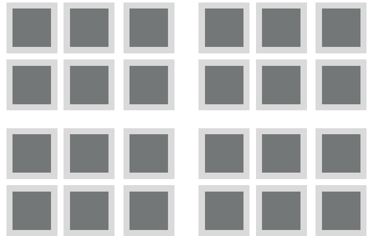



The closed court

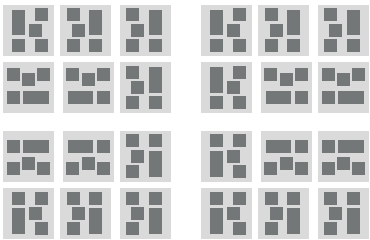

Axonometric viex
floorplan
Free ground level space

Hierarchy of space

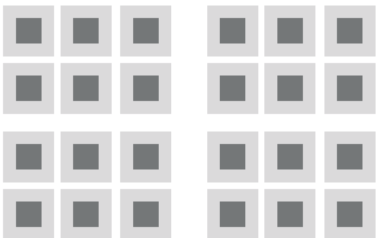
Spatial qualities



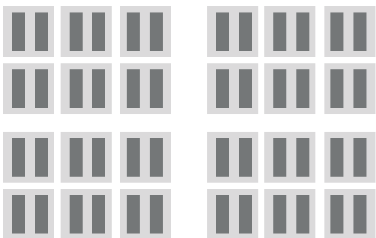
The closed block



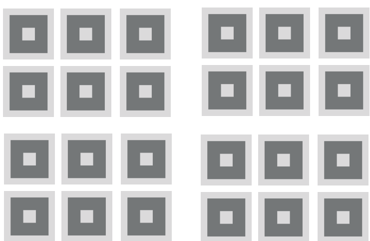
The Massena block



The freestanding object



The open court



The closed court

Variant exploration

During the design process three variants, each one prioritising one of the themes, were explored.

Density

A focus on developing density led to the development of the Urban Intensity variant. This variant's goal is to enable a very high density of activities within the area

Ecosystem Services

A focus on developing ecosystem services in the area led to the development of the Urban Nature variant. This variant's goal is to integrate the park into the city.

Liveability

A focus on developing liveability in the area led to the development of the Urban Accessibility variant. This variant's goal is to fully embrace transit oriented development.

The Urban Intensity variant's goal is to develop a high intensity environment. Through a high density, mix of functions and multipurpose use of space a new type of interaction environment is proposed.

The Urban Nature variant's goal is to develop an environment high in ecosystem services. To do this the current ecosystem services provided in the Westerpark are taken and strengthend through integration witht the district of Havenstad. A multipurpose green structure connects the blocks of the area.

The Urban Accessibility variant's goal is to develop an highly accessible environment with a hierarchy in spaces and routes, integrating transit in the design proposal. To do this the variant proposes a far reaching version of transit oriented development, integrating the various hubs in the urban fabric.

The High Line in New York City, 2018

People strolling and shopping at East Nanjing Road in Shanghai, 2018

Urban Intensity

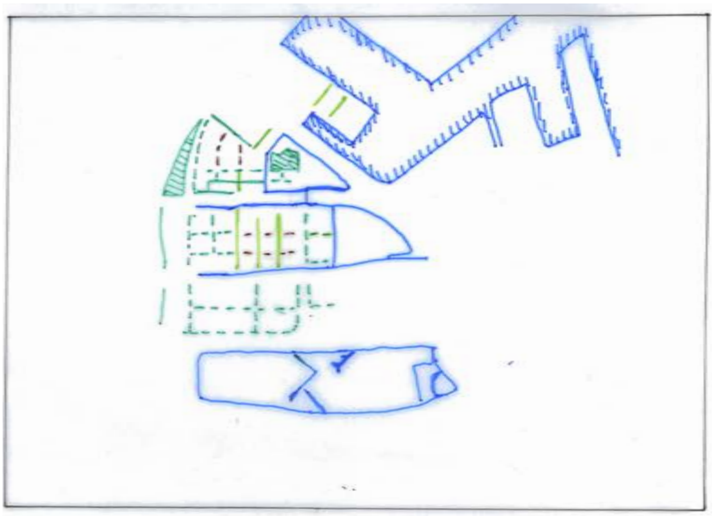
Increase interaction and density of activities

Men playing basketball on a rooftop court in Optics Valley, Wuhan. 2018

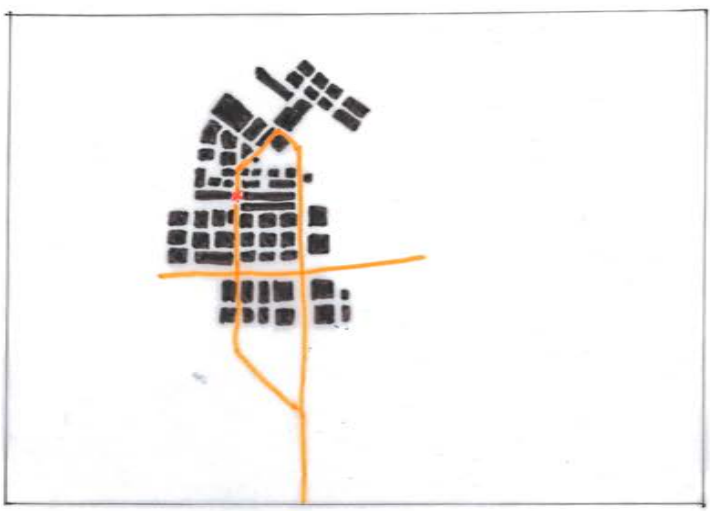
Station square Utrecht Centraal, 2018


Westerpark West
Zaan
emplacement

Variant mobility system
Introducing two additional stations



Green blue system
Water retention and drainage in the public space between the blocks.



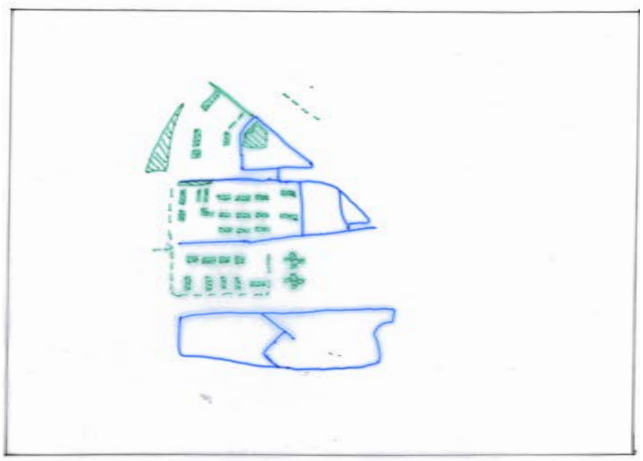
Grain of the built envelopes
Continuing on the current situation, much of the blocks have a high GSI.

Urban nature

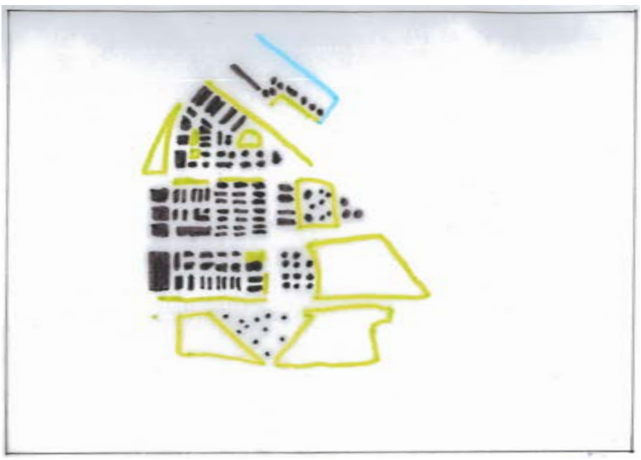
Reconnect the city to the natural systems


Zaan
emplacement
Westerpark West

Variant mobility system
Introducing two additional stations



Green blue system
Water retention and drainage can take place for a large part in the blocks themselves.



Grain of the built envelopes
The slab and element block typologies have a relatively low GSI.

People strolling and shopping at Wanda centre near Chuhehanje station in Wuhan, 2018

The view of Des Voeux in Central district in Hongkong from an elevated walkway, 2018

Urban accessibility

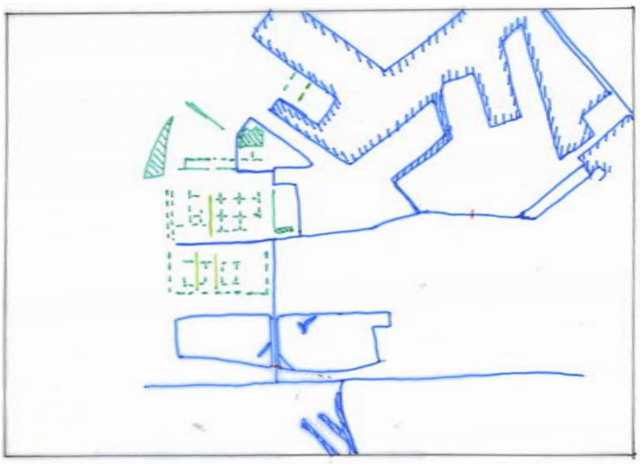
increase the permeability and connection to networks

The public elevated routes of Hong Kong, 2018

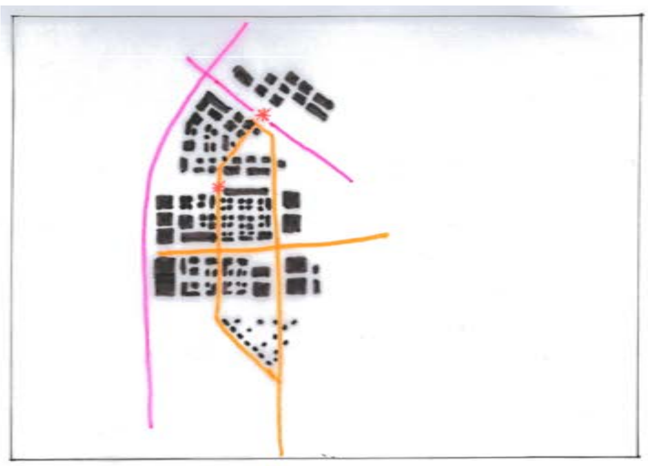
Elevated public space in the Netherlands at Stationsplein in Utrecht, 2018


zaan
emplacement
Westerpark West

Variant mobility system
Introducing two additional stations



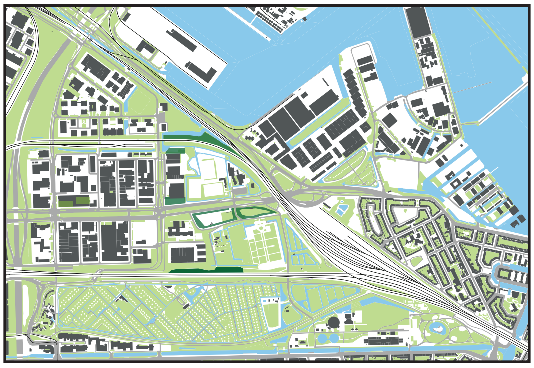
Green blue system
Water retention and drainage can partly take place within the individual blocks, in combination with public space.



Grain of the built envelopes
The GSI is between the Urban Nature and the Urban Intensity variant.

Comparison

Comparison of the current situation with the three variants, looking at the network, the block performance, and resulting spatial qualities. Looking at the topics of space, mobility and resilience.



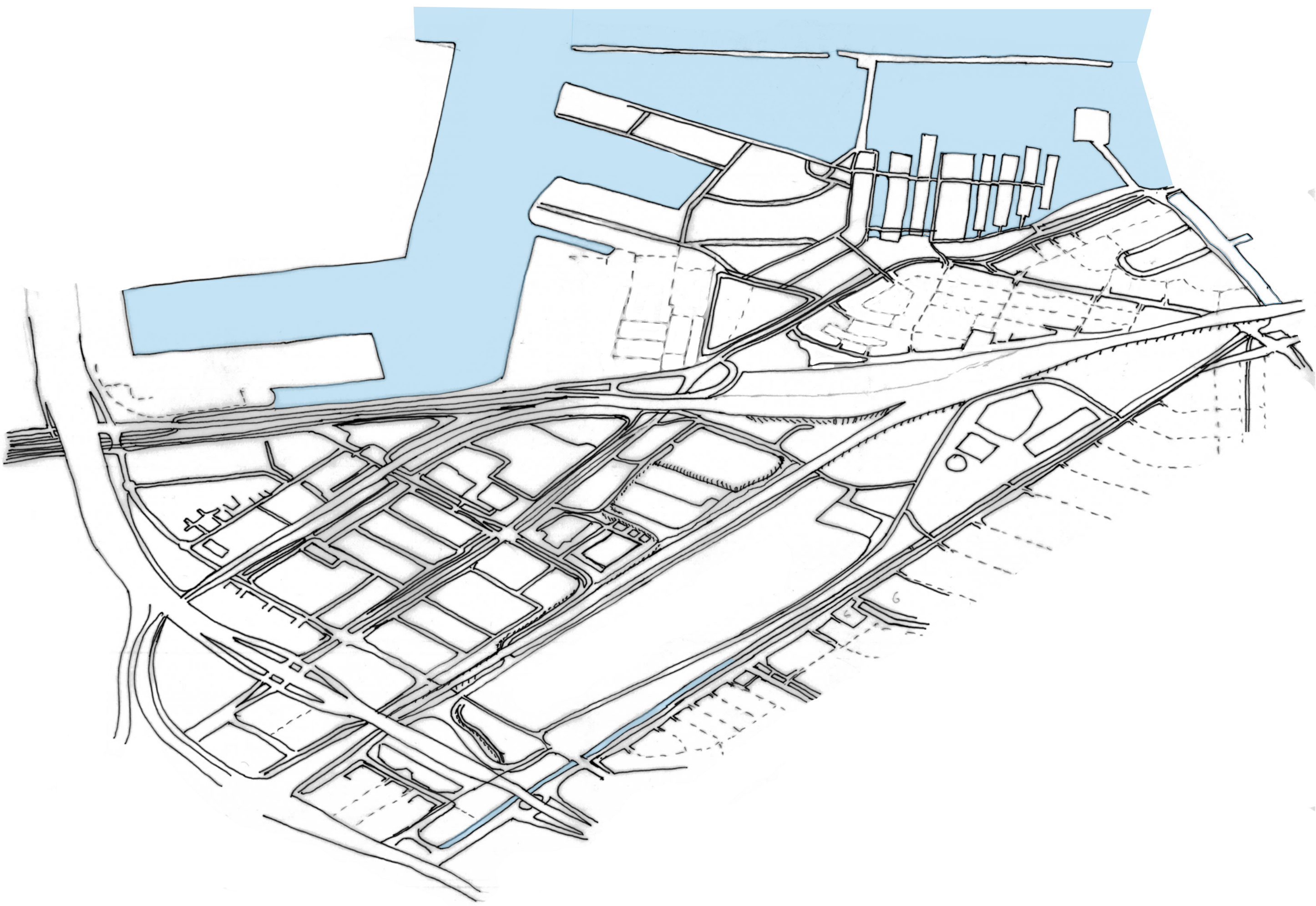
The current situation is an environment that is not designed for liveability, but rather for efficiency. The connections to the park are not very optimised and the connection to the metro station is obscure.

The Urban Intensity variant's has mostly expanded on the existing building footprints in an attempt to increase the population density. The main point of focus here has been the metro station as it attempts to fully embrace transit oriented development and multifunctionality of buildings and infrastructures.

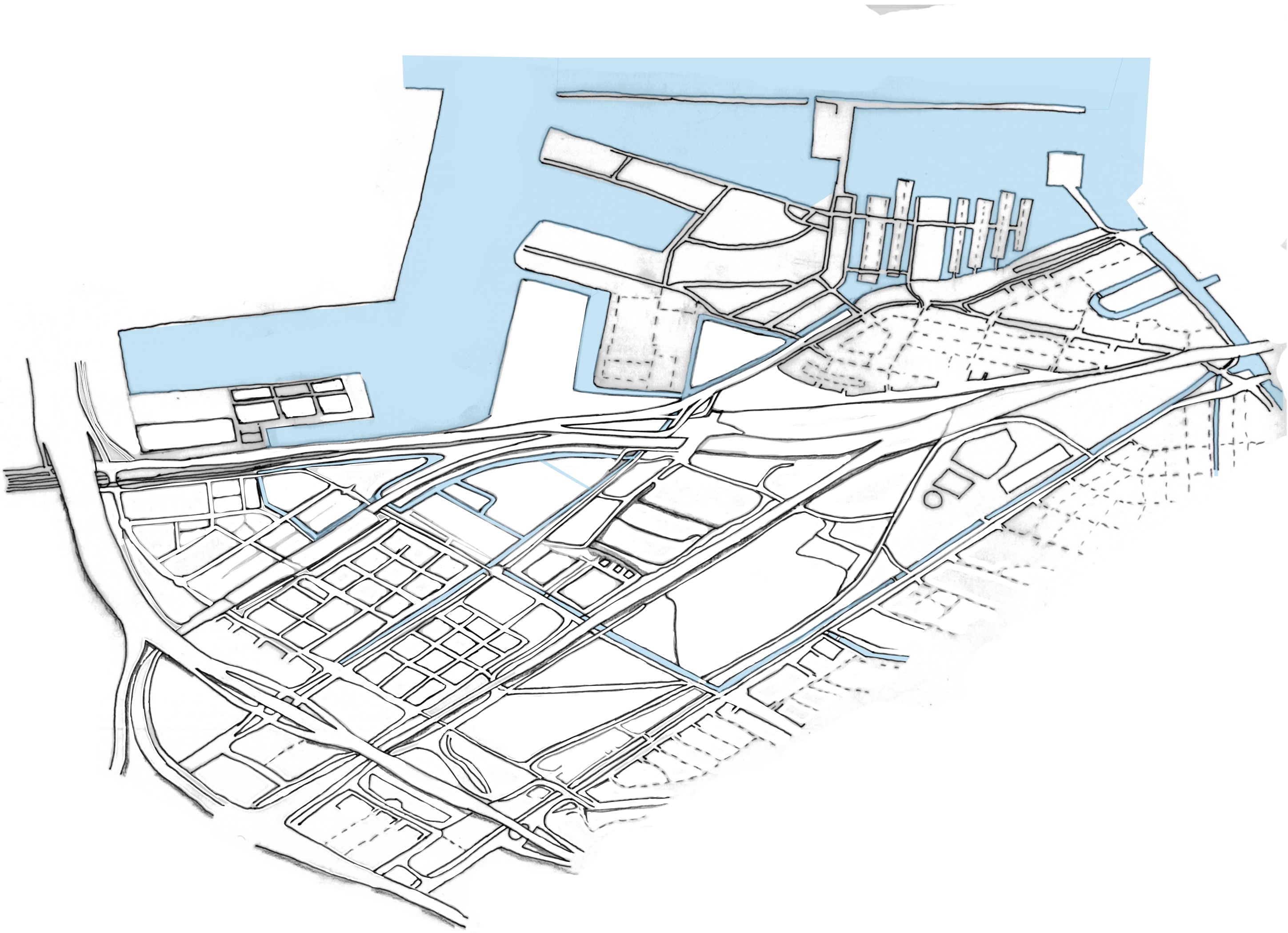
This variant strives to incorporate the park and by doing so offering the opportunity to future inhabitants to live in Groot Westerpark themselves.

In this variant the station becomes the veritable centre of the havenstad development. From here the connections emanate into the rest of the neighbourhood. The focus is on the human scale, so hierarchy of spaces, legible privacy zoning and the use of the canal as a new connection to the rest of the city.

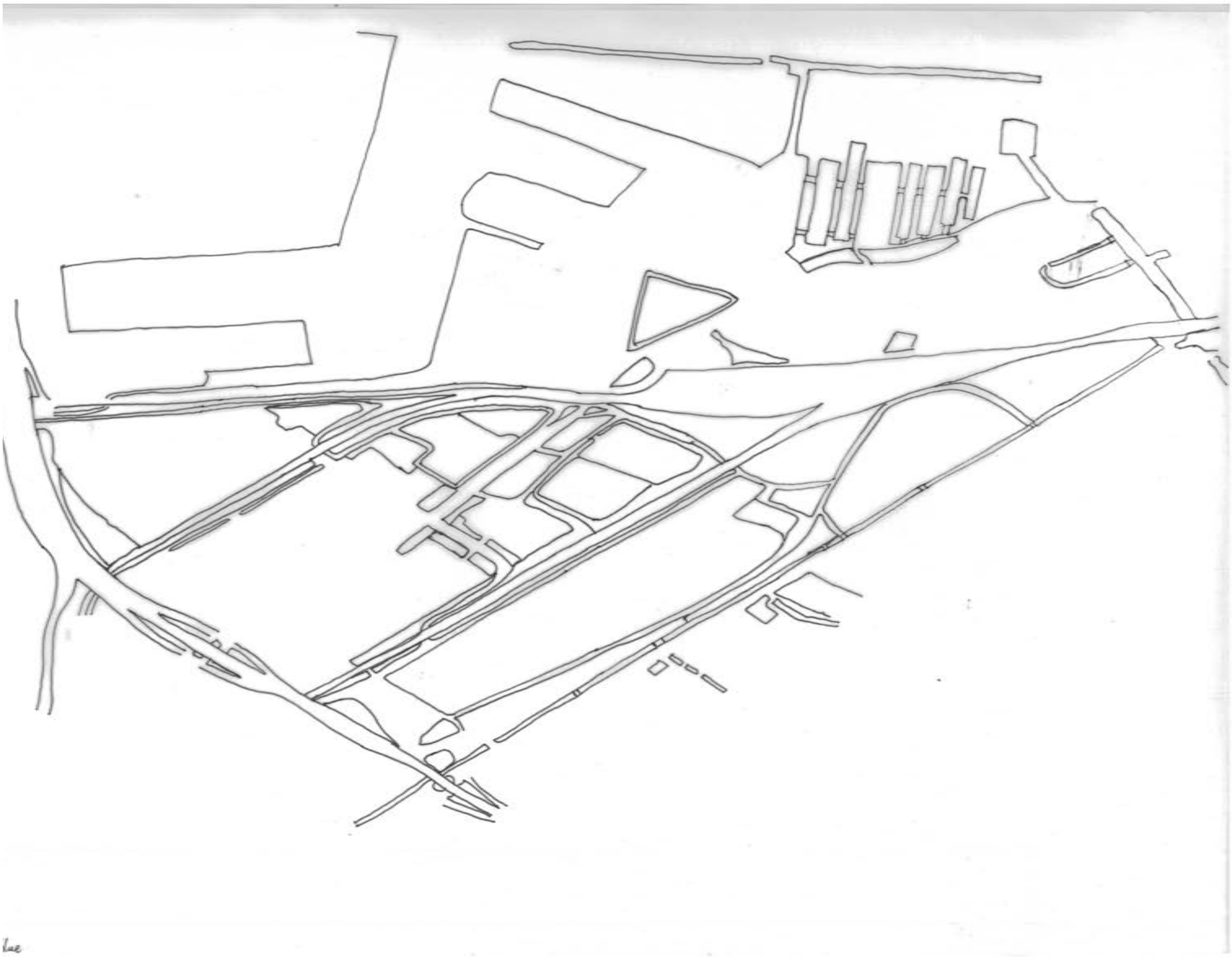
Design vision



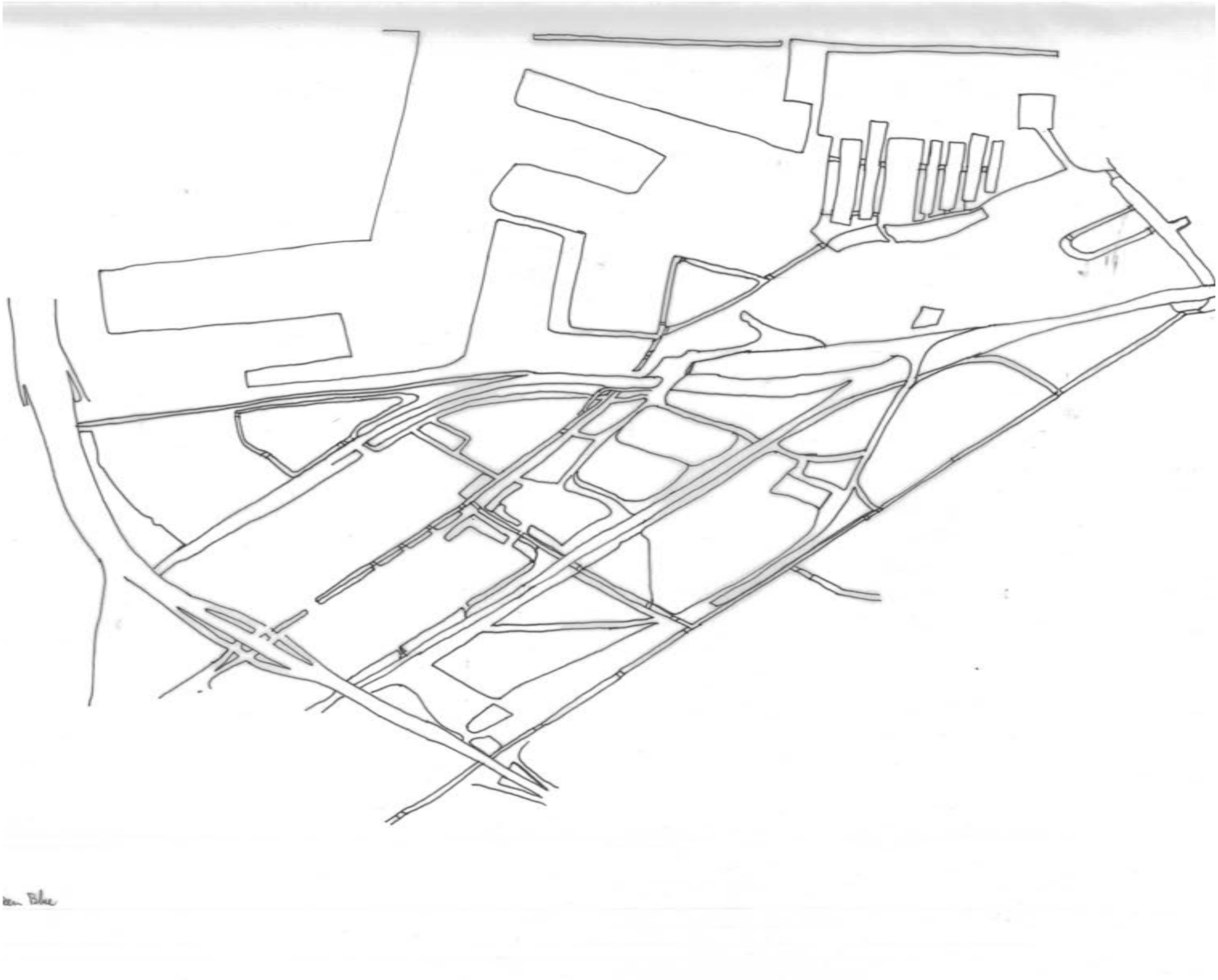
The current situation



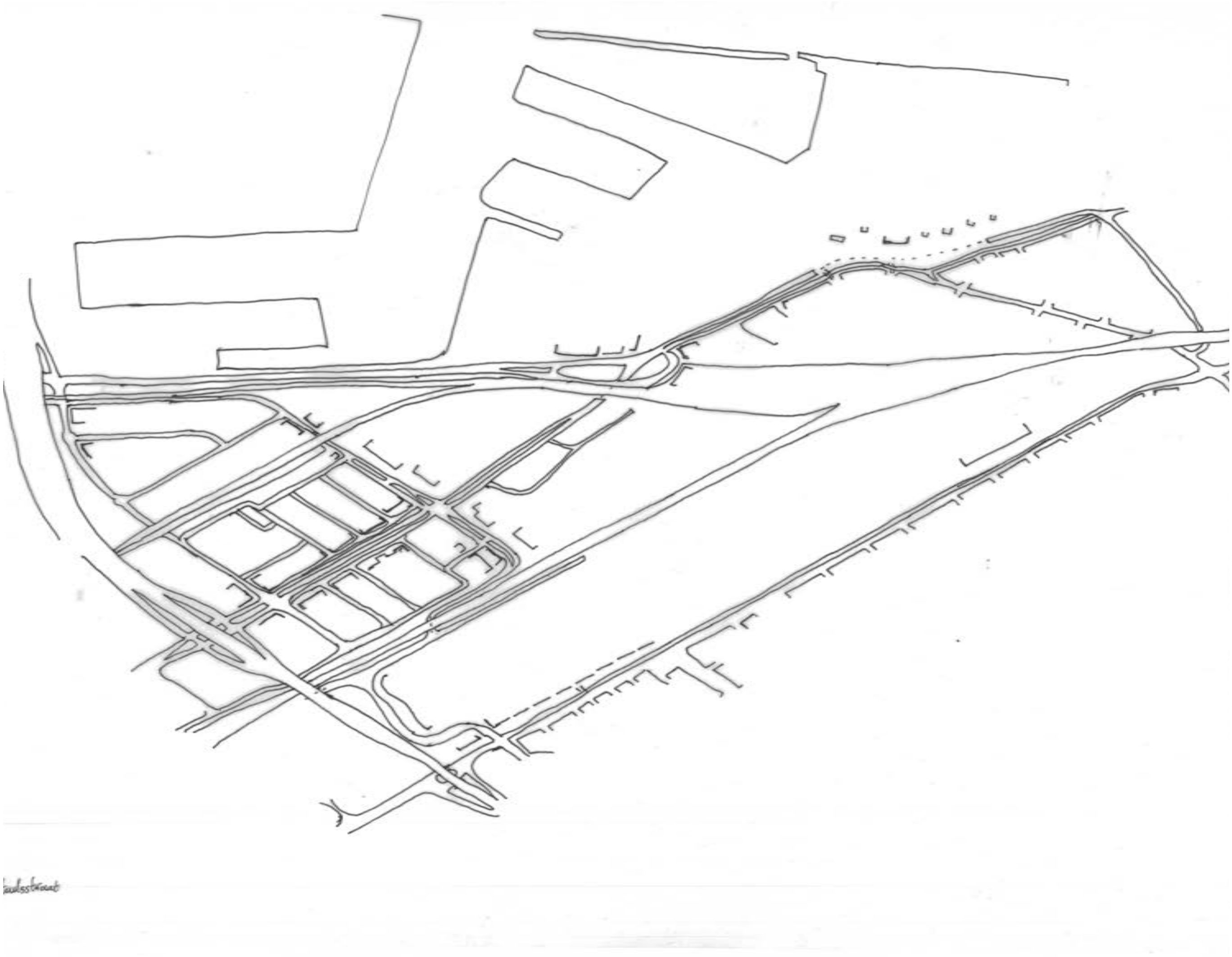
The potential new design of the area



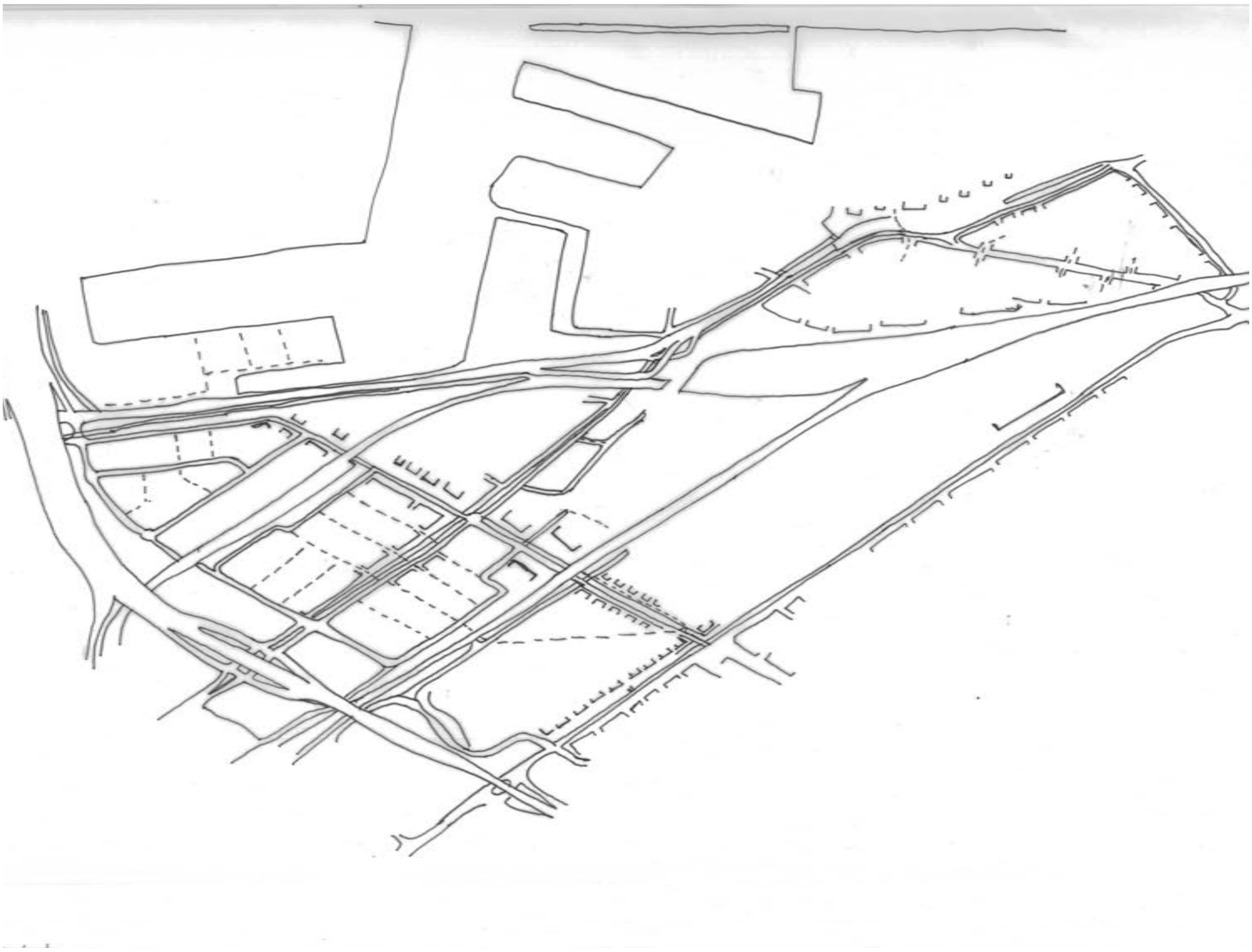
The current green blue system



The extended green blue system

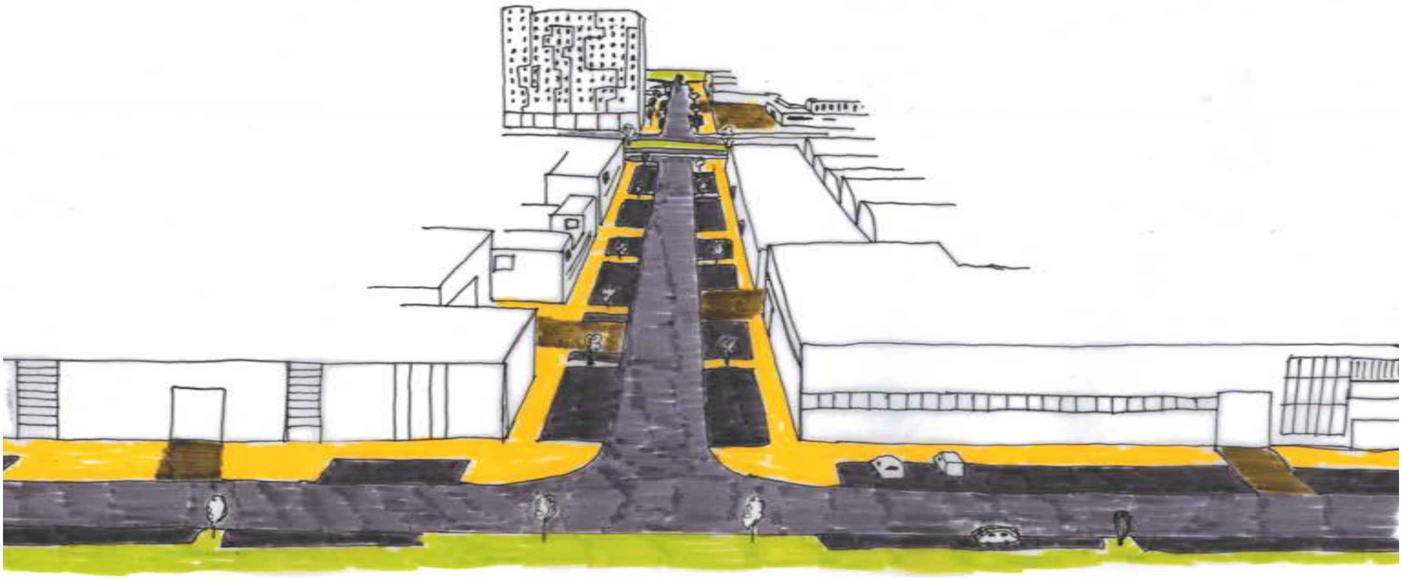


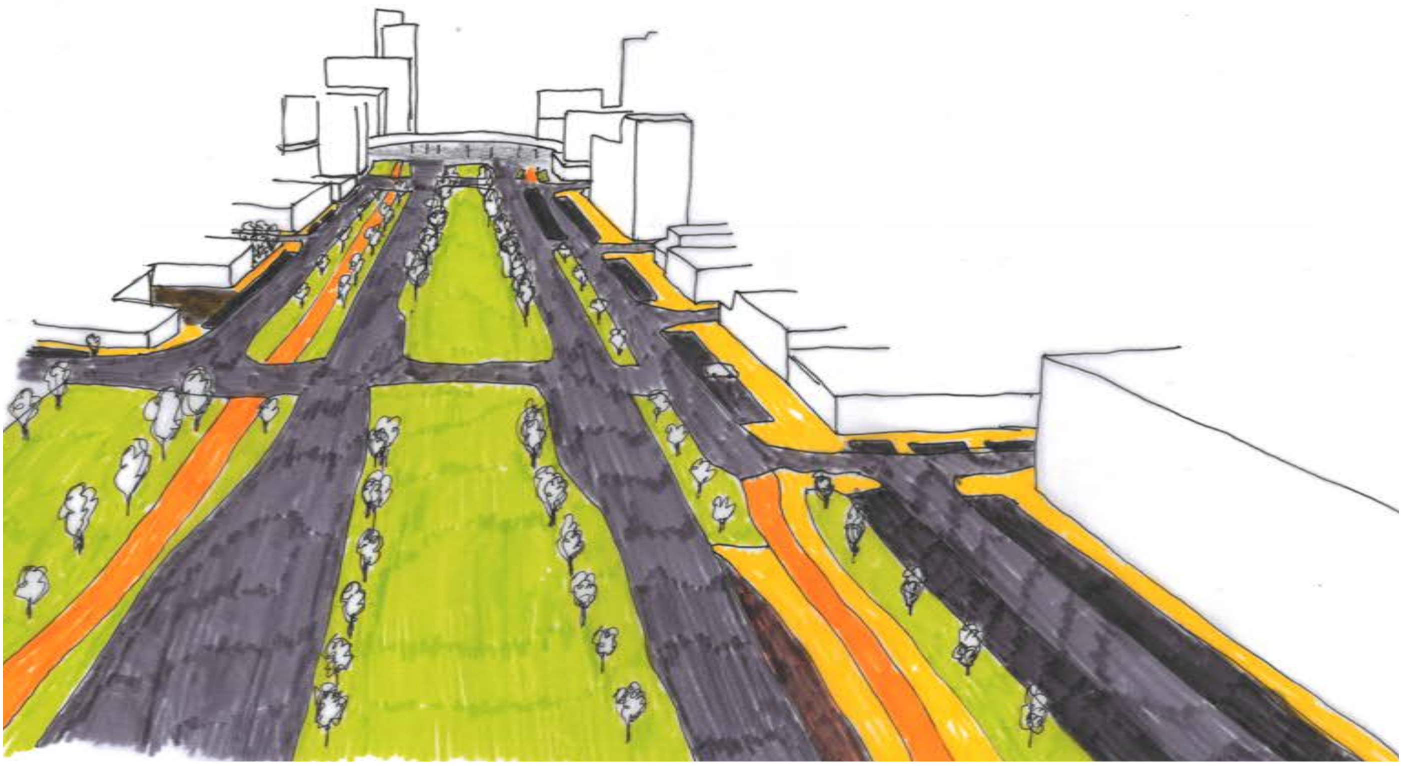
The potential for stadsstraten
currently the potential is low

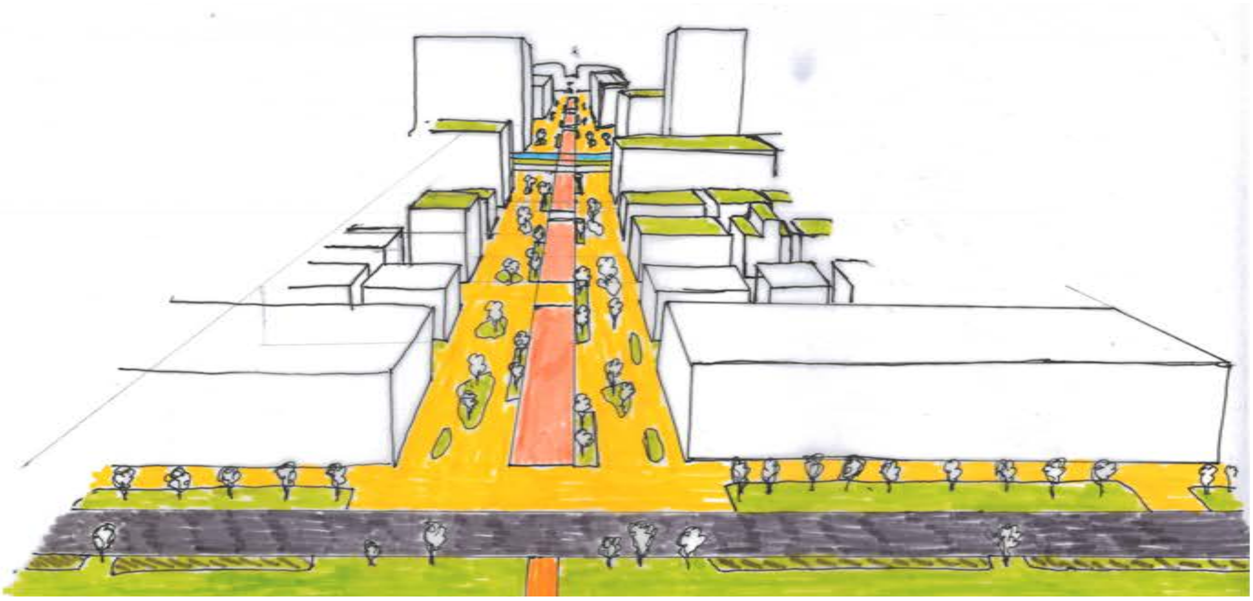


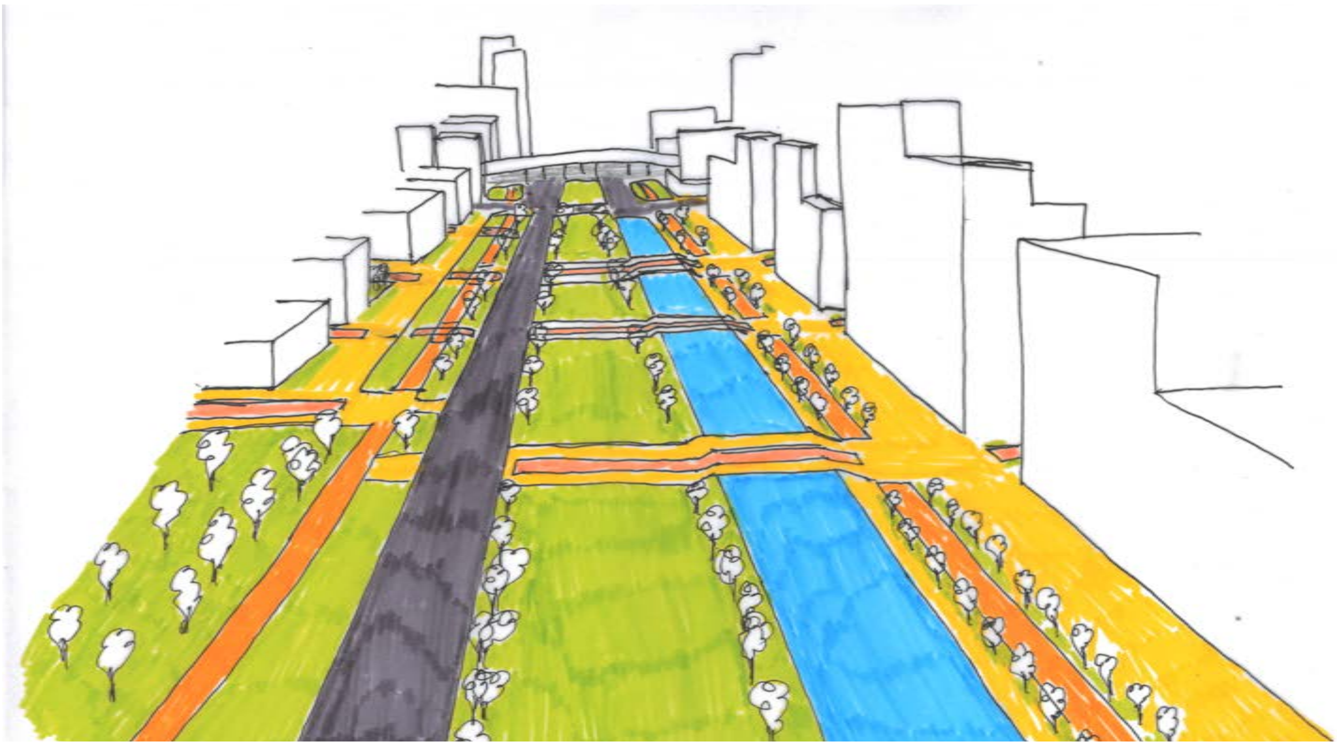
The potential for stadsstraten

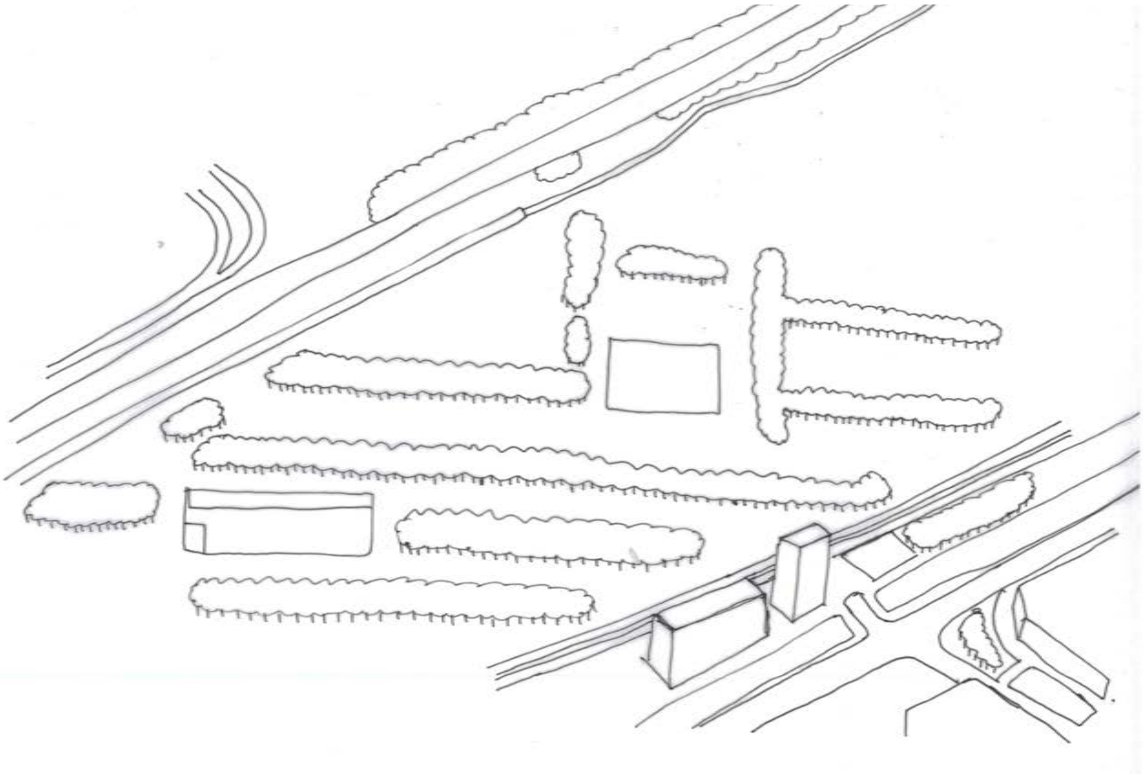
With the connection through the westerpark the area can be connected way better to the surrounding neighbourhoods.

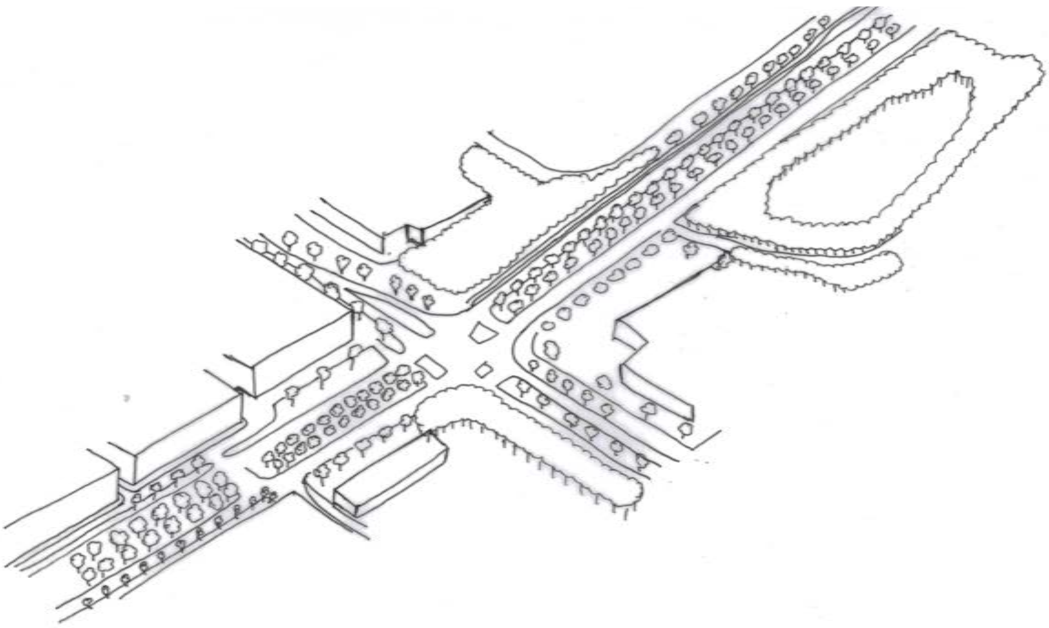


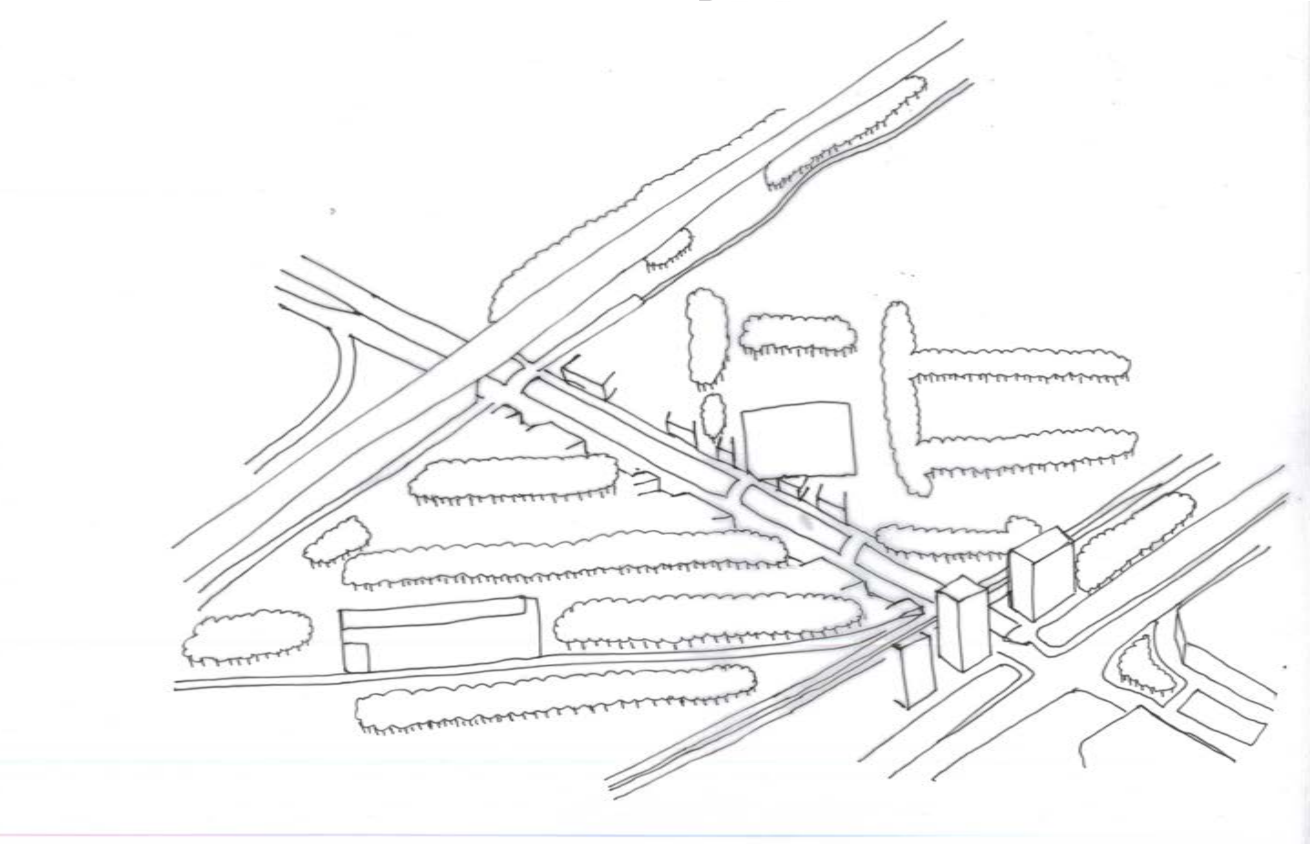


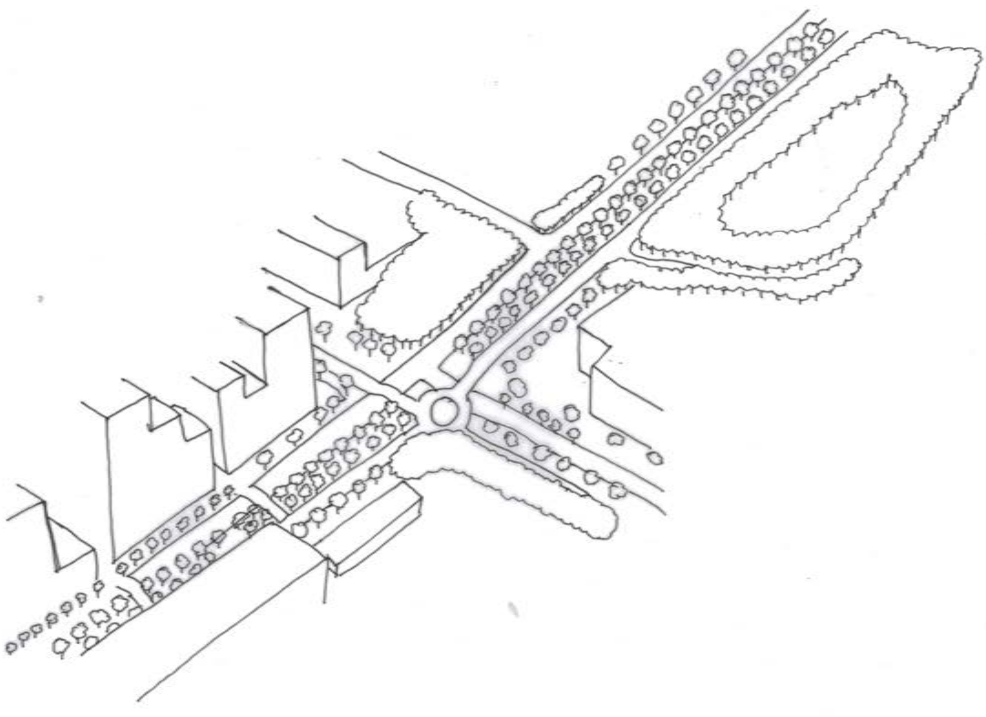


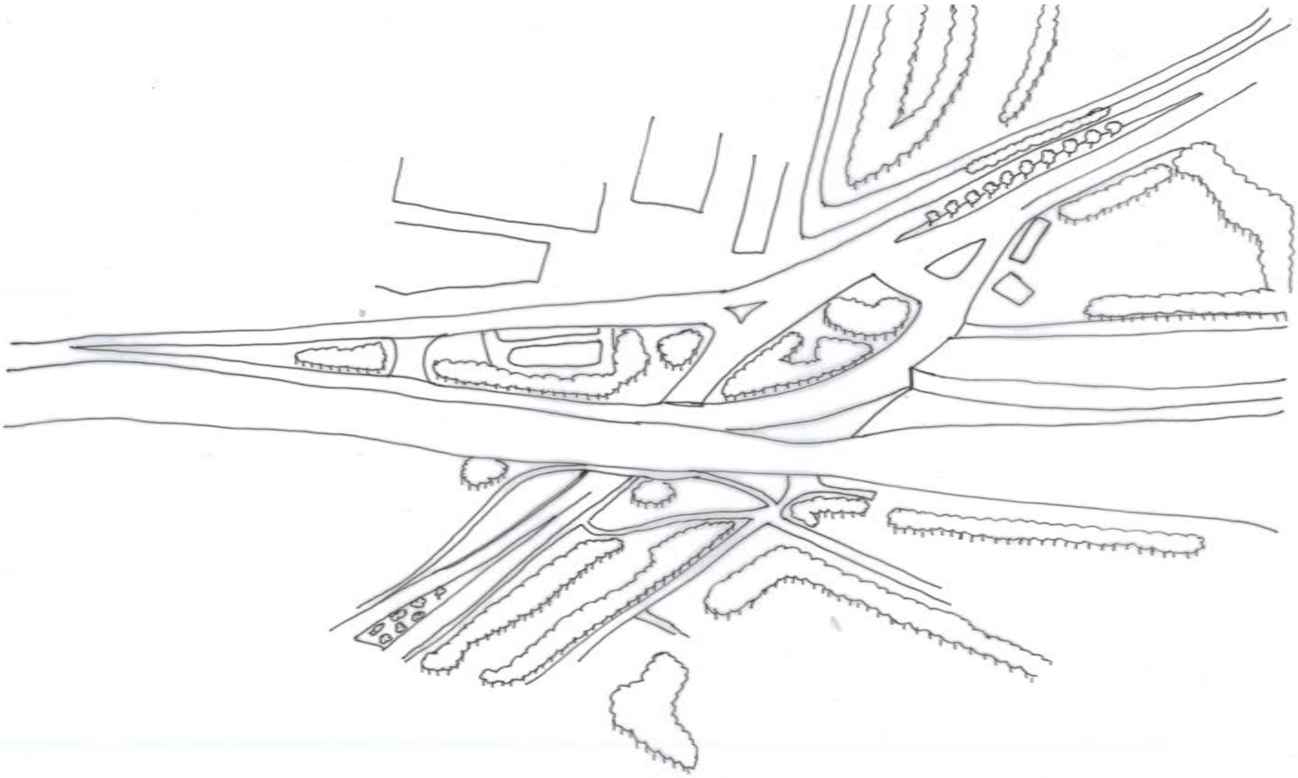




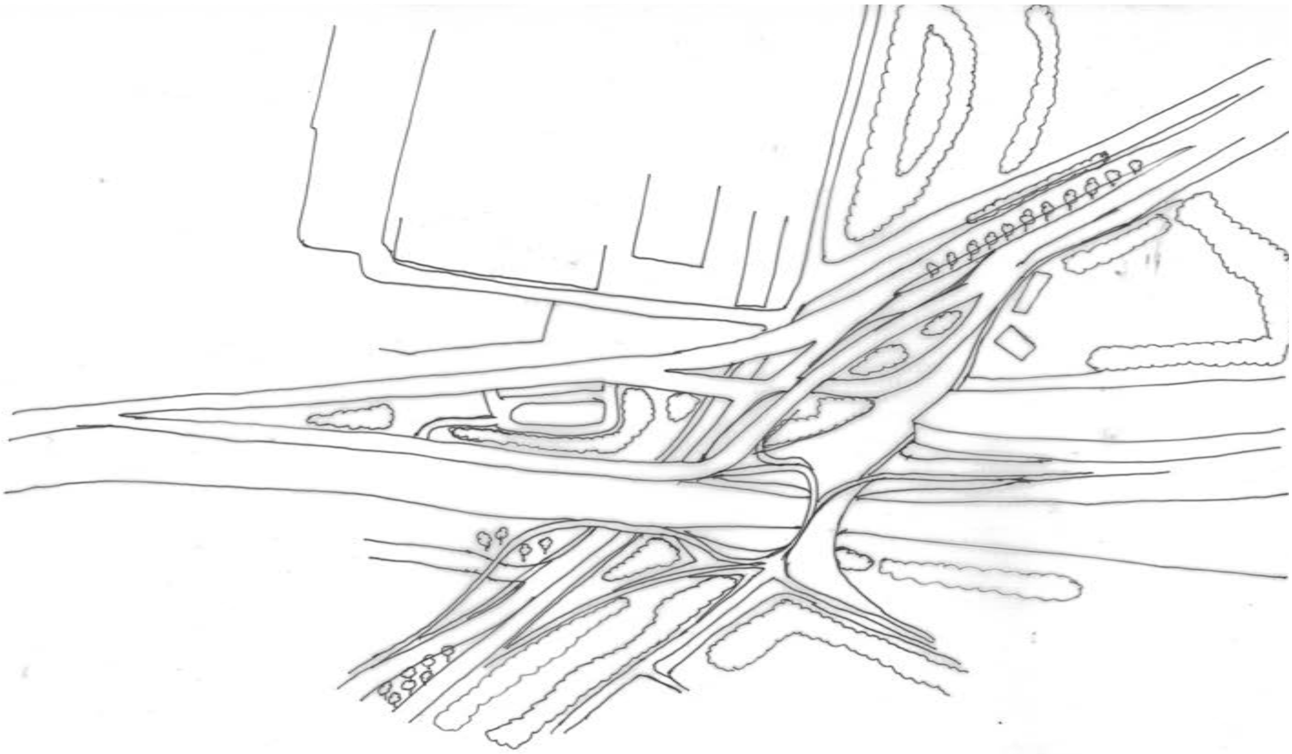


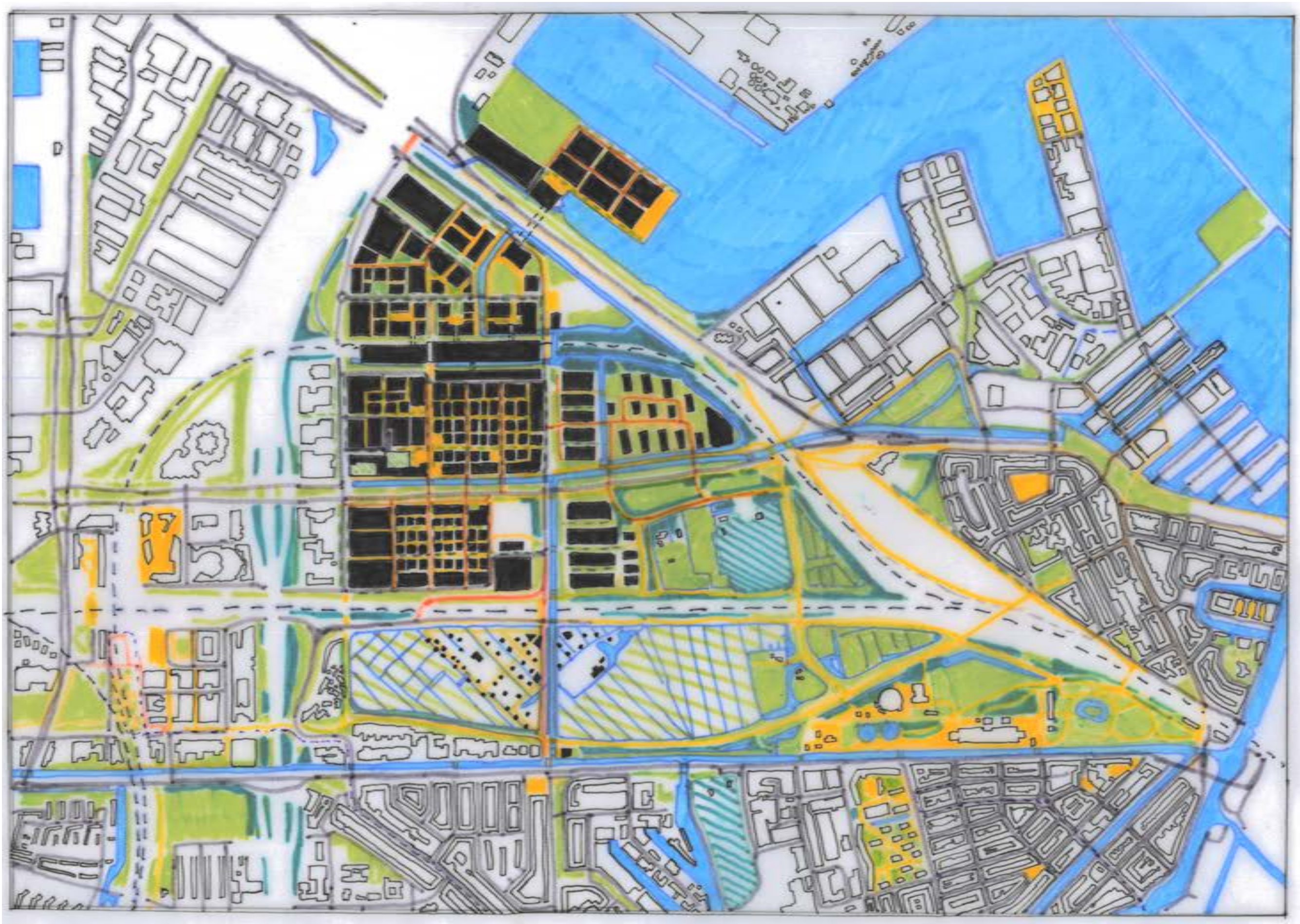


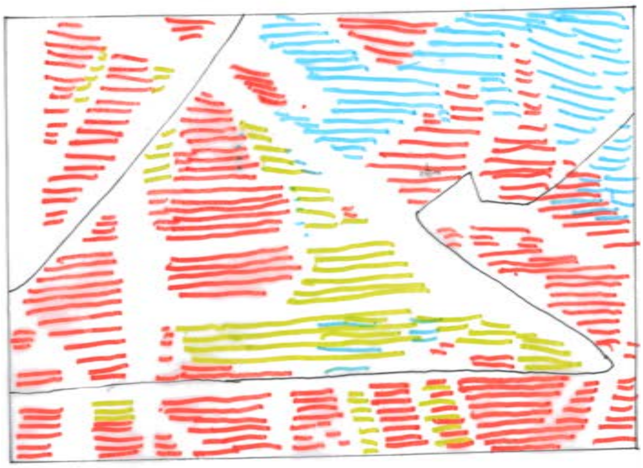




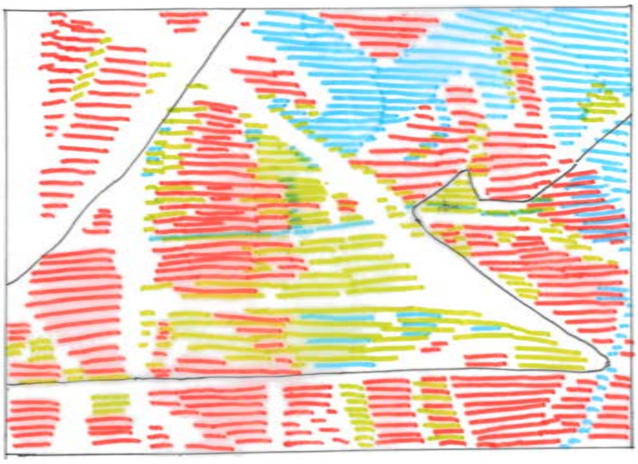
Current Hemweg X transformatorweg





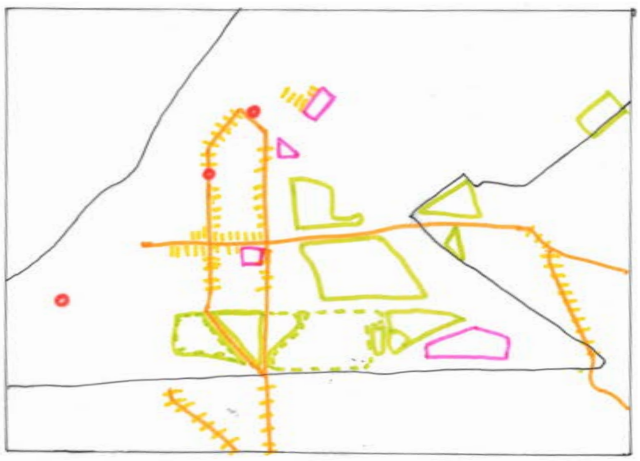


Current red, blue and green structure
The green and red areas have a hard separation

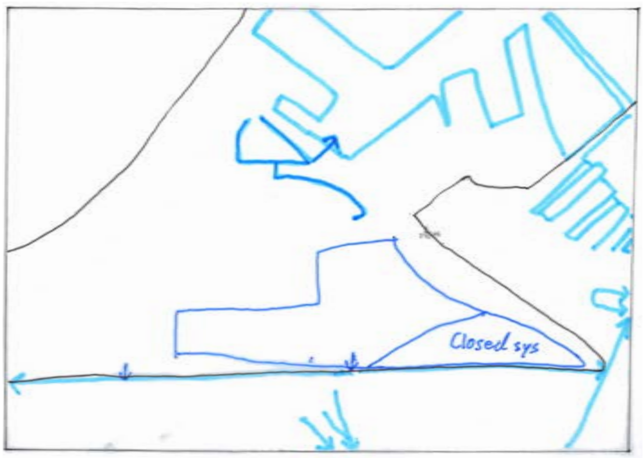


Proposed red, blue and green structure
The green and red areas flow into one another.

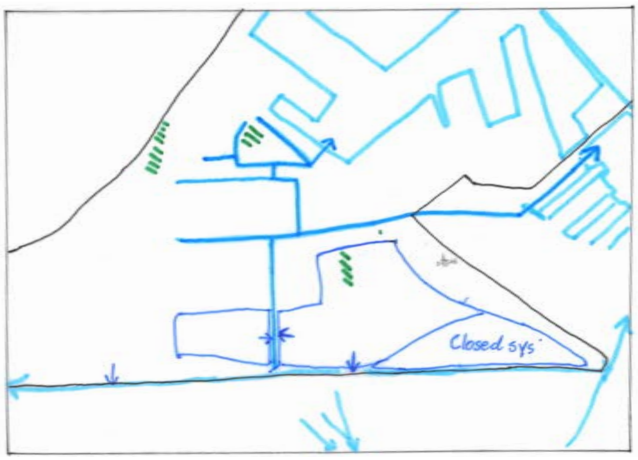
Current interaction environments and event space.
In the current situation the event locations (purple) are Thuishaven, Stadsperron and Westerpark. Isolatorweg and Sloterdijk (red dots) aren't connected to any of them



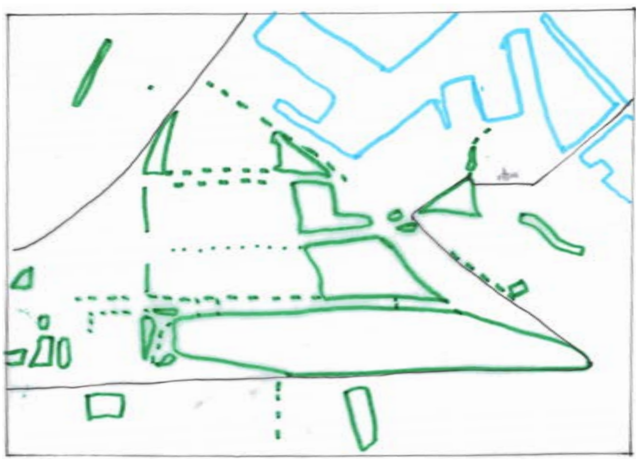
Proposed interaction environments and event space.
The design proposes the transformation of Isolatorweg and Contactweg into interaction environments (stadstraten in orange with yellow dash), as well as Havenfront as an event location/park. Here parts of the allotment garden have a public function as well.



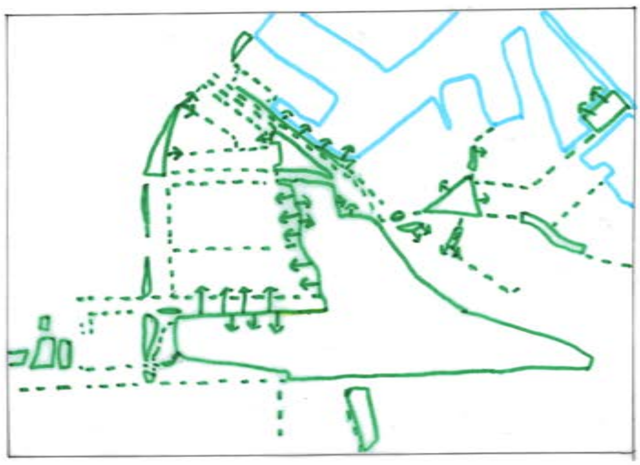
Current drainage system
The area comprises two different water systems, the "IJboezem" and the Overbrakerpolder(outline in blue). Most of the area, located outside the dike drains into the IJ at one point. The polder drains into the Haarlemmervaart canal on the south.



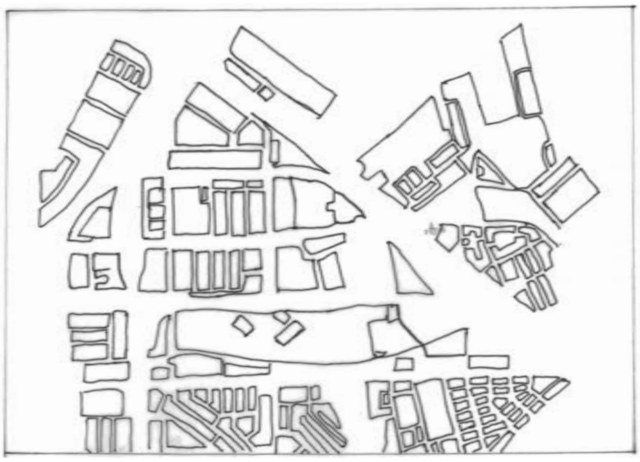
Proposed drainage system
The vision proposes the construction of additional canals, draining into the "IJboezem" and connecting the Haarlemmervaart to the "Stadsboezem" in two places. It also proposes several retention areas (green dash)



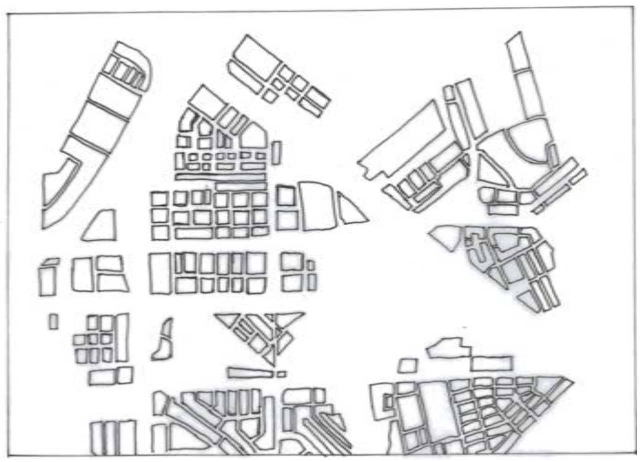
Current green network
There is a wide variety of individual green areas (green outline) strewn over the project area. Many have hard borders however.



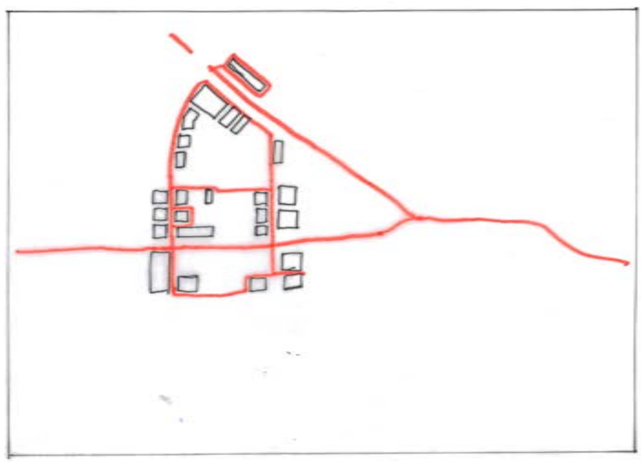
Proposed green network
Increase the penetration of the green areas (green arrows and dashed lines) into Havenstad and strengthen the identity of "Groot Westerpark".



Current net building blocks



Proposed net building blocks
Introduce reduced size blocks to enable a higher permeability of the area.



Proposed automobile route and maximum dependence
In order to reduce car depence, the number of blocks with permanent automobile access (red line) is to be reduced.


2.5
0
2.5
5
7.5
10 km

Design

In this chapter the design interventions are shown through the different scales that apply.

The proposal

People strolling through the former British concession in Wuhan, 2018

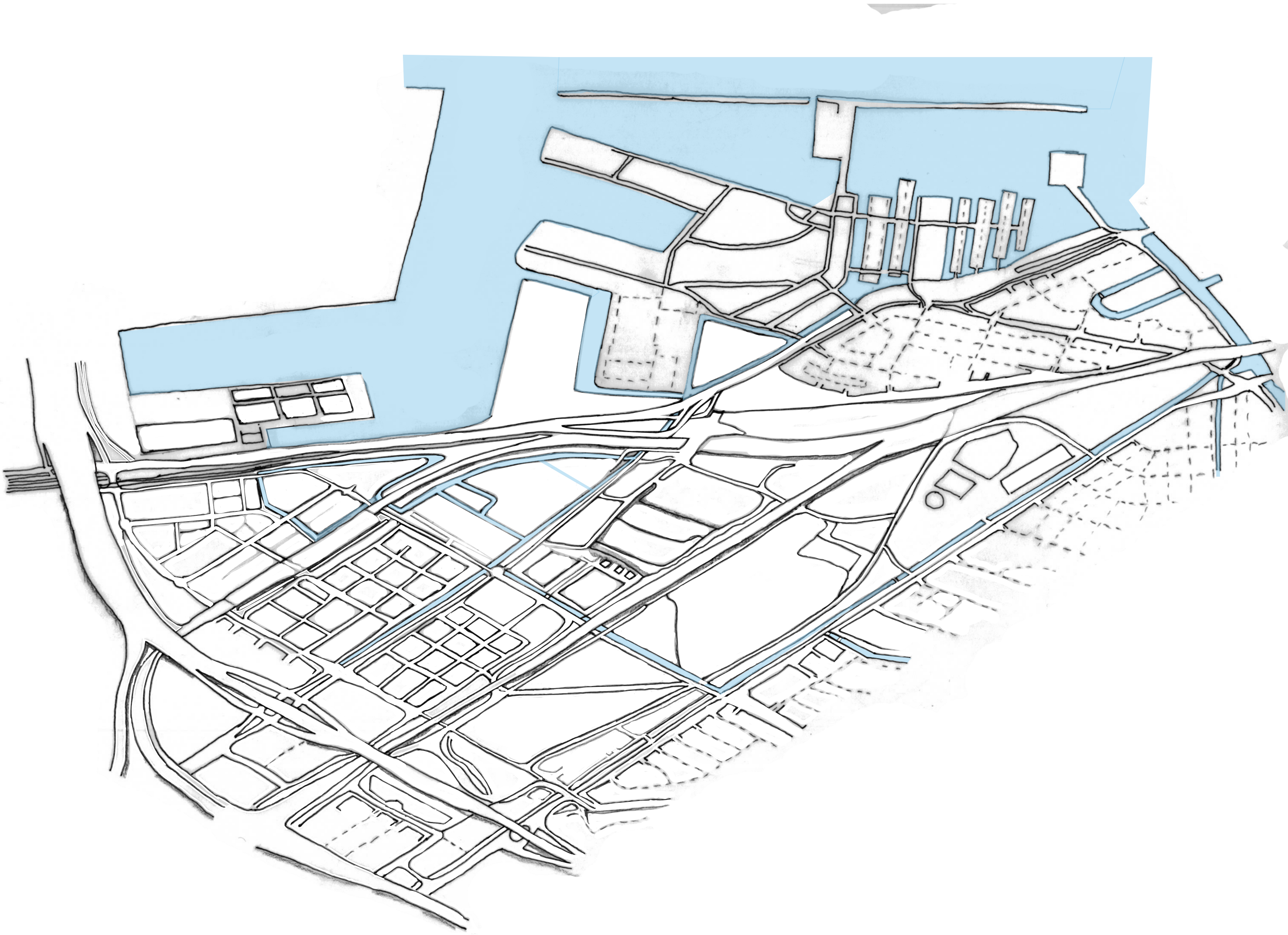
People shopping at Wanda Centre near Chuhehanje metro station in Wuhan, 2018

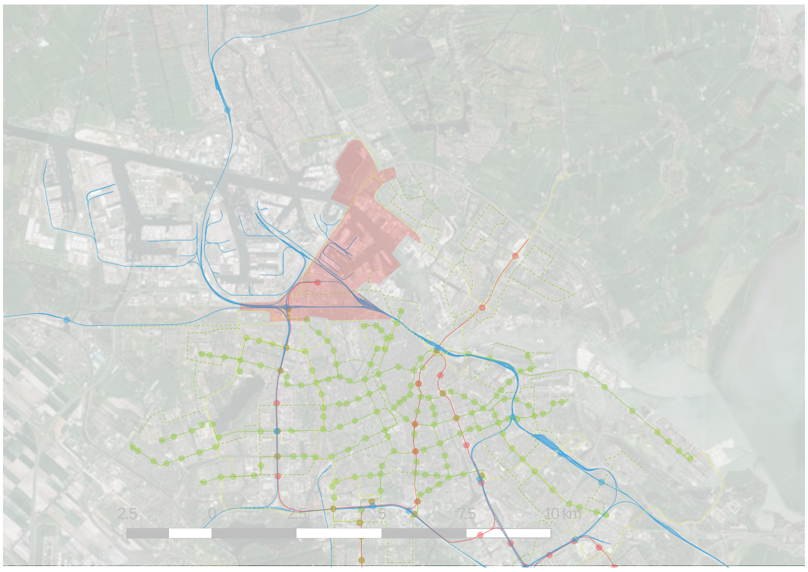
Havenstad eco-inclusive

Increase interaction and density of activities

A new space of interaction. The High Line in New York City, 2018

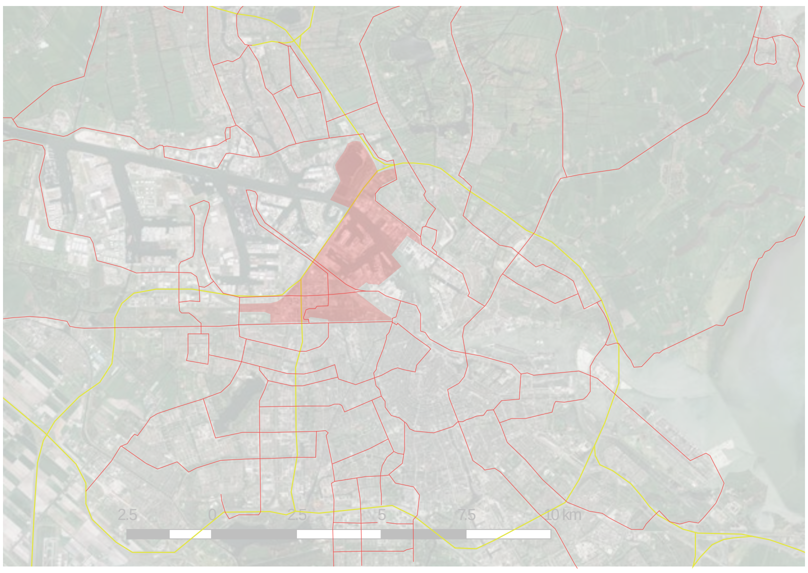
Various The High Line in New York City, 2018





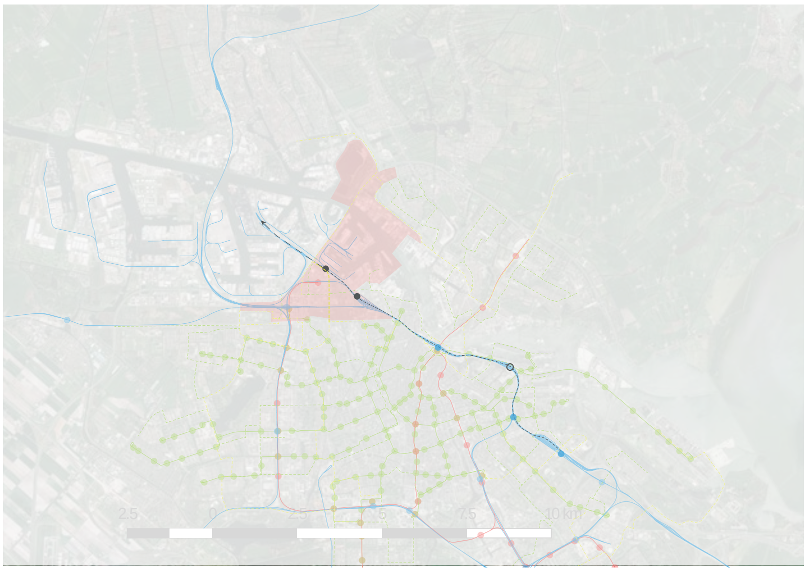
Public transit network
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

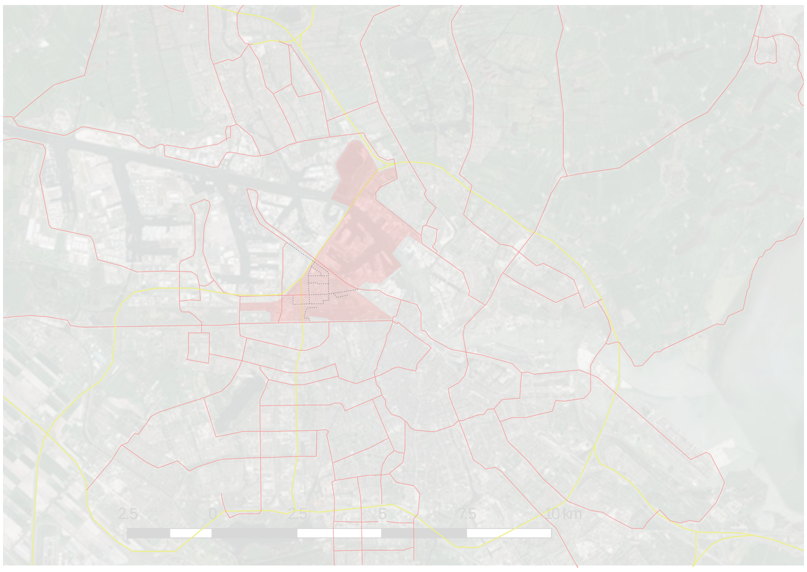
The image to the left shows that while the city of Amsterdam as a whole is strongly connected to through an extensive HOV public transit network consisting of metros and trams, Havenstad is not. However there is an extensive freight rail system present in the harbour.



Main road network
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

As is visible in the picture to the left, Havenstad has a strong connection to the A10 highway (yellow) and the main/ regional road network (red). It is intersected by various main roads.



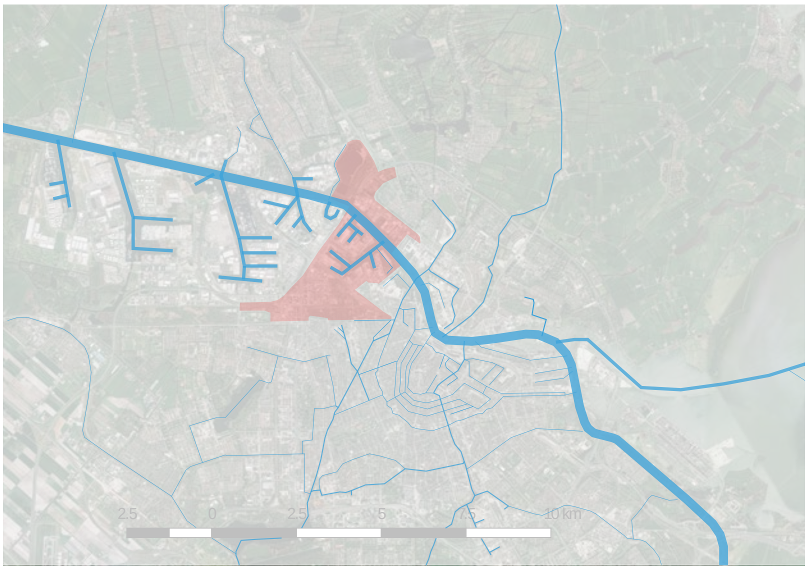


Public transit proposal
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

As is visible in the picture, the main change to the public transit in the scale of the s-train, similar in type to the s-bahn model applied in Germany, that uses the existing rail infrastructure, while adding two stations in the west direction and offering the opportunity to add one additional station. The S-train will be using some of the capacity that becomes available due to the transfer of trains to Amsterdam Zuid.

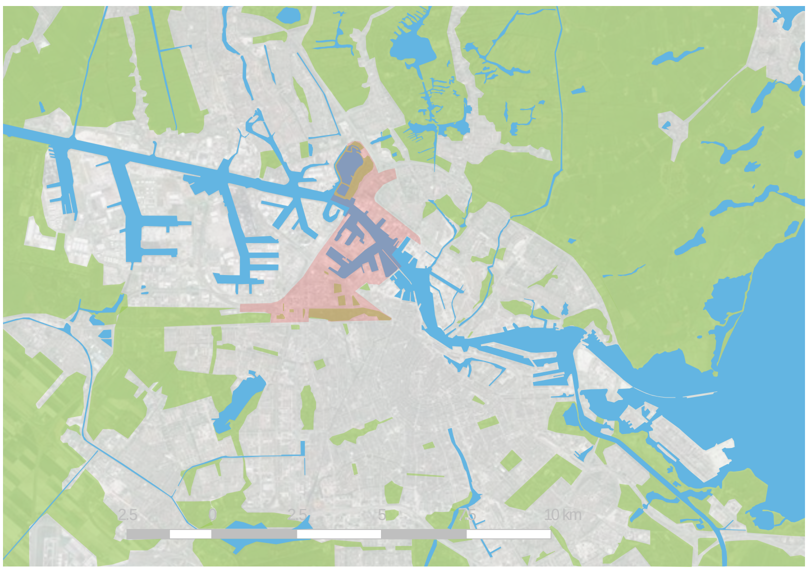
Road network proposal
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

Part of the mobility shift for Havenstad consists of the shift in priority from Transformatorweg to Hemweg. Through adaptation of the exisitng road system, the suitability of the roads bisecting the havenstad development is strongly decreased, in favour of traffic headed towards the area itself.



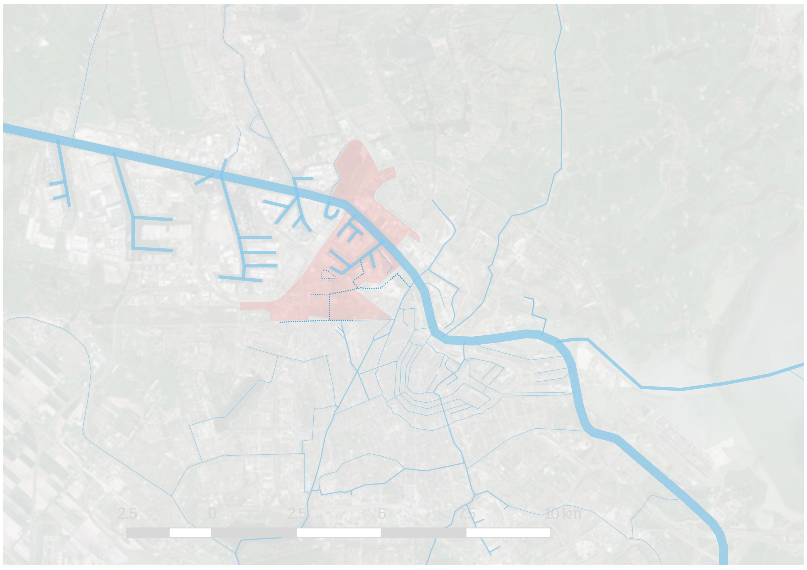
Water mobility
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

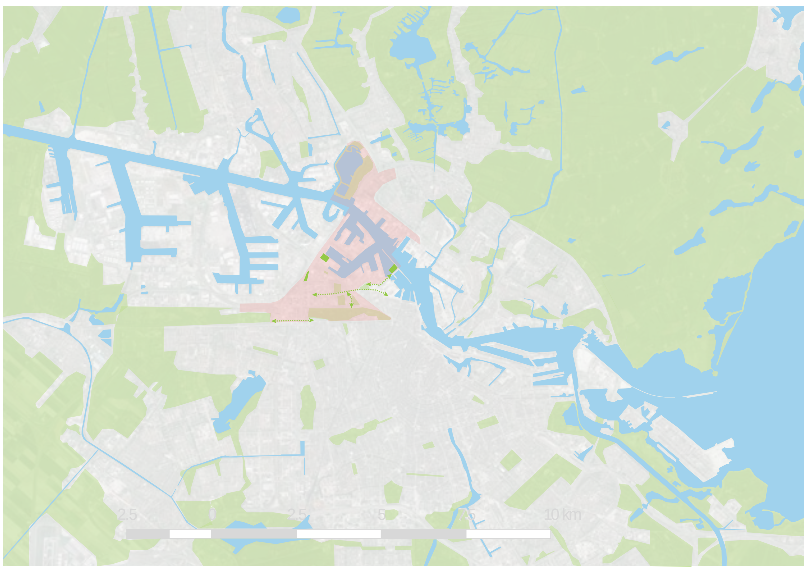
The image to the left illustrates the current routes for water travel and transport over water (blue). It is visible that the Havenstad area is only connected to the IJ part of this system.



Green blue area
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

Havenstad is located along one of the city's green wedges, the so-called Brettenscheg ends in the Westerpark. In addition to that it is also connected to the IJ.





Water mobility proposal
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

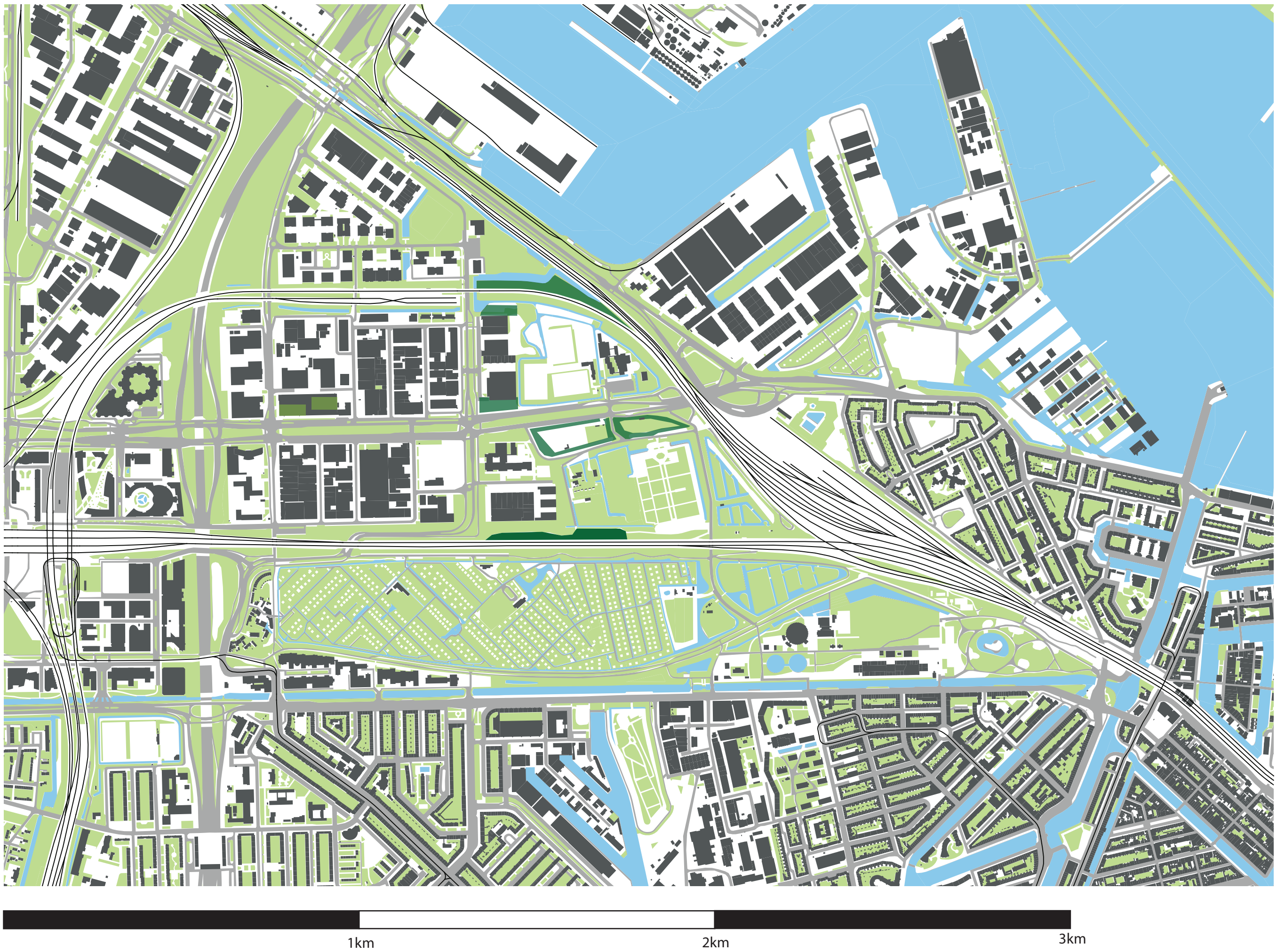
While the area needs more internal waterways to deal with the extent of rainfall and a high groundwatertable, this also allows for the opportunity to reintroduce shipping as a viable ,and potentially main, form of transport.

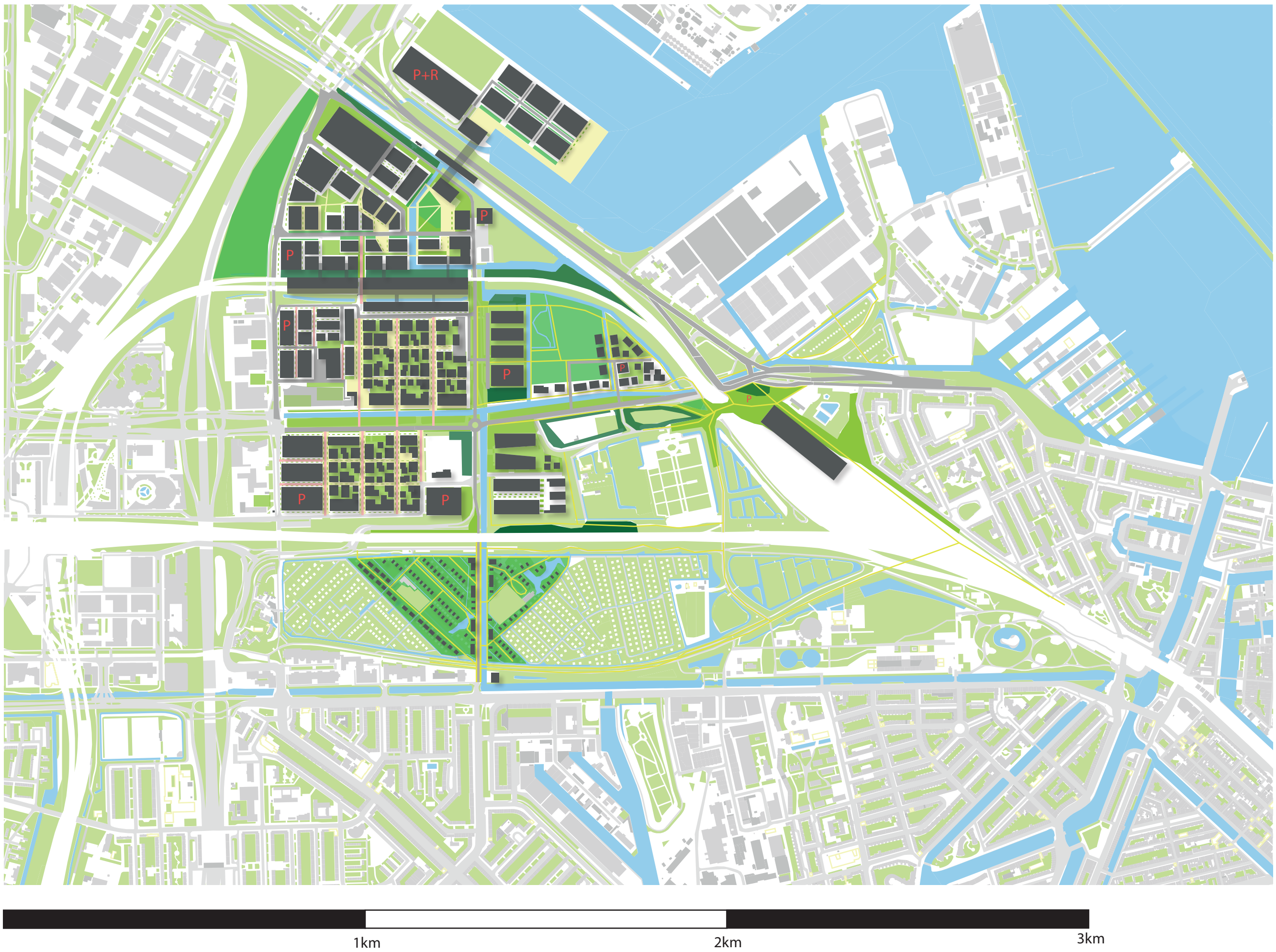
Through the creation of navigable canals throughout Havenstad an additional transport option becomes available for the district.

Green blue area proposal
Adaptation of Bing maps and Gemeente Amsterdam GIS data.

By strengthening the structure of the Westerpark into Groot Westerpark, an area with a variety of landscapes, the area can benefit not only Havenstad, but also improves the liveability of Spaarndammerbuurt and Houthavens.

District scale




P+R
P
1km
2km
3km

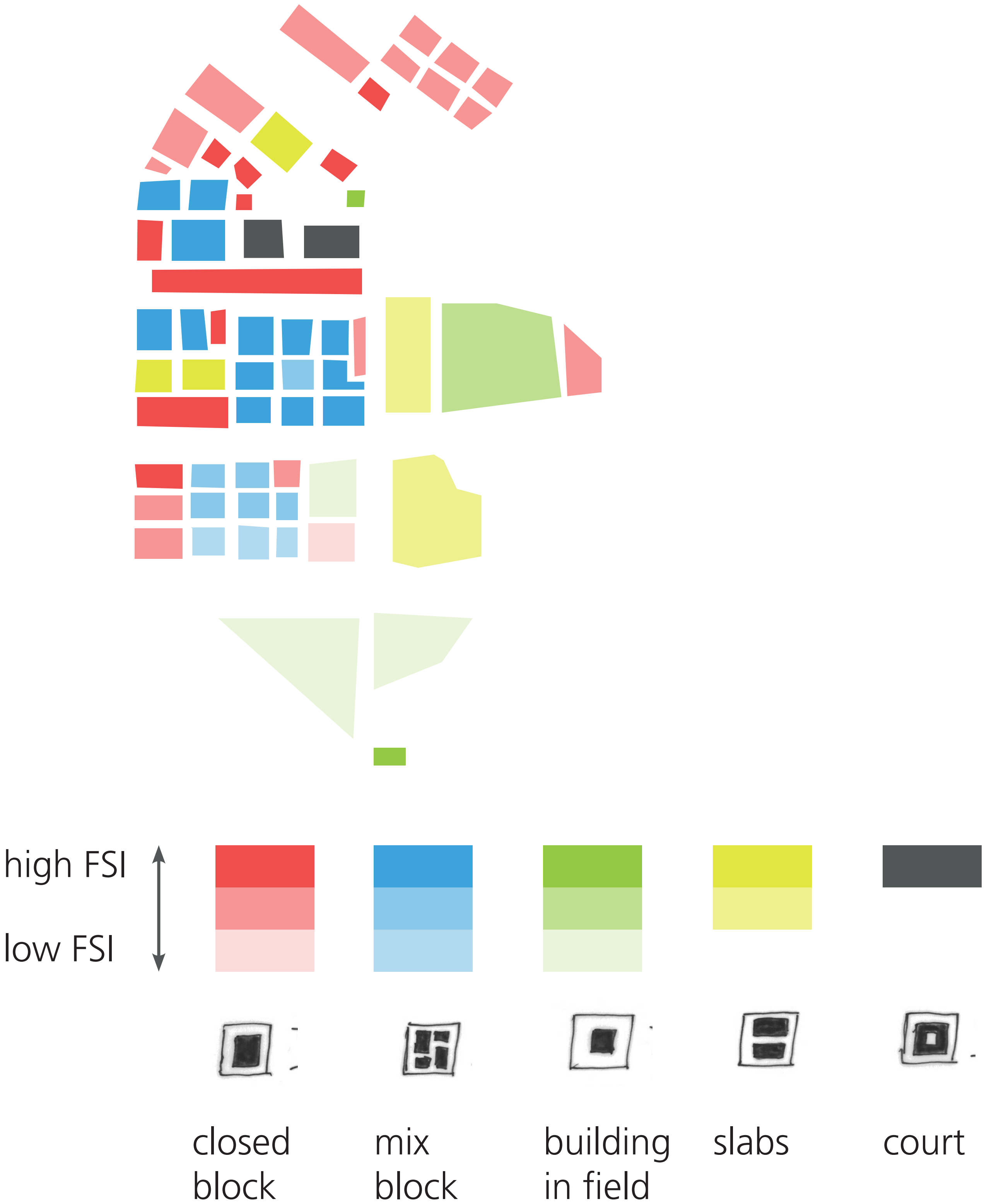
District scale

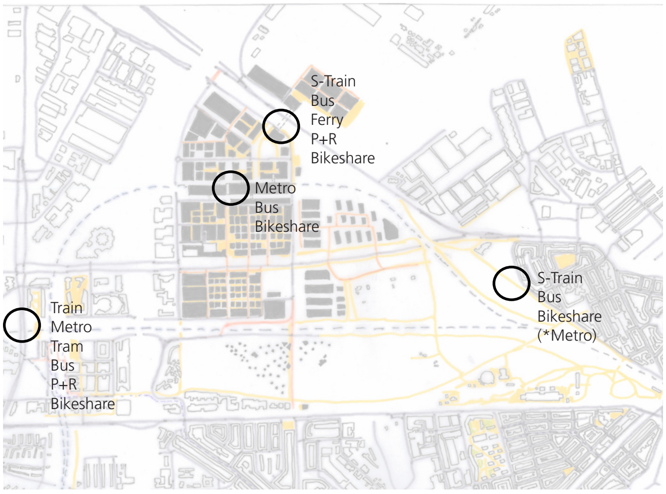
Current road structure
Much of the project area consists of roads for cars(public in black and private/permit zone in dashed red) in a grid like pattern. The exception is Groot Westerpark with its connections for active mobility (yellow).

Proposed road structure
The automobile grid is replaced by a combination of ring roads and shared spaces with accompanying speed limits. Some roads become inaccessible completely for private transport (orange).

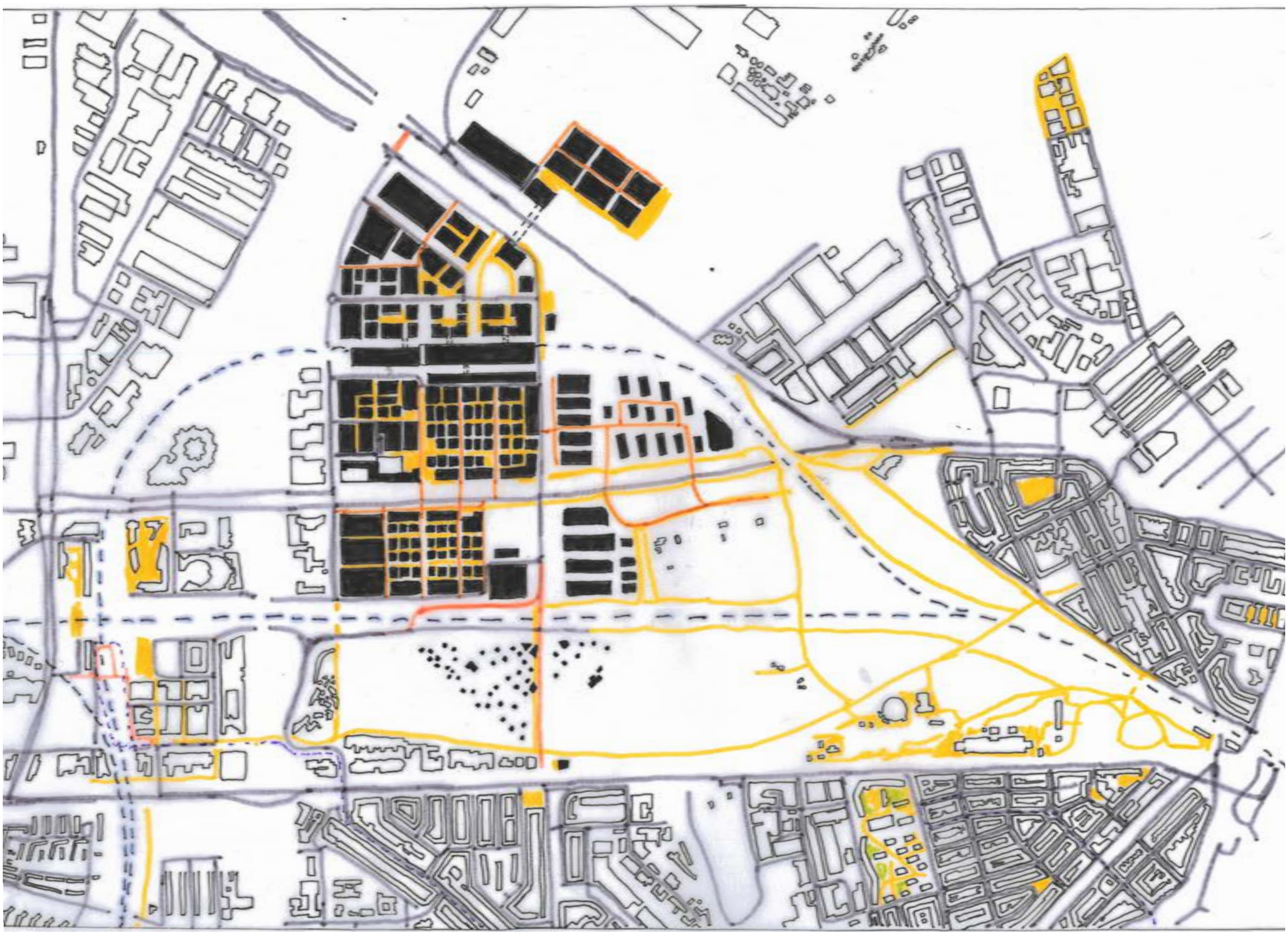
The current mobility system
The current mobility system is mostly dependent on car mobility(black), with public transit (purple and pink) being concentrated in Sloterdijk and the walking and cycling routes (orange) being concentrated in the the park area.

Current red, blue and green structure
The proposal is to increase the network density of the active mobility network, as well as designating space to public transport (red). Further an expansion of the public transport network(purple and pink) is to be accompanied by an expansion of the water mobility (blue).


high FSI
low FSI
closed block
mix block
building in field
slabs
court



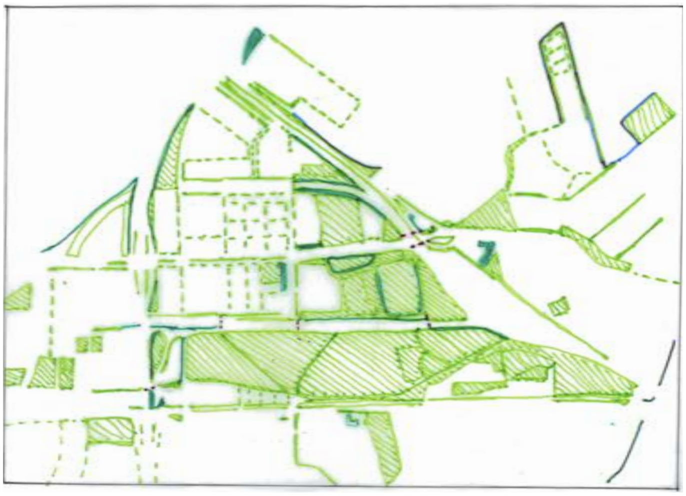
Hubs and their modalities



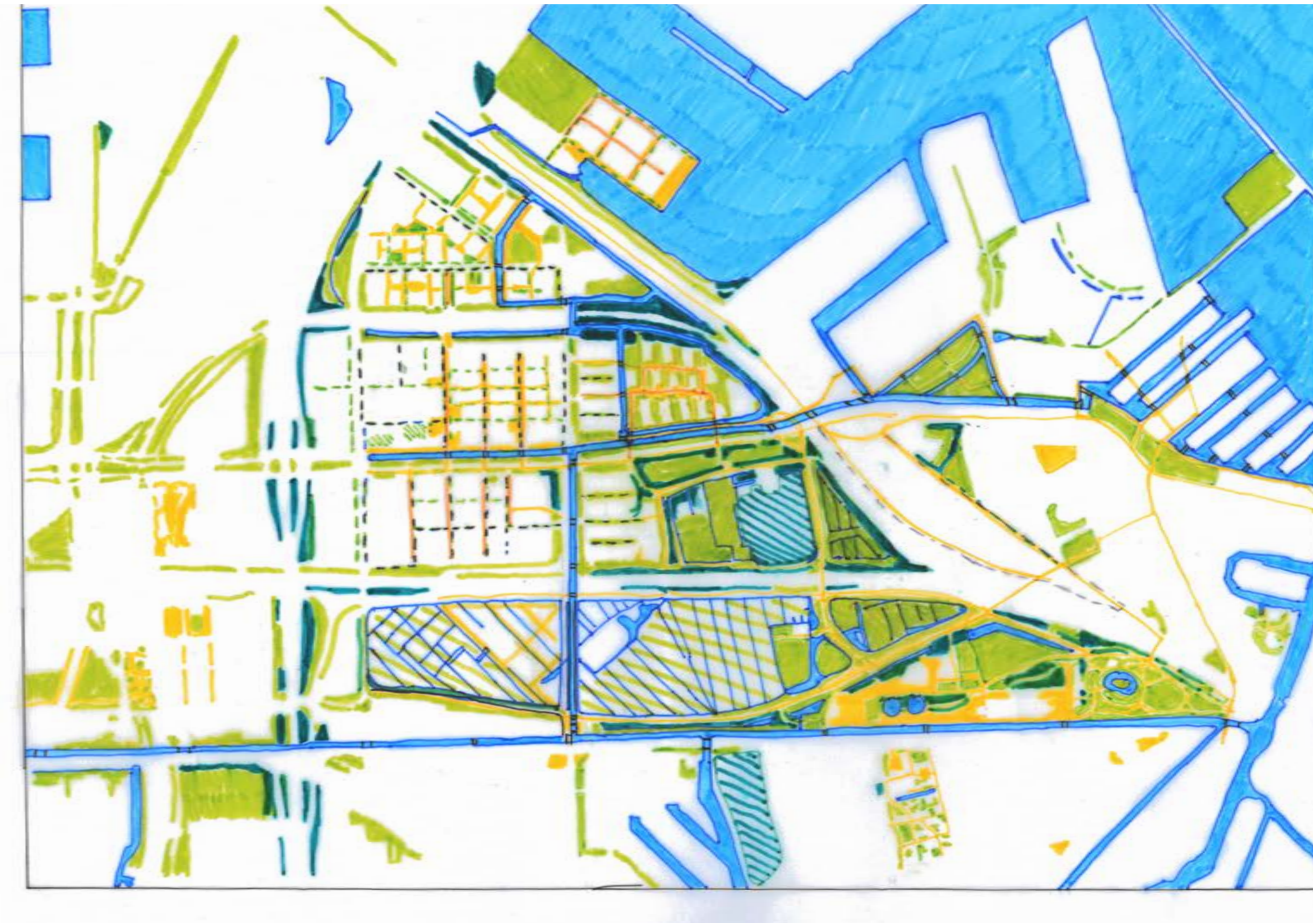
The proposed built envelopes with the pedestrian area

The area will have a large variation in parcelation in order to allow for different types of businesses and residential buildings.

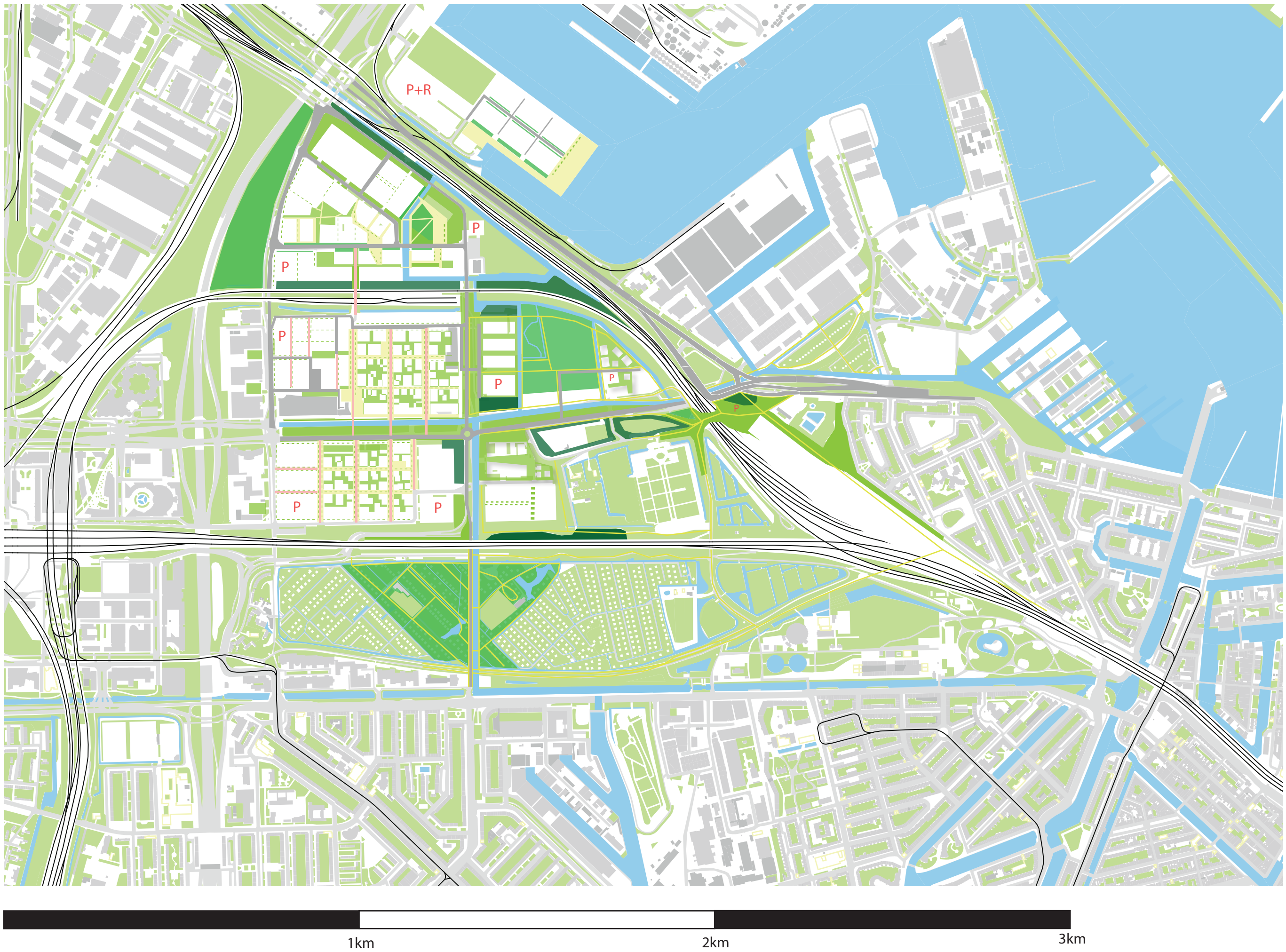
Proposed rainwater management system
The polder, with the exception of the western part of the allotment gardens maintains its current drainage system. Also flooding fields are introduced in the area.



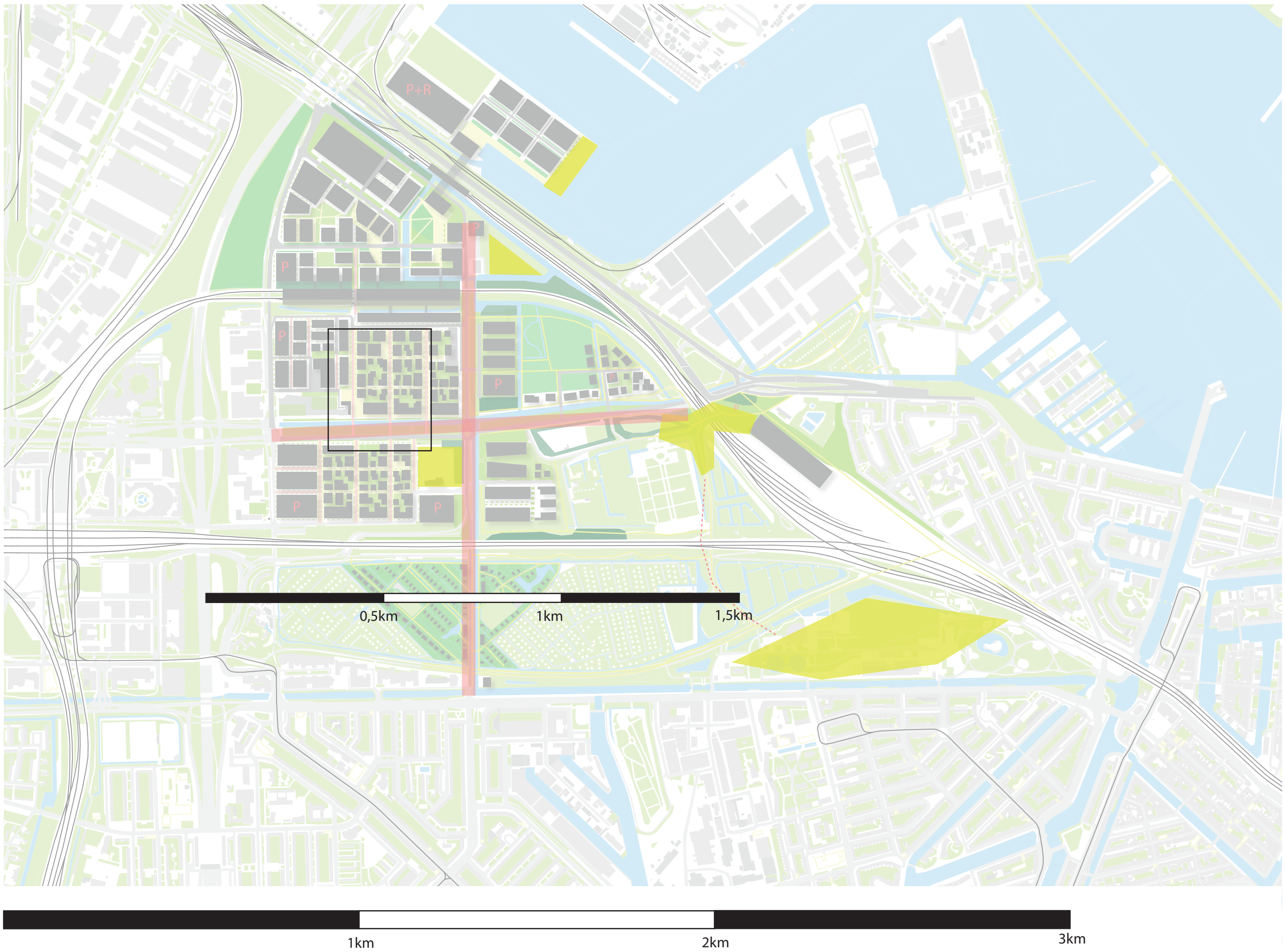
Proposed green structure
The proposed structure of the district



Vision for the greenblue system
Expanding on the qualities and the borders of Groot Westerpark, and introducing them to the rest of the district, through green connections and increased pedestrian and bycicle access to the park and surrounding neighbourhoods.

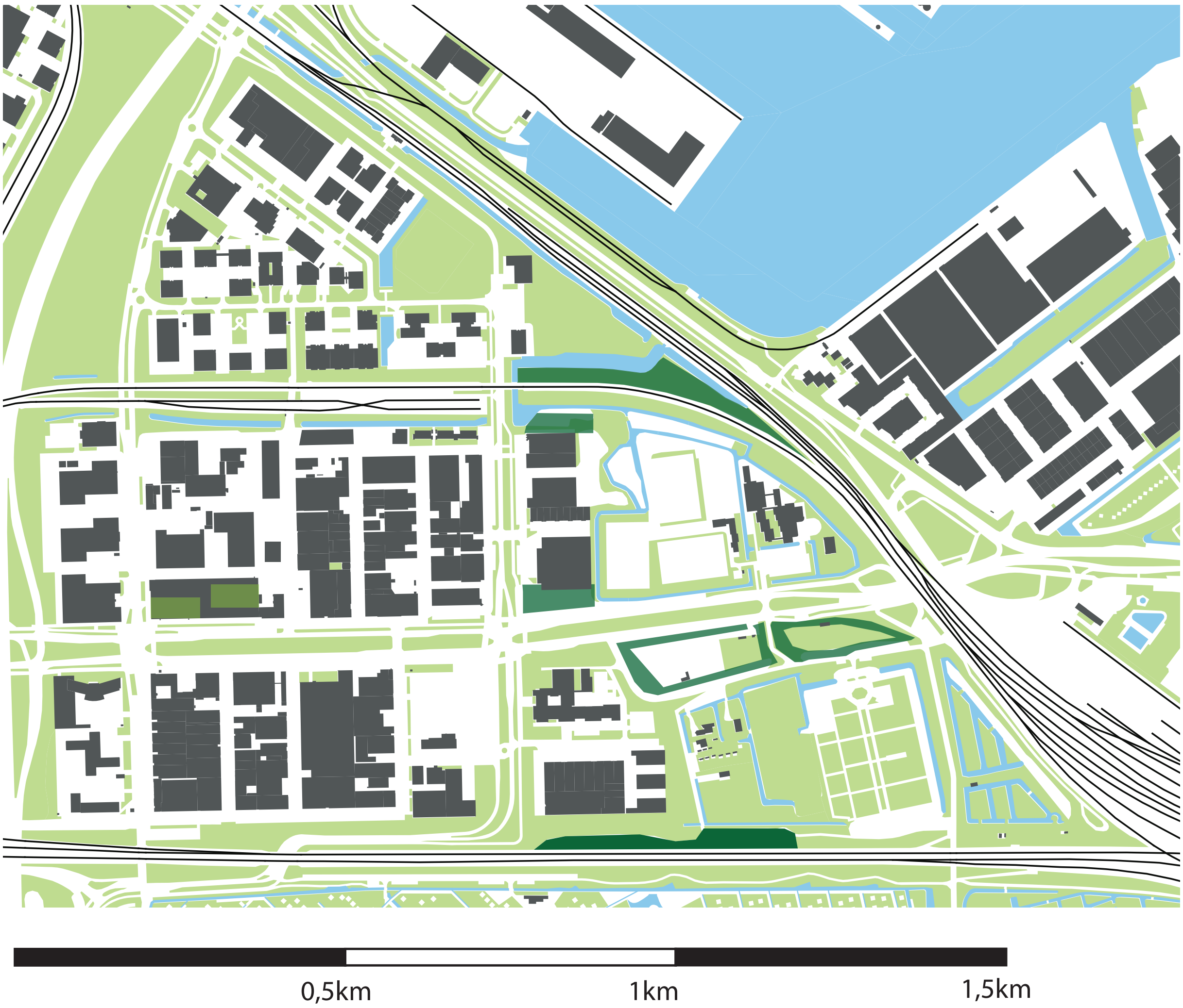


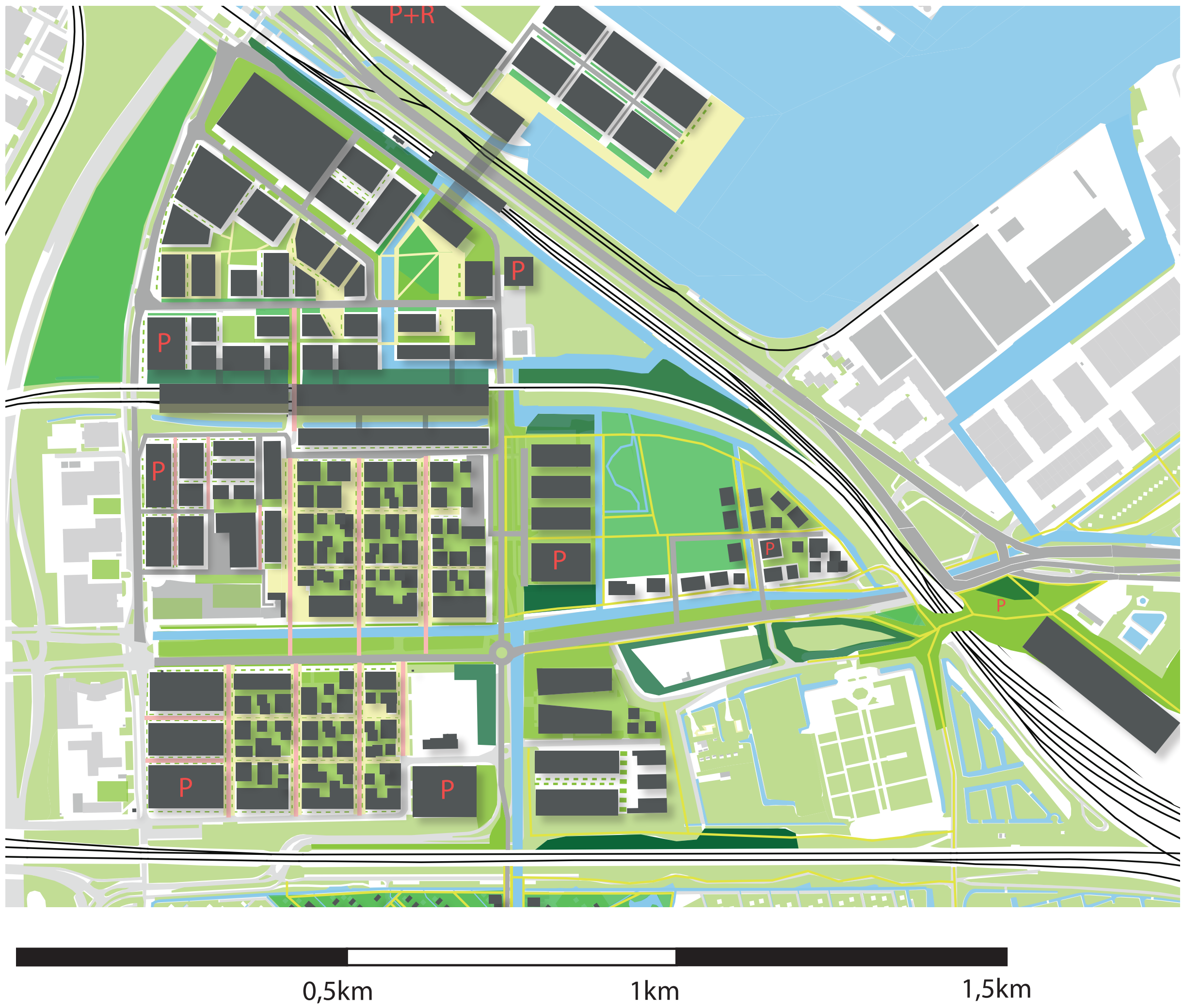
The park and public space system within the area

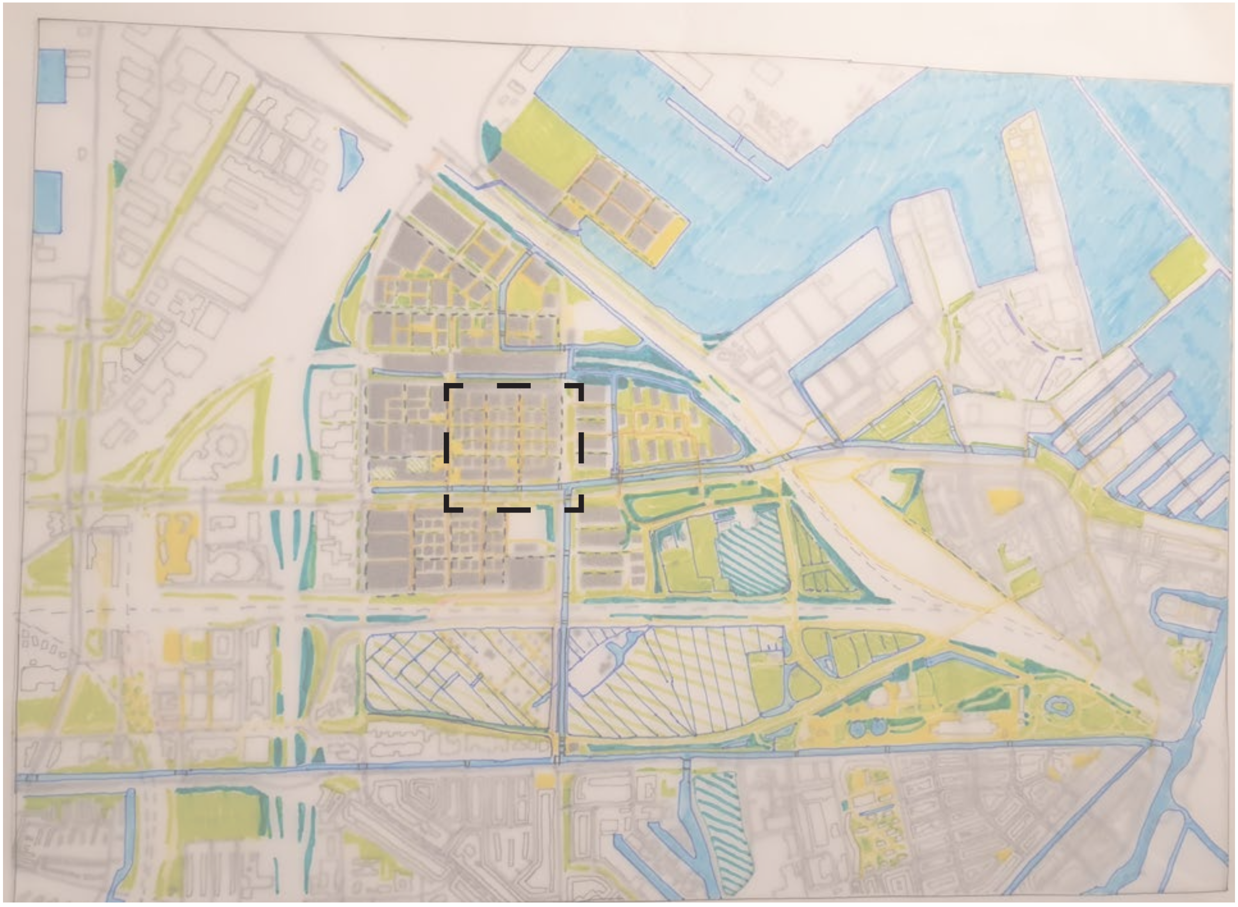


The attractions in yellow in the area.
The three existing attractions (Thuishaven, Stadspodium and Westergasterrein) are either connected to the park or to the “stadstraten”. The design expands on this system by adding 2 attractions connected to infrastructures, Parkbrug and Neptunusplein.

Neighbourhood scale

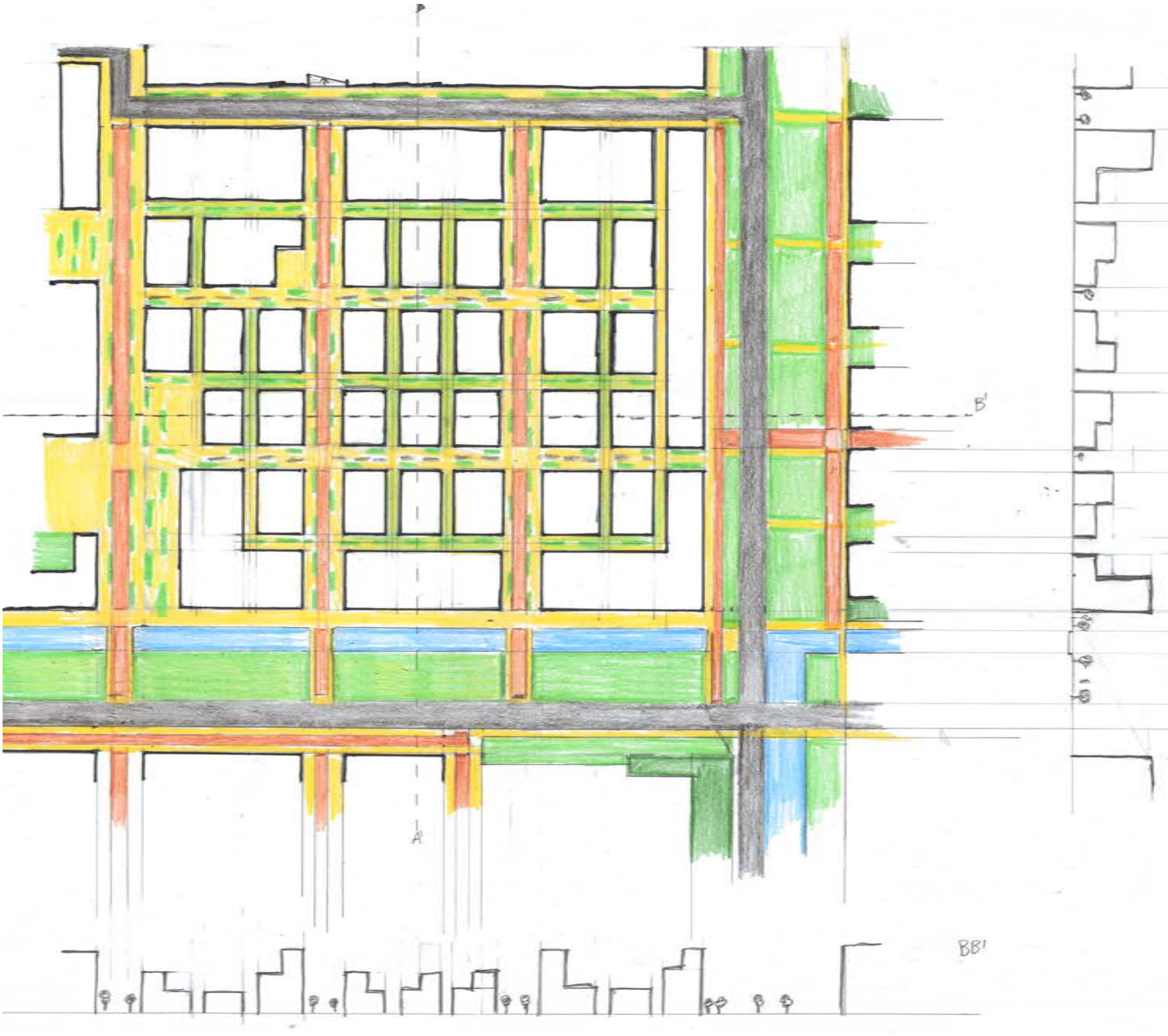



P+R
P
0,5km
1km
1,5km

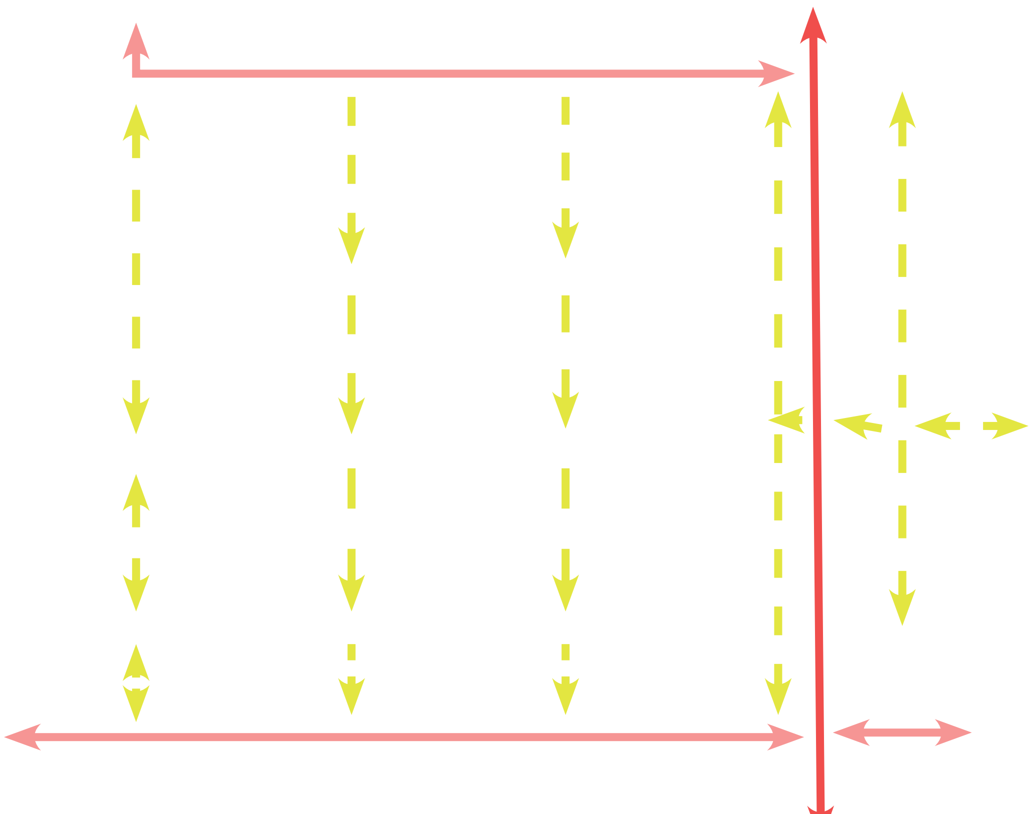


The location of the chosen ensemble

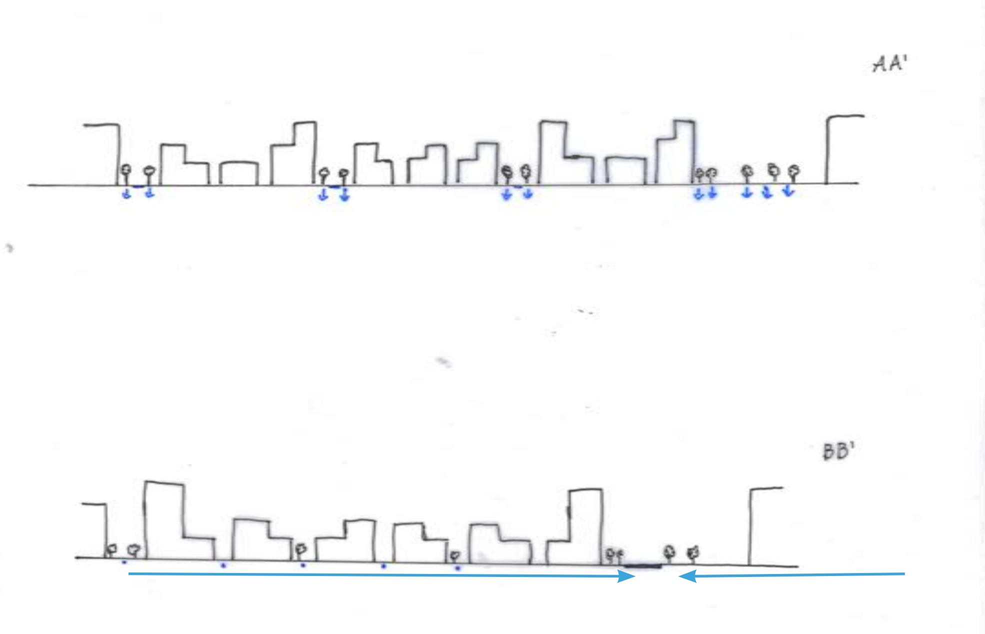
This ensemble, located next to the crossing of the Transformatorweg and the Contactweg is mostly pedestrian, including three shared roads with clear routing and conditional access for automobiles. This drawing shows the clear difference between the green boulevard type stadsstraat that is the Contactweg and the the pedestrian district type stadsstraat of Isolatorweg with its many squares..



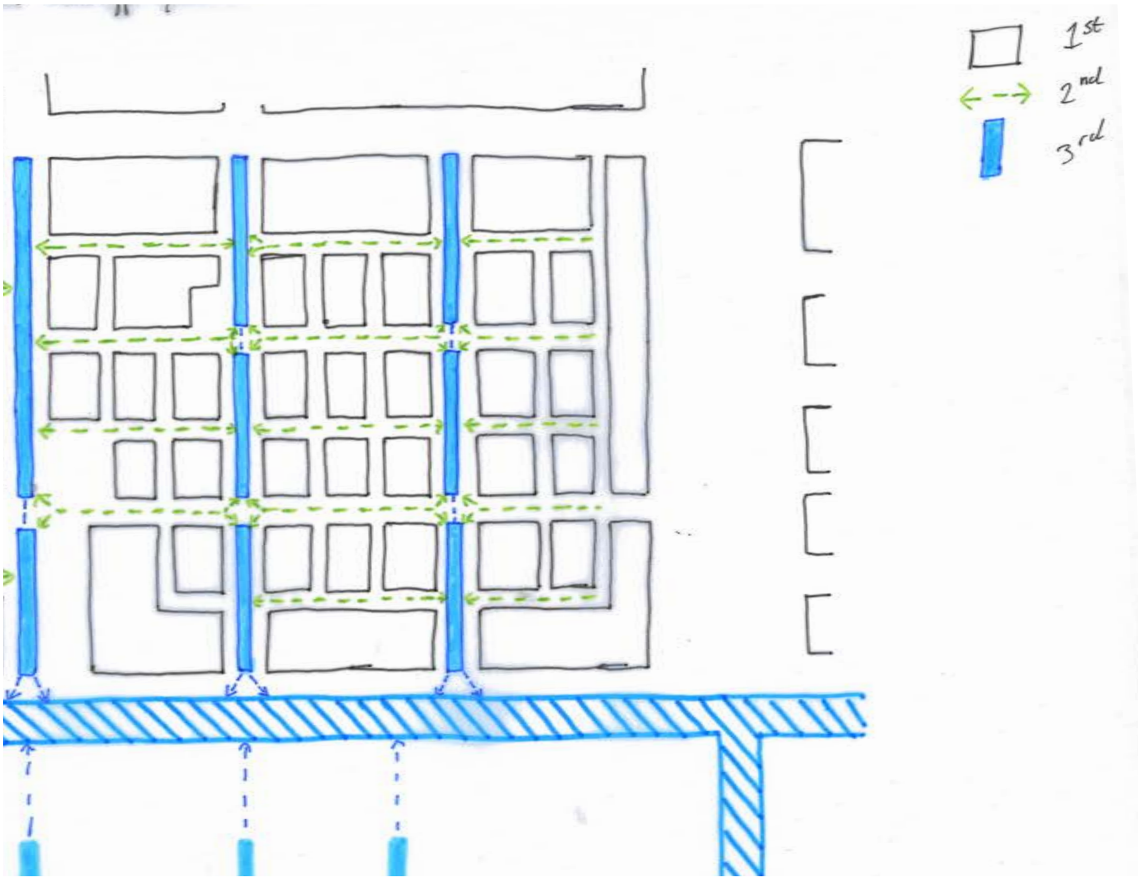
Original vision for the area



Driving directions for autobiles in and around the ensemble
Through the careful direction of the traffic in the area, automobiles attempting to get a shortcut can be deterred.



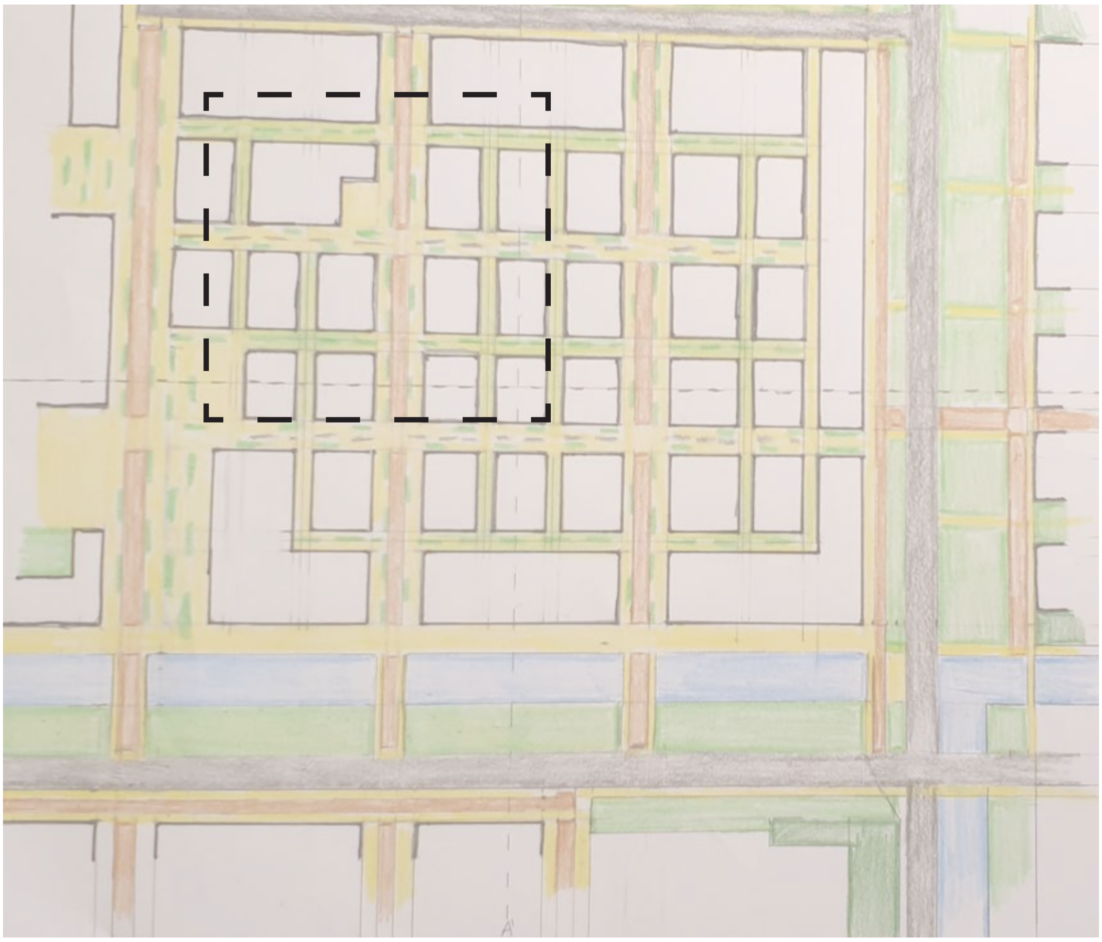
Infiltration
These sections show the infiltration and drainage



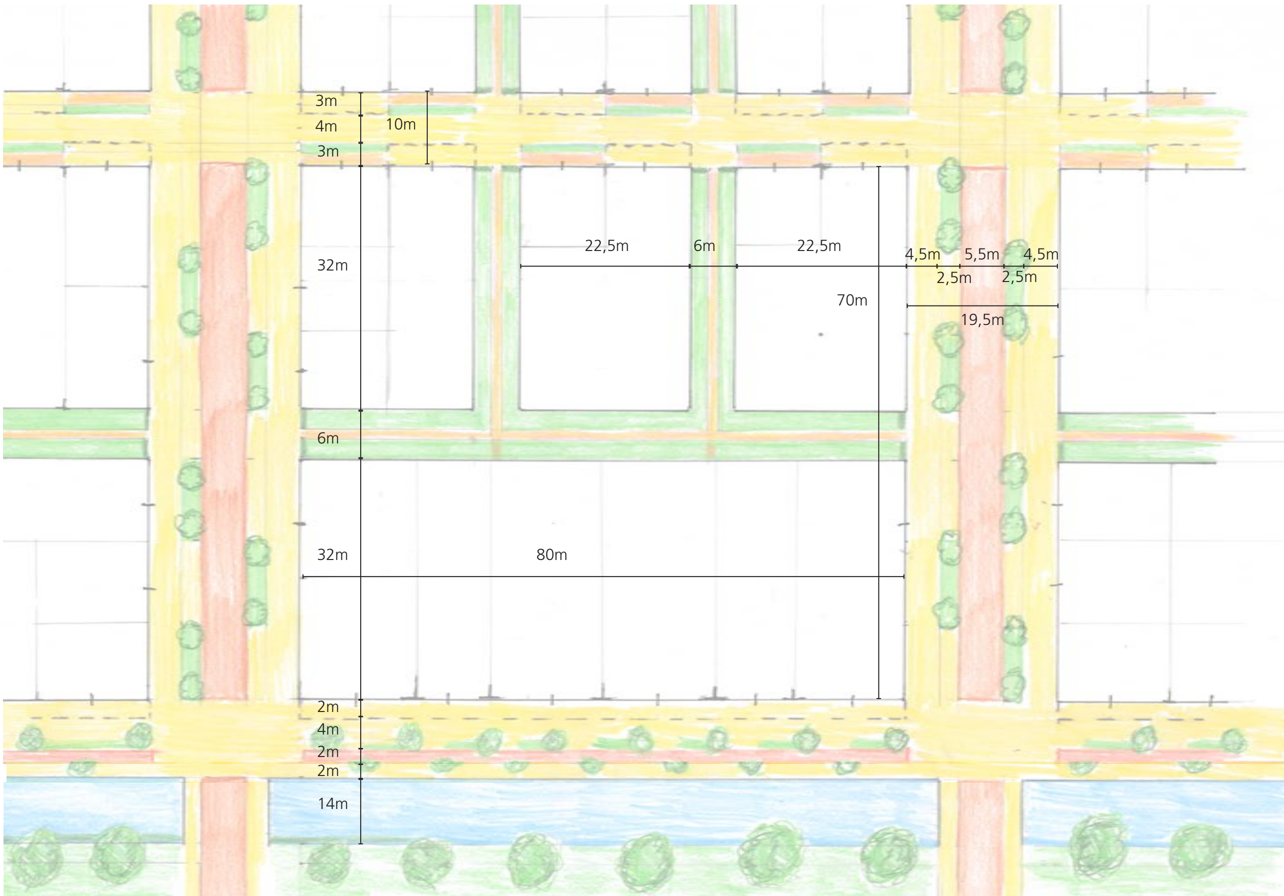
Ensemble Rainwater plan with cascade
During a high rainfall event the buildings themselves shall first retain as much water as they can. Judging by the municipality's ambition to realise the required 60mm capacity of which buildings take 40mm into account (Gemeente Amsterdam, 2017), the facilities in the public space will only be needed during a sustained rain. Those facilities prioritise infiltration, before transporting water to the canal. The principle is drawn below.

The Block and street scale

On this level the designs for space, function and resilience intersect on the living level.



The location of the chosen block

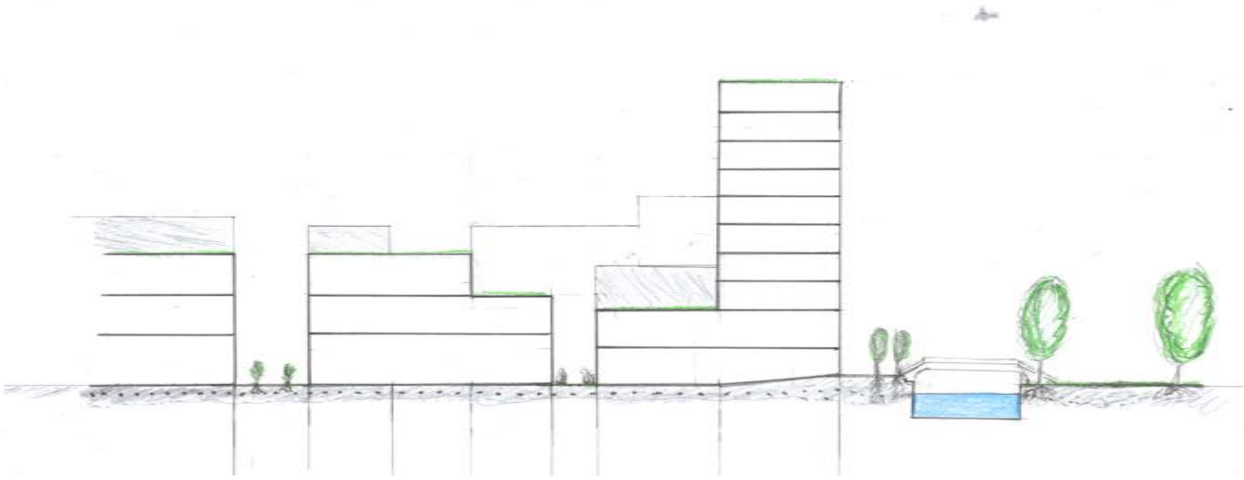


The block design vision

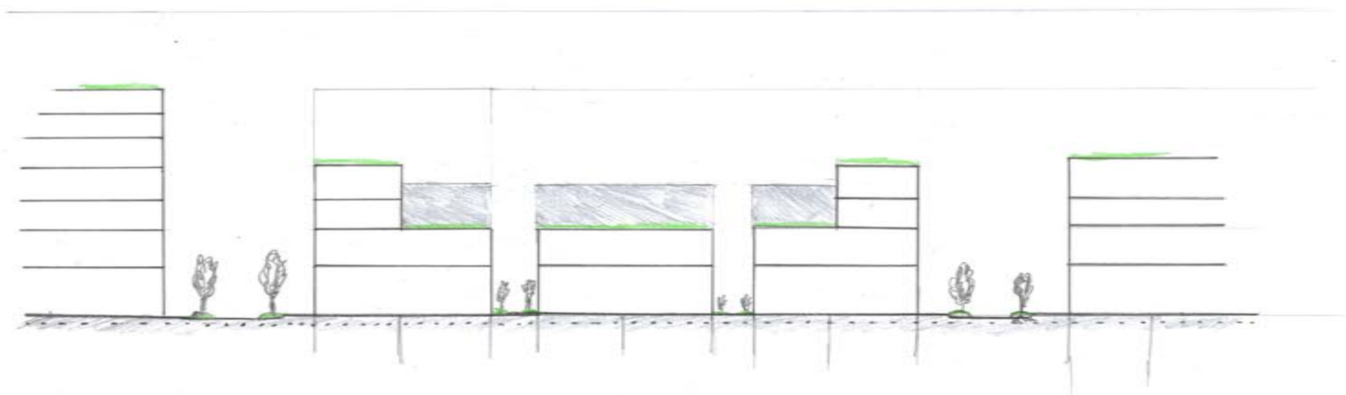
In this drawing the proposed subdivision of the ground floor is visible, as well s the introduction of a new collective domain between the private dwellings and businesses and the streets. The inner courts may vary in accessibility by outsiders. This is also the area were most rainwater retention capacity is located in this typology.

The north-south roads flanking the block allow for conditional automobile passage in a shared space road. During high rainfall, however, these automobile paths can become flooded, affording only emergency vehicles access.

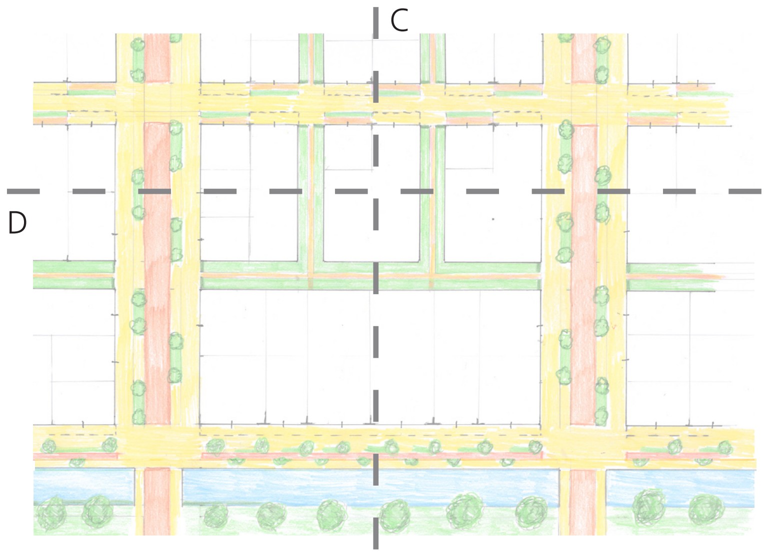
The East West roads are pedestrian in nature, although their dimensioning allows for access by selected services and emergency vehicles.

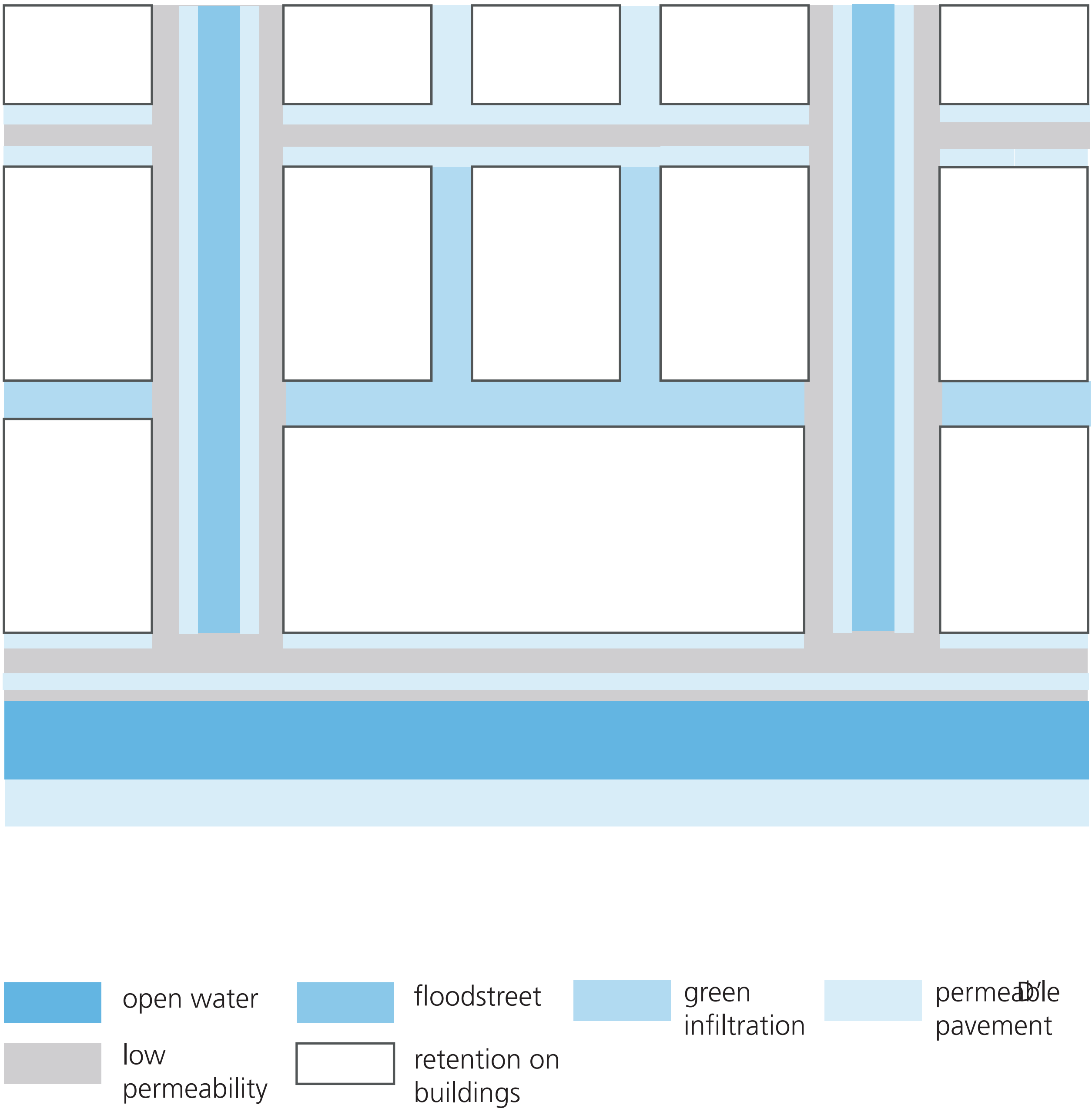


Section CC'

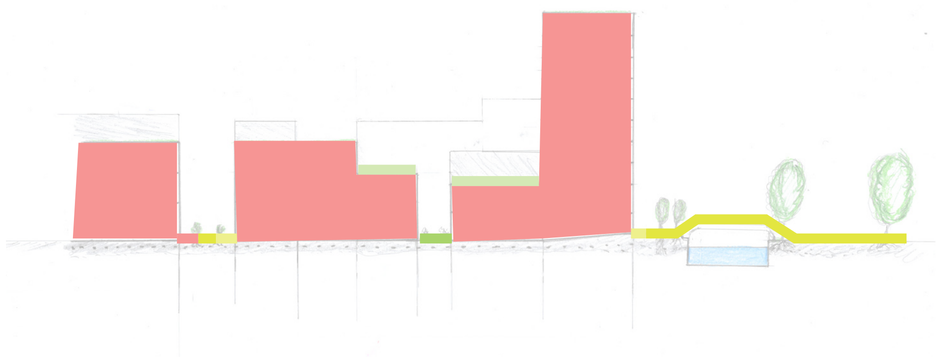


Section DD'





Water management concept



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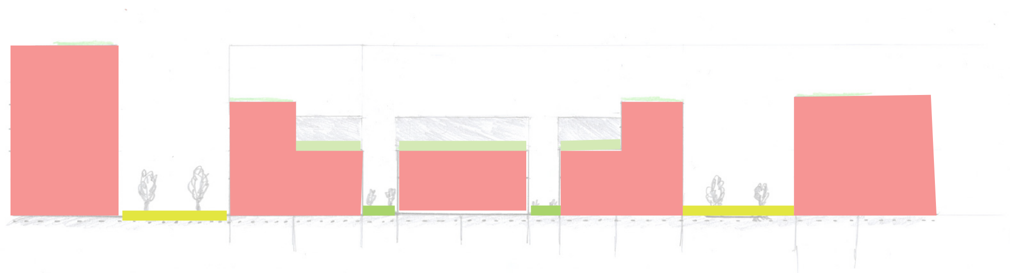
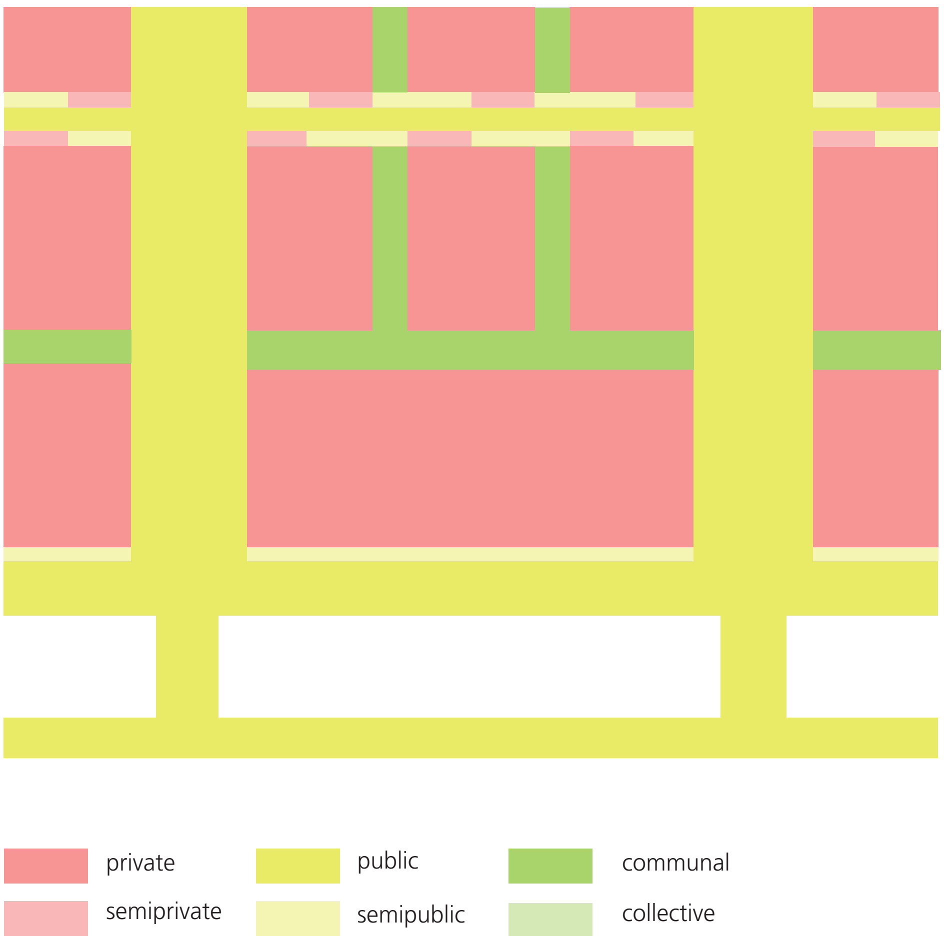
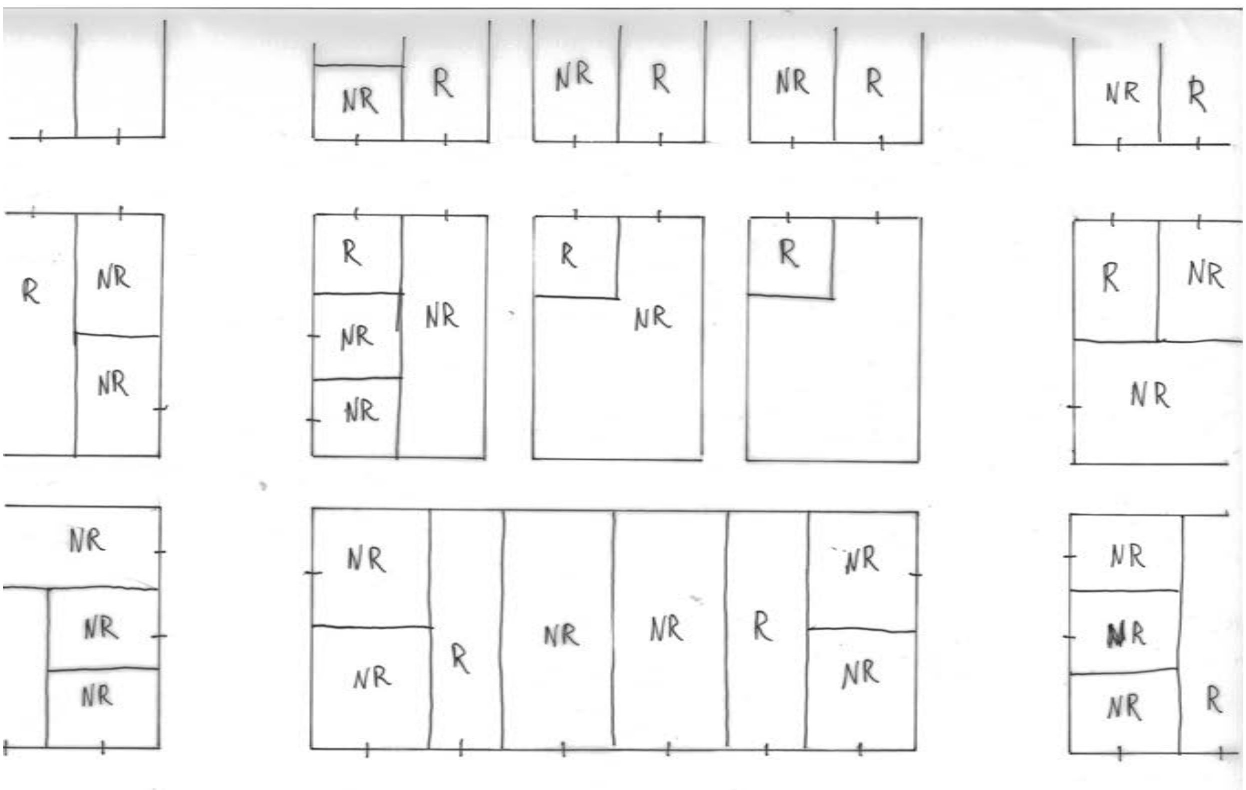


Section DD'

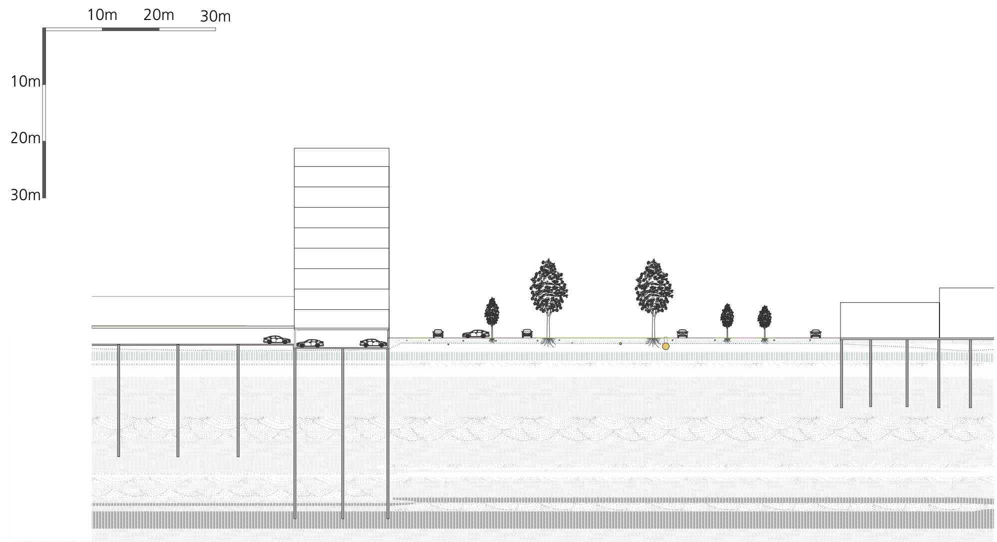


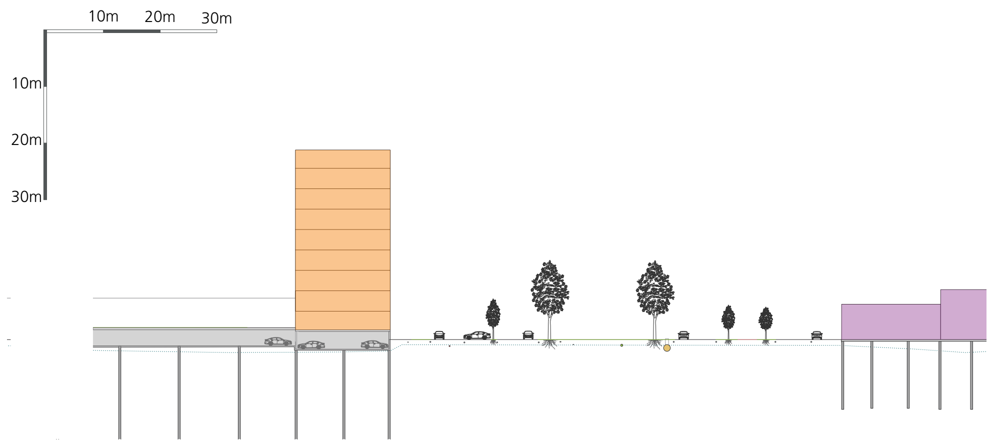


Residential and non residential

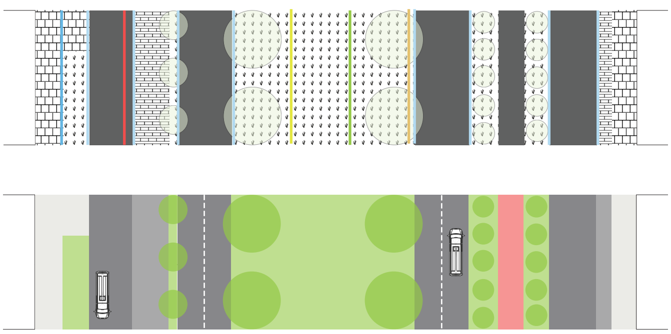
A proposal for the division into residential and non residential uses on the ground level. By mixing both uses, "eyes on the street" can be ensured during the day.

The Street

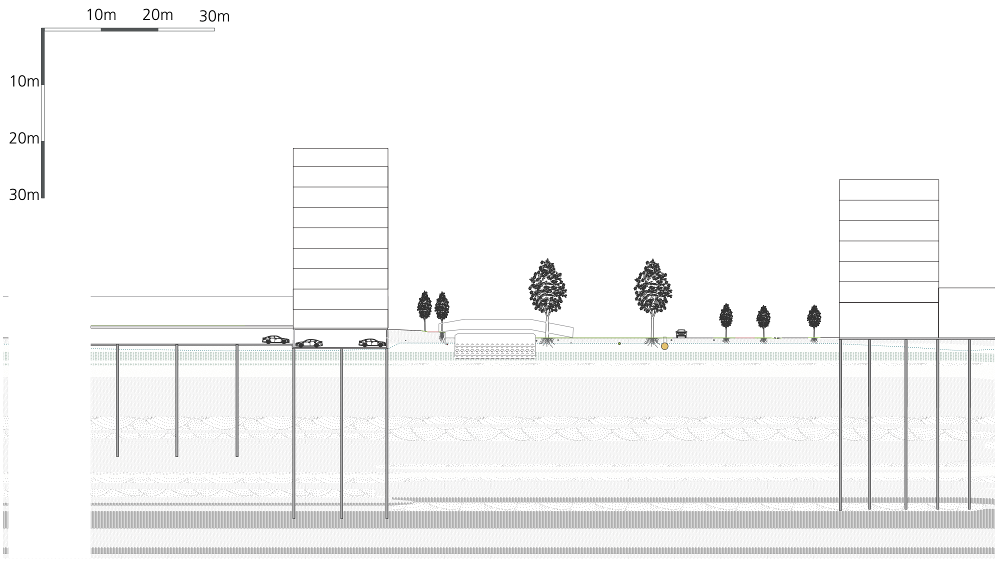




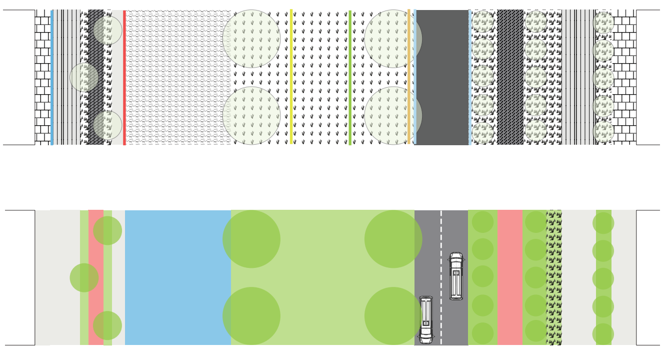
Transformatorweg profile current situation technical and functional section



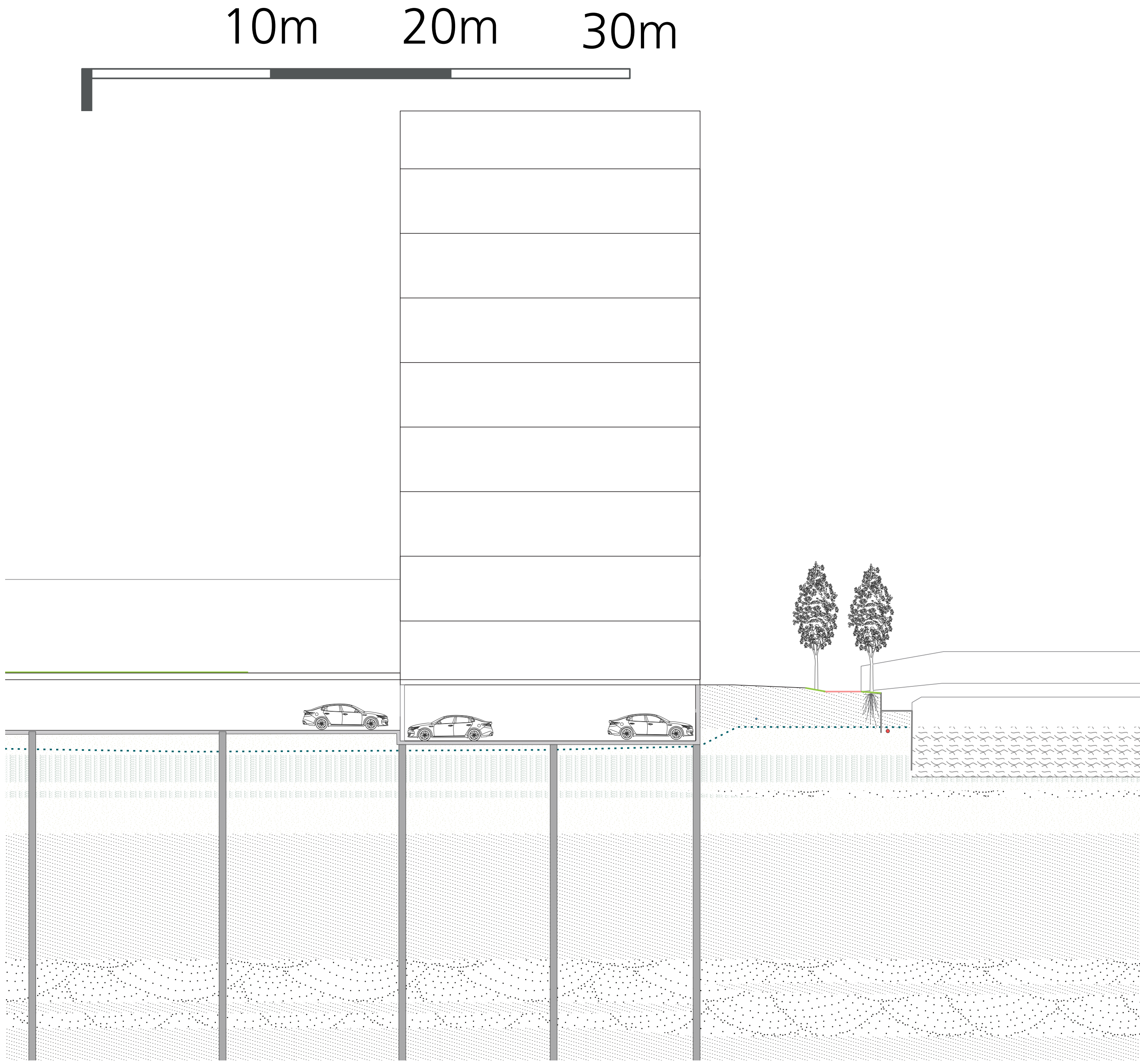
Transformatorweg slice current situation technical and functional section

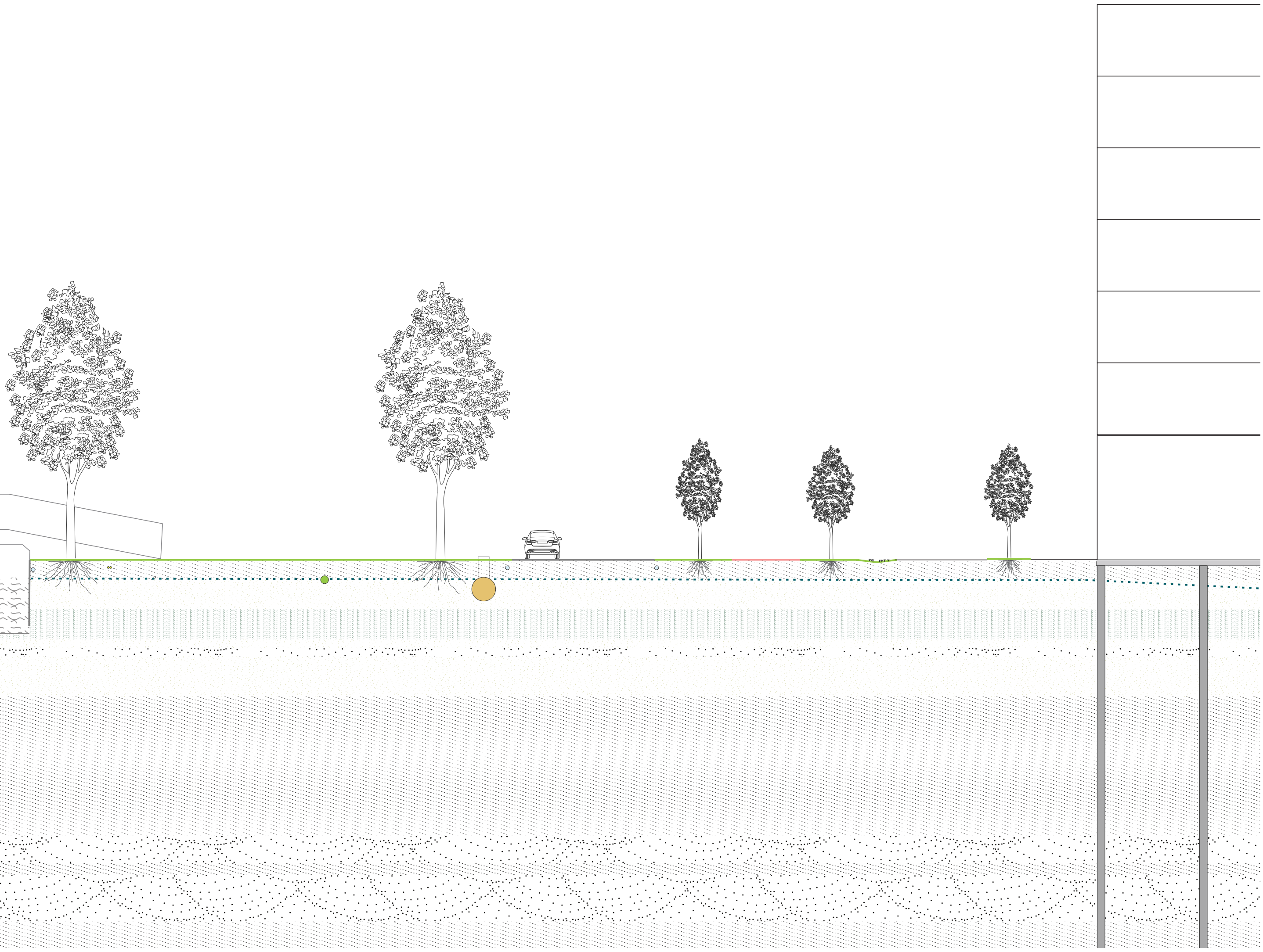


Transformatorweg profile future situation technical and functional section



Transformatorweg slice future situation technical and functional section

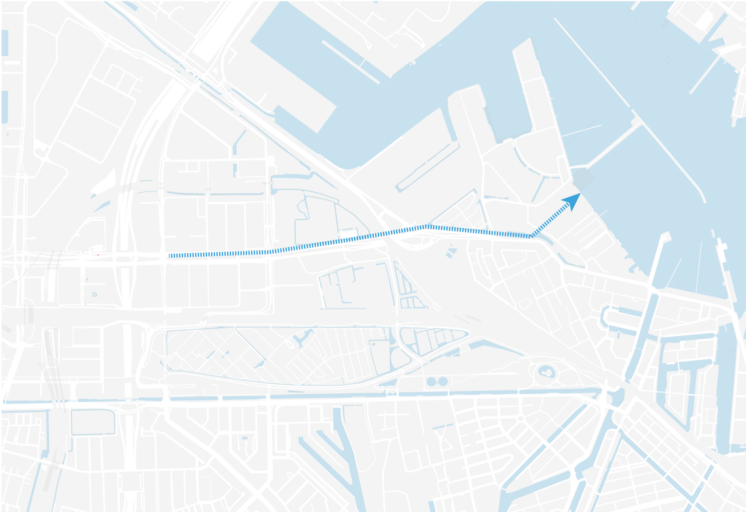

10m
20m
30m



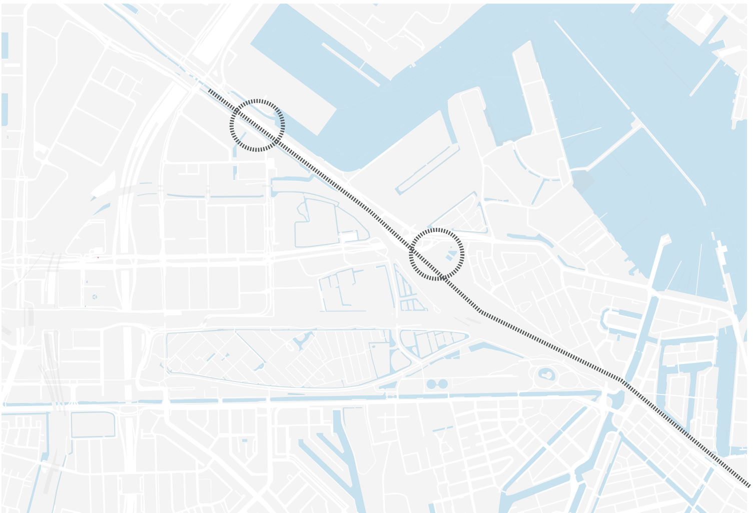
Phasing

This chapter shows the order in which different interventions will be taking place in the design.

Phase 1



The transformatorweg-Houthavens canal



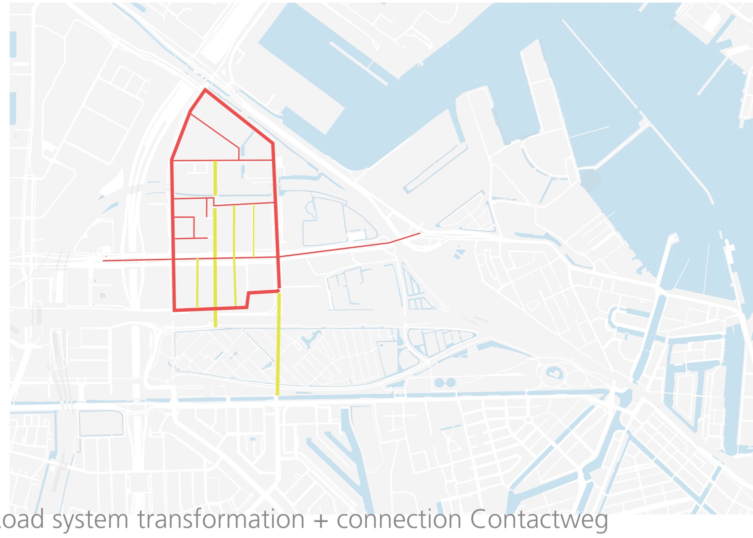
Hemweg and Westerpark station S-train

Priority shift Transformatorweg to Hemweg

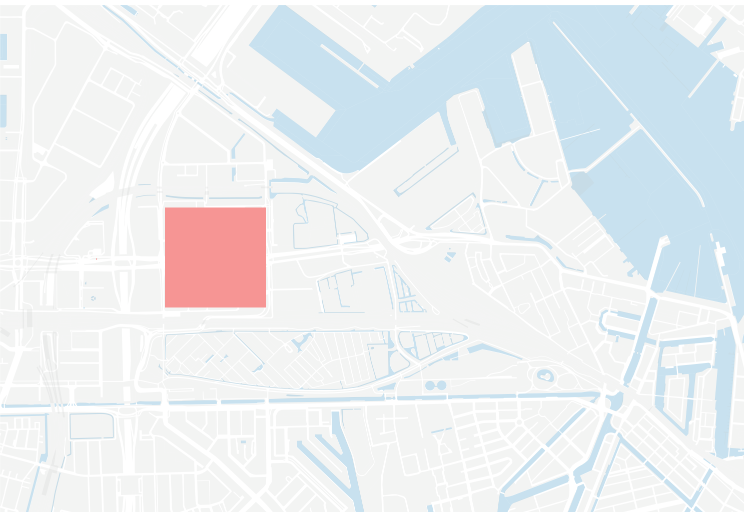
Phase 1: infrastructure and hubs
This phase takes place prior to the end of the convenant (2029) and is crucial for the future development of the Havenstad district. The infrastructure shift must precede the function shift.

Phase 2

Internal canals Havenstad



Road system transformation + connection Contactweg



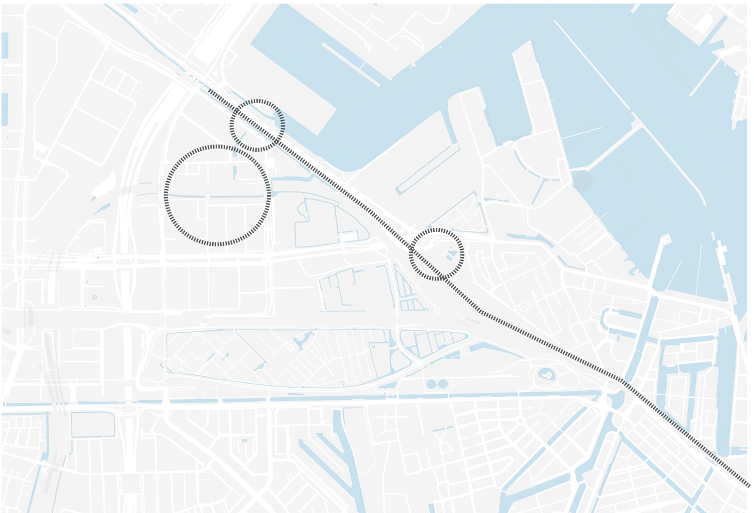
Introduction of the first housing

Phase 2: network adaptation and introduction of housing

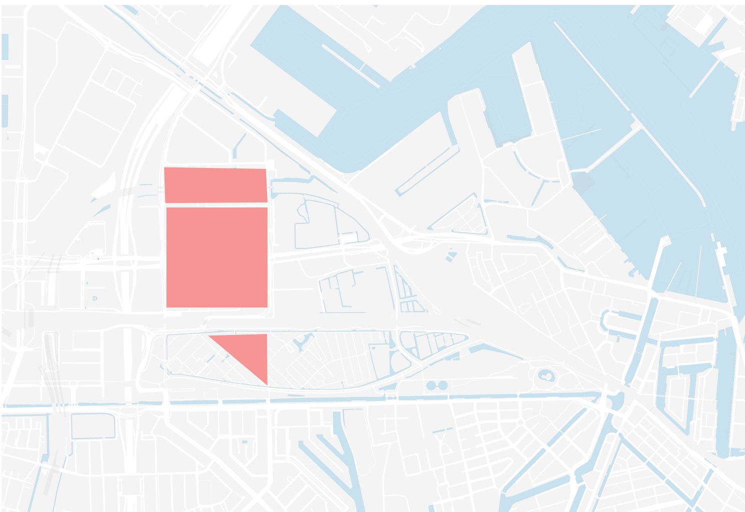
After the convenant ends, the road system will be transformed to create a more liveable environment and the water system will be expanded. This is also when the first housing gests introduced

Phase 3

Connecting internal canals to Haarlemmertrekvaart



Expansion of the hub development

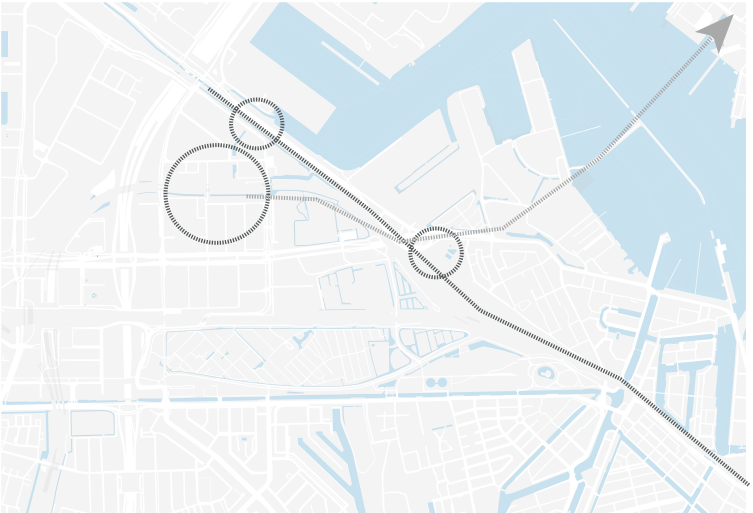


Development of the housing stock

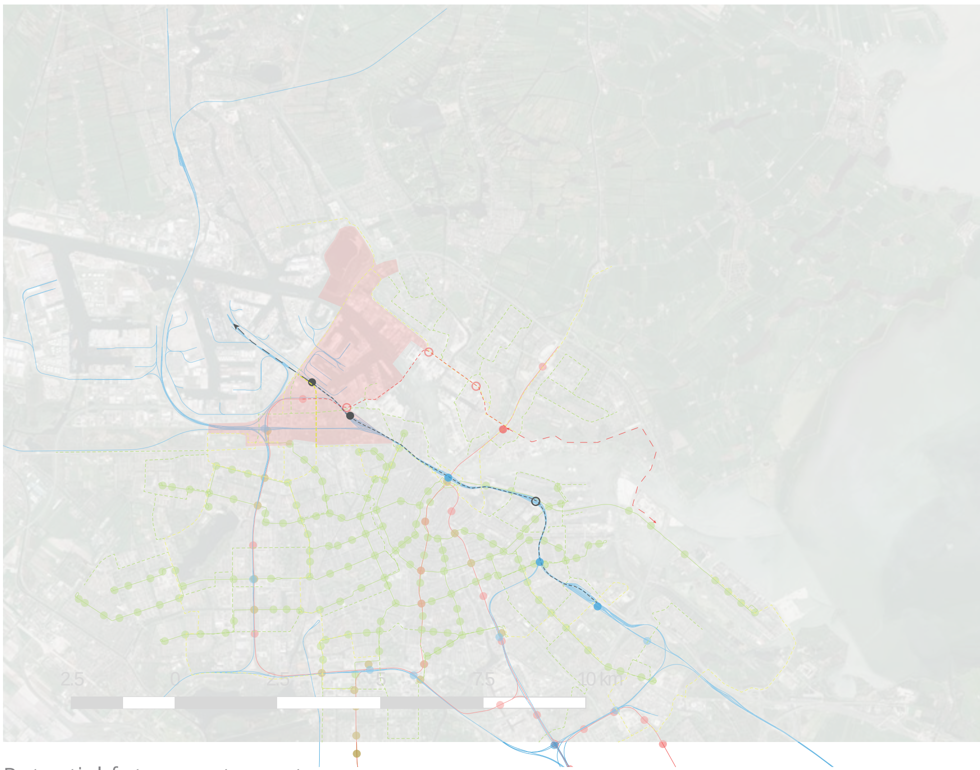
Phase 3: network consoidation and hub related development

Following this the canal system can be connected to the Haarlemmertrekvaart and further hub development and building development can take place.

Phase 4



Hub development and metro expansion



Potential future metro system

Phase 4: Future expansion of the system throughout the city.

Maintaining the S-train on the long term allows for an alternative expansion of the metro system through Noord. Here the Westerpark station would then be the node connecting both. Eventually the connection in Noord could even be expanded to Zeeburgereiland, opening a whole host of new development opportunities along the trajectory.

Conclusion

Conclusion

Considering the project's ambitions, developing a high-density resilient environment, with the potential to operate as a city for the future, the combination of the three themes density, liveability and ecosystem services proved to be main part of the project.

Before a design for a city of the future can be elaborated, the correlation between density, liveability and ecosystem services has to be truly understood. In this project this has been done through the development of guidelines stemming from literature, external input and reference studies. This allowed for a base the design, that in a further elaboration of this project could be developed into a pattern language for the resilient high-density city.

Developing a city for the future, capable of incorporating changes within its fabric, requires a transition from planning based on current socioeconomic patterns, towards an approach based on performative design. Adopting such a strategy, with a strong focus on the performance of the design, requires a strategic approach, based on the potential development.

Therefor this project has mostly focused on the infrastructure to base the development of the area on as this allows future flexibility for the development.
One of the project ambitions, namely the development of a more standard approach towards the urban design, proved a lot more challenging than was priorly envisioned. In the end it may have been a bit too ambitious to not only research how to integrate density, liveability and ecosystem services towards a more resilient system, but also develop an evidence based approach to the design.

However, this could be considered the groundwork, or foundation on which to base such a further design, allowing for a further elaboration of the climate resilience in the spatial design. Additional considerations pertaining to themes such as the circular economy could in the future also be part of the approach.

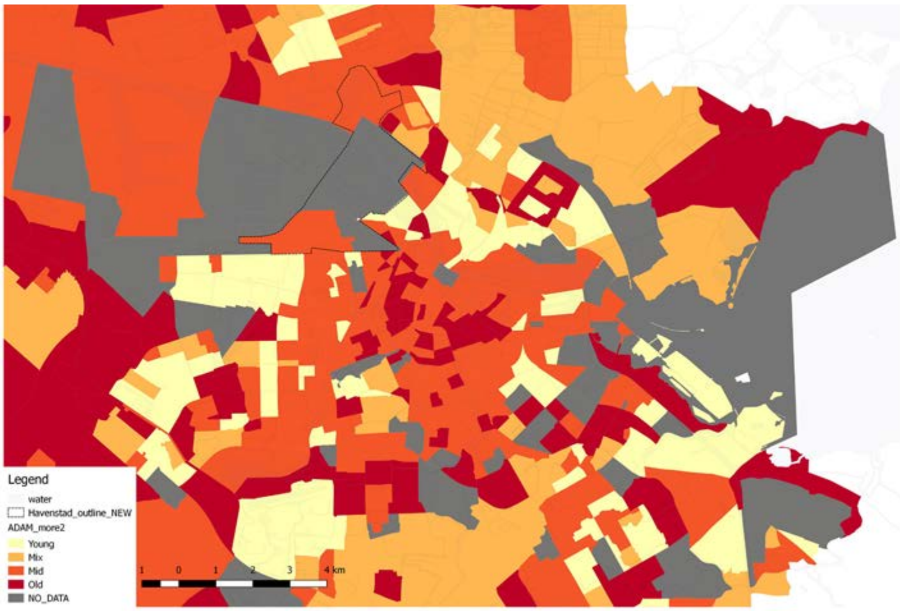
The interaction between production businesses and industries was unfortunately not further explored, but it could be a very interesting starting point to identify how the different positive and negative performances of businesses can be integrated within a district, allowing for a renewed mix.
Here mutual benefit should be at the helm of the design decisions.

This project could function as a start for further considerations. Where it does offer a pathway towards the development of the area, the situation with a wide variety of different stakeholders, responsibilities and ownership patterns require a research of their own prior to the development of this project.


Appendices


Index

A1: Socioeconomics of Amsterdam



Age distribution in various neighbourhoods
(Compiled using CBS wijk en buurtkaart 2018)

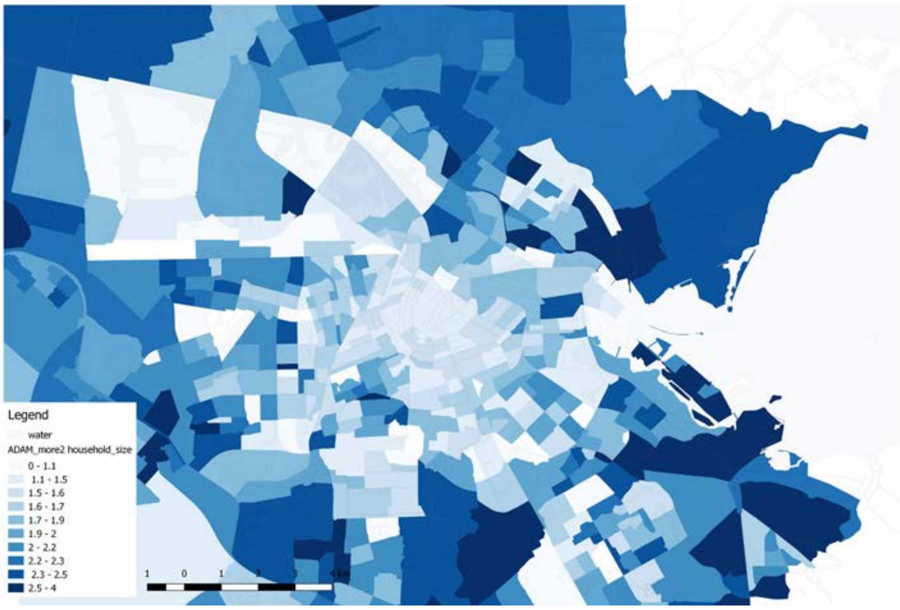
In this map the categories are set up in the following way:
65 and over > 15% and <15% under 14 is Old
65 and over < 15% and >15% under 14 is Young
65 and over < 15% and <15% under 14 is Mid
65 and over > 15% and >15% under 14 is Mix

It is clear that the population in Amsterdam is predominantly working age.

Percentage of dependents among the population
(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

This map expands further on the percentage of the population that is dependent on the working age population. Here all inhabitants that don't generally have an income through employment are included. These are the children and the population over 65.

The city consists mostly of working age population, with the percentage of dependents being higher outside of the centre



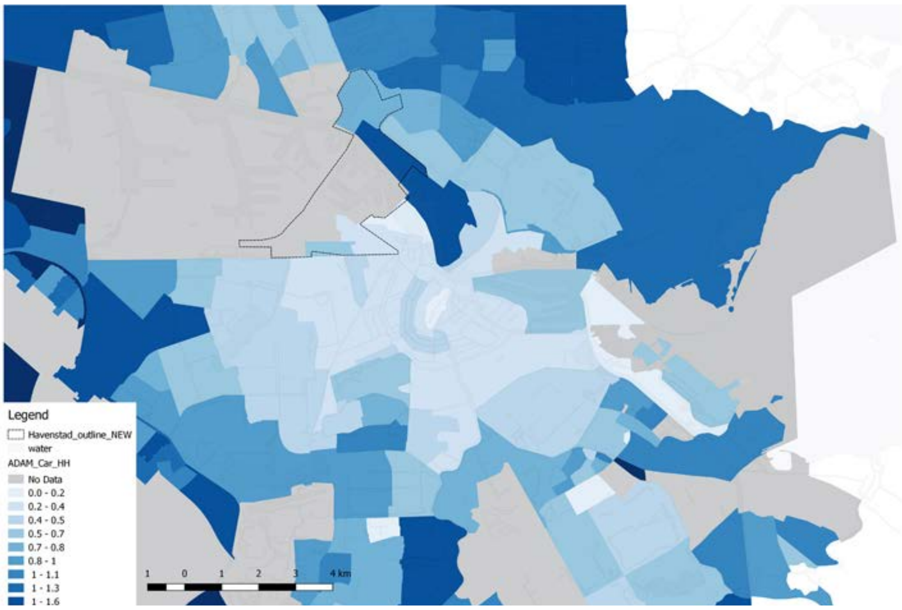
Average household size per neighbourhood
(Compiled using CBS wijk en buurtkaart 2018)

Here it becomes clear that on on average the city of Amsterdam has low household size when compared to its environment. The average household size of the Netherlands being 2,15 as of 2018. (CBS, 2019)

Percentage of single person households
(Compiled using CBS wijk en buurtkaart 2018)

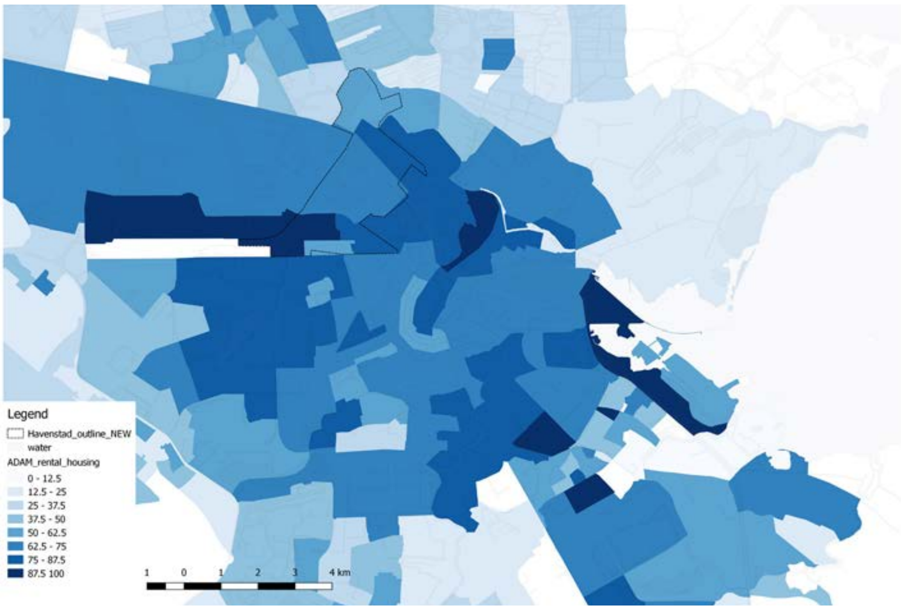
This map takes a further look into the percentage of single person households. On the whole it exceeds the prevalence of such households on the national scale. The national average being 38,1% (CBS, 2019). Here it strongly follows the built environment of the city of Amsterdam, in particular the areas along the 'Ring' seem to be well represented.

The average household size in the city of Amsterdam is low compared to the surrounding municipalities.



Number of cars per household
(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

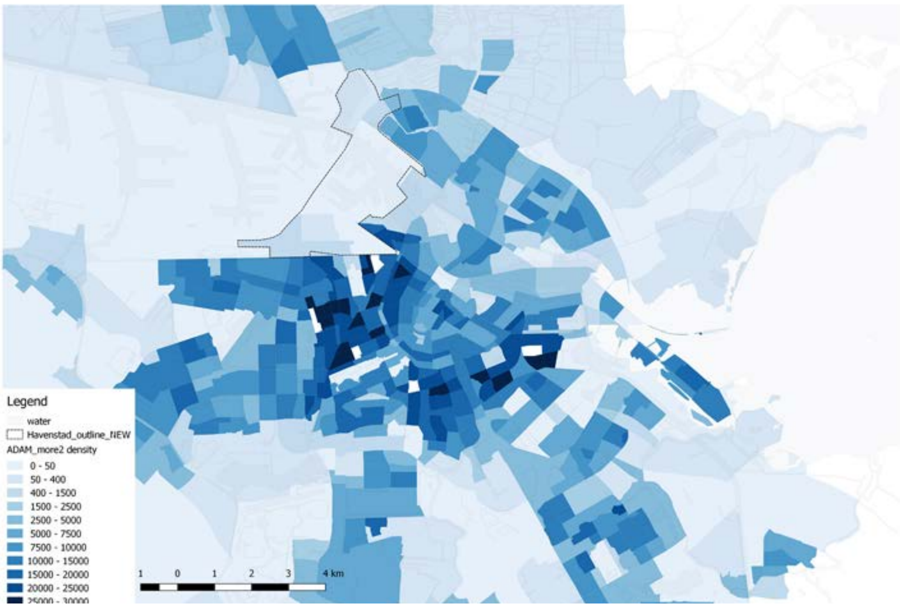
The number of cars per household is lower than the national average of 0,93 in the city of Amsterdam (CBS, 2016). This seems to be ower amongst the lower income neighbourhoods.



Percentage of rental houses
(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

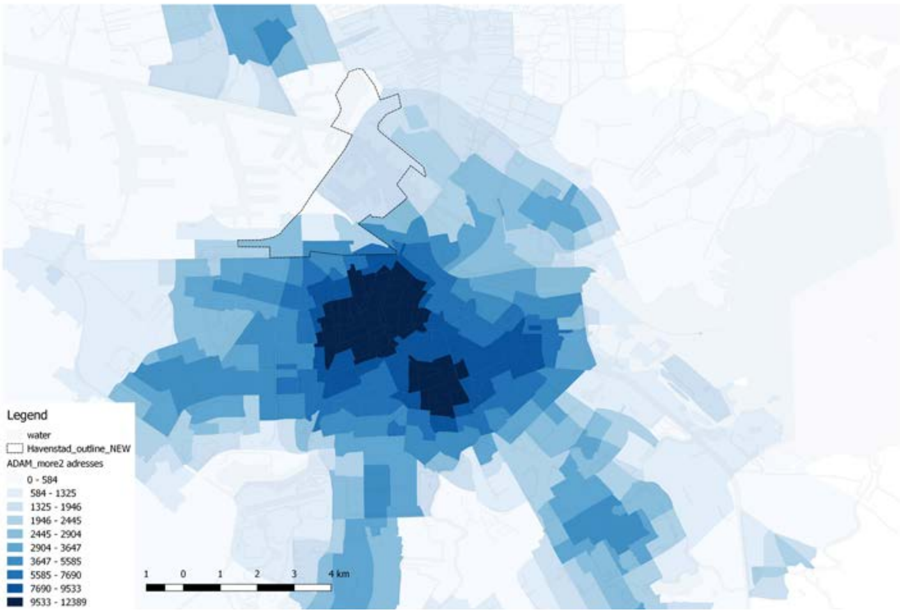
The city of Amsterdam has a high percentage of rental homes, a value that negatively correlates to the income.

Apart from neighbourhoods in the North and the fringes of the municipality, car ownership is low in the city of Amsterdam. The majority of the population lives in rental housing.



Population density per km2
(Compiled using CBS wijk en buurt-kaart 2018)

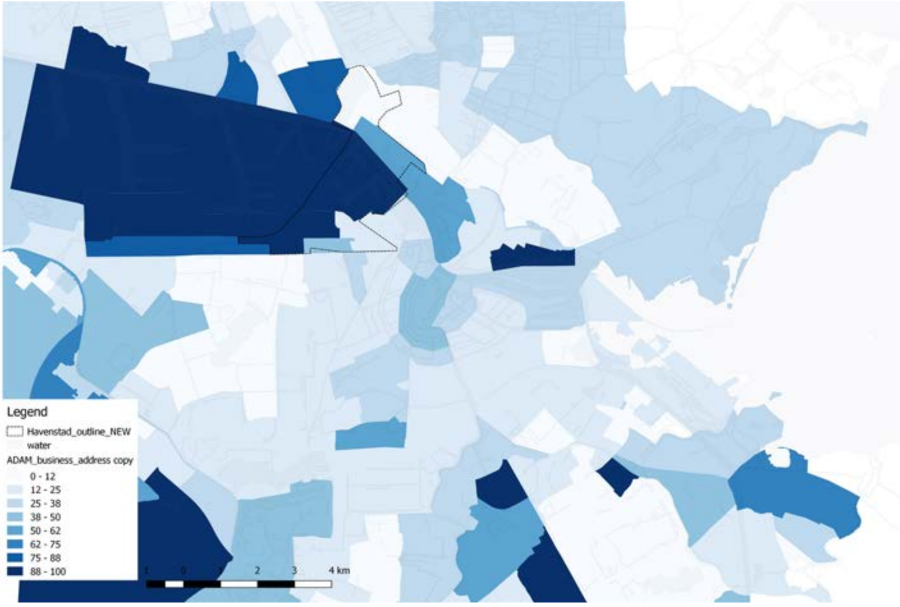
In this map the density of the population per km2 for the neighbourhoods has been shown. This map illustrates that the highest densities of population are present in the areas developed between 1903 and 1940.



Number of addresses per km2
(Compiled using CBS wijk en buurt-kaart 2018)

The density of addresses when seen together with the density of the population suggests there are either large numbers of dwellings present in the area or the dwellings are inhabited by large numbers of people.

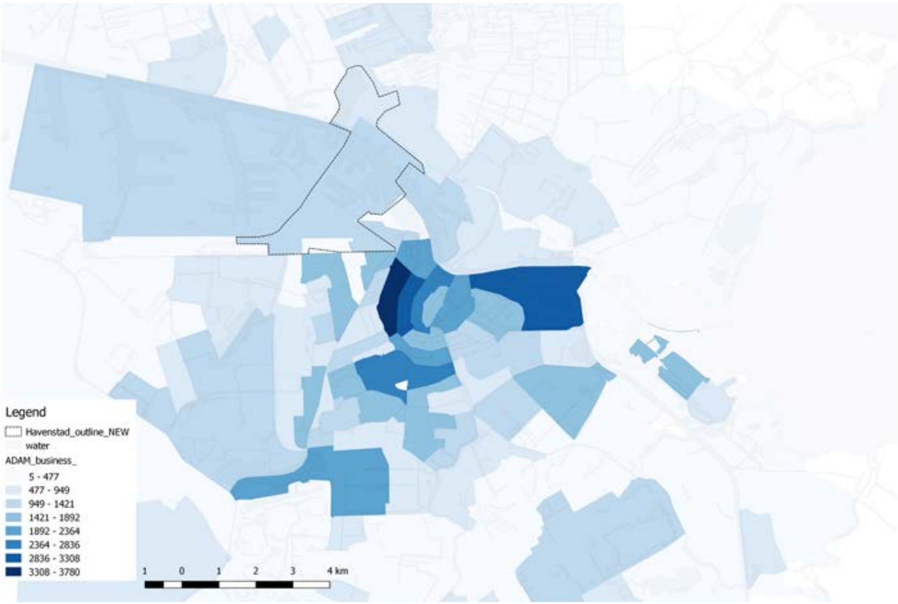
The population densities are the highest in the areas directly adjacent to the city centre, while the number of addresses is highest in both the centre and the areas directly adjacent. Both are low in Havenstad.



Percentage of businesses amongst addresses

(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

This map highlights the monofunctional business neighbourhoods in the city. Through this map it becomes visible that the centre of the city consists largely of mixed functions.

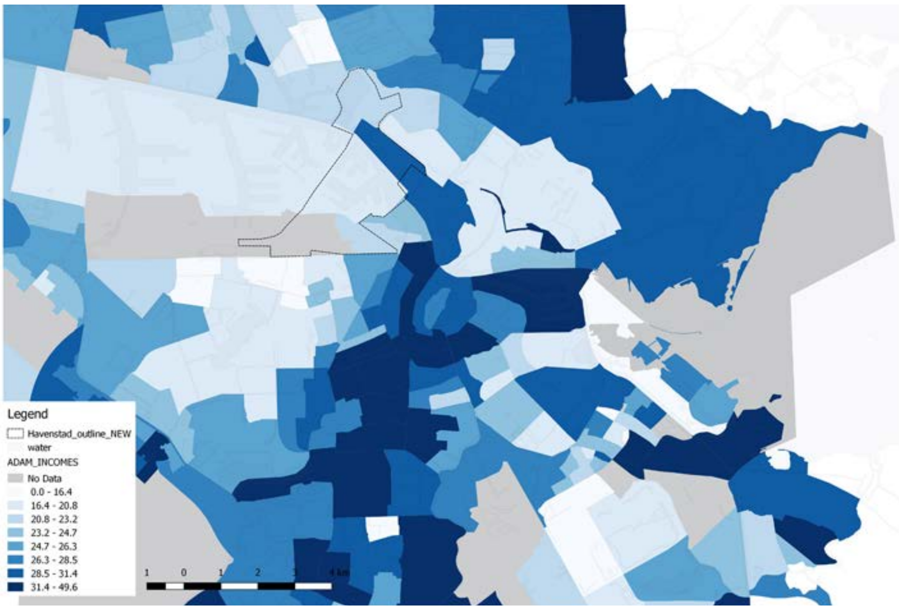


Number of businesses per neighbourhood

(Compiled using CBS wijk en buurtkaart 2014, due to unavailability of data for 2018)

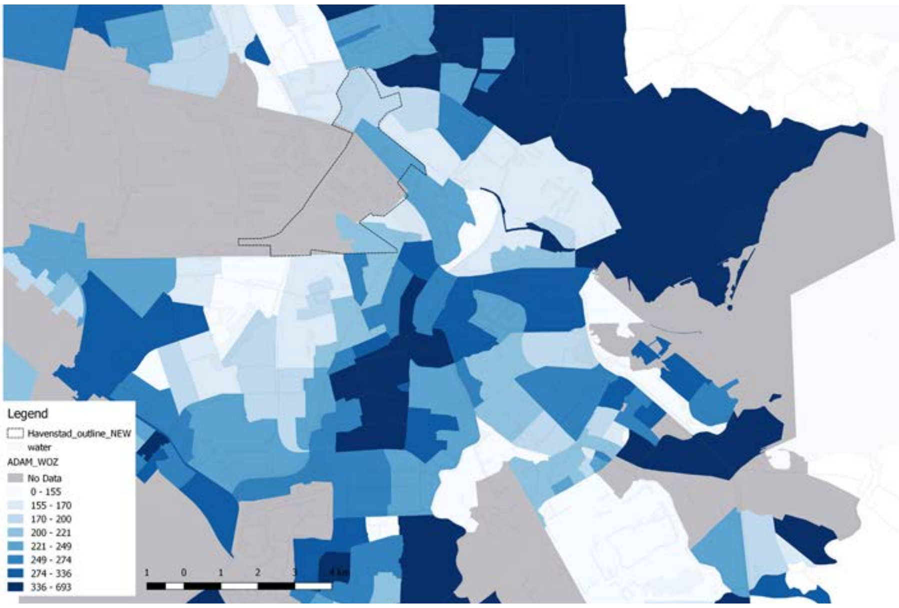
In this map it is visible that the largest number of businesses is present around the central parts of Amsterdam.

While the harbour has the highest percentage of businesses amongst addresses the absolute highest amount of businesses is located in the centre.



Average income level per inhabitant in the city
(Compiled using CBS wijk en buurt-kaart 2014, due to unavailability of data for 2018)

This map clearly shows the division of wealth in the city. Here the areas surrounding Havenstad are shown to have lower incomes.



WOZ- value in thousands of euros
(Compiled using CBS wijk en buurt-kaart 2014, due to unavailability of data for 2018)

The division in wealth becomes particularly clear through this map, as home values largely correlate to the income levels. Currently the average Dutch WOZ value sits at 230 thousand euros (CBS, 2018), a value already exceeded in large parts of Amsterdam in 2014.

The current citywide level is 340 thousand euros. According to the CBS this is an increase of nearly 48 percent (CBS, 2018).

The highest real estate values and the most affluent population of Amsterdam are predominantly located in the centre and the areas to the south of it.

A2: AMA socioeconomic data

Municipality	Jobs	Inhabitants	Job density (Jobs/Inhabitants	Area(in km2)	Density (Inhabitants/km2)	number of under 19	ratio over 65	ratio under 19	ratio 19-65	growth of municipality	working population	ratio jobs to working pop
Aalsmeer	15.000	31.373	0,478118127	20	1.569	7.832	0,176	0,249641411	0,574358589	5-10%	18019,352	0,83243837
Almere	81.000	200.914	0,40315757	129	1.557	52.616	0,096	0,261883194	0,642116806	>10%	129010,26	0,62785706
Amstelveen	53.000	89.294	0,593544919	41	2.178	19.658	0,19	0,22014917	0,58985083	>10%	52670,14	1,006262752
Amsterdam	637.040	844.947	0,75394078	165	5.121	165.475	0,119	0,195840686	0,685159314	>10%	578923,31	1,100387551
Beemster	3.620	9.205	0,39326453	70	132	2.033	0,199	0,220858229	0,580141771	5-10%	5340,205	0,677876598
Beverwijk	17.800	40.709	0,437249748	18	2.262	9.055	0,171	0,222432386	0,606567614	>10%	24692,761	0,72085904
Blaricum	3.510	10.201	0,344083913	11	927	2.022	0,265	0,198215861	0,536784139	0-5%	5475,735	0,641009837
Bloemendaal	5.870	22.826	0,257162884	40	571	5.427	0,265	0,237755191	0,497244809	0-5%	11350,11	0,517175605
Diemen	18.850	27.272	0,691185098	12	2.273	5.734	0,153	0,210252273	0,636747727	>10%	17365,384	1,08549284
Edam-Volendam	15.200	35800	0,424581006	54	663	7.136	0,176	0,199329609	0,624670391	0-5%	22363,2	0,679688059
Gooise Meren	20.820	56.935	0,365680162	42	1.356		0,35	0,32	0,33	0-5%	18788,55	1,108121702
Haarlem	64.930	159.229	0,407777478	29	5.491	34.331	0,166	0,21560771	0,61839229	5-10%	98465,986	0,659415527
Haarlemmerliede-Spaarnwoude	2.150	5.665	0,379523389	19	298	1.266	0,173	0,223477493	0,603522507	0-5%	3418,955	0,628847119
Haarlemmermeer	134.840	146.003	0,923542667	178	820	36.289	0,151	0,248549687	0,600450313	>10%	87667,547	1,538083414
Heemskerk	8.940	39.171	0,228230068	27	1.451	8.445	0,206	0,215593168	0,578406832	5-10%	22656,774	0,394583977
Heemstede	8.240	26.936	0,305910306	9	2.993	6.189	0,26	0,229766855	0,510233145	0-5%	13743,64	0,599550046
Hilversum	45.650	88.888	0,513567636	46	1.932	19.481	0,19	0,219163442	0,590836558	0-5%	52518,28	0,869221155
Huizen	12.860	41.382	0,310763134	16	2.586	9.292	0,198	0,224542071	0,577457929	0-5%	23896,364	0,538157186
Landsmeer	3.440	11.275	0,305099778	23	490	2.402	0,309	0,213037694	0,477962306	5-10%	5389,025	0,638334393
Laren	4.550	11.088	0,410353535	12	924	6.757	0,199	0,609397547	0,191602453	0-5%	2124,488	2,141692492
Lelystad	36.770	76.937	0,477923496	231	333	19.151	0,148	0,248917946	0,603082054	>10%	46399,324	0,792468442
Oostzaan	3.760	9.652	0,389556569	12	804	2.098	0,199	0,217364277	0,583635723	5-10%	5633,252	0,667465258
Ouder-Amstel	14.770	13.419	1,100678143	24	559	3.150	0,199	0,234741784	0,566258216	0-5%	7598,619	1,943774257
Purmerend	26.770	79.928	0,334926434	23	3.475	17.484	0,179	0,218746872	0,602253128	>10%	48136,888	0,556122365
Uitgeest	3.690	13.465	0,274043817	19	709	3.365	0,158	0,249907167	0,592092833	>10%	7972,53	0,462839274
Uithoorn	13.360	29.201	0,457518578	18	1.622	6.901	0,181	0,236327523	0,582672477	>10%	17014,619	0,785207121
Velsen	33.800	67.619	0,499859507	45	1.503	15.119	0,192	0,223591003	0,584408998	0-5%	39517,152	0,855324797
Waterland	4.510	17.290	0,260844419	52	333	3.763	0,22	0,217640255	0,562359746	0-5%	9723,2	0,463839065
Weesp	8.410	18.751	0,448509413	23	815	3.958	0,19	0,211082076	0,598917924	0-5%	11230,31	0,748866238
Wijdemeren	7.920	23.447	0,337783085	48	488	5.150	0,23	0,219644304	0,550355696	0-5%	12904,19	0,613754137
Wormerland	4.800	15.820	0,303413401	39	406	3.471	0,218	0,219405815	0,562594185	0-5%	8900,24	0,5393113
Zaanstad	63.800	153.679	0,415151062	74	2.077	34.891	0,173	0,227038177	0,599961823	0-5%	92201,533	0,691962464
Zandvoort	5.340	16.899	0,315995029	32	528	2.994	0,253	0,177170247	0,569829753	0-5%	9629,553	0,554542874

Municipality	car ownership ratio	cars/area ratio	car ownership	working people per dependents
Aalsmeer	0,46473082	729	0,868218901	1,741072598
Almere	0,372174164	579,6511628	0,592798421	1,557349053
Amstelveen	0,373485341	813,4146341	0,596131846	1,695343889
Amsterdam	0,241044705	1234,363636	0,317600662	1,459514567
Beemster	0,482889734	63,5	0,933823529	1,723716599
Beverwijk	0,410719988	928,8888889	0,696986119	1,648620825
Blaricum	0,527399275	489,0909091	1,115951048	1,862946253
Bloemendaal	0,489135197	279,125	0,957465055	2,011081831
Diemen	0,326158698	741,25	0,484028949	1,570480676
Edam-Volendam	0,363407821	240,9259259	0,570864414	1,600844244
Gooise Meren	0,444102924	602,0238095	0,798894155	3,03030303
Haarlem	0,356310722	1956,37931	0,553544598	1,617096486
Haarlemmerliede-Spaarnwoude	0,481023831	143,4210526	0,926870748	1,656939035
Haarlemmermeer	0,445641528	365,5337079	0,803886926	1,665416736
Heemskerk	0,443950882	644,0740741	0,798402277	1,72888691
Heemstede	0,46035046	1377,777778	0,853054485	1,959888356
Hilversum	0,396228962	765,6521739	0,656256987	1,692515444
Huizen	0,470373592	1216,5625	0,888123375	1,73172789
Landsmeer	0,454545455	222,826087	0,833333333	2,092215197
Laren	0,533459596	492,9166667	1,143437077	5,219139859
Lelystad	0,403706929	134,4588745	0,677027705	1,658149158
Oostzaan	0,454309988	365,4166667	0,832542244	1,713397519
Ouder-Amstel	0,413965273	231,4583333	0,70638352	1,765978792
Purmerend	0,404989491	1407,391304	0,680642584	1,660431393
Uitgeest	0,438544374	310,7894737	0,781084656	1,688924344
Uithoorn	0,454778946	737,7777778	0,83411846	1,716230025
Velsen	0,440334817	661,6666667	0,786782581	1,711130397
Waterland	0,43637941	145,0961538	0,774243202	1,778221162
Weesp	0,384779478	313,6956522	0,625433426	1,669677863
Wijdemeren	0,532477503	260,1041667	1,138934501	1,817006724
Wormerland	0,4494311	182,3076923	0,8163031	1,777480158
Zaanstad	0,388081651	805,9459459	0,634204958	1,666772721
Zandvoort	0,434641103	229,53125	0,768787942	1,754910119

Socioeconomic data of the AMA
Data compiled using data from CBS (2015)

The two car ownership columns can be explained as follows: The car ownership ratio column shows the cars ownership over the entire population, while the car ownership column shows the car ownership ratio of the population over 18 years old. (Those who can potentially have a driver's license)

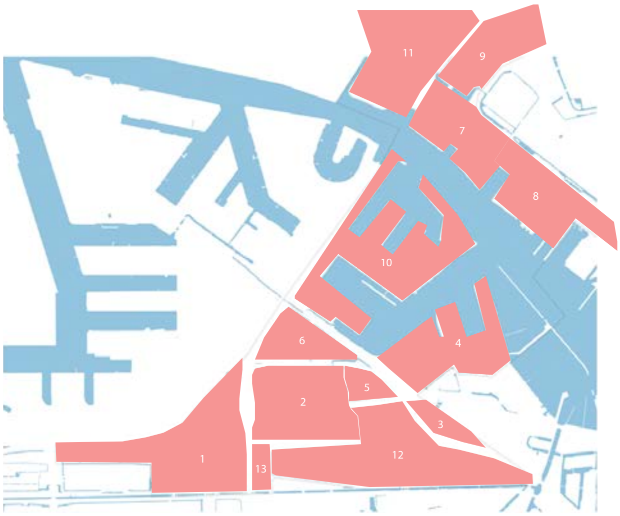
city district	population	land area	population density	jobs
centrum	86522	8,04	13740	80000
nieuw west	144004	32,38	4468	65000
noord	89906	49,01	2269	25000
oost	126157	30,56	7627	70000
west	141004	9,89	15286	45000
zuid	139523	17,41	9342	110000
zuidoost	84071	22,08	4393	60000
Poort	192		10	5000
Havenstad*	125000	4,155	30084,23586	57729

Socioeconomic data of Amsterdam districts
Data compiled using data from OIS (Gemeente Amsterdam, 2017) and the Ontwikkelvisie (Gemeente Amsterdam, 2017)

*Havenstad is projected on to the area to compare it with the other city districts.

Gemeente Amsterdam (2017). **Kerncijfers Amsterdam 2017 Amsterdam: Gemeente Amsterdam, Dienst Onderzoek, Informatie en Statistiek**

A3: Havenstad development data



Jobs per district vs population density

The various neighbourhoods of Havenstad(Gemeente Amsterdam, 2017, p.104).

1	Sloterdijk Centrum
2	Sloterdijk I
3	Zaanstraat Emplacement
4	Minervahaven
5	Sportpark Transformatorweg
6	Alfadriehoek
7	Cornelis Douwes 0-1
8	Cornelis Douwes 2-3
9	Melkweg Oostzanerwerf
10	Coen en Vlothaven
11	Noorderplas
12	Groot Westerpark
13	Sloterdijk Dorp

	neighbourhood	area in m2	current GFA m2	future GFA m2	GFA change m2	future rGFA m2	future wGFA m2	change wGFA	current jobs	future jobs
1	Sloterdijk Centrum	662000	521922	1058264	102,76286	529132	529132	1,381432475	14036	15036
2	Sloterdijk I	561000	360311	1122000	211,39765	897600	224400	-37,72046926	4731	7480
3	Zaanstraat emplacement	91000	11748	182000	1449,1999	145600	36400	209,8399728	40	1213
4	Minervahaven	582000	229278	1162000	406,80833	929600	232400	1,361665751	7411	7747
5	Sportpark Transformatorweg	94000	5437	188000	3357,7892	150400	37600	591,5578444	20	1253
6	Alfadriehoek	260000	106959	520000	386,1676	416000	104000	-2,766480614	1748	3467
7	Cornelis Douwes 0-1	345000	100539	690000	586,30084	552000	138000	37,2601677	1306	4600
8	Cornelis Douwes 2-3	480000	179300	960000	435,4155	768000	192000	7,083100948	2210	6400
9	Melkweg Oostzanerwerf	310000		146600		117280	29320			266
10	Coen en Vlothaven	770000	204810	1540000	651,91641	1232000	308000	50,38328207	869	10267
total		4155000	1720304	7568864	339,97247	6055091,2	1513772,8	-12,005506	32371	57729

	neighbourhood	jobs change	current FA per job m2	future FA per job m2	current labour category	future labour category	current dwellings	future dwellings
1	Sloterdijk Centrum	7,124536905	37	35,19100825	Havenstad average	Havenstad average	0	7410
2	Sloterdijk I	58,10610865	76	30	extensive labour	Havenstad average	0	11220
3	Zaanstraat emplacement	2932,5	293	30,00824402	extensive labour	Havenstad average	0	1820
4	Minervahaven	4,533801106	31	29,99870918	Havenstad average	Havenstad average	0	11620
5	Sportpark Transformatorweg	6165	272	30,00798085	extensive labour	Havenstad average	0	1880
6	Alfadriehoek	98,3409611	61	29,99711566	extensive labour	Havenstad average	0	5200
7	Cornelis Douwes 0-1	252,2205207	77	30	extensive labour	Havenstad average	0	6900
8	Cornelis Douwes 2-3	189,5927602	81	30	extensive labour	Havenstad average	0	9600
9	Melkweg Oostzanerwerf			110,2255639		extensive labour	0	1600
10	Coen en Vlothaven	1081,472957	235	29,99902601	extensive labour	Havenstad average	0	15400
total		78,33554725						72650

	neighbourhood	current FSI	future FSI	projected population	pop dens per km2	area in km2
1	Sloterdijk Centrum	0,788401813	1,59859	12967,5	19588,36858	0,662
2	Sloterdijk I	0,642265597	2	19635	35000	0,561
3	Zaanstraat emplacement	0,129098901	2	3185	35000	0,091
4	Minervahaven	0,393948454	1,99656	20335	34939,86254	0,582
5	Sportpark Transformatorweg	0,057840426	2	3290	35000	0,094
6	Alfadriehoek	0,411380769	2	9100	35000	0,26
7	Cornelis Douwes 0-1	0,291417391	2	12075	35000	0,345
8	Cornelis Douwes 2-3	0,373541667	2	16800	35000	0,48
9	Melkweg Oostzanerwerf	0	0,4729	2800	9032,258065	0,31
10	Coen en Vlothaven	0,265987013	2	26950	35000	0,77
total		0,41403	1,82163	127137,5	30598,67629	4,155

	neighbourhood	r increase cars	rcar space needed m2	parking percentage rGFA	wcar spaces required	wcar space needed m2
1	Sloterdijk Centrum	1482	37050	7,002033519	2116,528	52913,2
2	Sloterdijk I	2244	56100	6,25	897,6	22440
3	Zaanstraat emplacement	364	9100	6,25	145,6	3640
4	Minervahaven	2324	58100	6,25	929,6	23240
5	Sportpark Transformatorweg	376	9400	6,25	150,4	3760
6	Alfadriehoek	1040	26000	6,25	416	10400
7	Cornelis Douwes 0-1	1380	34500	6,25	552	13800
8	Cornelis Douwes 2-3	1920	48000	6,25	768	19200
9	Melkweg Oostzanerwerf	320	8000	6,821282401	117,28	2932
10	Coen en Vlothaven	3080	77000	6,25	1232	30800
total		14530	363250	5,999083878	7325,008	183125,2

	neighbourhood	car park area m2	parking percentage GFA
1	Sloterdijk Centrum	89963,2	8,50101676
2	Sloterdijk I	78540	7
3	Zaanstraat emplacement	12740	7
4	Minervahaven	81340	7
5	Sportpark Transformatorweg	13160	7
6	Alfadriehoek	36400	7
7	Cornelis Douwes 0-1	48300	7
8	Cornelis Douwes 2-3	67200	7
9	Melkweg Oostzanerwerf	10932	7,457025921
10	Coen en Vlothaven	107800	7
total		546375,2	7,21872133

Development data of Havenstad
Data compiled using data from the MER Havenstad (Gemeente Amsterdam, 2017)

The gross average space requirement for parking per car was set at 25m2. This not only includes the space where the car is stationed, but also the required space for accessing the space.

A4: Climate labels and waterlabels

Berging	Waterlabel
0 mm	G
≥ 2 mm	F
≥ 7 mm	E
≥ 18 mm	D
≥ 30 mm	C
≥ 44 mm	B
≥ 60 mm	A
≥ 80 mm	A+
≥ 110 mm	A++

Water labels and the corresponding amount of water retention.
Source: Waterlabel. Retrieved on 13-09-2019 from https://waterlabel-v1.lizard.net/

Waterlabel is made possible through a cooperation of the Amstel Gooi en Vecht water board, the municipality of Den Haag, the municipality of Rotterdam, de Waag and Amsterdam Rainproof.

	Overlast regen	Hitte	Droogte	Overstroming
A	Geen water	< 38°	< 1 m	< 20 cm
B	< 5 cm	38° - 40°	1 – 2 m	20 - 50 cm
C	5 - 10 cm	40° - 42°	2 – 4 m	50 – 200 cm
D	10 - 23 cm	42° - 44°	4 – 8 m	200 – 500 cm
E	> 23 cm	> 44°	> 8 m	> 500 cm
	Verschil maximale waterdiepte en drempelhoogte (uitgaande van een hevige bui van 93 mm/70 min)	De gevoelstemperatuur op een hele warme zomerdag rondom uw woning (peildatum 1 juli 2015)	De diepste grondwaterstand in de zomer rondom uw woning	De hoogte van het water in uw huis als gevolg van een dijkdoorbraak (gebaseerd op kaarten Europese Richtlijn Overstromingsrisico's)

Climate labels as defined by Blue label

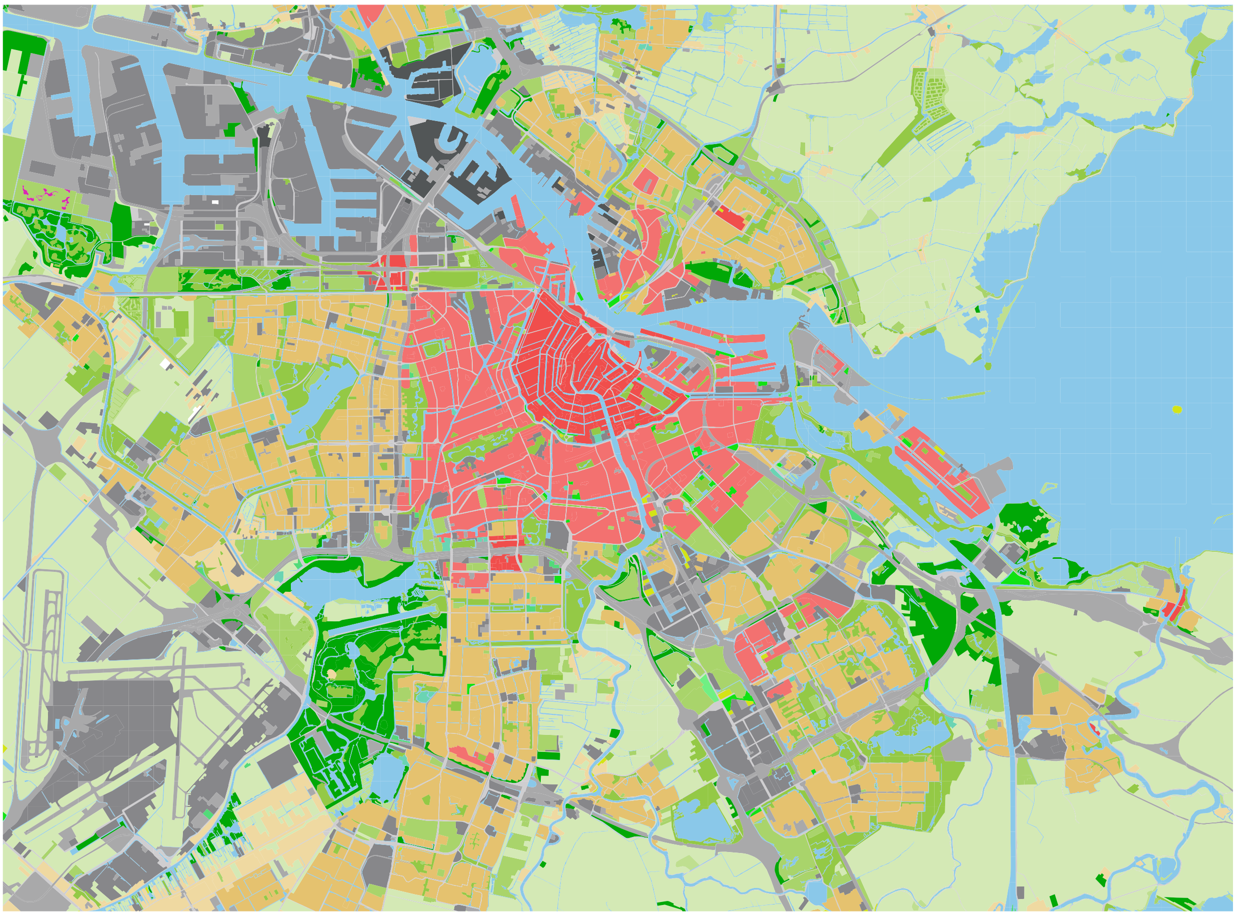
Source: Blue label. Retrieved on 13-09-2019 from https://bluelabel.net/

Blue label is a joint venture of Achmea, Royal Haskoning and Nelen & Schuurmans.

A5: Atmosphere layer

Climatope maps of Amsterdam

The map below shows the expected climatopes of Amsterdam, based on the typologies. These have been defined based on the book Climate in the city. (Lenzholzer, 2015)



2.5 0 2.5 5 7.5 10 km

- city centre climatope
- city climatope
- city periphery climatope
- garden city climatope
- industrial estate climatope
- commercial district climatope
- railway yard climatope
- water climatope
- forest climatope
- park climatope
- open landscape climatope

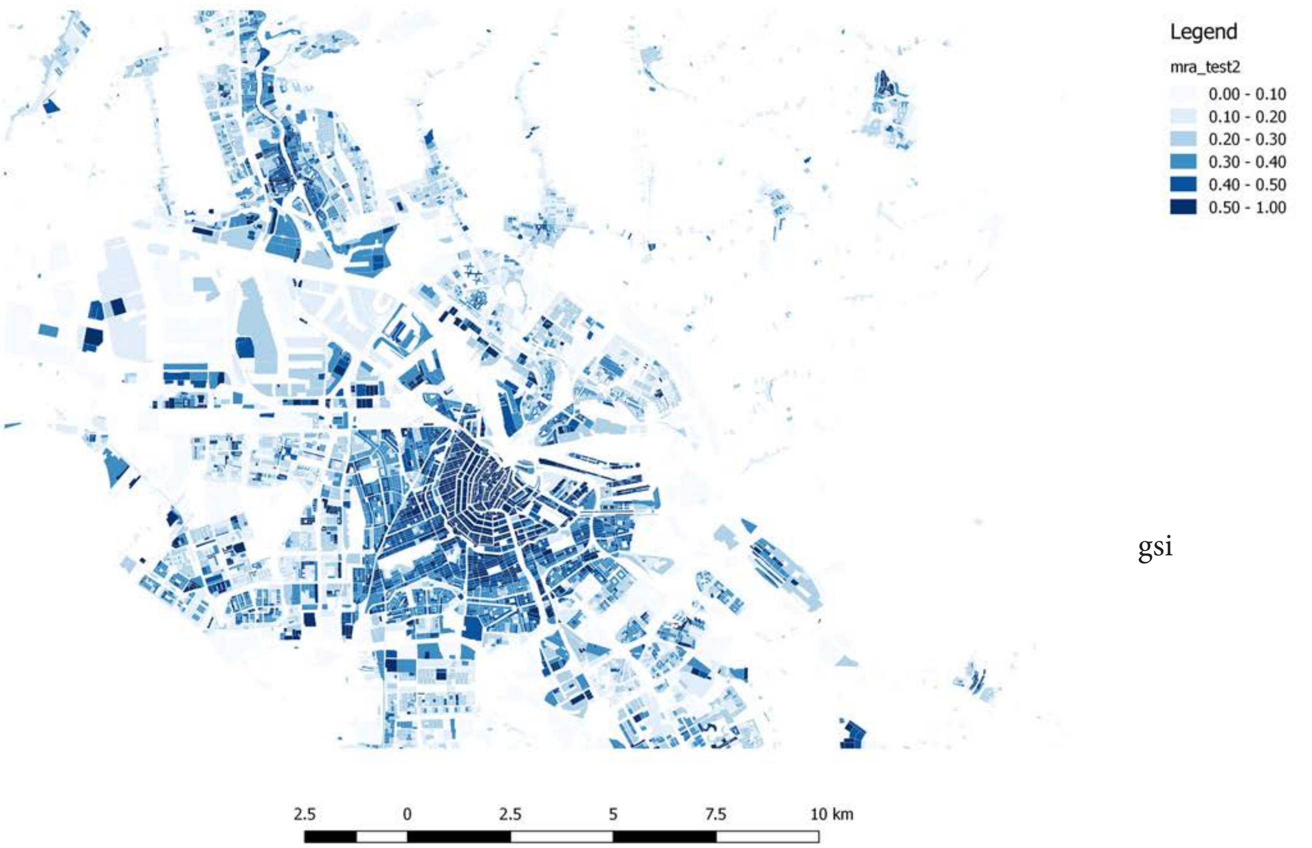
Sound

Sound

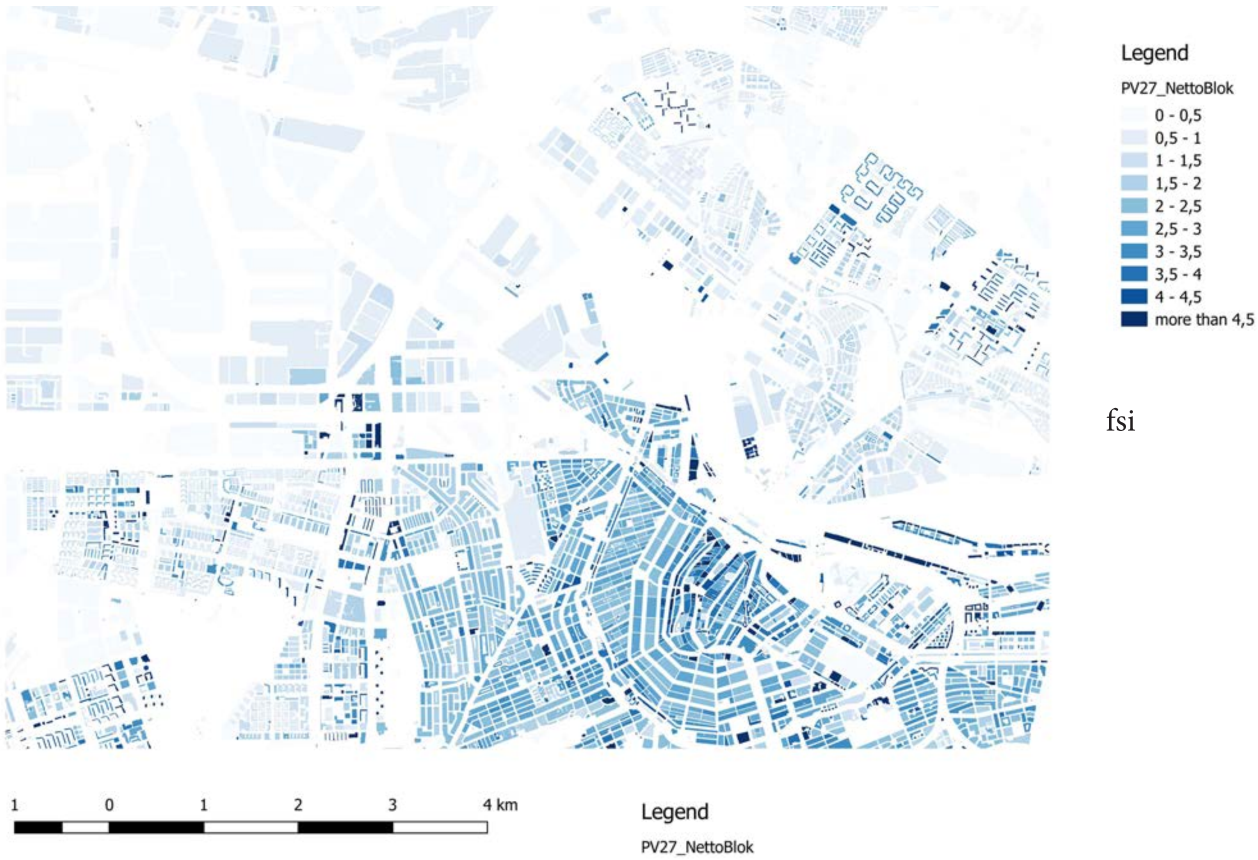
One of the main reasons for the convenant had to do with sound. As is visible below, the project area is exposed to a high amount of traffic sound from the railways, the main roads and the highway.

A6: Place syntax

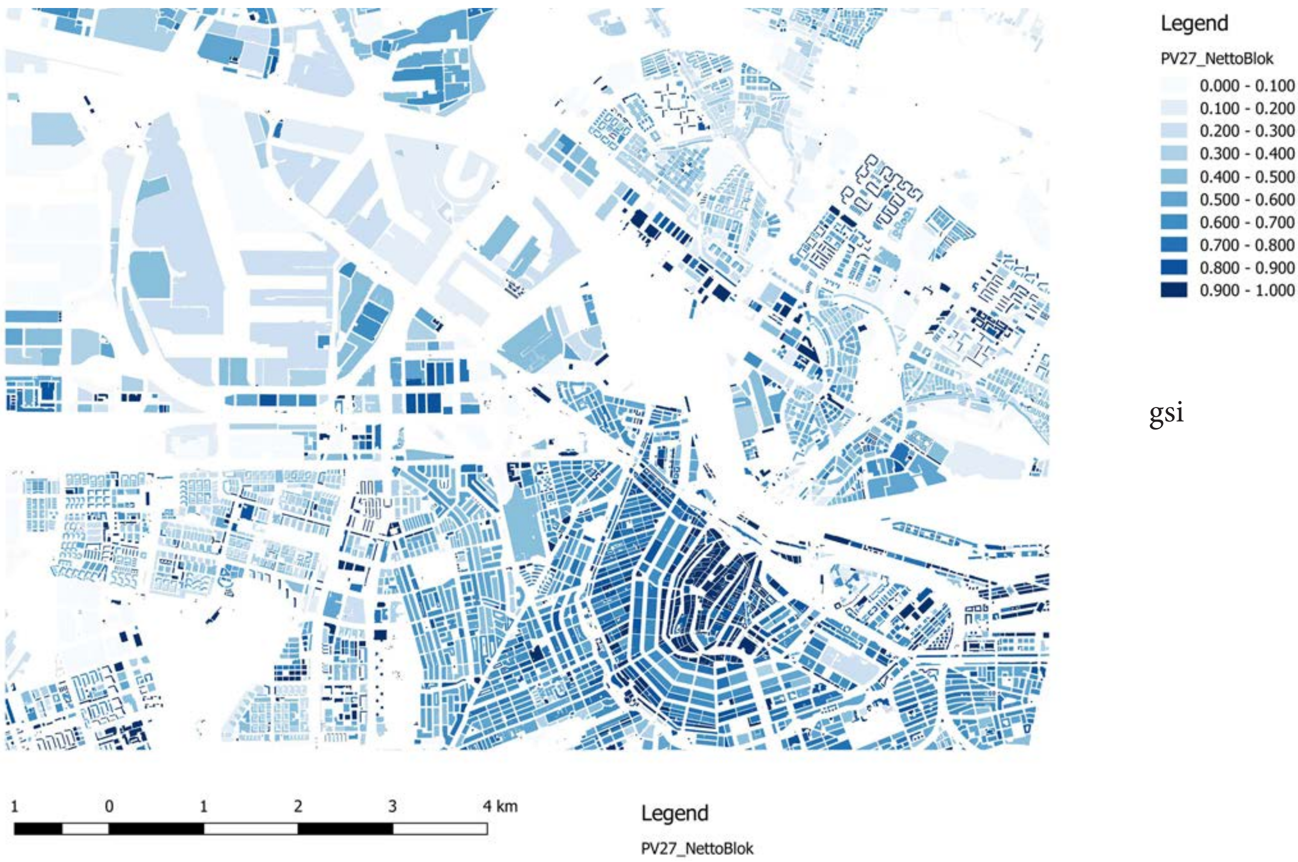
fsi



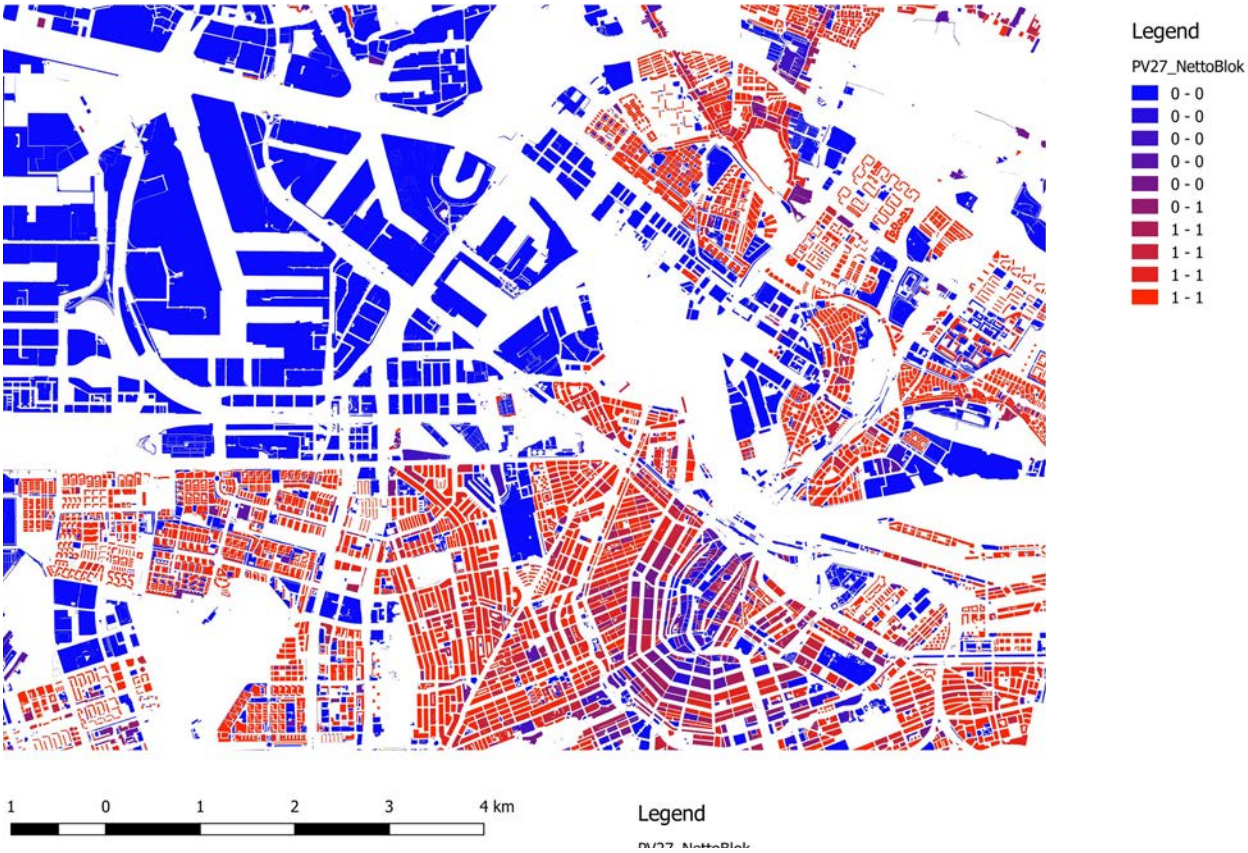
gsi


Legend
PV27_NettoBlok
0 - 0,5
0,5 - 1
1 - 1,5
1,5 - 2
2 - 2,5
2,5 - 3
3 - 3,5
3,5 - 4
4 - 4,5
more than 4,5
1
0
1
2
3
4 km
Legend
PV27_NettoBlok

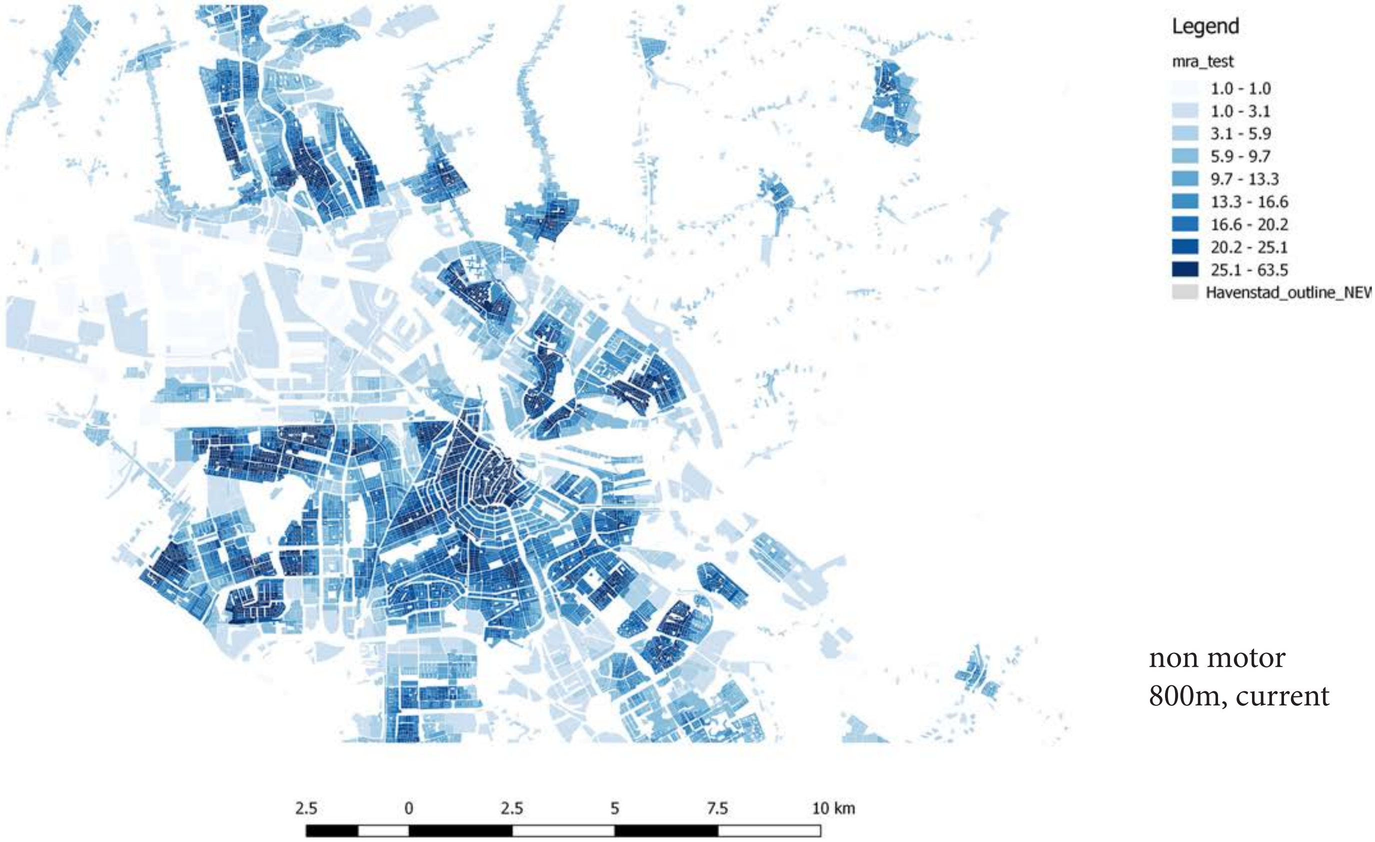
fsi


Legend
PV27_NettoBlok
0.000 - 0.100
0.100 - 0.200
0.200 - 0.300
0.300 - 0.400
0.400 - 0.500
0.500 - 0.600
0.600 - 0.700
0.700 - 0.800
0.800 - 0.900
0.900 - 1.000
1
0
1
2
3
4 km
Legend
PV27_NettoBlok

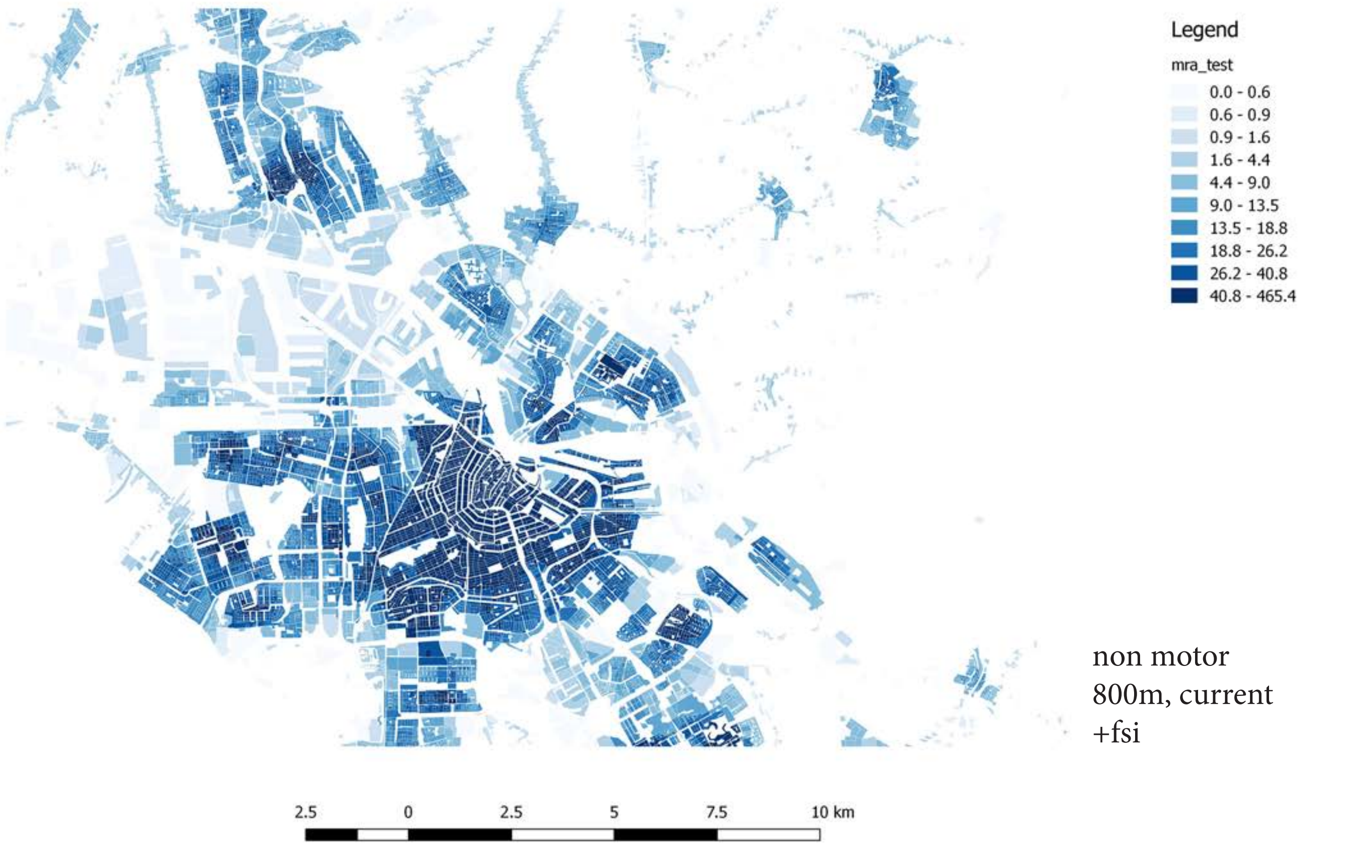
gsi



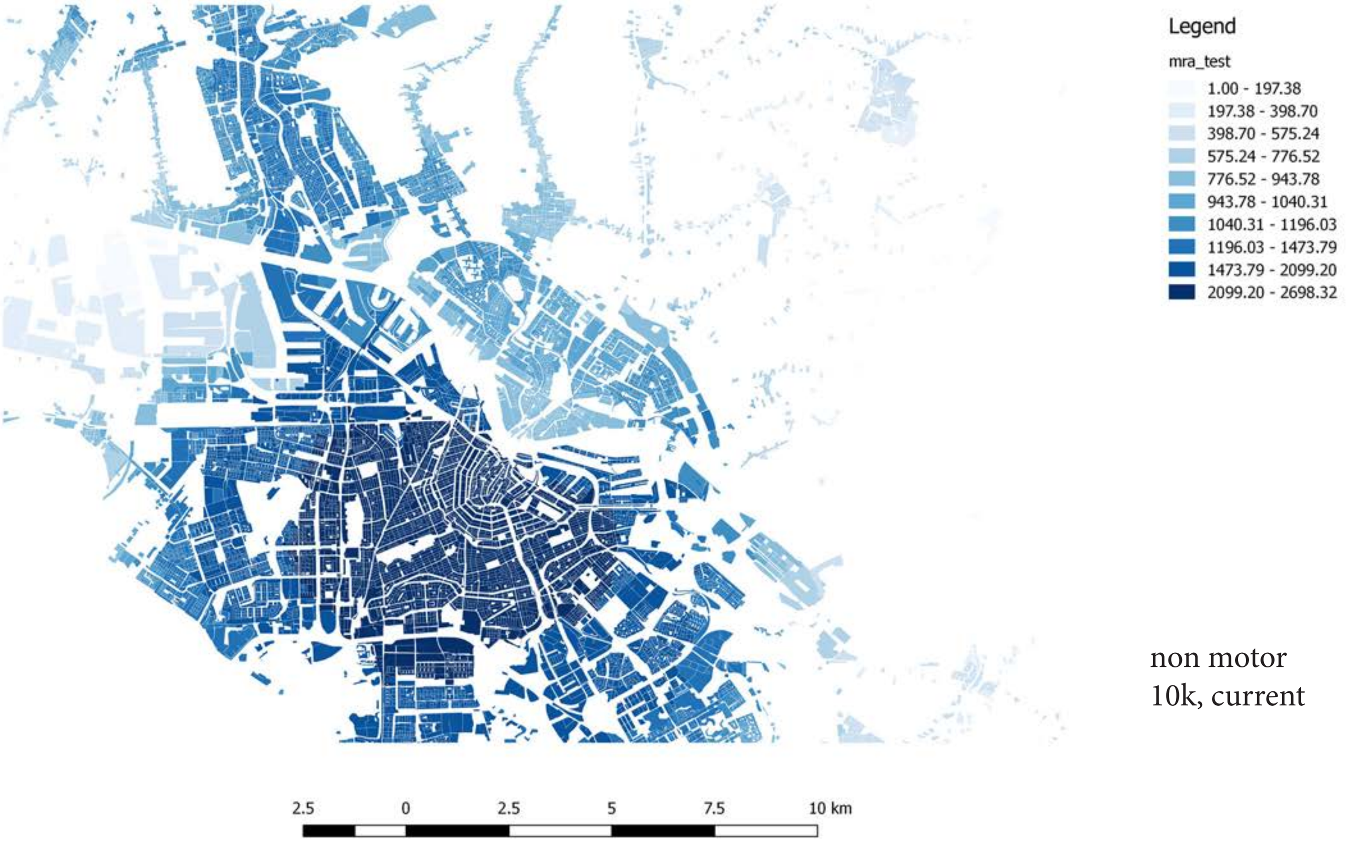
BAG, DDK, BGT en BRT (Kadaster); BBG en Wijk- en Buurtgrenzen (CBS); ruimtelijkeplannen.nl; ESRI; bewerking PBL



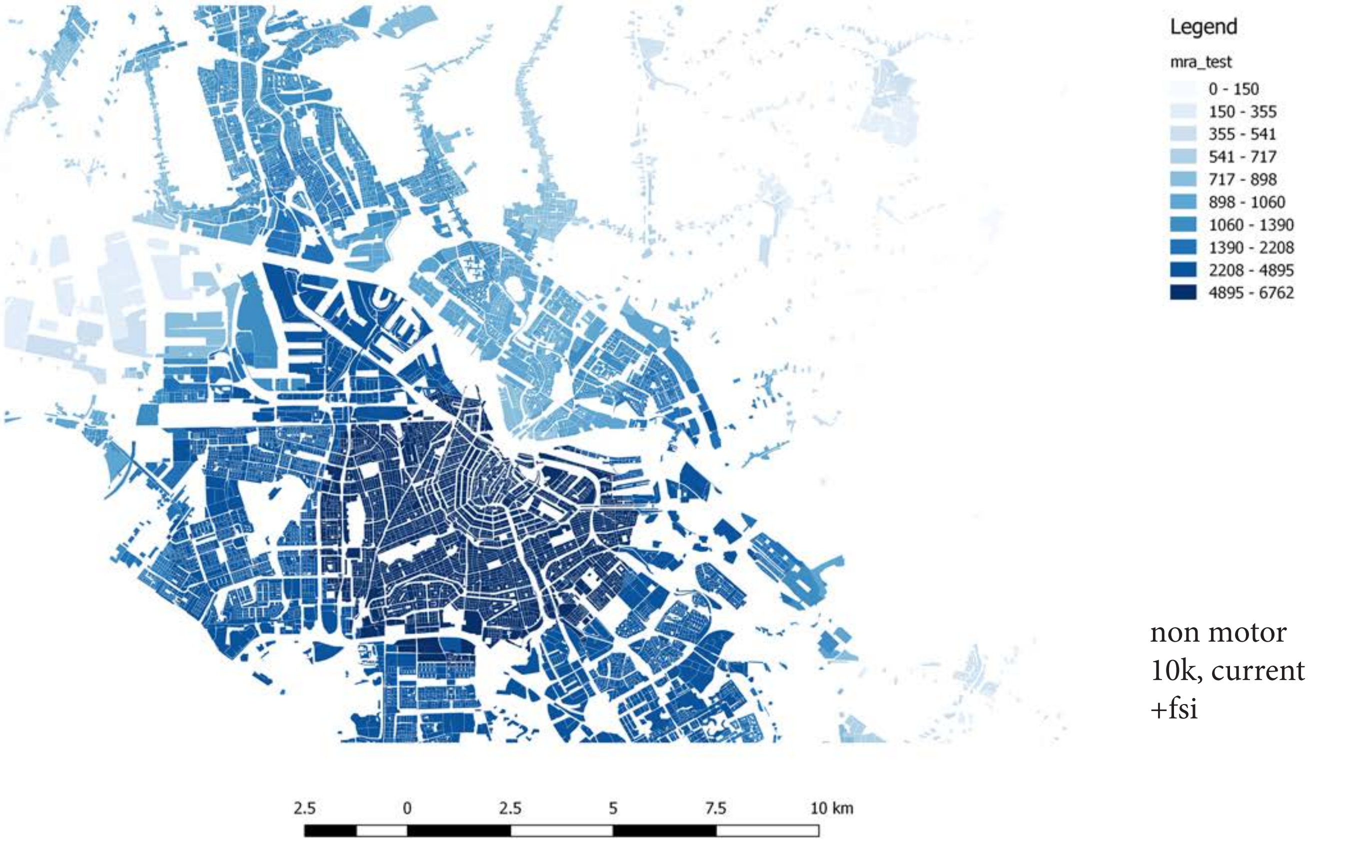
non motor
800m, current



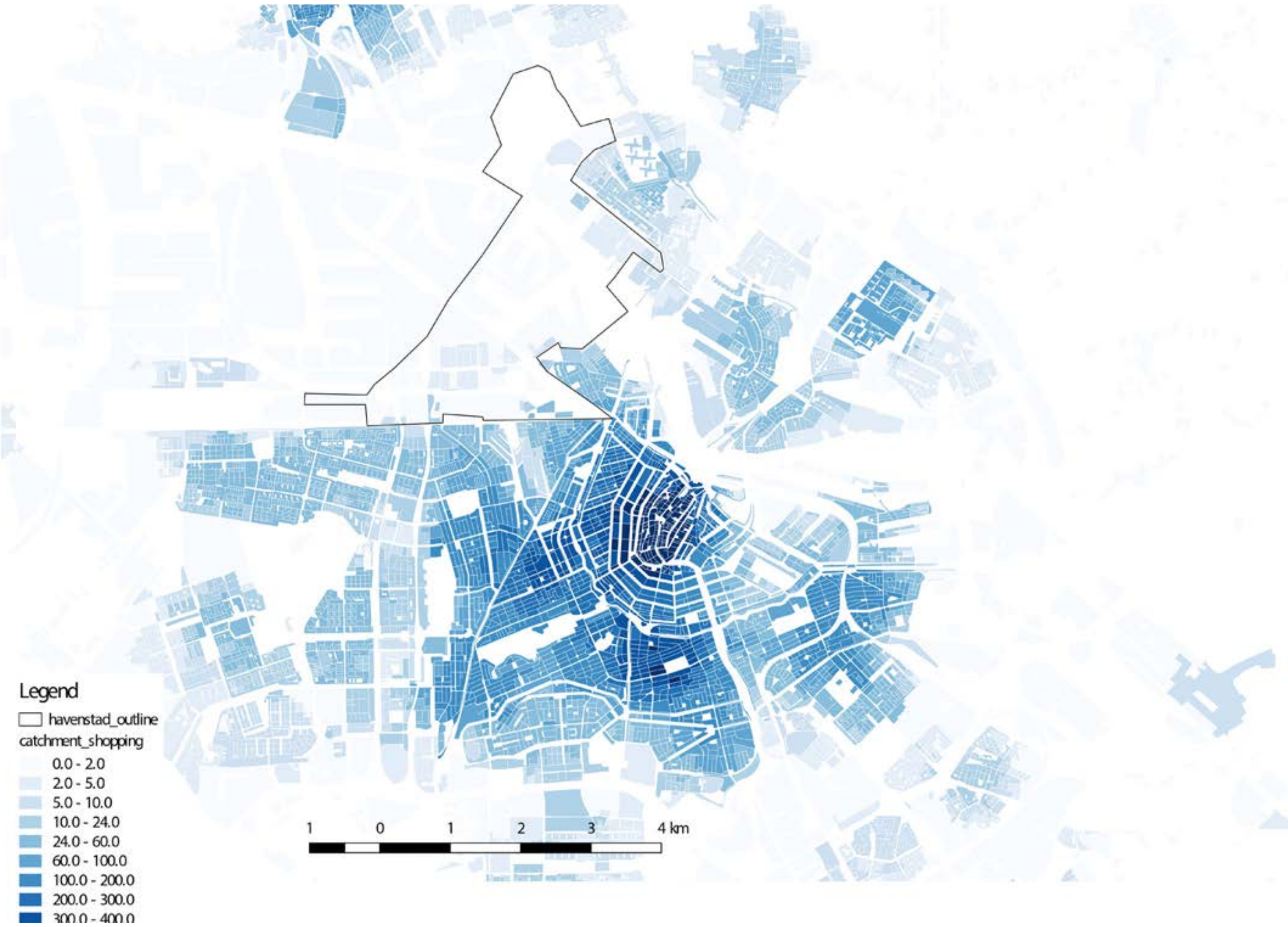
non motor
800m, current
+fsi



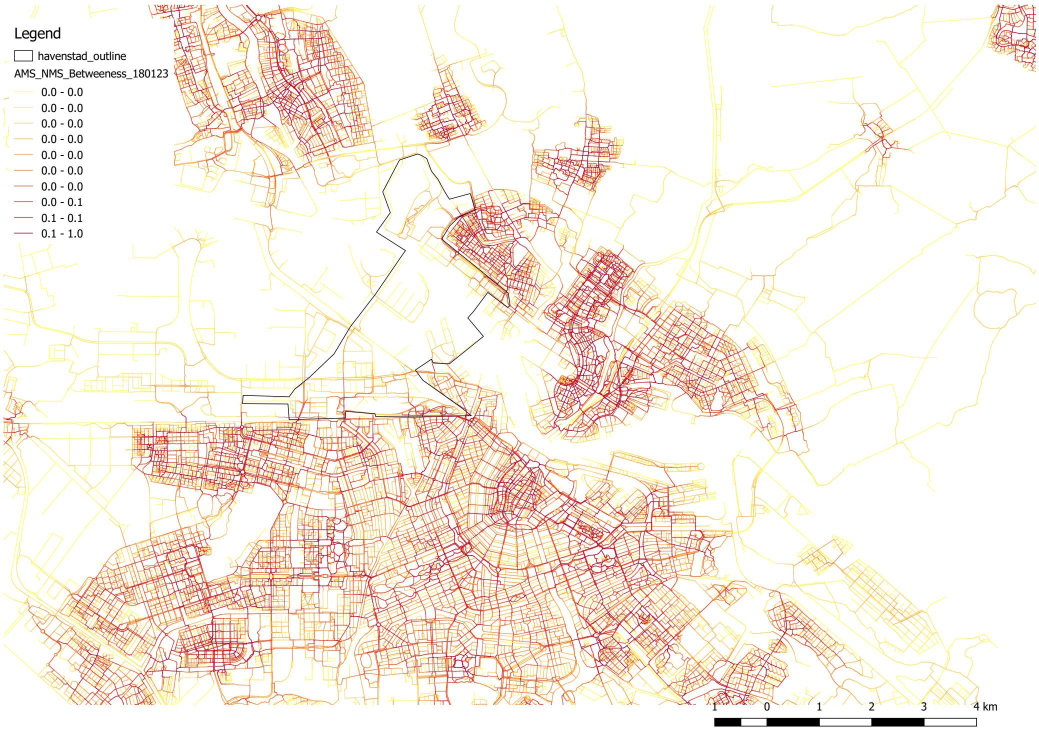
non motor
10k, current



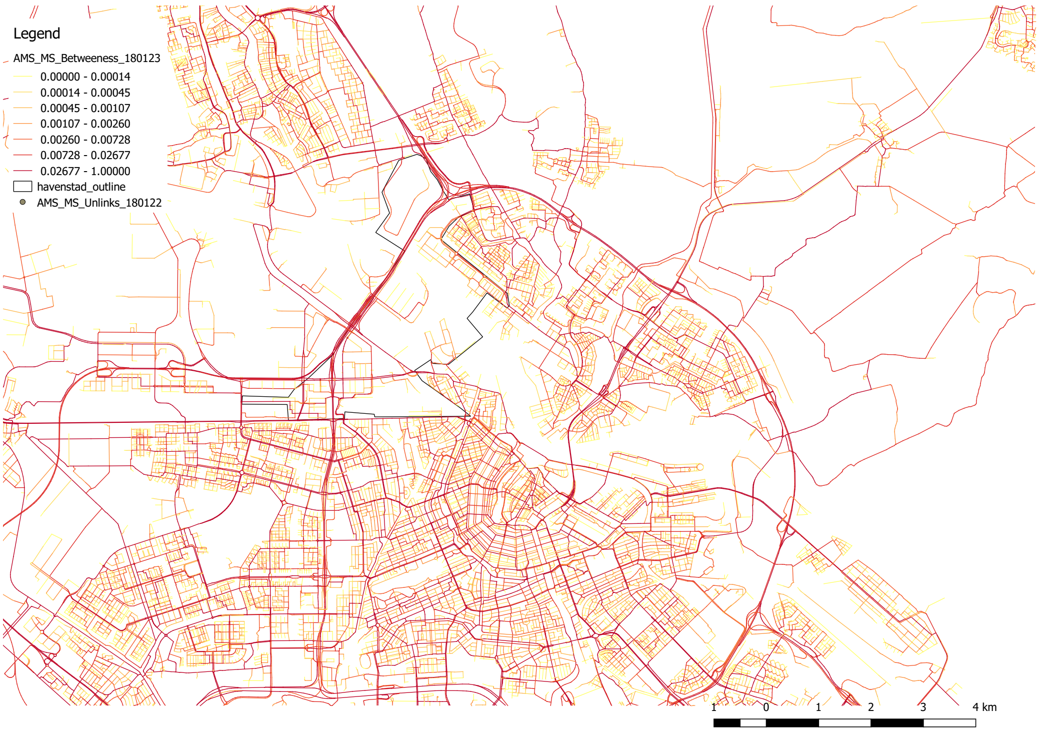
non motor
10k, current
+fsi


Legend
havenstad_outline
catchment_shopping
0.0 - 2.0
2.0 - 5.0
5.0 - 10.0
10.0 - 24.0
24.0 - 60.0
60.0 - 100.0
100.0 - 200.0
200.0 - 300.0
300.0 - 400.0
1
0
1
2
3
4 km

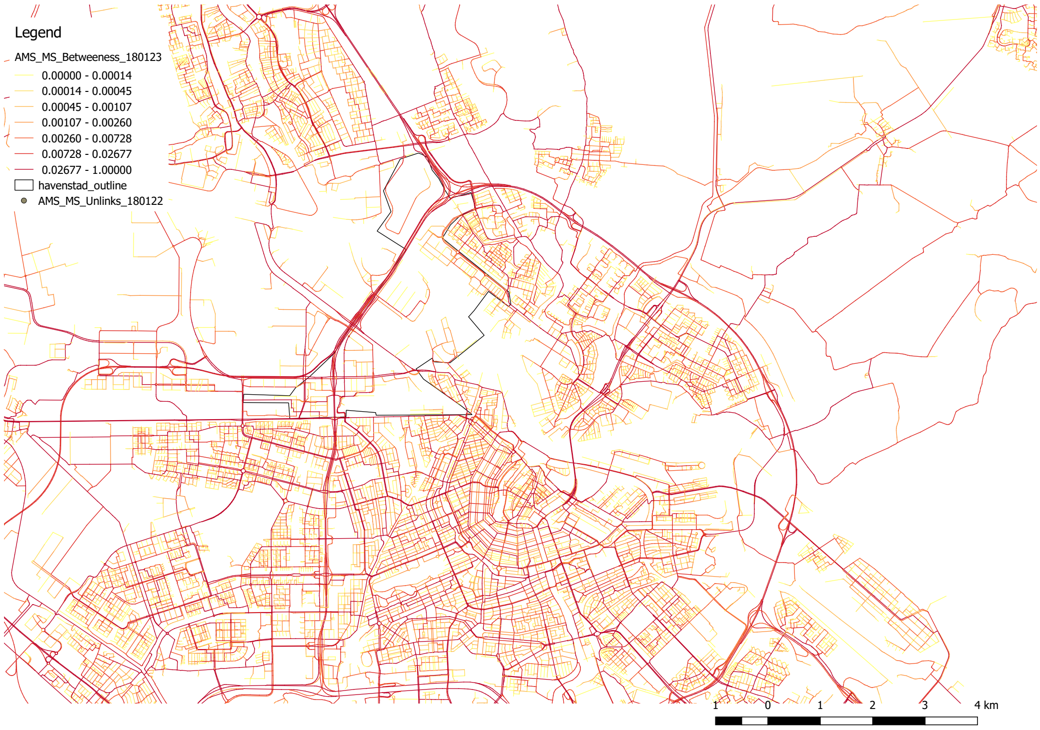
A7: Network betweenness



PLACEHOLDER section dike



PLACEHOLDER WATER MOBILITY



A8: Waterflow calculations

PLACEHOLDER blocks for water flow

BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m²**

explanation: is to make meters in the formula

is the amount of rainwater in m³ falling per hour

is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m²	x 30 mm water in 1 hour = m³ water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *	remarks:
UNPAVED									
private									
Garden open soil (private)		0	15	50	0.1 m3/m2	15	0	0	
public									
Surface water		0	0	0	0.5 m3/m2	0	0	0	* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives
Rain garden, infiltration field		0	25	75	0.1 m3/m2	60	0	0	
Lawn, green belt, shrub (public)		0	15	50	0.1 m3/m2	15	0	0	
Playground, footpath		0	5	5	0.1 m3/m2	5	0	0	
Vegetated swales		0	10	10	0.5 m3/m2	30	0	0	
PAVED									
private									
Roofs – sloping		0	1	0	0	0	0	0	
Roofs – flat, tar		0	5	0	0.05 m3/m2	10	0	0	
Green roofs – extensive		0	10	0	0.1 m3/m2	15	0	0	
Green roofs – intensive		0	25	0	0.2 m3/m2	15	0	0	
Garden tiled		0	3	8	0.05 m3/m2	5	0	0	Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?
public									
Roads, car parks – asphalt		0	1	0	0.05 m3/m2	5	0	0	
Roads, car parks – porous asphalt		0	1	40	0.05 m3/m2	5	0	0	
Roads, car parks – brick		0	3	10	0.05 m3/m2	5	0	0	
Roads, car parks – porous pavement		0	3	40	0.05 m3/m2	5	0	0	
Sidewalk, terraces –tiles		0	3	8	0.05 m3/m2	5	0	0	

total private area in m²	0	0	total of water
total public area in m²	0	0	total of water
Total area in m² and total m3 water	**0**	**0**	

sewer capacity:	20 mm per day		
	1,7 mm in 2 hours	0	m³ directly to sewer
mm of water going to the sewer in 2 hours:	############	0	m³ delayed to the sewer
		99	m³ to natural system
		0	= total amount of water m3 that enters your area
		0	= **total of surplus in m³**

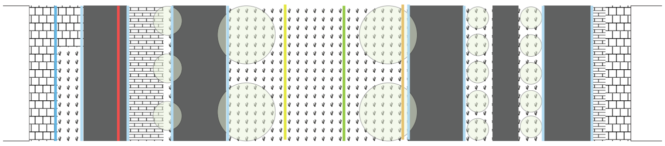
% open water: ############

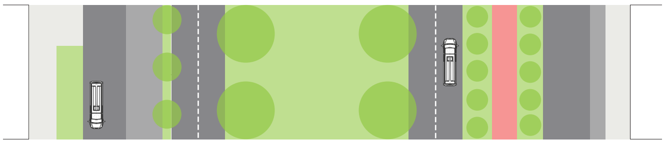
NB. when there is open water, you can store 0,5 m³ per m² open water; when there is not, you have to find another solution

PLACEHOLDER WATER EXCEL FOR BLOCK PERFORMANCE

Water Excel
(Van De Ven, Hooijmeijer, Aalbers,personal communication, 2018)

Transformatorweg current 30mm





BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m²**

explanation: is to make meters in the formula

is the amount of rainwater in m³ falling per hour

is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m²	x 30 mm water in 1 hour = m³ water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *	remarks:
UNPAVED									
private									
Garden open soil (private)	0	0	15	50	0.1 m3/m2	15	0	0	
public									
Surface water	0	0	0	0	0.5 m3/m2	0	0	0	* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives are
Rain garden, infiltration field	0	0	25	75	0.1 m3/m2	60	0	0	
Lawn, green belt, shrub (public)	618,5	18,555	15	50	0.1 m3/m2	15	-52,5725	0	
Playground, footpath	0	0	5	5	0.1 m3/m2	5	0	0	
Vegetated swales	0	0	10	10	0.5 m3/m2	30	0	0	
PAVED									
private									
Roofs – sloping	0	0	1	0	0	0	0	0	
Roofs – flat, tar	0	0	5	0	0.05 m3/m2	10	0	0	
Green roofs – extensive	0	0	10	0	0.1 m3/m2	15	0	0	
Green roofs – intensive	0	0	25	0	0.2 m3/m2	15	0	0	
Garden tiled	0	0	3	8	0.05 m3/m2	5	0	0	Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?
public									
Roads, car parks – asphalt	518,5	15,555	1	0	0.05 m3/m2	5	15,0365	15,0365	
Roads, car parks – porous asphalt	0	0	1	40	0.05 m3/m2	5	0	0	
Roads, car parks – brick	123,5	3,705	3	10	0.05 m3/m2	5	0,8645	0,8645	
Roads, car parks – porous pavement	0	0	3	40	0.05 m3/m2	5	0	0	
Sidewalk, terraces –tiles	176,5	5,295	3	8	0.05 m3/m2	5	1,9415	1,9415	

total private area in m²	0	0	total of water
total public area in m²	1437	43,11	total of water
Total area in m² and total m3 water	**1437**	**43,11**	

sewer capacity: 20 mm per day

1,7 mm in 2 hours

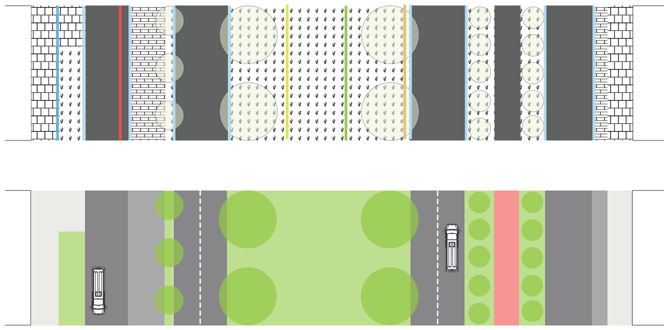
mm of water going to the sewer in 2 hours: **21,7990226**

17,8425	m³ directly to sewer
0	m³ delayed to the sewer
99	m³ to natural system
-34,73	= total amount of water m3 that enters your area
17,8425	= **total of surplus in m³**

% open water: **0**

NB. when there is open water, you can store 0,5 m³ per m² open water; when there is not, you have to find another solution

Transformatorweg current 60mm



BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,03 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m^2**

explanation:
- 0,001 is to make meters in the formula
- 0,03 is the amount of rainwater in m^3 falling per hour
- 2 is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss
Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m^2	x 30 mm water in 1 hour = m^3 water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *
UNPAVED								
private								
Garden open soil (private)	0	0	15	50	0.1 m3/m2	15	0	0
public								
Surface water	0	0	0	0	0.5 m3/m2	0	0	0
Rain garden, infiltration field	0	0	25	75	0.1 m3/m2	60	0	0
Lawn, green belt, shrub (public)	618,5	37,11	15	50	0.1 m3/m2	15	-34,0175	0
Playground, footpath	0	0	5	5	0.1 m3/m2	5	0	0
Vegetated swales	0	0	10	10	0.5 m3/m2	30	0	0
PAVED								
private								
Roofs – sloping	0	0	1	0	0	0	0	0
Roofs – flat, tar	0	0	5	0	0.05 m3/m2	10	0	0
Green roofs – extensive	0	0	10	0	0.1 m3/m2	15	0	0
Green roofs – intensive	0	0	25	0	0.2 m3/m2	15	0	0
Garden tiled	0	0	3	8	0.05 m3/m2	5	0	0
public								
Roads, car parks – asphalt	518,5	15,555	1	0	0.05 m3/m2	5	30,5915	30,5915
Roads, car parks – porous asphalt	0	0	1	40	0.05 m3/m2	5	0	0
Roads, car parks – brick	123,5	3,705	3	10	0.05 m3/m2	5	4,5695	4,5695
Roads, car parks – porous pavement	0	0	3	40	0.05 m3/m2	5	0	0
Sidewalk, terraces –tiles	176,5	5,295	3	8	0.05 m3/m2	5	7,2365	7,2365
total private area in m^2	0	0	total of water					
total public area in m^2	1437	43,11	total of water					
Total area in m^2 and total m3 water	**1437**	**61,665**						

remarks:

* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives are

Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?

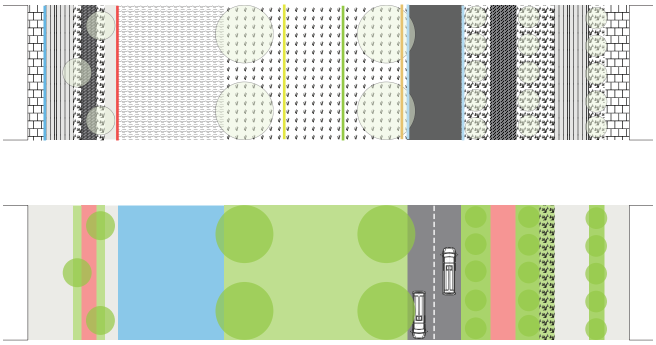
sewer capacity: 20 mm per day
1,7 mm in 2 hours
mm of water going to the sewer in 2 hours: **51,7990226**

42,3975	m^3 directly to sewer
0	m^3 delayed to the sewer
99	m^3 to natural system
8,38	= total amount of water m3 that enters your area
42,3975	= **total of surplus in m^3**

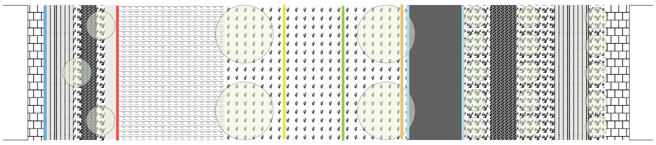
% open water: **0**

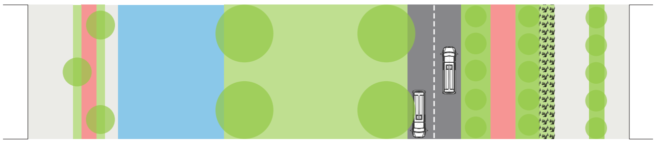
NB. when there is open water, you can store 0,5 m^3 per m^2 open water; when there is not, you have to find another solution

Transformatorweg design 30mm



Transformatorweg design 60mm





BK3TE4 ST water flow calculation sheet

version 021018

formula: **surplus (or shortage) of water = (0,06 - (depression storage * 0,001) - (2 * infiltration loss * 0,001)) * surface m²**

explanation: 0,001 is to make meters in the formula

0,06 is the amount of rainwater in m³ falling per hour

2 is per hour so needs to be doubled to show 2 hours

NB. Calculation is suitable for a flat urban area, with sandy topsoil

NB. Column specific storage is the base for setting depression loss and infiltration loss

Colum for Delay is the time it takes to discharge, only when it is over 30 mins it can be taken ito account.

Land cover type:	Your area surface in m²	x 60 mm water in 1 hour = m³ water	Depression storage [mm]	Infiltration loss [mm/h]	Specific storage capacity	Delay [min]	Your area water coming in	Your area without 'negatives' *
UNPAVED								
private								
Garden open soil (private)	0	0	15	50	0.1 m3/m2	15	0	0
public								
Surface water	249,2	14,952	0	0	0.5 m3/m2	0	14,952	14,952
Rain garden, infiltration field	250,01	15,0006	25	75	0.1 m3/m2	60	-28,75115	0
Lawn, green belt, shrub (public)	432	25,92	15	50	0.1 m3/m2	15	-23,76	0
Playground, footpath	0	0	5	5	0.1 m3/m2	5	0	0
Vegetated swales	35,6	2,136	10	10	0.5 m3/m2	30	1,068	1,068
PAVED								
private								
Roofs – sloping	0	0	1	0	0	0	0	0
Roofs – flat, tar	0	0	5	0	0.05 m3/m2	10	0	0
Green roofs – extensive	0	0	10	0	0.1 m3/m2	15	0	0
Green roofs – intensive	0	0	25	0	0.2 m3/m2	15	0	0
Garden tiled	0	0	3	8	0.05 m3/m2	5	0	0
public								
Roads, car parks – asphalt	127,5	7,65	1	0	0.05 m3/m2	5	7,5225	7,5225
Roads, car parks – porous asphalt	96,83	5,8098	1	40	0.05 m3/m2	5	-2,03343	0
Roads, car parks – brick	0	0	3	10	0.05 m3/m2	5	0	0
Roads, car parks – porous pavement	150,8	9,048	3	40	0.05 m3/m2	5	-3,4684	0
Sidewalk, terraces –tiles	95,94	5,7564	3	8	0.05 m3/m2	5	3,93354	3,93354
total private area in m²	0	0	total of water					
total public area in m²	1437,88	86,2728	total of water					
Total area in m² and total m3 water	**1437,88**	**86,2728**						

remarks:

* when the formula result is negative (column H), it changes to 0 (column I). To calculate the actual surplussurface water is always 0 for this calculation (column I), because there is no runoff. But it does add to the larger water unit. So to be able to relate this in %, you need to know how much. Therefore in column H the negatives are

Does it concern the front or the back garden? Does the rainwater run off to the sewer system or not?

sewer capacity: 20 mm per day

1,7 mm in 2 hours

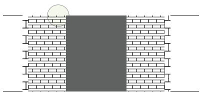
mm of water going to the sewer in 2 hours: **51,27121375**

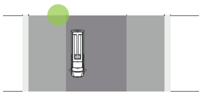
11,45604	m³ directly to sewer
0	m³ delayed to the sewer
99	m³ to natural system
-30,53694	= total amount of water m3 that enters your area
12,52404	= **total of surplus in m³**

% open water: **17,33107074**

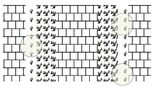
NB. when there is open water, you can store 0,5 m³ per m² open water; when there is not, you have to find another solution

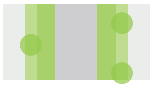
Elementenstraat current 30mm





Elementenstraat current 60mm





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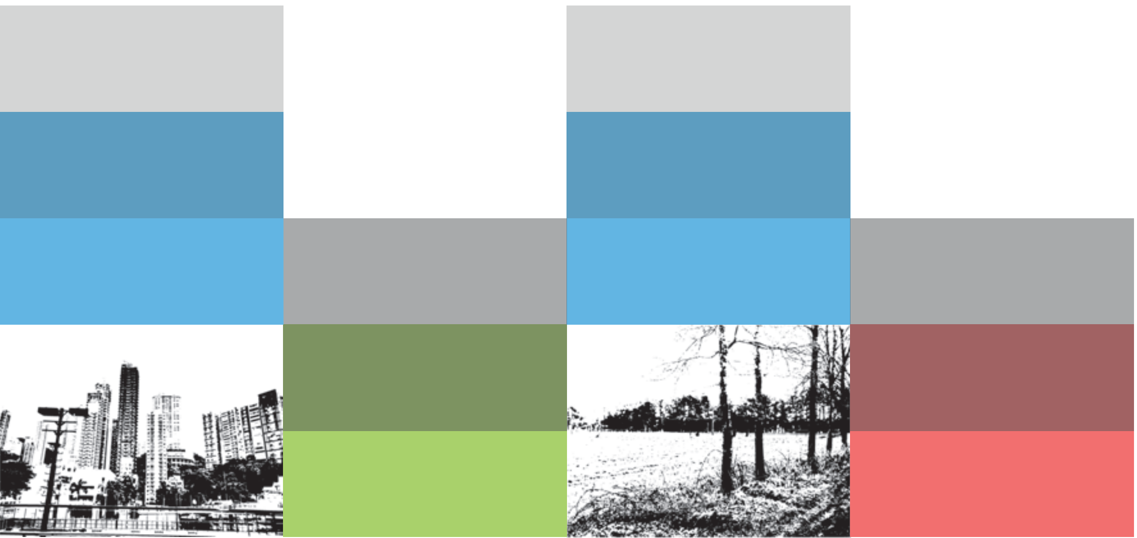

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