MSc Thesis Civil Engineering
Kaj Kreijen
November 2023

Creating space for climate adaptation through shifting to green mobility

From Cars to Climate Resilience

TU Delft Delft University of Technology | ambient

Creating space for climate adaptation through shifting to green mobility

By

Kaj Johanna Franciscus Kreijen

4588185

in partial fulfilment of the requirements for the degree of

Master of Science
In Civil Engineering – Water Management

at the Delft University of Technology,
to be defended publicly on November 17th 2023.

Supervisors:

Dr. Ir. Jeroen Langeveld	TU Delft
Dr. Erik Mostert	TU Delft
Dr. Ir. Eva Nieuwenhuis	Ambient B.V.
Ir. Ekaterina Andrusenko	TU Delft

An electronic version of this thesis is available at http://repository.tudelft.nl/

Preface

Before you lies the report of my master's thesis, entitled: "Creating space for climate adaptation through shifting to green mobility". The research was conducted from April to November 2023 as part of the master program Water Management at the Delft University of Technology, faculty of Civil Engineering. This study was carried out in collaboration with Ambient B.V., through a graduation internship. They introduced me to this incredibly interesting and relevant topic. While writing the thesis, I learnt a ton about mobility and urban water management policy and how to perform a sometimes not so straightforward research.

For the past seven months, I have had a lot of help from my supervisors, colleagues at Ambient, experts in the mobility, urban planning and water sector whom I have had the privilege of interviewing, and many others. I would like to express my gratitude to all of you. In particular, I would first of all like to thank my supervisors. Eva, for supporting me throughout the whole process, always providing very useful feedback, giving greatly appreciated input and being very understanding. I am greatly impressed by how you always managed to make time, despite having quite a busy schedule, at a time when you also managed to complete your PhD. Jeroen, for always giving concise and practical feedback, trusting me to bring this research to a successful end and reminding me of how much fun the subject is. Erik, for joining the committee for the last few months and giving your perspective on the research. Martine, for being my second supervisor during the first part of the thesis and helping to narrow down the research topic. Ekaterina, for your great advice, help with the cross sections and our interesting discussions.

I would like to express my gratitude to my colleagues at Ambient for always being so welcoming and helpful. To everyone I got to interview, this was one of the most enjoyable parts of the research. The engaging conversations I had were a tremendous contribution to my thesis. And to Steven Puylaert for providing valuable insights and a critical perspective on my research from a mobility perspective.

Finally, I want to thank my parents, brother and grandparents, and especially Oma Mielie, thank you for inspiring me and reminding me of what is really important. Lastly I would like to thank my friends and roommates and, of course, Mona for always being there regardless of the distance. I look forward to the adventure that lies ahead of us.

Kaj Kreijen
Rotterdam, November 2023

Summary

Climate change increases the urgency of spatial adaptation to extreme heat, pluvial floods and droughts in urban areas. To accelerate climate adaptation efforts, Dutch government organisations have agreed to work towards a climate adaptive and water resilient country by 2050 in the Delta Plan on Spatial Adaptation (DPSA). The implementation of Blue Green Infrastructures (BGI) in urban areas offers a solution to achieve climate adaptivity and water resilience by restoring the natural water balance, storing and infiltrating rainwater and having a cooling effect on their surroundings. In parallel with the ambition to adapt to the effects of climate change, there is a noticeable shift in transport modes in Dutch urban areas. Municipalities are actively promoting sustainable and healthy means of transport, such as walking and cycling, while reducing car dependency, through steering policies and active urban planning.

This research examines the potential for climate adaptation, resulting from the transition to green mobility, in urban areas in the Netherlands. Various research methods as part of a desk study and an exploratory multiple case-study, are applied to answer the main research question:

*''**What** is the potential impact of the transition to **green mobility** on the implementation of **Blue-Green Infrastructure (BGI)** in urban areas in the Netherlands?''*

The desk study includes a literature review on the impacts of climate change in urban areas, various forms of BGIs, and the green mobility transition. It also describes the Dutch context of climate adaptation and the mobility transition, through a review of relevant policy documents.
Subsequently, an exploratory case-study was conducted, examining six cases at three spatial scales (City, Neighbourhood and Street scale). The case study provided insights into the spatial relation between the mobility transition and climate adaptation. For each case data was gathered through a review of relevant policy documents and an interview survey. The effect of different mobility scenarios was assessed through spatial design and GIS analyses. In addition, seven semi-structured interviews were held with water, mobility and climate adaptation experts from municipalities considered in the case-study. The interviews revealed different perspectives on the relation between mobility and climate adaptation, and identified several challenges for effective climate adaptation. The study findings can be summarised in the following three main aspects.

Increase in green space (spatial relation) - City scale cases demonstrated the potential to increase green space in different mobility scenarios compared to the current state. This was especially apparent in highly urbanised areas with a strong need for climate adaptation. Multiple design scenarios with different mobility measures, such as parking space removal and driving lane reduction, were analysed to study this spatial relation. The study results suggest that the conversion of road area might be a more effective tool to meet climate adaptation goals at a city level than the reduction of parking spaces.

Climate adaptation potential - Detailed cases at a neighbourhood and street scale showed that reallocated urban area can provide the space needed for BGI (e.g. rain gardens, permeable pavement). In this way, climate adaptation goals related to heat and pluvial flooding can be met. The results also suggest that the implementation of rain gardens or other drainage facilities, in addition to traditional greenery and permeable pavement, is necessary and effective to provide sufficient water storage capacity. However, detailed case-by-case assessments are required to determine how policy objectives can be met.

Challenges - The interview survey and case-study revealed several barriers to the successful implementation of BGI and to harnessing the potential of the green mobility transition. Often mentioned challenges included *a lack of uniform policy goals, a lack of urgency*, *concerns about funding and maintenance of BGI, resistance to parking reductions,* and *insufficient collaboration between municipal departments*.

The study recommends future research to consider economic implications, and other urban transitions (e.g. energy transition and housing challenge). In addition, it may be useful to explore more case studies and conduct interviews with a more diverse group of stakeholders. Policy recommendations include defining clear climate adaptation and mobility goals, improving collaboration between municipal departments, 'mainstreaming' climate adaptation into mobility policies and conducting case-specific assessment on meeting policy goals.

In summary, this preliminary study emphasizes the potential of the green mobility transition to enhance urban climate adaptation and water resilience in the Netherlands. Cities can improve their liveability and become more climate adaptive by adopting an integrated approach that reallocates urban area for cars to space for active forms of mobility and BGI. This can contribute to well informed urban planning and policy decisions.

Samenvatting voor beleidsmakers (Dutch)

Nederlandse steden worden geconfronteerd met complexe transitieopgaven, zoals duurzame mobiliteit en klimaatadaptatie. Deze masterscriptie onderzoekt hoe de mobiliteitstransitie ruimte zou kunnen maken voor klimaatadaptatie.
De onderzoeksmethodiek bestaat uit twee delen: een bureaustudie en een verkennende studie van meerdere casussen. De bureaustudie bestaat uit een verkenning van relevante wetenschappelijke literatuur over klimaatadaptatie, verschillende groenblauwe maatregelen (Engels: Blue Green Infrastructure - BGI) en de 'groene' mobiliteitstransitie. Daarnaast zijn belangrijke beleidsdocumenten geanalyseerd, om de Nederlandse context in kaart te brengen. De bureaustudie leverde de volgende constateringen op:

- Gevolgen van klimaatverandering: Stedelijke gebieden in Nederland krijgen meer te maken met de gevolgen van klimaatverandering zoals; extreme hitte, wateroverlast en droogte, om de effecten hiervan te beperken zijn klimaat adaptieve maatregelen noodzakelijk.
- Nederlandse adaptatie strategie: Nederlandse overheidsorganisaties streven naar een klimaatbestendige en waterrobuuste inrichting voor 2050, zoals afgesproken in het Deltaplan Ruimtelijke Adaptatie (DPRA). Een van de zeven ambities van het DPRA is het benutten van meekoppelkansen met andere acties of doelen.
- Groenblauwe ingrepen voor klimaatadaptatie: Groenblauwe maatregelen zoals regentuinen en water passerende verhardingen zijn effectieve middelen om de gevolgen van klimaatadaptatie in de stad te beperken.
- Groene mobiliteitstransitie: (Hoog)stedelijke mobiliteit verandert, duurzame en gezonde vervoerswijzen, zoals lopen, fietsen en het OV, krijgen prioriteit. In gemeentelijke mobiliteitsplannen is een verschuiving te zien weg van een auto gerichte aanpak, bijvoorbeeld met autoluw beleid[1]. Hierdoor blijft er mogelijk ruimte over voor andere stedelijke functies zoals groen en klimaatadaptatie.

De verkennende studie van meerdere casussen is uitgevoerd op drie ruimtelijke schalen (stad-, buurt- en straatniveau) en bestaat uit een analyse van relevante gemeentelijke beleids-documenten, interviews en een ontwerp-scenario-analyse. Dit heeft geleid tot de volgende inzichten in de relatie tussen de mobiliteitstransitie en klimaatadaptatie:

- Toename van groen in de stad: De casussen op stadsniveau laten de potentie voor een toename van groen zien, met name in hoog stedelijk gebied waar klimaat-adaptatie hard nodig is. Extra groen kan worden gerealiseerd door ruimte die nu is gereserveerd voor auto's (parkeerplaatsen en wegen) anders te gaan gebruiken. De onderzoeks-bevindingen suggereren dat het aanpassen van wegen de grootste ruimtelijke verandering teweeg kan brengen op stadsniveau.
- Potentieel voor klimaatadaptatie: Verkennende ontwerpstudies op buurt en straat niveau laten zien dat, als deze ruimte gebruikt wordt voor klimaat adaptieve oplossingen, hitte, wateroverlast en droogte kunnen worden gereduceerd en adaptatie doelstellingen kunnen worden gehaald. De resultaten suggereren dat de aanleg van

[1] Bron: https://www.kimnet.nl/actueel/nieuws/2023/09/26/veel-gemeenten-zetten-in-op-autoluwe-stad

regentuinen of andere voorzieningen nodig en effectief is om te zorgen voor voldoende wateropslagcapaciteit. Er zijn echter gedetailleerde beoordelingen per situatie nodig om te bepalen hoe beleidsdoelen kunnen worden behaald.

- Uitdagingen: Het benutten van het potentieel dat de groene mobiliteitstransitie biedt voor klimaatadaptatie brengt uitdagingen met zich mee. Gevonden barrières zijn onder meer; inconsistente beleidsdoelen, zorgen over financiering en onderhoud van klimaat adaptieve maatregelen, weestand bij het opheffen van parkeerplaatsen en onvoldoende samenwerking tussen gemeentelijke afdelingen.

Naar aanleiding van de door deze studie inzichten verkregen zijn enkele beleidsaanbevelingen opgesteld om het potentieel van de groene mobiliteitstransitie voor klimaatadaptatie te benutten:

- Definieer duidelijke en uniforme klimaatadaptatiedoelen op nationaal als op lokaal niveau. Hiermee kan worden voorkomen dat groen uiteindelijk verloren gaat aan infrastructuur voor de auto. Dit heeft onder andere te maken met standaard auto georiënteerd beleid en het ontbreken van strikte normen voor klimaatadaptatie. Denk bij nieuwe klimaatadaptatiedoelen aan een landelijke groennorm of richtlijnen voor de realisatie van een minimale hoeveelheid waterberging in de openbare ruimte.
- Bevorder actieve en gezonde mobiliteit en verminder de ruimte voor gemotoriseerd verkeer (parkeerplaatsen en wegen). Maak duurzaam mobiliteitsbeleid gericht op het bevorderen van gezondheid, leefbaarheid en veiligheid naast het reduceren van emissies. Zorg voor goede alternatieven voor de eigen auto, zoals deelvervoer, (H)OV en fietsverbindingen. Met deze aanpak kan schaarse ruimte worden vrijgemaakt voor klimaatadaptatie. Hanteer bijvoorbeeld het STOMP-ontwerpprincipe[2].
- Werk aan een integrale aanpak en bevorder de samenwerking tussen gemeentelijke afdelingen verantwoordelijk voor mobiliteit, stedenbouw en klimaatadaptatie. Benut meekoppelkansen en maak klimaatadaptatie een integraal onderdeel van het mobiliteitsbeleid. Maak daarnaast gebruik van verschillende financieringsbronnen en fondsen voor infrastructurele projecten die zowel duurzame mobiliteit als klimaatadaptatie bevorderen.
- Voer voor elk stedenbouwkundig ontwerp een toets uit op overeenstemming met de omgevingsvisie en beleidsdoelen. Deze toets is nodig omdat beleidsdoelen per gemeente verschillen en fysieke omstandigheden variëren.
- Betrek bewoners bij de mobiliteitstransitie en enthousiasmeer mensen voor het toevoegen van groen en klimaatadaptatie maatregelen. Verlagen van de maximale snelheid of opheffen van parkeerplaatsen stuit soms op weerstand. Laat daarom de voordelen van meer groen in de straat zien, bijvoorbeeld door tijdelijk bomen in bakken te plaatsen op parkeerplaatsen.

Dit verkennende onderzoek laat het potentieel van de groene mobiliteitstransitie voor een klimaat adaptieve en waterrobuuste inrichting van Nederlandse steden zien. De verkregen inzichten en aanbevelingen dragen bij aan het nemen van weloverwogen beslissingen op het gebied van mobiliteit, klimaatadaptatie en stedenbouw.

---

[2] Bron: https://www.crow.nl/kennis/bibliotheek-verkeer-en-vervoer/kennisdocumenten/toepassen-stomp-ontwerpen-met-de-menselijke-maat

Contents

List of figures

List of tables

Nomenclature

Glossary

Accessibility	The degree to which individuals can easily reach and use essential services, regardless of their physical abilities or circumstances.
Climate adaptation	Strategic planning and implementation of measures and policies aimed at reducing the impacts of climate change, such as extreme weather events and rising temperatures
Climate adaptation measures	Plans and actions, including physical solutions like permeable pavements and rain gardens that mitigate the impacts of climate change
Green mobility transition	Transition towards active and healthy forms of mobility (e.g. walking, cycling and public transport), shifting away from car orientated mobility approach and prioritising green infrastructure
Mobility	The physical movement of people, including modes of transportation such as walking, cycling, driving cars, riding public transport.
Model split	the percentage of travellers using a particular mode of transport compared to the ratio of all trips made
Urban planning	The technical and political processes for designing and shaping the built environment, including transport planning in urban areas.

Abbreviations

BGI	Blue Green Infrastructure
DPRA	Deltaplan Ruimtelijke Adaptatie
DPSA	Delta Plan on Spatial Adaptation
NBS	Nature Based Solutions
Sc	Scenario
SUDS	Sustainable Urban Drainage Systems
UHI	Urban Heat Island

1. Introduction

Due to urbanization, population growth and rapid climate change the need for well designed, climate- and water resilient urban areas increases. The Dutch government has set the goal for a water resilient and climate adaptive country in 2050, in the Delta Plan on Spatial Adaptation (DPSA) (DeltaPlan Ruimtelijke Adaptatie (DPRA)). Rainfall events are getting increasingly more extreme, due to climate change. This increases the likeliness of pluvial flooding in urban areas and calls for adequate water management (Delta Programme Commissioner, 2017). At the same time, extended periods of drought and extremely warm days are becoming increasingly common (KNMI, 2021). Last summer serves as an example, a rainy spring was succeeded by a record long period of drought in June[3]. This was followed by extreme rainfall, leading to water on the streets and even damage to houses in Limburg[4].

Adapting to the changing climate can be done by implementing Blue-Green Infrastructure (BGI) in the urban environment. BGIs can help to cope with extreme precipitation, restore biodiversity, improve air quality and other urban and climatic challenges (Fenner, 2017). BGI can contribute to restoring the natural water balance in urban areas, improving infiltration and increasing rainwater retention (Pochodyła *et al,* 2021). Adding more greenery and trees in urban areas helps mitigating the effects of climate change by improving thermal comfort in cities, balancing water flows and providing multiple other ecosystem services (Demuzere *et al*, 2014).

Parallel to the climate adaptation efforts, the national government and Dutch municipalities are stimulating cleaner and more active forms of mobility, in order to cope with increasing urbanization and create a healthy, accessible and pleasant city for their inhabitants. Recently, chairman of the Scientific Climate Council and government's chief climate advisor, Jan Willem Erisman, suggested that widespread car ownership may no longer be self-evident in the future. To reach a climate-neutral transportation system in the Netherlands, a radical shift away from privately owned petrol cars and a transition towards shared and public transportation is needed[5].
In various cities, urban mobility plans aim to contribute to mitigate climate challenges, such as reducing CO_2 emissions and noise pollution, improve air quality and make cities climate resilient. New mobility policies prioritize the allocation of space for public transport, bicycles, and pedestrians, and concurrently reduce the space available for roads and cars (Gemeente Rotterdam, 2020), (Gemeente Utrecht, 2021). There is a noticeable trend in how people move within cities and how urban mobility is changing. Car usage is declining and inhabitants of highly urbanized areas, in the Netherlands, make more movements by bicycle, on foot or by public transport (KiM, 2019). During the lockdowns, because of the

[3] Source: https://www.nrc.nl/nieuws/2023/06/14/al-bijna-een-maand-valt-er-nauwelijks-regen-in-nederland-is-dat-bijzonder-a4167136 Accessed August 2023
[4] Source: https://www.rtlnieuws.nl/nieuws/nederland/artikel/5392165/wateroverlast-belgie-limburg-maas-namen-stortregen-extreem-weer Accessed August 2023
[5] Source: https://www.ad.nl/binnenland/wordt-het-adieu-auto-autobezit-voor-iedereen-is-straks-niet-langer-vanzelfsprekend~a419dbbd/ Accessed September 2023

COVID-19 pandemic, significant changes to human mobility patterns were observed (KiM, 2021). Even though, the long term effects of the pandemic on mobility were unknown (Faber and Hamersma, 2021), the lock-downs emphasized the importance of access to green space in urban areas (Venter *et al*, 2020). This provided an additional impetus for municipalities in the Netherlands to increase the policy attention to urban green spaces (De Vries *et al,* 2022).

The transition to sustainable mobility could provide space for climate adaptation and water resilient infrastructures, if mobility plans are translated into less space for cars, (i.e. less roads and parking spaces), and more space for greenery and BGI. The integration of green mobility initiatives with climate adaptation measures and BGI presents a possible spatial synergy, wherein these systems reinforce one another. Such synergies can lead to more sustainable societies (Nieuwenhuis *et al*, 2021).

1.1. Research gap

In recent years, extensive research has been conducted in the field of Sustainable Urban Planning (Dong *et al*, 2019; Kumar *et al*, 2020; Scoones *et al*, 2020), Mobility and Land Use (Anastasiadou *et al*, 2023; De Vos *et al*, 2015; Nieuwenhuijsen, 2020), as well as the field of Climate Adaptation and Land Use (Demuzere *et al*, 2014; Graça *et al*, 2022; Hurlimann *et al*, 2021). These areas have witnessed significant scientific attention due to their influence on shaping urban environments and addressing sustainability challenges. However, the relationship between urban mobility and climate adaptation remains largely unstudied. There is a clear gap in the existing literature when it comes to understanding how urban transportation systems interact with climate resilient infrastructure. This thesis seeks to address that research gap by examining the relationship and unexplored potential that arises from combining mobility strategies with Blue Green Infrastructure (BGI) to improve urban (water) resilience and climate adaptation.

1.2. Problem statement

Climate adaptive urban planning is needed to cope with the effects of climate change, and other urban challenges. Municipalities pay increasing attention to the added value of green areas and BGI as a tool for climate adaptation. BGIs and greenery require additional space in cities. The transition to other forms of mobility, i.e. less car usage more space for pedestrians, bikes and shared mobility, could provide this space. The extent of the potential for climate adaptation and BGI remains, yet uncertain. Consequently, it poses a risk that the mobility transition may not fully benefit urban climate adaptation.
Exploratory conversations with mobility experts, conducted at the start of this research, confirmed that the effect of the mobility transition on water management and climate adaptation is rather unknown by professionals in the fields of mobility and water management. Therefore, climate adaptation is still underemphasized in urban mobility plans, while other benefits of the sustainable mobility transition, such as CO_2 reduction, improving health and liveability are prominently mentioned.

1.3. Research goal

This study aims to make cities more climate adaptive and water resilient by showing the potential of the mobility transition for greenery and Blue Green Infrastructure (BGI). Additionally, the study aims to unravel some issues that may hinder the effective integration of climate adaptation and green mobility initiatives. Hereby, this research contributes to the available knowledge on the relation between the urban mobility transition and climate adaptation. This could provide valuable insights that can lead to policy recommendations, and reduce the risk of leaving potential for climate adaptation unexploited.

1.4. Research questions

In order to reach the research goal of this thesis a main research question is formulated. Some multi-interpretable concepts from this question are further clarified.

- Main research question

What *is the potential impact of the transition to* ***green mobility*** *on the implementation of* ***Blue-Green Infrastructure (BGI)*** *in urban areas in the Netherlands?*

What – The space that could be used for BGI because of different mobility scenarios and how this could contribute to climate adaptation.

Green Mobility – Mobility in urban areas is changing, reducing dependence on cars and promoting sustainable modes of transport (e.g. walking, cycling, public transport and shared mobility) and green spaces.

BGI – Climate adaptive or sustainable urban (drainage) infrastructures, which help restore the natural water balance and provide various ecosystem services. For example greenery, trees, rain gardens and permeable pavement.

Sub-research questions are formulated to answer the main question, these questions are allocated by research method.

- Desk study

1) Why is climate adaptation needed in urban areas?
2) What is climate adaptive and water resilient urban planning according to literature?
3) What is the Dutch context of climate adaptation and mobility policy?

- Case study

4) How much green space could potentially be added in urban areas, on three spatial scales for different design and mobility scenarios?
5) How could this green space be used to make urban areas more climate adaptive and water resilient?

- Interview survey

6) How do professionals view the relation between the mobility transition and climate adaptation?

1.5. Research approach

The potential impact of the mobility transition on climate adaptation and water resilience is assessed through a combination of a desk study, literature review, policy document analysis, case studies on three spatial scales, interviews with experts and design scenario analyses.

The desk study consist of a literature study and a review of policy plans. The literature study should provide the theoretical background for the thesis research. The review of policy plans examines grey literature to get a better understanding of the Dutch context on climate adaptation and the mobility transition.

The case study explores the impact of the transition to green mobility on urban land use and the potential for BGI and climate adaptation. On three different spatial scales multiple design and mobility scenarios are assessed.

A semi-structured interview survey with professionals in the field of water management, urban planning and mobility is conducted, as a part of the case study research strategy. The interviews provide background information for the case study and help to gain insight into perspectives on sustainable mobility and climate adaptation.

1.6. Scope and key assumptions

Since the topic of this thesis research is complex a scope, i.e. the boundaries and extent of the research project, must be defined. The essential elements of the scope are:

- The geographical scope of the research is the Netherlands. All cases are located in Dutch municipalities. The aim is to choose varied cases and work them out in depth. Only public space is considered.

- This study only examines the potential of existing urban areas, excluding new development projects. To assess the potential, it is assumed that all the freed space is used for climate adaptation.

- The green mobility transition can be interpreted in many ways, for instance switching to electric vehicles to reduce greenhouse gas emissions is also considered as sustainable mobility, and could be included in the definition for the green mobility transition. In this study the green mobility transition is defined as reduced car dependency (i.e. less parking and road surface) and increased space for climate adaptation, and other mobility modes (such as, cycling, walking and public transport).

- The thesis concentrates on exploring climate adaptation challenges related to heat, drought, and flooding in a specific urban context. Other climate adaptation challenges, such as restoring biodiversity are noted but shall not be considered further.

- The effect of other challenges or transitions that need space in the city and influence urban land use, such as the energy transition and housing challenges, are not considered in this thesis.

1.7. Research outline

Chapter 2 provides the theoretical background for the other parts of the research study. It is buildup of two parts, a literature review and desk study on policy documents. The literature study provides insights in the need for climate adaptation, different types of climate adaptation measures (or BGI) and the mobility transition. The review of policy documents examines climate adaptation and the mobility transition in a Dutch context.
Chapter 3 describes the research methods that were applied. It introduces and explains the way the research and case study was structured. Chapter 4 presents the case study results, divided on three spatial scales. Each individual case study contains a review of specific policy documents and a design scenario analysis. Chapter 5 synthesizes the findings from the case study and interview survey, compares the finding from this research to existing scientific literature and reflects on the research limitations in the discussion. Chapter 6 draws conclusions from the research and answers the main research question. Lastly, chapter 7 gives policy recommendations arising from this study and provides some recommendations for future research.

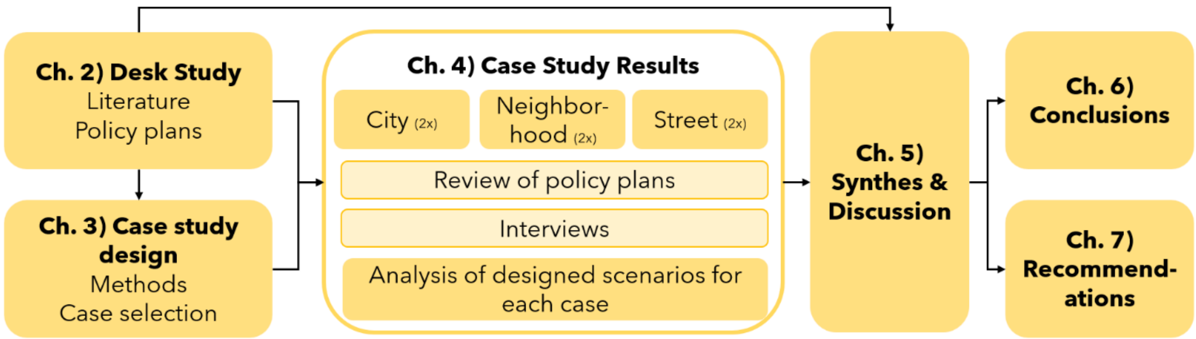

Figure 1 Visualizes the research design

2. Theoretical background

2.1. Literature study

2.1.1. Need for climate adaptation

Anthropogenic activities have most certainly caused a rapid change in the earths' atmosphere, ocean, cryosphere and biosphere, according to the Intergovernmental Panel on Climate Change (IPCC). Human influence has, among other things, led to increased levels of greenhouse gas (GHG) in the atmosphere, increased global mean sea levels, more frequent hot extremes, increased global surface temperatures and more frequent and intense heavy precipitation events (IPCC, 2021).
Simultaneously, more people are living in cities leading to urbanization. This results in major land use changes (Dong *et al,* 2019), and intensifies the impact of climate change (He *et al,* 2019). In the Netherlands, the consequences include more extreme precipitation events leading to urban flooding, an increase in the likelihood of droughts and cities facing more intense heat due to global warming and the urban heat island effect (KNMI, 2021). These three consequences of climate change and urbanization will be discussed in this subsection.

Urban flooding
Changes in the timing and intensity (depth) of rainfall events, caused by climate change, are expected to bring about notable shifts in the flooding events experienced across numerous urban areas of the world (Miller *et al*, 2017). Urban floods results from a combination of factors, including increased urbanization, altered land use patterns and changing precipitation patterns driven by climate change. Urban flooding can include pluvial, fluvial, groundwater and coastal flooding (Hammond *et al*, 2013). This thesis will only include pluvial urban flooding. Extreme rainfall events combined with impervious surfaces and limited drainage causes urban flooding. Adequate urban water management and sustainable drainage infrastructure is needed to mitigate the impacts of urban flooding.

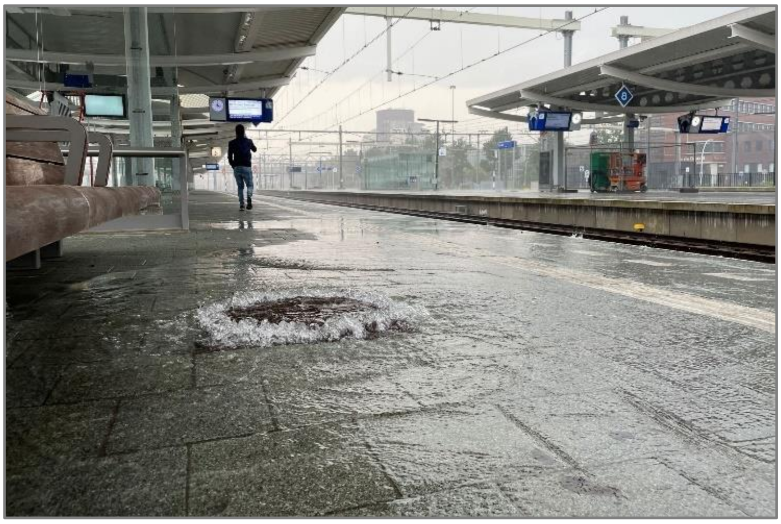

Figure 2 Overflowing sewers during an extreme summer rainstorm, on the 9th of July 2023 in Zwolle, the Netherlands. (Author's own picture).

Drought

A drought is an extended period of deficient rainfall to meet the demand, leading to water scarcity and significant ecological, social, and economic impacts. Due to climate change droughts will occur more frequently and intensify in the Netherlands (Machairas *et al*, 2022). This poses a major risk, the wooden pile foundations of historical buildings in the Netherlands are at risk of falling dry and deteriorating. In recent years, urban droughts, and their consequences, have gained increased scientific attention (Orimoloye *et al*, 2021).

Droughts can have negative effects on urban ecosystems, including stress on and wilting of trees and vegetation in parks and urban green spaces. Prolonged dry periods can negatively impact urban ecology and limit the colling effect of urban green spaces (Kraemer *et al*, 2022). The limited availability of water during dry periods must be taken into account when designing and maintaining urban green infrastructure.

Urban heat

The first time the Urban Heat Island (UHI) effect was mentioned is already more than 200 years ago, in 1818 by meteorologist Luke Howard. His field measurements observed a significant increase in temperature in the city of London compared to the surrounding rural areas (Mills, 2008).

Previous studies found that cities in the Netherlands experience a significant UHI. On average a daily maximum temperature difference or UHI of 2.3 K can be experienced. A significant relation between decreased UHI and surface area covered by green vegetation was found as well (Steeneveld *et al,* 2011).

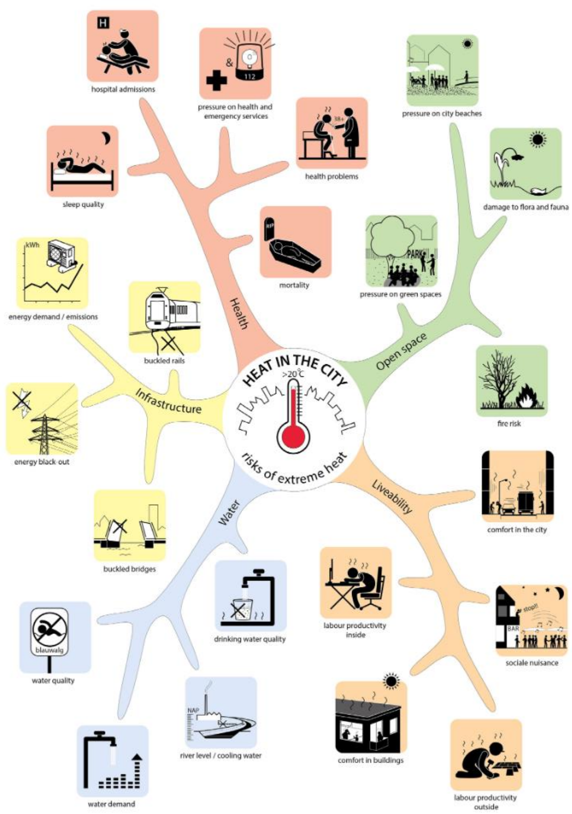

Figure 3 Risk of extreme heat in the city and the consequences (Source: Klok, et al, 2016).

Many local governments in the Netherlands have or had insufficient knowledge and understanding of the importance of heat stress related impacts (Klok, *et al,* 2016). Recently, the subject of heat stress is higher on the agenda. A standard heat stress test method has been developed by the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu (RIVM)). All Dutch government organizations have agreed upon performing these stress tests in the DPSA (2018). However, it was found that municipalities still struggle with defining the urgency of the problem and finding arguments to implement climate adaptation measures.

2.1.2. Blue Green Infrastructure (BGI)

Cities are increasingly focusing on purposeful planning and designing of BGI as a means to achieve sustainability and create climate and water adaptive urban areas (Demuzere *et al, 2014)*. Many cities have adopted strategies for sustainable development and a sensible use of resources. These strategies often include implementing BGI, because they offer a significant potential in addressing multiple urban challenges related to resource management, including climate adaptation and mitigation, sustainable consumption and production, air quality improvement, and water management. (McGrane *et al*, 2016). Apart from the term BGI, these inventions or systems know many other names. Some of the most used terms in literature are Nature-Based Solutions (NBS), Sustainable Urban Drainage Systems (SUDS), Blue-Green Infrastructure (BGI), Green Infrastructure (GI) and Low-impact development (LID) (Woo, 2020). In this thesis research the term BGI will mostly be used as it is a commonly used and understood term, which encompasses both technical solutions such as permeable pavement and natural elements such as trees.
Since around the year 2000 the BGI concept has been gaining research attention. The three most popular forms of BGI reported in literature are Bioretention systems or raingardens, Permeable pavements and Green roofs (Pochodyła *et al.*, 2021). In this section of the literature study each of these concepts, except green roofs, will be discussed. Green roofs are excluded from this literature review, because green roofs are an intervention in the private space, in this research only the public space is considered.

Urbanization leads to disturbances in the natural water balance and hydrological cycle, increasing impervious surfaces prevent infiltration and alter runoff processes (McGrane *et al*, 2016). This combined with climate change is leading to extreme heat, urban flooding and drought in cities. Applying blue and green infrastructure on a large urban scale for stormwater management and control is a main part of the concept of 'Sponge Cities'. The novel concept of sponge cities gained scientific attention since 2014, is closely related to the concept of 'water sensitive cities', and aims on restoring the natural water balance in cities. Characteristics of sponge cities are the capabilities to store, infiltrate, absorb, purify and drain stormwater. Hereby it enhances the natural ecosystem and provides a more pleasant urban environment for people and other organisms (Ka *et al,* 2018).

How BGI can help restore the natural water balance and thereby make cities more resilient to a changing climate is shown in Figure 4. Research has been done on implementing BGI on large scale, it was found that by employing a combination of various BGI measures urban runoff can significantly be reduced, reaching up to approximately 90% of the yearly runoff volume (Versini *et al*., 2018).

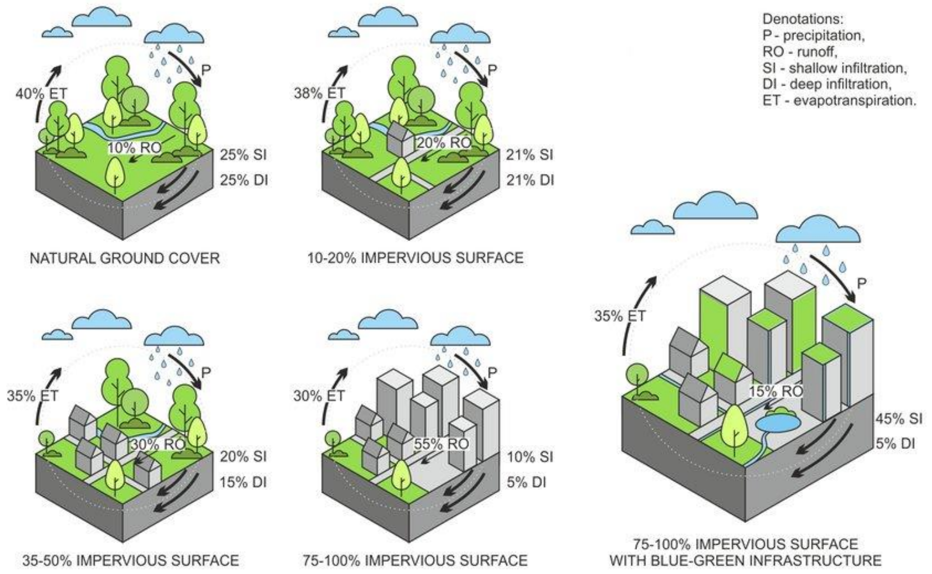

Figure 4 Disturbances in the natural water balance and the effect of BGI (Source: Pochodyła et al., 2021).

Rain garden/ Bioswales

Rain gardens or bioswales have become one of the most used urban storm water management techniques. They harness the natural capabilities of vegetation and soil to store, infiltrate and treat runoff (Davis *et al*, 2009).

Rain gardens and bioswales are typically created as shallow, landscaped depressions or basins. They are strategically located to intercept and store runoff from impervious surfaces like roofs, driveways, and roads. Rain gardens are usually planted with a variety of selected vegetation and bioswales could be vegetated with solely grass (Ekka *et al*, 2021).

The hydraulic functioning depends largely on design choices, site specific characteristics and maintenance. The advantages include their ability to remove some of the contaminants from infiltrated water. Additionally, by locally infiltrating rainwater, they help to replenish groundwater, which is crucial given the increasing drought conditions. Moreover, the vegetation in rain gardens contributes to enhancing urban biodiversity (Siwiec *et al*, 2018).

Figure 5 Rain garden between road and sidewalk. Heerlenseweg, Landgraaf. (Author's own picture).

Permeable/ Porous pavement

Another form of BGI considered in this study is permeable pavement. Permeable pavement have a wide range of names and applications, and are commonly applied. The first forms of permeable pavements were applied in the Netherlands in the 1970's.

Their main function is to infiltrate stormwater and restore the charging of groundwater in urban areas. This helps to prevent drought, biodiversity loss and heat stress. During heavy rainfall events, it lowers the water volume in sewer systems preventing sewage overflows and reducing stress on waste water treatment plants, which helps to control water management costs (Bouwmeester, 2023).

Permeable pavements are used for many different applications; car parks, low-traffic streets, footpaths, driveways, etcetera. In general, these types of pavements are less suitable for high traffic loads, as they can damage the systems. Four different types of permeable pavements are identified in literature; Permeable interlocking concrete pavers (PICP), Concrete and plastic grid pavers (CGP and PGP), Porous asphalt (PA) and Porous concrete (PC) (Mullaney *et al,* 2013). This thesis will in particular consider the concrete grid paver form of permeable pavement. There are a number of reasons for this, this type of paving is widely used under car parks, has the largest proportion of unpaved surface and can therefore be planted with grass. An example can be seen in Figure 6, a green car park.

Figure 6 Parking space on permeable pavement. Bentincklaan, Rotterdam. (Author's own picture).

Newly installed permeable pavements must have an infiltration capacity of at least 194 mm/h in the Netherlands (Boogaard *et al,* 2019). Maintenance is required in order to keep satisfactory infiltration rates and prevent the systems from clogging. Research showed that, after many years of service, the performance of permeable pavement systems is still considered acceptable (Boogaard *et al,* 2014). Nonetheless, due to a lack of knowledge on functioning, maintenance, reliability, cost and benefits of permeable pavements widespread adoption of the technology remains limited. Urban water managers and policy makers are hesitant to apply the permeable pavement technology on a large scale (de Graaf Van Dinther, 2021).

Trees and vegetation

Besides the more technical forms of BGIs, trees and vegetation play an important role in urban climate adaptation. Shashua-Bar *et al* (2012) showed that Trees and greenery are more effective in cooling urban streets than altering the colours of walls or altering road widths for increased ventilation. Additionally the study suggested that people significantly appreciate greenery in streets in aesthetic terms and that proposals to increase the amount of vegetation in streets are more common in streets with a high amount of greenery (Klemm, *et al.* 2015).

Surface temperatures are highly effected by the surface type and whether or not the surface is vegetated. This was already shown by a study performed in Frankfurt in 1982. A small green area lowered local temperatures with 3 to 3.5 K (Bernatzky, *et al.* 1982). Additionally other benefits such as filtering of polluted air, reducing noise and supplying oxygen were mentioned. A study on the impacts of street greenery on thermal comfort in Utrecht shows that the average measured mean radiant temperature (T_{mrt}) is 4.9 K lower in streets with 39% tree cover compared to streets without trees. In general a relation could be derived stating that 10% added tree cover in streets reduces the radiant Temperature with 1 K (Klemm, *et al.* 2015). A study in Manchester, UK, showed that surface temperature of vegetated areas (grass) could be up to 24 degrees cooler on a summer day compared to paved surfaces (asphalt, concrete) (Armson, *et al.* 2012). The same study found that globe temperatures measured 1.1 meter above the surface are less effected by the surface type but highly influenced by the mount of shading. Globe temperatures measured in tree shaded areas where 5-7 K lower compared to globe temperatures in full sun. This shows the importance of grass covered surfaces and tree canopy cover in cooling urban areas and mitigating the UHI effect. It is suggested that a large number of small green plots is more effective in urban areas than a few larger areas. To ensure a significant cooling effect by grass covered areas water stress must be avoided and sufficient water must be available to the vegetation.

The ability of urban green spaces to cool down their surroundings has also been called the Urban green space cooling effect in literature and can be expressed in cooling effect intensity (CEI) and cooling effect distance (CED). Several studies showed that small sized green spaces between 0.02 ha (200 m^2) and 0.3 ha (3000 m^2) already exhibit an average CEI between 0.5 and 4.5 K (Aram, *et al.* 2019).

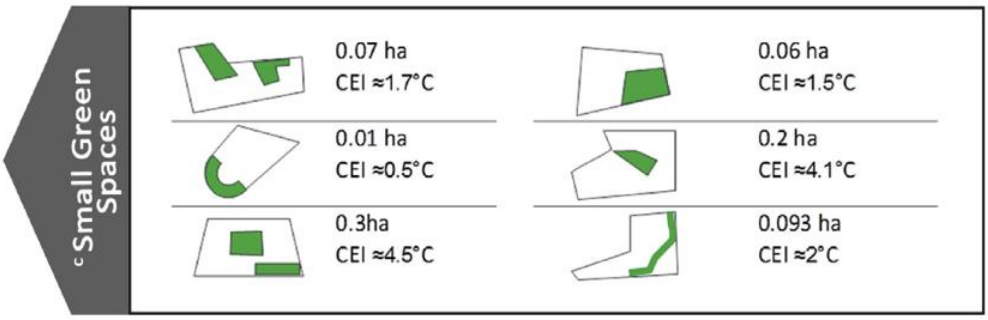

Figure 7 Cooling effect intensity of small urban green spaces with different shapes. (Source: Aram, et al. 2019).

Hydraulic parameters of Blue Green and Gray Infrastructure

Tabel 1 provides a list of storm water storage and discharge capacities of blue, green and grey infrastructures. The values are found in scientific and grey literature and are either design standards or empirically tested values. The types of BGI included are discussed in this section (2.1.2). The hydraulic capacities of grey infrastructures (sewer system and street storage) are needed to make assumptions for the water balances used in the case studies performed in this thesis. It should be noted that found design standards and empirical values for infiltration rates of permeable pavements and rain gardens are in a wide range. Specific designs and local conditions such as soil infiltration capacity ultimately determine the effective infiltration capacity.

Tabel 1 Summary of hydraulic parameters of Blue Green and Gray drainage systems based on available literature

Drainage system	Function	Capacity	Empirical test / design standard	Description	Reference
(Separated) Sewer system	Water storage	8 mm	Design standard	Area connected to sewer	Langeveld *et al*, (2019)
	Discharge capacity	22 mm/h	Design standard	Area connected to sewer	Langeveld *et al*, (2019)
Street storage	Water storage	0-30 mm	Design standard	Between curbs	Langeveld *et al*, (2019)
Permeable pavement	Infiltration	250 – 2500 mm/h	Design standard	SUDS manual standard	Ballard *et al*, (2015)
		122 – 373 mm/h	Empirical test	Multiple infiltration tests in the Netherlands	Lucke *et al*, (2014).
		220 mm/h	Empirical test	70 infiltration test in 11 Dutch municipalities (Mean)	Veldkamp *et al*, (2020)
		97.2 mm/h	Design standard	Minimum required infiltration after installation of a new permeable pavement	OCW (2008)
Unpaved area	Water storage	10 mm	Design standard	Default model parameter value	Stichting RIONED (2019)
	Infiltration	15 mm/h	Design standard	Minimum design infiltration rate	Global Designing Cities Initiative. (2023).
		10 mm/h	Design standard	Default model parameter value	Stichting RIONED (2019)
Bioretention systems and Rain gardens	Water storage	150 – 300 mm	Design standard	SUDS manual standard	Ballard *et al*, (2015)
	Infiltration	100-300 mm/h	Design standard	SUDS manual standard	Ballard *et al*, (2015)
		245 – 1600 mm/h	Empirical test	Small and large scale infiltration test in Norway	Venvik, *et al.* (2020)

2.1.3. Mobility transition

The mobility transition refers to a fundamental shift in urban transportation systems and practices, aimed at creating more sustainable ways of moving within cities. The European Union's transport transformation policy towards sustainable mobility is largely focused on reducing GHG emissions and is part of the European Green Deal (European Commission, 2021). Objectives of the mobility transition include reducing traffic congestion, lowering greenhouse gas emissions, enhancing urban liveability, and improving accessibility for all residents. Many European cities, including Paris, Amsterdam, Oslo and Brussels, have already adopted mobility policies to reduce car dependency.
This thesis research will mainly focus on the aspects of the mobility transitions that reduce the allocated space for cars and prioritize other modalities such as bicycling, walking, shared and public transport. In addition, the concept of changing mobility in order to allocate urban space to BGI or greenery is proposed. The overall phenomenon will be referred to as the 'Green Mobility Transition'. Three aspects are further examined to study the mobility transition; *Reducing parking spaces, Reducing road space* and *Car free urban areas*.

Reducing parking spaces

An important aspect of the green mobility transition, for this study, is the reduction of on-street parking space within urban areas. Many European cities such as Amsterdam, Oslo and Paris have already started reducing the amount of on-street parking spaces, and intend to continue this trend. Parking policy has gained increasing attention in urban planning and has evolved from reactive regulation and control to proactive city planning that incorporates supply restraints and even removal strategies (Mingardo *et al,* 2015). Contemporary urban planning recognizes the importance of reducing parking spaces to promote sustainable and efficient transportation systems. Some studies suggest that parking management is one of the main solutions to alleviate urban congestions (Shen *et al,* 2020) and a tool for promoting sustainable transport in urban neighbourhoods (Kirschner *et al,* 2020). Multiple studies show that parking supply regulations are an effective tool to influence car ownership and travel behaviour (Christiansen *et al,* 2017; Gou, 2013) ,

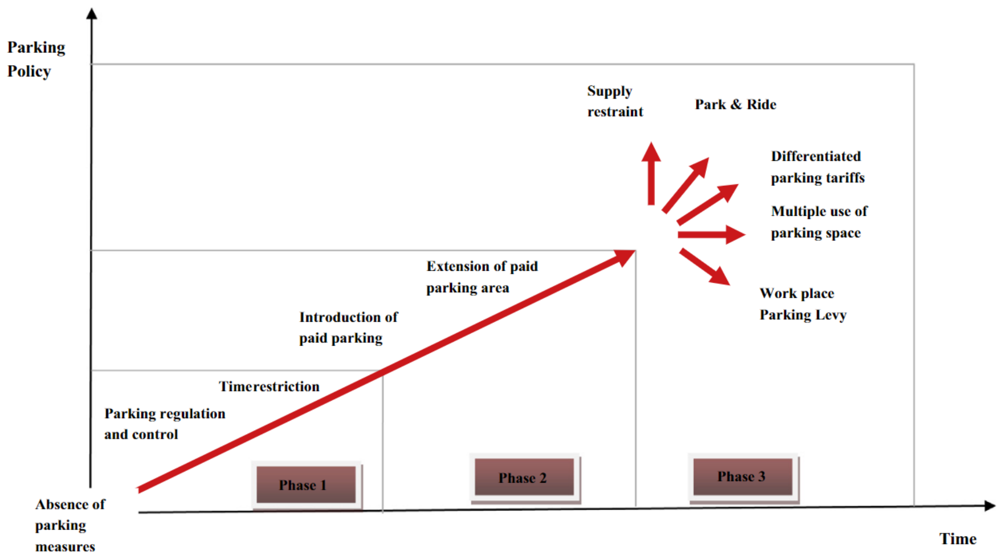

Figure 8 Development stages of urban parking policies (Source: Mingardo et al, 2015)

Novel developments, such as mobility hubs and shared mobility services, have emerged as potential solutions to address the challenge of limited available urban space. Shifting away from privately-owned modes of transportation and moving towards shared transportation and mobility provided as a service is also known as the concept of MaaS (Mobility as a Service) and is receiving increasing interest in the scientific literature (Arias-Molinares, 2020). These developments optimise the use of means of transport, reduce the need for extensive parking infrastructure, and encourage alternative modes of transportation. They reduce privately owned car-dependence and improve accessibility and liveability of urban areas (Weustenenk *et al,* 2023).

Figure 9 Mobility hub in the centre of Rotterdam offering shared bicycles and scooters (Author's own picture)

Lane reduction and road narrowing

Another important aspect of the green mobility transition, for this research, is the narrowing of road widths and the re-evaluation of traffic lane allocations. Traditional road design often prioritised motorized vehicle flow and high-speed traffic, resulting in wide (separated) road surfaces that occupy valuable urban space. However, in the past decades a different approach to street design is emerging (Hamilton-Baillie, 2008). The concept of 'shared space' is highly regarded, emphasizing the significance of accommodating various transportation modes and creating safer and more liveable urban environments (Jayakody *et al,* 2018).

The current urban traffic system has largely been designed from a car orientated perspective, in order to improve cyclist and pedestrian safety there are essentially two widely applied option. Either separating motorized and non-motorized traffic, or combining road functions and reducing the speed of motorized traffic (Wegman *et al,* 2008). Many Dutch municipalities (i.a. Rotterdam, Amsterdam, Utrecht) are currently adopting the second principle in urban areas and are implementing a general speed limit of 30 km/h in city centres and residential neighbourhoods. There are many recent examples in these cities of 2x2 lane roads that have been converted into 2x1 lane roads.

Narrowing road widths can help encourage car drivers to reduce their speeds (Bella, 2013). One way to narrow road widths is by converting lanes into shared spaces, such as bicycle streets. The number of bicycle streets has been growing in the Netherlands, and in many urban areas where space is limited it is considered as a solution to create a more balanced and inclusive urban infrastructure that accommodates pedestrians, cyclists, and motorized traffic. The bicycle street has been applied in many different design options and a number of design rules have been established (Van Boggelen *et al,* 2019).

Car free zones and city centres
Lastly, an important part of the green mobility transition is the transition towards car free areas. Privately owned cars have dominated the second half of the twentieth century and have a profound influence on the design of our cities. Recently, multiple cities have proposed plans to become (partly) private car free. Particularly in Europe, the idea for car-free or parking-free neighbourhoods resonates. This development shows great potential to positively change the urban landscape (Foletta *et al,* 2011).
Different policies must reduce car traffic and stimulate active mobility modes such as walking and cycling. Reasons to adopt this strategy are mainly greenhouse gas reduction and improve public health (Nieuwenhuijsen *et al*, 2018). Multiple studies have shown that limited car use and walkability has positive effects on the physical and mental health of neighbourhood residents (Renalds *et al,* 2010; Smith *et al,* 2017). Additional benefit is that non-car-oriented neighbourhoods can provide space for greenery (Melia, 2010). This logically offers opportunities for BGI and climate adaptation.

2.2. Dutch context of climate adaptation and the mobility transition

This chapter discusses some of the key policy documents on climate adaptation and mobility, explaining the Dutch context and key policy frameworks. The overview will not contain an exhaustive list of documents, only those most relevant to this study will be highlighted. The desk study on policy documents is divided into two sections; climate adaptation and mobility.

The national government presents its long-term vision for the living environment of the Netherlands in the National Strategy on Spatial Planning and the Environment (*Nationale Omgevingsvisie - NOVI*). It is the first integrated national strategy document and an instrument of the new Environment and Planning Act *(Omgevingswet)*. The NOVI is self-binding for the national government and serves as a guiding document for provinces and municipalities in establishing their own spatial planning and environmental visions.
Two of the four priorities of the NOVI is 'space for climate adaptation and the energy transition' and 'strong hand healthy cities and regions'. These priorities are translated into some relevant policy choices; The Netherlands must be climate resilient and water robust by 2050 (resilient to extreme heat, drought and flooding) and An efficient and sustainable mobility system contributes to a healthy living environment. (Ministry of the Interior and Kingdom Relations, 2020).

2.2.1. Policy documents on climate adaptation in the Netherlands

According to Mees *et al.* (2023) the governance structure to adapt to the risk of climate change is quite complex in the Netherlands. Adaption is not seen as a separate policy domain, but the implementation of climate adaptation relies on other sectoral policies and should be integrated. In this light the national government, municipalities, water boards and provinces collectively established the Delta Plan on Spatial Adaptation (DPSA) in 2018, which sets the goal for a climate adaptive and water resilient country by 2050. The DPSA is part of the national delta programme and outlines concrete actions to ensure that the policy guidelines made in the delta decisions are translated into tangible projects. The DPSA focusses on four issues; water logging, heat stress, drought, and urban flooding. It is structured around seven key ambitions, ranging from mapping out vulnerability to responding to calamities (Delta Programme Commissioner, 2017).
A second prominent policy document regarding climate adaptation in the Netherlands is the National Adaptation Strategy (NAS). The NAS complements the National Delta Programme and like the Delta Programme it was commissioned by the Ministry of Infrastructure and Water State and calls for an integrated approach to climate adaptation. Unlike the Delta Programme, which focuses mainly on water safety, the NAS has a broader perspective on adaptation (NAS, 2016).

One of the seven key ambitions of the DPSA is Capitalising on linkage opportunities, which focusses on combining adaptation measures with other goals or spatial tasks, such as the energy transition, transition towards a circular economy and the mobility transition. Linking climate adaptation to the mobility transition tends to be underexposed and hardly mentioned in documents and tool providing information on linkage opportunities, such as the Guide to Smart Climate Adaptation Linkage, developed in the context of the DPSA (NWK KBS, 2020).

These tools and others providing information on several climate adaptation areas are collected in a central database. The most well-known and comprehensive database is the "Knowledge Portal Climate Adaptation" (*Kennisportaal Klimaatadaptatie*) (Mees *et al*, 2023). It is a spin-off of the Delta Programme and has been developed by the national government, it aims to provide information, tools and examples for everyone engaged in climate adaptation. One of the tools is the Climate Impact Atlas (*Klimaateffectatlas*), which provides an initial impression of the (future) threats of climate change in the Netherlands. The information from this tool is used in the case studies to determine in which places the need for climate adaptation is the highest.

Despite these efforts to process available knowledge and expedite the implementation of climate adaptation measures, many municipalities still struggle with translating national adaptation ambitions to effective practices. One reason for this may be an 'institutional void'; the lack of policy frameworks with clear norms and agreements on adaptation (Van den Ende *et al,* 2022). Municipal climate adaptation strategies differ greatly between municipalities in the Netherlands, both in form and content (Brouwer, 2021). Most strategies refer to the goals and ambitions of the DPSA, but often remain generally descriptive without setting concrete goals. Mees *et al,* (2018) suggests that following the Danish model by making climate adaptation strategies obligatory for municipalities, could be a powerful policy instrument to overcome barriers to climate adaptation measures.

Currently, the national government is working towards a less non-committal approach to climate adaptation[6]. For example, a study by the Wageningen University and the Netherlands Environmental Assessment Agency examines the feasibility of a greenspace norm in urban areas. Greenery in urban areas has positive effects on heat, drought and flood mitigation, a national green space standard could for example be; 30% tree canopy cover per neighbourhood (Snep *et al,* 2022).

[6] Source: https://www.rijksoverheid.nl/documenten/kamerstukken/2023/03/23/kamerbrief-over-landelijke-maatlat-voor-een-groene-klimaatadaptieve-gebouwde-omgeving Accessed: September 2023

2.2.2. Policy documents explaining the mobility transition in the Netherlands

This subsection describes the Dutch context of the mobility transition. First the current trends and future expectations of urban mobility will be discussed, followed by a short overview of some important reports of the CROW knowledge institute, which advice municipalities on infrastructure and mobility.

Once every two years the Netherlands Institute for Transport Policy Analysis (KiM) publishes a mobility report in which the most important developments and current numbers on mobility in the Netherlands are presented. These publications provide relevant knowledge for the development of mobility policy to the Ministry of Infrastructure and Water Management and other governmental organizations. The most recently published mobility report is from 2021, this publication is however less useful as it mainly reports on the effects, whether temporary or not, of the covid pandemic and lockdowns (KiM, 2021). Therefore, the 2019 report provides the most reliable information on the development of mobility in The Netherlands. It showed that among residents of high density urban areas in the Netherlands, the shares of transport modes cycling, walking and train increased between 2005 and 2015, while the shares of car driver and passenger decreased (KiM, 2019). In other words; the 'modal split' (defined by Ungvarai, 2019 as: 'the percentage of travellers using a particular mode of transport compared to the ratio of all trips made') is shifting to more active and sustainable mobility in highly dense urban areas in the Netherlands, as can be seen in Figure 10.

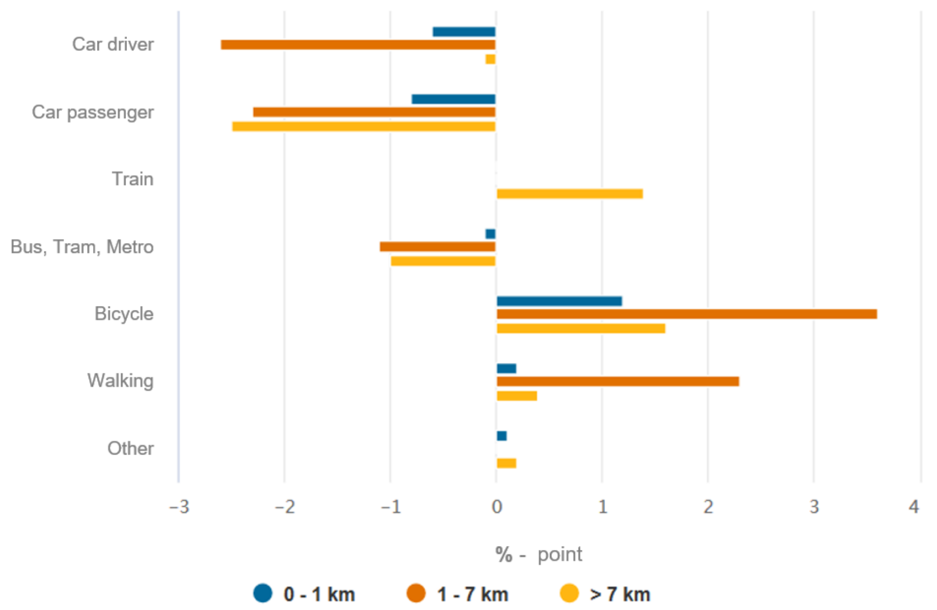

Figure 10 Development of the modal split in highly urbanised urban areas in the Netherlands between 2005-2015 (Source: KiM, 2019)

This trend is noticed and confirmed by the most recent study of the KiM institute, published in September 2023. It reports on the observed trend in many Dutch municipalities committed to a low car city or car free areas (Jorritsma *et al*, 2023). In many municipal mobility plans, a shift can be observed from a car-oriented policy (mobility-based planning) to a broader socially-oriented approach (accessibility-based planning). Reasons for this policy choice include; increasing the quality of the urban space, stimulating active mobility, increasing traffic safety and creating space for other functions such as greenery. According to the study, measures to reduce car use in municipalities can be divided in three categories:

- Built environment: densifying cities and mixing functions.
- Parking: reducing the number of parking spaces, introducing or increasing parking fees and parking permits, and facilitating remote parking at hubs.
- Roads and streets: measures that regulate traffic flow and restrict driving speed.

Mainly examples of measures from the last two categories were found in scientific literature presented in section 2.1.3 mobility transition.

An important organization for municipalities to gain expertise, share information and shape policies related to mobility, in the Netherlands, is the CROW institute. It serves as a platform for professionals and governmental organizations that focuses on knowledge development and information dissemination in the fields of traffic, transportation, infrastructure, and public space planning.

One of their publications is related to "STOMP" designing principle, which is frequently applied by mobility experts in the Netherlands (CROW, 2021). "STOMP" is an acronym in Dutch and it represents "Stappen, Trappen, Openbaar Vervoer, Mobility as a Service (MaaS) en Particuliere auto", which translates to "Walking, Cycling, Public Transport, Mobility as a Service (MaaS), and Private Car". In respective order of priority. The design principle prioritizes sustainable forms of mobility and fits well with the green mobility transition as described earlier.

At street level, this design principle is often translated into the use of bicycle streets (or 'fietsstraten' in Dutch). In a bicycle street, the roadway is shared by cars and cyclists and the car is subordinate to the bicycle. Combining these types of modalities leaves more space for other functions (such as greenery) in the street design. A 2005 CROW publication presents the design guidelines (CROW, 2005). Bicycle streets are applicable in streets with low car intensity, the maximum speed must be set to 30 km/h, the road must have a small width of roughly 5 meters and their function should be clearly marked with road signs as shown in Figure 11.

Figure 11 Bicycle street signing

3. Methodology

This chapter describes and discusses the research methods used to answer the research questions. It is divided in two subsections; one covering the methods used for the desk study and one covering the methods used for the case study.

3.1. Desk study

A desk study was performed to gain a broader understanding of climate adaptive and water resilient urban planning and the green mobility transition. A literature study provided insight in the need for climate adaption, the types and function of BGI in urban planning and theoretical background of the mobility transition. This answered the first two research questions. A review of policy documents discussed climate adaptation and the mobility transition in a Dutch context and provided answers to the third and fourth research questions.

3.1.1. Literature review

Relevant literature was found in a structured way as describes in this section. For each research topic, as suggested in the literature review sections in chapter 2.1, state of the art literature was found according to TU Delft library guidelines (TUlib, 2023). This guidelines provided useful information on how to find and evaluate relevant literature. The quality of the articles reviewed was always assessed by looking at the authors' publication history, the date of publication, the citation score and the quality of the journal in which the articles were published.

The first part of the literature research focused on finding general scientific insights that showed the relevance for climate adaptation with search operators such as “urban heat” and “climate adaptation” used in the search queries. The second part of the review focused on state of the art forms of BGI with search operators such as “rain gardens” and “retention capacity” used in the search queries. The third part of the review focused on finding available literature on mobility policy and future perspectives with search operators such as “parking policy”, “mobility” and “urban land use” used in the search queries.

The found literature led to new insights and synonyms for relevant terms, this was used as a starting point to find the needed literature. Citation analyses was applied for some specific articles. According to Nicolaisen (2007) citation analysis represents the analysis of bibliographic references in scientific articles. Relevant researchers identified in the reference lists were identified and their work was added to the literature review.

3.1.2. Review of policy documents

The review of policy documents focused on two themes, climate adaptation and the sustainable mobility transition, in a Dutch context. Since the volume of documents is too extensive to cover exhaustively, a small selection of the most influential and leading documents is discussed in section 2.2.

Starting point in explaining the Dutch context for climate adaptation is the Delta Plan on Spatial adaptation (DPSA). For the mobility transition, the mobility reports from the Netherlands Institute for Transport Policy Analysis (KiM), formed the basis for the policy documents review.

In addition, several policy documents were reviewed per case study in order to provide a comprehensive background of the case study and determine the municipal goals regarding climate adaptation and mobility. In total, more than 35 municipal documents were analysed for this purpose, varying from municipal governance agreements, mobility visions and climate adaptation strategies to specific urban planning visions and architectural plans.
Appendix A - Review of policy documents, contains a list of policy documents relevant to the case studies. All documents used for this study are openly accessible and found with web searches.

3.2. Case study

Within each case study multiple methods were applied to build the case, find insights and answer the fifth, sixth and seventh research question. First the design of the case study will be shown, then each individual method will be explained.

3.2.1. Case study design

As stated in the introduction little is known of the interaction between the mobility transition and climate adaptation. Because of the limited existing research and complexity of the topic an exploratory, multi case-study research strategy is chosen (Priya, 2021). This strategy allows for an in-depth and flexible research design, which enables to study diverse perspectives through multiple cases. Using real world examples provides more details and nuances in cases. An exploratory case study can lead to formulation of new theories by inductive reasoning. The findings of this multiple case-study can offer practical insights for policymakers and urban planners on the potential for BGI through a change in mobility in urban areas.
Six cases, in the Netherlands, for which new mobility goals or plans existed that were known to the author were selected to use in this study. The case study design is based on the Multiple Case Study Method developed by Yin (2003). It is divided in 6 steps, indicated in Figure 12, the methods used are shown per step. The first step, developing research questions and determining the research methods is discussed in chapter 1. The methods used in step 2, 3 and 4 are discussed in this chapter. The individual case study results are presented in chapter 4. Step 5 and 6 are covered in chapter 5 and 6 of this report.

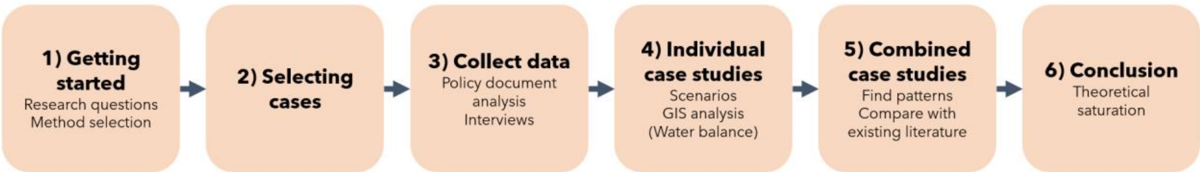

Figure 12 Multiple case study research design, schematic overview

3.2.2. Case selection

In order to give valuable information and context related to the potential impact of the transition to green mobility on the implementation of BGI in urban areas, six cases on three different spatial scales were selected. Some interviewees (See section 3.2.4) suggested that different dynamics can be expected in the city centre compared to residential areas. Choosing cases with different urban characteristics allows for multiple contexts to be examined. To give a more complete picture, case studies are examined at three different spatial scales, namely; city, neighbourhood, and street scale. The selected cases are diverse in terms of location, urban characteristics and scale. Large scale case studies have a low level of detail and analysed the amount of space that could be reallocated due to changing mobility. Secondly, the city scale cases examined whether this reallocated space will become available in the places where climate adaptation is needed. In this way, they show the potential of the mobility transition. The cases on a smaller spatial scale provided a more detailed understanding of the fulfilment of this potential and how it can contribute to climate adaptation.

Cases were selected through online research and suggestions from supervisors or interviewees. In selecting the cases, the amount of information that could be found was of great importance. Preference was given to cases where an interview with a professional working in the relevant municipality was possible. An overview of the selected case study areas, their spatial scale and if an interview was conducted is shown in Tabel 2. The location of the study areas is shown in Figure 13.

Tabel 2 Overview of the case study areas

Nr	Case study area	Spatial scale	Interview
1	Utrecht	City scale	Yes
2	Rotterdam	City scale	Yes
3	Stadspark, Apeldoorn	Neighbourhood scale	Yes
4	Taagdreef, Utrecht	Neighbourhood scale	Yes
5	Kanaalstraat, Utrecht	Street scale	Yes
6	Edeseweg, Ede	Street scale	Yes

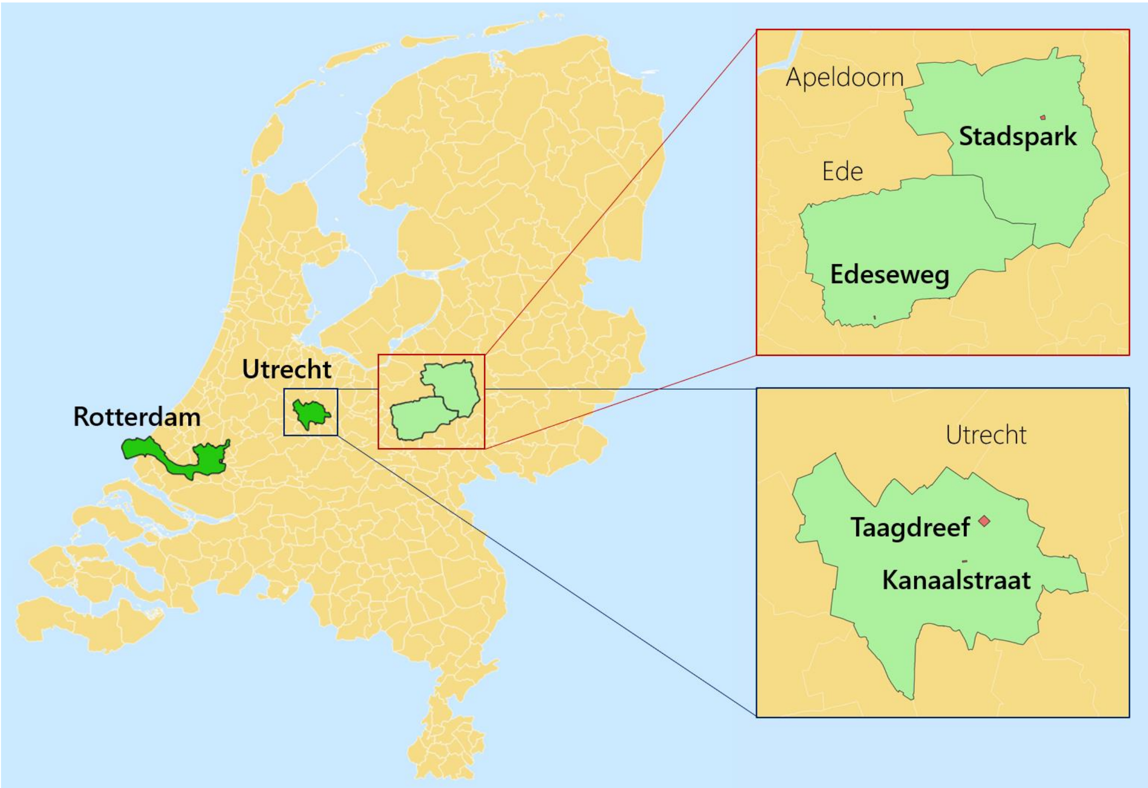

Figure 13 Showing a map of the Netherlands with the location of the case study areas

3.2.3. Policy documents analysis

Policy documents such as municipality mobility plans and climate adaptive street designs were analysed to give in-depth insight and provide data for the case analysis. The exact type of policy documents analysed differed for each case and spatial scale. City scale cases roughly estimated the area available for climate adaptation by interpreting municipal mobility ambitions. This is mostly found in municipal policy documents, such as the mobility vision (*mobiliteitsvisie*) or municipal sewage plan (*gemeentelijk rioleeringsplan*).
On smaller spatial scales online available policy documents, such as urban development plans or specific street designs (*voorlopig ontwerp*), were analysed to give a more detailed view on how streets or neighbourhoods will be redesigned.
Data was extracted from the policy documents based on a coding framework of recurring themes: 'mobility objectives', 'mobility expectations', 'climate adaptation objectives' and 'climate adaptation measures'. An overview of the analysed policy documents per case is included in Appendix A. The most important findings are listed in each case study description in chapter 4.

3.2.4. Interviews

This research method was used to gain insight in the perspectives of professionals involved in the mobility transition, climate adaptation or urban planning. In this subsection the selected interview survey method, participant selection process, data collection and analysis are discussed. For each case study, an attempt was made to conduct an interview with an employee of the relevant municipality. In the end, 7 participants from different municipalities and fields of expertise participated in the study.
Data extracted from the interview survey was used in the case studies. This was done in two ways, firstly as input for the design scenarios within a case and secondly the interviews were used to reflect on the study results.

Interview survey method
A flexible interview method was chosen due to the complexity of, and possibly widely diverse views on the research topic. Performing qualitative semi-structured interviews provided sufficient opportunities to notice and explore these views, while simultaneously maintaining consistency across the cases (Adams, 2015). According to Adams (2015) this research method follows a four step approach. Fist sufficient knowledge about the topic should be gained. Second, an interview guide with flexible and open questions should be drawn up. Third, the interviews should be performed with carefully selected participants. Finally, gathered data and information should be analysed and presented. This design is represented in Figure 14.

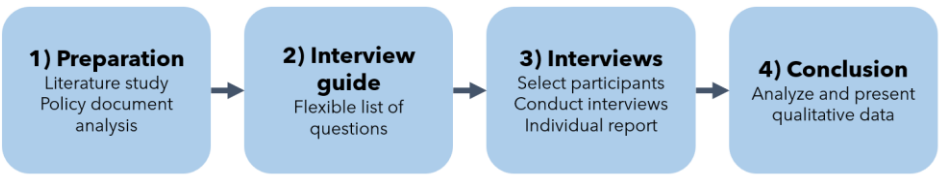

Figure 14 Interview survey design, schematic overview

Participant selection

Interviewees were approached trough the network of the involved supervisors[7]. In some cases, the initial contacts suggested to interview one of their colleagues, as they expected that these participants would better match the research criteria. This is also known as 'snowball' sampling (Parker et al, 2019). Relevant stakeholders who could provide information to the case study research were invited to participate in the study. Eventually seven professionals participated. Tabel 3 shows the interview survey participants, their expertise and the municipality where they work.

Tabel 3 List of interviewees

Interviewee (#)	Expertise	Municipality
1	Urban planning	Rotterdam
2	Water management and climate adaptation	Apeldoorn
3	Ecology and climate adaptation	Apeldoorn
4	Mobility	Apeldoorn
5	Urban planning	Apeldoorn
6	Water management and climate adaptation	Utrecht
7	Climate adaptation	Ede

Data collection and analysis

An interview guide with open-ended questions was developed according to the methods described by Kalllio (2016). The questions explore the participants' views on green mobility, climate adaptation and BGI and their perceptions on the relationship between the mobility transition and climate adaptation. The interview guide, containing the basic list of topics discussed and questions asked is included in Appendix C. For each participant some questions were added that were relevant for the specific case, based on policy document analysis or previous interviews. Prior to the interviews, information about the study was sent by email and informed consent was obtained from each interviewee. Handwritten notes were taken during the interview. A paraphrased summary of each interview was prepared after the interview and shared with the interviewee. The data were only used in the study after the interviewees had given their approval. For data analysis, the collected interview results were coded according to four themes: 'mobility transition', 'climate adaptation', 'challenges for climate adaptation' and 'opportunities for climate adaptation'.

[7] Mostly though the network of the graduation internship company Ambient B.V.

3.2.5. Scenarios

To explore different future possibilities of the green mobility transition and its potential for BGI, a (design) scenario analysis was carried out. This research strategy, which actively employs designing within the research process, is also known as a 'research through design' (RtD) method (Lenzholzer *et al,* 2013).
The same general approach was applied for each case, in order to keep the cases consistent and comparable. This approach is schematically shown in Figure 15. At least the existing situation (Scenario 0) and two mobility scenarios (Scenario 1 and 2) were analysed. If scenario 2 did not meet the climate adaptation goals, an additional third scenario, which attempted to meet the policy goals and ambitions, within the conventions of the case study, was analysed. If a proposed redesign for a specific street or neighbourhood was available this functioned as either scenario 1 or 2, depending on the mobility measures applied (either parking space or road width reduction, or both).
Even though this approach was applied for each case, the cases were intrinsically different. The methods used differed by spatial scale and are described below, in addition to which each case (design) scenario was based on specific conditions, such as the objectives, ambitions and expectations of the municipality. This information was obtained through an analysis of policy documents and the interview survey.

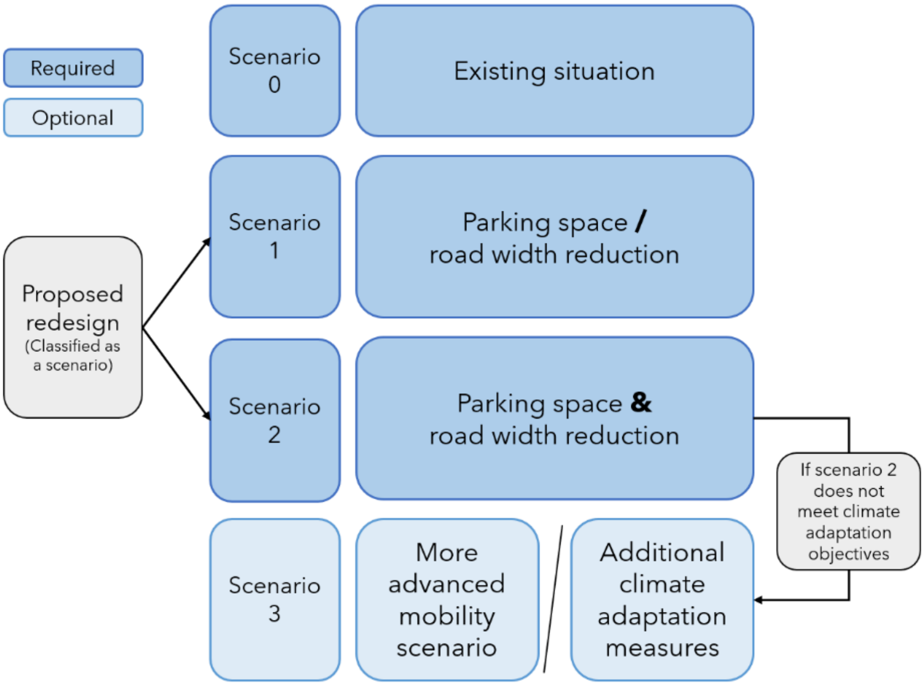

Figure 15 Schematic overview showing the basic principles for scenario design

For each mobility scenario, the implications for climate adaptation or the possible implementation of BGI was assed. In addition, it was determined whether applicable climate adaptation goals were met. On a city and neighbourhood scale the possible amount of green area was examined. For the scenarios on a street level both the amount of green area and the water storage capacity was calculated, in order to examine storm water resilience. The technical method for this examination is described in section 3.2.6.

3.2.6. GIS analysis or Water balance

For each scenario a GIS analysis was applied. The software QGIS was used, which is an open source geographical information system (QGIS, 2023). Relevant geospatial data was collected from multiple sources. Mainly PDOK data was used to find land use data from the study area such as road areas, buildings, etcetera. Some applicable datasets were Top10NL and the BGT. The QGIS software was used to analyse and visualise the data by creating aerial view images of each scenario and calculating the area per surface type. In the street scale case studies, cross sectional views were made based on these aerial images. The further processing and analysis of the data differed according to the spatial scale of the case and is described below.

City scale

At this spatial scale the potential for BGI was assessed, by estimating the area that could be used for BGI due to a changed mobility. This amount of area was added to the existing green area, in order to asses if this could be sufficient to reach the climate adaptation goal (amount of green space) of the municipality. The current amount of green area in each case is known and the data collected by the Klimaateffectatlas (2023) is used, which is part of the national Delta Plan on Spatial Adaptation. This data set uses satellite imagery in the summer to determine the amount of green space in aerial view and differentiates between grey (paved), low green and trees. A differentiation is also made between types and functions of areas such as public space, private space, roofs and water. This is done by taking multiple national data sets as input, such as the BRK (cadastral plots) and Top10NL (Basic Topographical Registration).

Each scenario results in an amount of grey area, previously used for cars, that can be transformed into green. This area is added to the already existing green area per neighbourhood in the municipality. The percentage of green public area in each neighbourhood is calculated according to Equation 1, the method used by the Klimaateffectatlas (2023).

Equation 1 estimates the percentage of green area per neighbourhood

$$Green\ area\ (\%) = \frac{A_{public\ green} + A_{public\ trees} + A_{public\ transformed}}{A_{public} + A_{public\ trees}} * 100\% \quad (1)$$

The three scenarios were defined based on the approach described in section 3.2.5. The application of this approach on city scale is described below, per scenario.

Scenario 1

According to Figure 15, scenario 1 applies either parking space removal or road width reduction. In the city scale scenarios parking space reduction was chosen. The amount of parking spots that were estimated to be reduced was based on policy documents and interviews.

A public parking spot has to be at least 2.5m wide and 5m long (NEN, 2013), thus a parking spot has a minimum total surface area of 12.5 m^2. It was assumed that the parking spaces will be removed proportionally over the public area in neighbourhoods where less than 40% is green, as seen from above.

Scenario 2

The second scenario combined parking spot removal and road width reduction. Because cars claim relatively more public space compared to the other transportation forms, a change in mobility could lead to a surplus in public area which could be used for BGI. Cars, public transport and bicycles demand on average 29.4, 7.4 and 5.4 m^2 of traffic space, respectively (Brunner *et al,* 2018). Comparing the current model split to the estimated model split in about 20 years resulted in a calculated percentage of less required road surface. This percentage was calculated according to Equation 2.

Equation 2 estimates the average percentage of road reduction

$$Road\ surface\ reduction\ (\%) = \frac{(\%_{cars,0} * A_{cars} + \%_{PT,0} * A_{PT} + \%_{Bikes,0} * A_{Bikes}) - (\%_{cars,1} * A_{cars} + \%_{PT,1} * A_{PT} + \%_{Bikes,1} * A_{Bikes})}{\%_{cars,0} * A_{cars} + \%_{PT,0} * A_{PT} + \%_{Bikes,0} * A_{Bikes}}$$ [8][9]

After the average road width reduction was estimated, this percentage was multiplied with the current road surface area per neighbourhood. The dataset containing the types of roads, size and location was downloaded on the open PDOK service. The BGT map (*Basisregistratie Grootschalige Topografie*) was used. This data set distinguishes between road types. Such as highways, regional roads and streets. Because highways, runways and other undefined types of roads are not likely to be changed or reduced in size, only the main roads, local roads and streets are considered in this study. These types of roads will be used to calculate the amount of relocatable public space, which can be turned into green area, according to Equation 3. The percentage of green area per neighbourhood was calculated according to Equation 1.

Equation 3 estimates the amount of transformed road surfaces per neighbourhood

$$A_{public\ area\ transformed} = \%_{Road\ surface\ reduction} * (A_{main\ roads} + A_{local\ roads} + A_{streets})$$

Scenario 3

The third scenario is the most utopian scenario. The amount of parking places removed and percentage of road surfaces transformed was estimated based on the previous scenario and interviews. These percentages were larger than estimated in scenario two and resulted in neighbourhoods with the highest percentage of green area.

---

[8] Percentages are the share per transportation mode in de modal split. Subscript 0 indicates the current modal split and 1 the expected modal split.

[9] Areas per transportation mode area based on the demanded area (Brunner *et al,* 2018).

Assumptions

In the scenarios and calculations multiple assumptions had to be made in order to find the expected amount of public space that could be transformed. In this subsection the most important assumptions are listed and discussed.

- Reduction of parking spaces is assumed according to information from policy documents, interviews and the general trend in Dutch municipalities.
- It is assumed that parking spaces are removed in the urbanised part of the city, proportionally over the area of highly urbanised neighbourhoods with less than 40% green public surface.
- Change in ways of transportation is assumed according to the modal split as indicated in municipal mobility visions for 2040. A different modal split will result in a changed spatial claim, areas are assumed according to (Brunner *et al,* 2018).
- The BGT data set is used to determine the amount of public space occupied by roads. Only main roads, local roads and streets are included in the estimation. Highways, regional roads, park & ride locations and runways are excluded. Reduction in road area, because of a changing modal split is distributed proportionally over the current road surfaces.
- When determining the amount of greenery in the scenarios, no account is taken of the area of tree canopies, only low greenery is added. Because of this the percentage of green public area could be underestimated.
- Lasty, the utopian assumption is made that all transformed space is used for greenery.

Neighbourhood scale

In scenarios at this spatial scale the amount of green space, for multiple scenarios, was estimated in more detail. Maps showing the aerial view of the case study area and amount of green space per scenario were made with QGIS and shown in the results chapter. Available spatial plans or redesigns were analysed. This was used as a scenario and either fitted scenario 1 or 2 according to Figure 15. Depending on this classification one of the other scenarios was designed and analysed. Additionally a third scenario was added if scenario 2 did not meet the municipal climate adaptation goals.

Assumptions

The percentage of green area is accurately determined for each scenario using QGIS. The amount of green area is based on satellite images during summer, when tree canopies are the largest and this is assumed to be normative. It is assumed that, after the reconstruction of the neighbourhoods, tree canopy surface areas are as indicated in the proposed spatial designs. Even though it is known that it takes several years before tree canopies are full grown.

Street scale
Identical to the case studies on a neighbourhood scale, the proposed redesign of the street was classified as either scenario 1 or 2, according to Figure 15, depending on the specific design. According to this classification one of the other scenarios was designed and analysed. Additionally, a third scenario was added if scenario 2 did not meet the municipal climate adaptation goals, both in terms of percentage of green area and water storage capacity. For each scenario a top view street designs was made and is presented in appendix B, the area per surface type was calculated using QGIS, cross sections were made and the storage capacity of each design was estimated.

In the street scale case studies for each scenario a water balance was made in order to calculate the storm water storage capacity and examine water resilience. Part of the input parameter values were based on default values presented by STOWA (2019). Traditional sewer design capacity is assumed for both the combined and separated sewer systems, according to the traditional design storm with a 2 year return period (Bui08). This is about 22 mm/h sewer discharge and 8 mm sewer storage. Street storage capacity was assumed to be 30 mm. Hydrological data on BGI such as infiltration rates and storage capacity per surface type are presented in section 2.1.2 - Blue Green Infrastructure (BGI). This was used to make hydrologic assumptions for the water balance calculations and are presented in Tabel 4. It should be noted that the real infiltration capacity of these urban water storage and drainage facilities depends on many factors, such as the infiltration surface, permeability of the subsurface (k-value) and groundwater levels. Soil improvements are often required to guarantee desired infiltration capacities and the infiltration capacity is variable over time due to clogging, for instance (Stichting RIONED, 2019). The water balance with assumed hydraulic parameter values gives an estimation of the storm water storage capacity. Site specific conditions determine the actual storage capacity, this could require additional measurements and computations.

Furthermore, it was assumed that all stormwater is treated in the case study area, thus that there is no runoff into adjacent areas, and that no water evaporates. Specific information to estimate the water storage capacity is presented per case

Tabel 4 List of equations to calculate street storm water storage capacity

Storage type	Equation	Description
Sewer storage	V_{sewer} = 8 [mm] * A_{runoff} + 22 [mm/h] * A_{runoff}[10]	Storage capacity in the sewage pipes and discharge capacity to surface water through overflow.
Street storage	V_{street} = Average road depth [mm] * A_{road} (+Average road depth [mm] * $A_{parking}$)	Storm water that can be stored between road curbs in the street profile. Depends on curb height and road design. Parking spaces could be located between curbs and temporarily store water.
Unpaved area storage	$V_{unpaved}$ = 10 [mm] * $A_{unpaved}$ + 15 [mm/h] * $A_{unpaved}$	Minimum storage and infiltration of unpaved areas in the street profile.
Bio-retention system or Raingarden storage	V_{SUDS} = 150 [mm] * A_{SUDS} + 250 [mm/h] * A_{SUDS}	Average estimated storage and infiltration capacity of relatively small SUDS, such as a raingarden.
Permeable pavement storage	$V_{permeable}$ = 180 [mm/h] * $A_{permeable}$	Average estimated infiltration capacity of permeable pavements. Applicable under low-traffic roads and parking areas.

Assumptions

In order to calculate the water storage capacities and make a hydrological balance assumptions needed to be made. The most important assumptions are:

- The system is completely empty before the storm event occurs. Therefore, the full storage capacity of e.g. sewers and rain gardens can be used.
- The magnitude and intensity of the storm event is based on municipal climate adaptation goals, a rainfall event with an duration of one hour is selected to test the water resilience of the study area.
- Private gardens and roofs are disconnected from the street and the sewer. Therefore only rainfall in the public space needs to be processed.
- The climate adaptation measures and storage types are assumed to have a hydraulic capacity as indicated in Tabel 4. Even though it is known that these values are difficult to generalise and depend on specific conditions such as design and permeability of the subsoil. The hydraulic parameter assumptions were discussed with an expert of the thesis internship company.
- Lastly, no account is taken of the height profile of the street. The study area is assumed to be completely flat, without run-off from adjacent areas. Moreover, there will be no accumulation of water and the rainwater will be able to flow into the designated storage facilities.

[10] The total case study (public) surface area is connected to the sewage system

4. Case study results

4.1. City scale

4.1.1. Utrecht

With almost 370 thousand inhabitants Utrecht is the 4th largest municipality in the Netherlands (CBS, 2023). It is the fastest growing city of the Netherlands and expects to have a population of 455 thousand people in 20 years (Utrecht, 2021). The municipality of Utrecht has set the goal to ensure that all important facilities are quickly accessible for its residents, this is further specified in the mobility vision (Utrecht, 2021). The municipality of Utrecht has a total surface of 9925 hectares (CBS, 2014). The current percentage of green public surface area per neighbourhood is shown in Figure 16. On average 47% of the total public area of the municipality is green, as seen from above (Klimaateffectatlas, 2023).

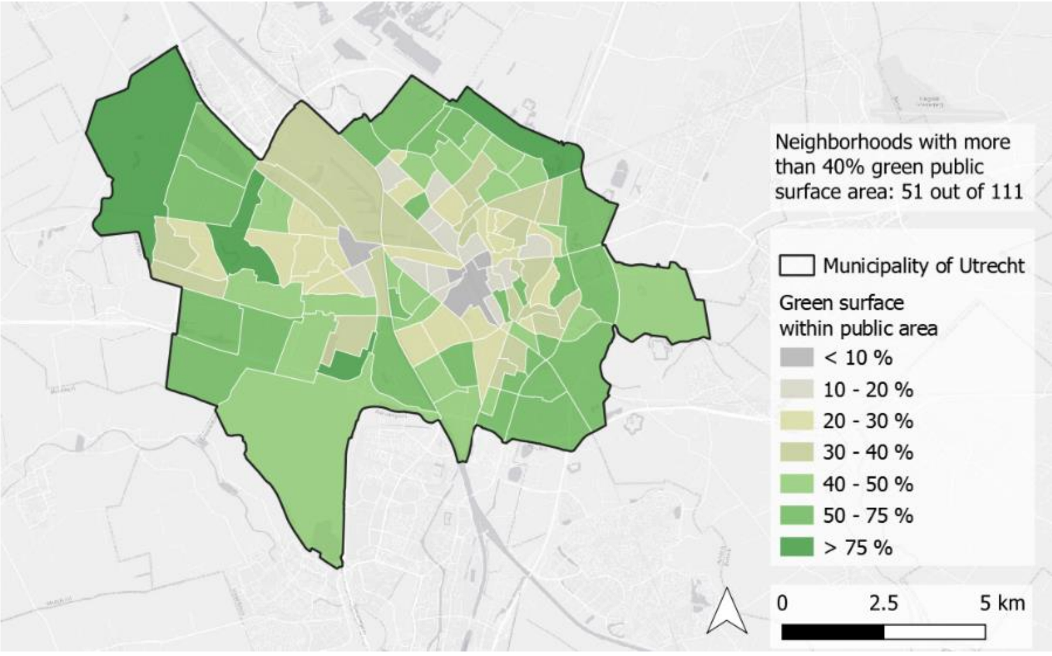

Figure 16 Percentage of green (greenery and trees) in the public area per neighbourhood in Utrecht (Sc0) (Data source: Klimaateffectatlas, 2023)

To show the Urban Heat Island effect in Utrecht and identify the places in the city which feel the warmest on a summer day, a heat stress map has been made by the municipality. Performing such a climate stress-test is an ambition of all Dutch governments expressed in the Delta Plan on Spatial Adaptation (2018). The map clearly shows the highest heat stress in the city centre, where the percentage of green is the lowest, according to Figure 17.

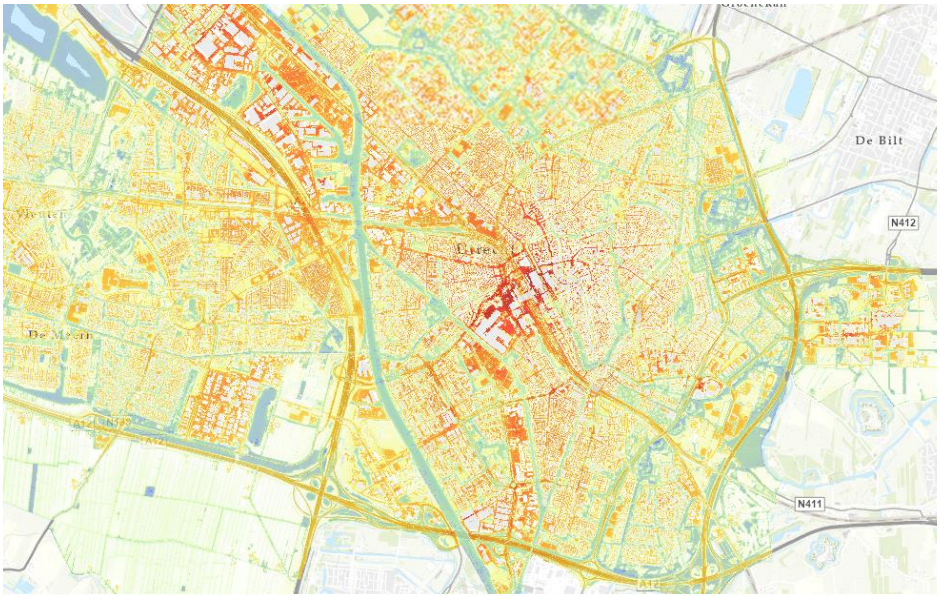

Figure 17 Heat stress map of Utrecht 2014 (Source: Gemeente Utrecht, 2023)

Information from policy documents

In the desk study policy documents, applicable to the case study (such as the mobility plan, urban planning strategy and municipal sewage plan) were found and reviewed. The information found in these mobility and climate adaptation documents is used to estimate the potential amount of freed space for climate adaptation in different mobility scenarios. Next to this the policy document analysis should give insights in the municipalities' climate adaptation goals, ambitions and actions and how the city of Utrecht translates the national DPSA into local policy. An overview of the policy documents that have been reviewed and applicable information, can be found in Appendix A.

The most important findings in terms of mobility expectations, goals and ambitions are:

- Remove 0.5% to 1.0% of the on-street parking spaces in the city each year.
- Roads in urban areas are transformed from 50km/h to 30km/h. This lowers the width requirement for roads and thus the total road surface.
- Share for each modality (Modal split); cars, bicycles and public transport is expected to change from 47%, 32% and 21% to 33%, 41% and 26%, respectively, by 2040.

The most important findings in terms of goals and ambitions for climate adaptation are:

- At least 40% green area (as seen from above), in every neighbourhood, for both public areas and private terrain, before 2050. (heat).
- Create a water resilient public space, by creating enough water storage capacity of the public space to prevent damage in case of an extreme precipitation event of 80 mm of rainfall within one hour. (pluvial flood).
- Store and use at least 90% of the yearly precipitation. (drought).
- Storage capacity of at least 15mm.

Scenarios

Based on the goals and ambitions specified in the policy documents and conversations with experts; three scenarios regarding expected mobility (in 2040) are defined. For each scenario different assumptions are made and some assumed parameters are chosen in a range of values leading to range in amount of reallocated space available for BGI.

1) Reduction of on-street parking spaces with 0.75% each year till 2040.
2) Reduction of on-street parking spaces with 0.75% each year till 2040 and a reduction of road surface area. The total road surface can be reduced by lowering maximum speed limits, narrowing roads and removing double lane motorways. The average road surface reduction is based on the change in modal split expected in 2040 as described in section 3.2.6.
3) Reduction of on-street parking spaces with 25% and a reduction of road surface area. It is assumed that 30% of the of the surface areas of roads that could be reduced in size will be transformed to green area. Reducing the current road surface can be achieved by multiple mobility measures, such as lane reduction, reduction of the maximum speed and narrowing roads, introduction of a one-way road policy, and more.

Results

How the effect of the three scenarios is calculated is described in the methodology section 3.2.6. The specific assumptions made for this case are described below and the result of each scenario is shown with multiple maps.

1) Scenario 1

Currently the municipality of Utrecht counts about 150.000 public parking spaces (autoweek, 2021). Removing 0.75% of these places on a yearly basis will lead to 12.0% or 18 thousand transformed parking spots in 2040. This leads to an increase of the total amount of green public area, as can be seen on Figure 18. On average 49% of the total public area of the municipality is green, as seen from above, this is an increase of 2 percent compared to the current situation. The number of neighbourhoods with more than 40% green public area does however not increase and remains 51 out of 111.

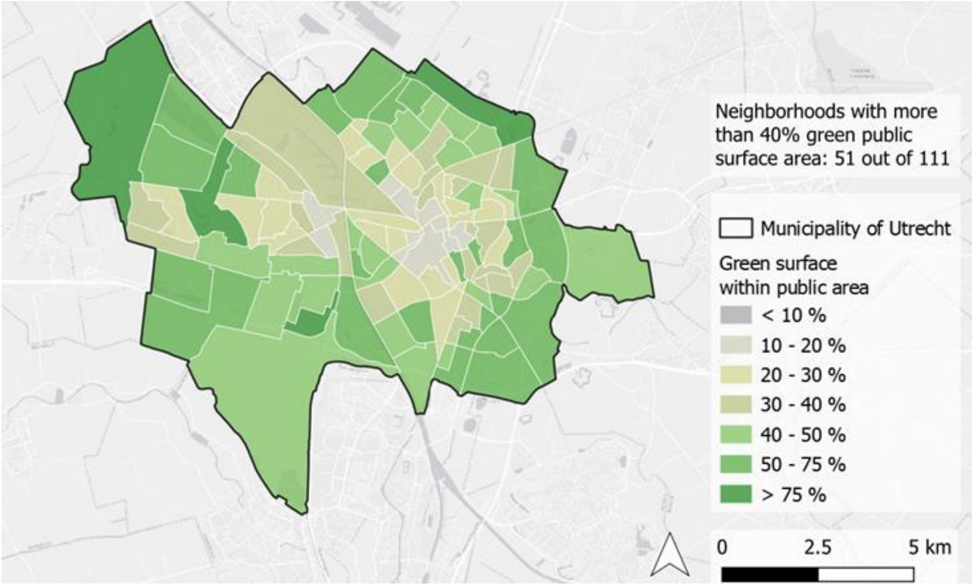

Figure 18 Percentage of green (greenery and trees) in the public area per neighbourhood in Utrecht (Sc1)

2) Scenario 2

The balance in transportation modes is expected to change in Utrecht and the municipality actively stimulates the usage of other forms of transportation than cars (Gemeente Utrecht, 2021). The share of trips made by car is expected to decrease and bicycle and public transport to increase. The previously mentioned expected mobility change (change in modal split) could result in 18% surplus road area. The complete road network of Utrecht is shown in Figure 19.

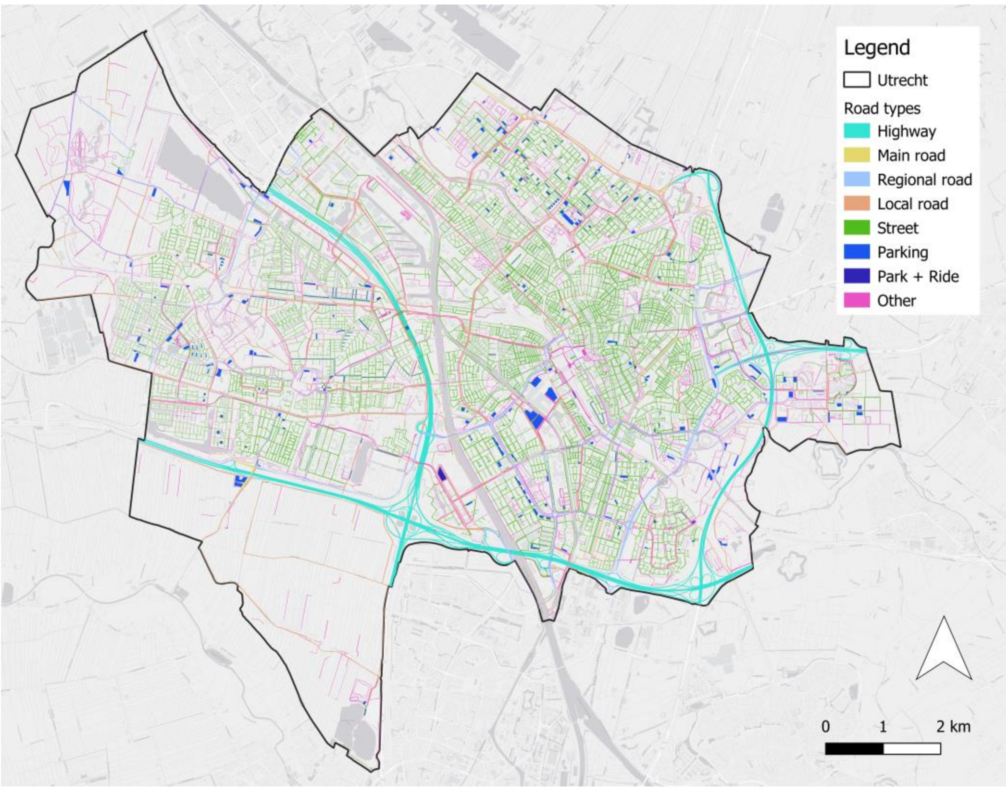

Figure 19 Shows the road network of Utrecht, divided in multiple categories. (Data source: PDOK, 2023).

The same reduction of parking spaces as suggested in scenario 1 is applied. Transforming these parking spaces and (part of the) road surface into green area will lead to a higher amount of green public area, shown in Figure 20. The average percentage of green public area, as seen from above, increases to 52%. The number of neighbourhoods meeting the climate adaptation target of 40% green space per neighbourhood rises to 67.

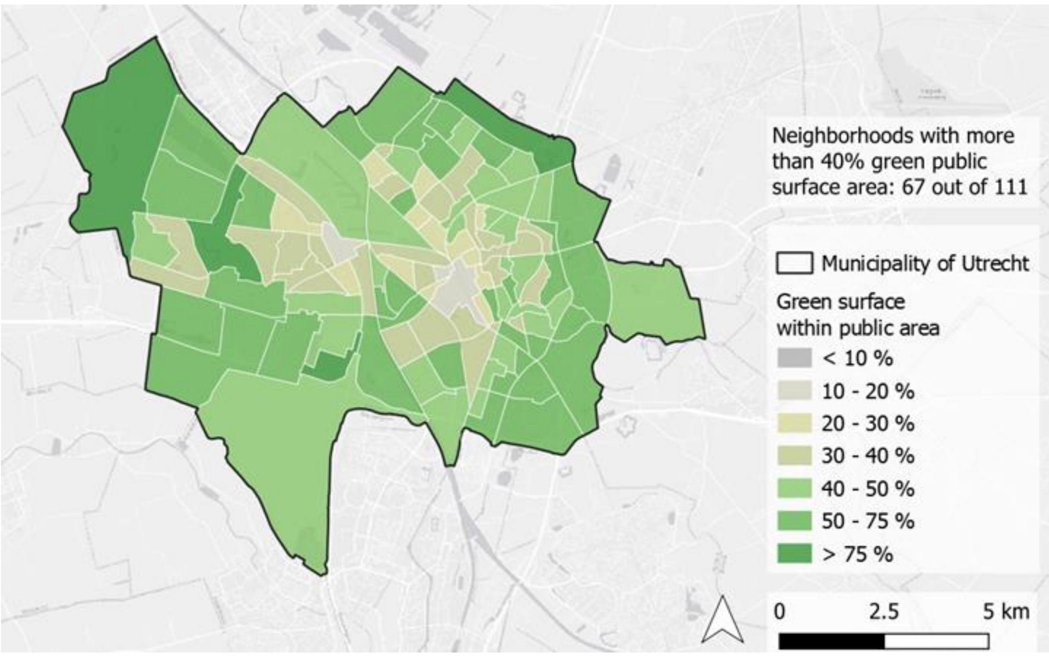

Figure 20 Percentage of green (greenery and trees) in the public area per neighbourhood in Utrecht (Sc2)

3) Scenario 3

This is the most utopian scenario in which a maximum reduction of parking space and transformation of roads into green area is assumed. 25% of the parking spaces will be transformed. The reduction of parking spaces and already expected change in mobility forms will lead to less need for road surface. Given the expected effect in scenario two, this scenario assumes 30% transformation of the current road area. Transforming this previously paved area into BGI will significantly contribute to reaching the climate adaptation goal of 40% green area in each neighbourhood. The amount of green public surface area in scenario 3 is shown in Figure 21. The average percentage of green public area in the whole municipality increases to 55%. The amount of neighbourhoods with more than 40% green area increases to 86 out of 111 . The percentage of green area in the city centre (about 30%) is significantly higher than in the current situation (about 15%).

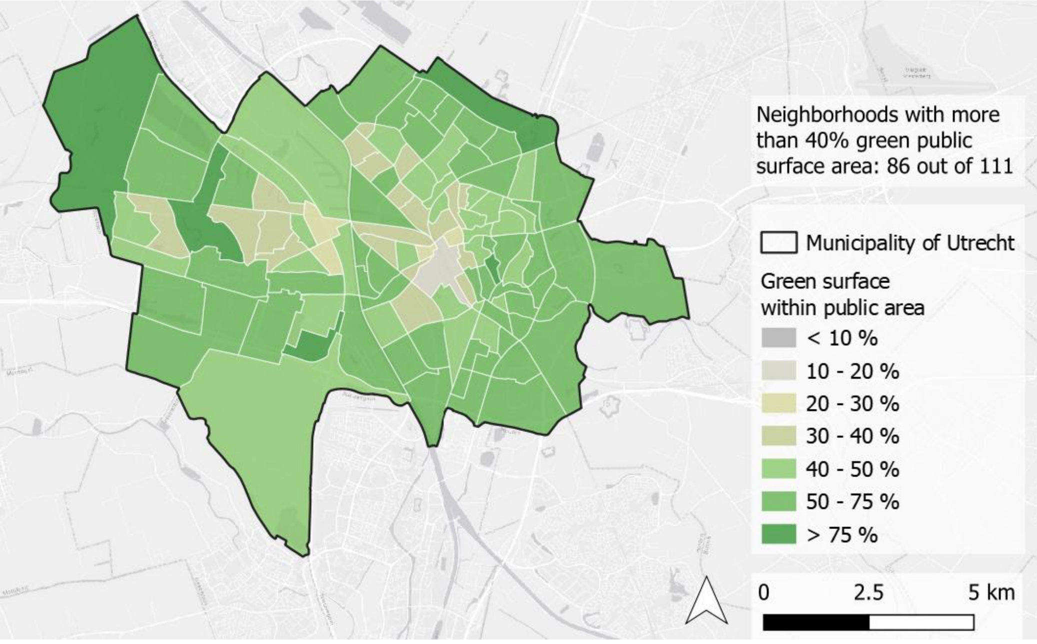

Figure 21 Percentage of green (greenery and trees) in the public area per neighbourhood in Utrecht (Sc3)

Additional remarks

Removing parking spaces in the paid parking zone comes at the expense of parking revenue. This is one of the objections to this mobility measure, which was mentioned in the municipal mobility vision. Parking spaces in city centres are often expensive and a substantial source of revenue for the municipality. This revenue loss has to be considered when transforming paid parking spaces into BGI.

Furthermore, redesigning the public space and adding this much greenery will be difficult to finance. The budget allocated for municipal water tasks alone cannot fully cover the costs of increasing greenery. In Utrecht, climate adaptation has now gained higher priority in mobility projects within the municipality compared to the past. As a result, certain projects such as adding greenery and trees can be financed with combined municipal fundings. There is ongoing consideration of establishing a separate funding mechanism, such as a green fund, to accelerate the implementation of climate adaptation measures.

4.1.2. Rotterdam

Having more than 660 thousand inhabitants, Rotterdam is the second largest city in the Netherlands. The city is home to one of the largest harbours in Europe and which consumes a large part of the total municipal area, 27579 hectares (CBS, 2014), is used for harbour related activities. Due to this history and the fact that the city was bombed during the second world war, destroying a large part of the buildings in the city centre, the city of Rotterdam has a unique character, unlike other Dutch cities. Restauration works were based on the architectural principles of modernism, creating areas with strictly separated functions and prioritized car traffic, neglecting the need for trees and green (Van der Hoeven, 2013).
An interview with a representative of the municipal urban planning department provided insight in the current urban planning policies and how these came to be. In 2005, urban design consultant Jan Gehl, advised the city of Rotterdam to create an attractive public space were people can meet each other, with room for cyclist, pedestrian and urban green (Bakker, 2017). This initiated a new planning paradigm for Rotterdam resulting in the "City Lounge" concept, which has now been replaced by the "Rotterdamse Mobiliteits Aanpak (RMA)". This led to the transformation of the Coolsingel, where space was created by transforming the 4 lane road to a 2 lane road. More projects like these are planned and are named "stadsprojecten". The mobility and planning visions are leading in these projects, space for car traffic will be limited and traffic will be diverted around the city centre as much as possible. A new balance in transport space is created with these projects, where more green space and climate adaptation can be incorporated as well.
Due to the high level of urbanization in Rotterdam the need for climate adaptation is urgent. Research showed that the nocturnal UHI in Rotterdam can be more than 7 K, on a summers night. During a summer day the temperature difference between downtown Rotterdam and the city parks is about 4 K, especially high-density urban areas with little greenery are prone to experience a high UHI effect (Heusinkveld, *et al.* 2014). In 2011, TNO, Deltares and the Wageningen university, among others, conducted a study on the UHI effect in Rotterdam at the request of the municipality. From this it followed that heat stress can be dangerous and potentially lethal in Rotterdam, in the current climate and projected climate scenarios. To counter the negative effects of heat stress, the report gives a number of no and low regret measures to apply at street level. These include reducing the paved surface and adding greenery, trees and permeable pavement (Gemeentewerken Rotterdam, 2011). Currently, most neighbourhoods in the centre of the city and the industrialized harbour have a low amount of green, this can be seen on Figure 22. On average 43% of the total public area of the municipality is green, as seen from above (Klimaateffectatlas, 2023).

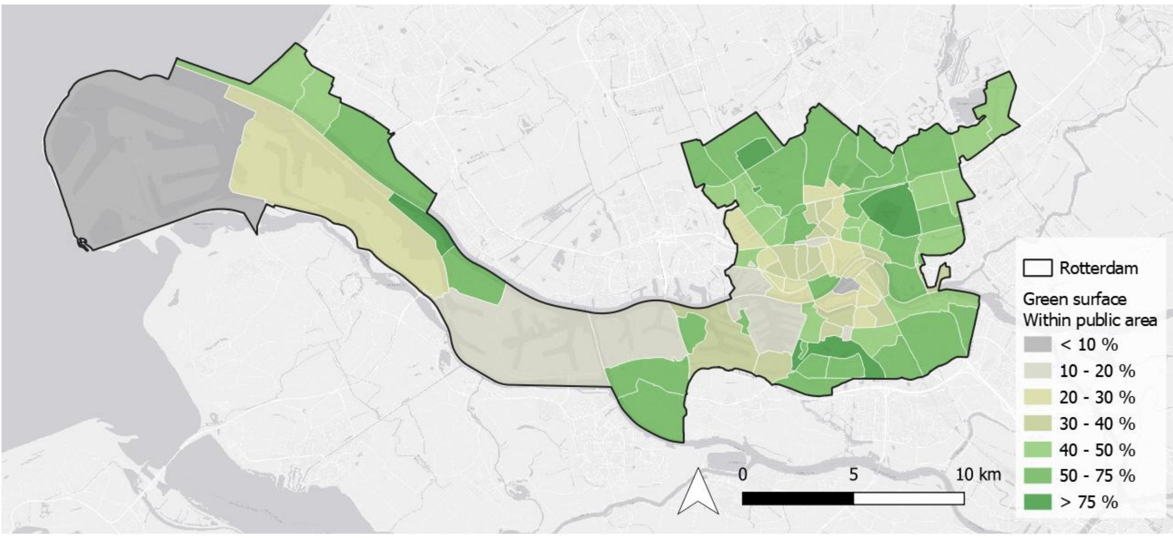

Figure 22 Percentage of green (greenery and trees) in the public area per neighbourhood in Rotterdam (Sc0) (Data source: Klimaateffectatlas, 2023).

Information from policy documents

In the desk study policy documents, applicable to the case study (such as the mobility plan, urban planning strategy and water vision) were found and reviewed. The information found in these mobility and climate adaptation documents is used to estimate the potential amount of freed space for climate adaptation in different mobility scenarios. Next to this the policy document analysis should give insights in the municipalities' climate adaptation goals and actions and how the city of Rotterdam translates the national Delta Plan on Spatial Adaptation into local policy. An overview of the policy documents that have been reviewed, the document type and applicable information found is given a table in Appendix A.

The most important findings in terms of mobility expectations, goals and ambitions are:

- Roads in urban areas are transformed from 50km/h to 30km/h, when possible. This lowers the width requirement for roads.
- Lower the car intensity in the city centre.
- Mobility share (modal split) for cars, bicycles and public transport is expected to change from 156, 121 and 114 to 139, 188 and 166 thousand number of trips per day, respectively.

The most important findings in terms of goals and ambitions for climate adaptation are:

- Realize 20 extra hectare of green
- Requirements for different normative precipitation events:
    - 20 mm/h: No water on the street, water retained in sewer
    - 48 mm/h: Little water on the street accepted
    - 70 mm/h: Water on the street accepted for a few hours. Damage or large-scale disruptions are not accepted.

Scenarios
Based on the goals and ambitions specified in the policy documents and conversations with experts three scenarios regarding expected mobility (in 2040) are defined. For each scenario different assumptions are made and some assumed parameters will be chosen in a range of values leading to range in the amount of reallocated space available for BGI for every scenario.

1) Reduction of parking spaces with 12%. Parking spaces will be removed in areas with a low percentage of green public area. The city of Rotterdam aims to reduce the amount of car traffic in the city centre. One way to do this is by reducing the available parking spots and offering suitable parking options on the edge of the city centre. The mobility vision states that realizing efficient P+R facilities and parking hubs are implemented to achieve this goal.
2) Reduction of parking spaces with 12% and a reduction of road surface area. The total road surface can be reduced by lowering maximum speed limits, narrowing roads and removing double lane motorways. The average road surface reduction is based on the change in modal split expected in 2040 as described in section 3.2.6.
3) Reduction of parking spaces with 25% and a change in mobility form leads to smaller and less road surface. It is assumed than 20% of the of the surface areas of roads that could be reduced in size will be transformed to green area. Reducing the current road surface can be achieved by multiple mobility measures, such as lane reduction, reduction of the maximum speed and narrowing roads, introduction of a one-way road policy, etc.

Results
How the effect of the three scenarios is calculated, which assumptions are made and how this could change the amount of green public space, is described below.

1) Scenario 1

Currently the municipality of Rotterdam gives room to about 250.000 public parking spaces. Of these, about 82 thousand are regulated (paid) on and off street parking places in the city centre (Mingardo, 2020). Therefore, it is estimated that the city of Rotterdam has roughly 200.000 public parking places. The former parking vision of Rotterdam defined the desire to remove 3000 on-street parking spots by 2020 (Gemeente Rotterdam, 2016). The cities former mobility vision describes that this measure is taken in order to allocate space for parking and all other spatial needs on street fairly (Gemeente Rotterdam, 2017). The shortage of parking spaces will be (partly) compensated by building new car parks and P+R facilities on the outskirts of the city. Removing 12.0% is equal to 24 thousand parking spots. Given that an average parking place is approximately 12.5 m^2 big, this provides an area of 300 thousand square meter (30 hectare) available for BGI. Thus, removing only 12% of the parking spaces in the municipality would offer enough space to be able to reach the goal of the city of Rotterdam to create 20 hectares of extra urban green space. Figure 23 shows that this change significantly increases the amount of green space in the most paved parts of the city. On average the amount of green space, as seen from above, increases to 43% over the whole municipality.

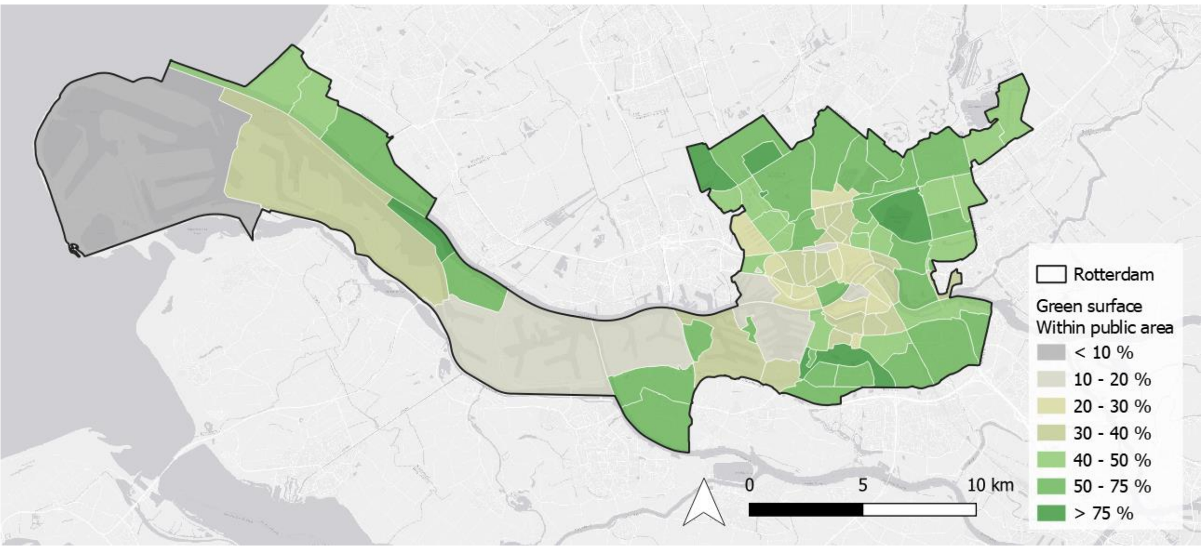

Figure 23 Percentage of green (greenery and trees) in the public area per neighbourhood in Rotterdam (Sc1)

2) Scenario 2

According to the mobility vision of Rotterdam (Rotterdamse Mobiliteits Aanpak) the most used modes of transportation are expected to change (Gemeente Rotterdam, 2020). Leading to a new modal split in 2040, as mentioned earlier. Biking will become the dominant transportation mode and the municipality is actively stimulating this trend. Because public transport and cycling use relatively less public space compared to cars, the total amount of space needed for transportation is expected to be roughly 8% less space in 2040. In Figure 24 the road network of Rotterdam is shown.

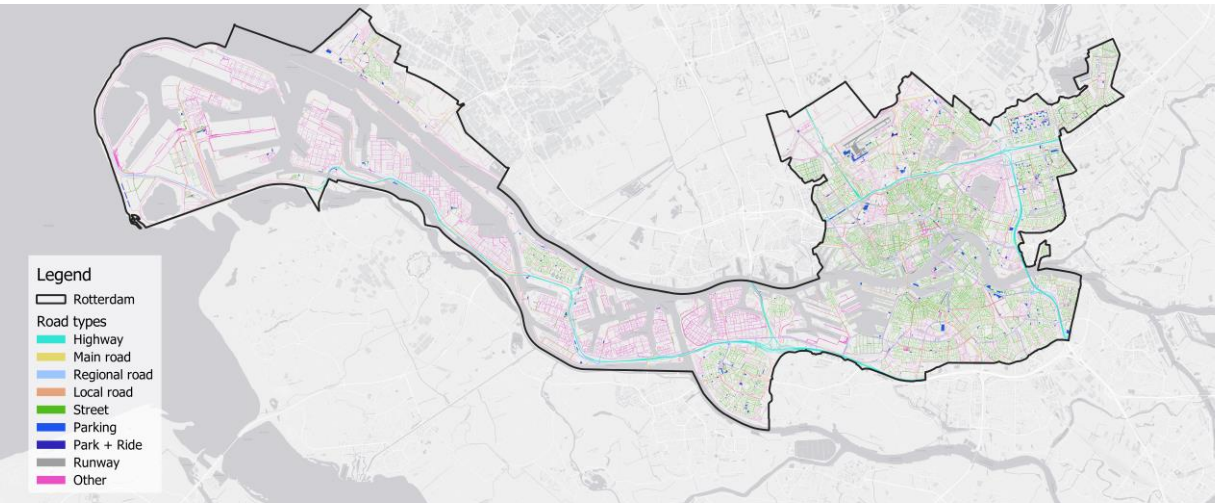

Figure 24 Shows the road network of Rotterdam, divided in multiple categories. (Data source: PDOK, 2023).

To estimate the potential for BGI, 8% of the current surface area of some of these roads will be transformed into greenery. The road types that are included in this estimation are main roads, local roads and streets. Transforming these paved areas drastically increases the amount of green area in most neighbourhoods, especially in and around the city centre as can be seen in Figure 25. The amount of green public area, as seen from above, is about 44% on average over the whole municipality.

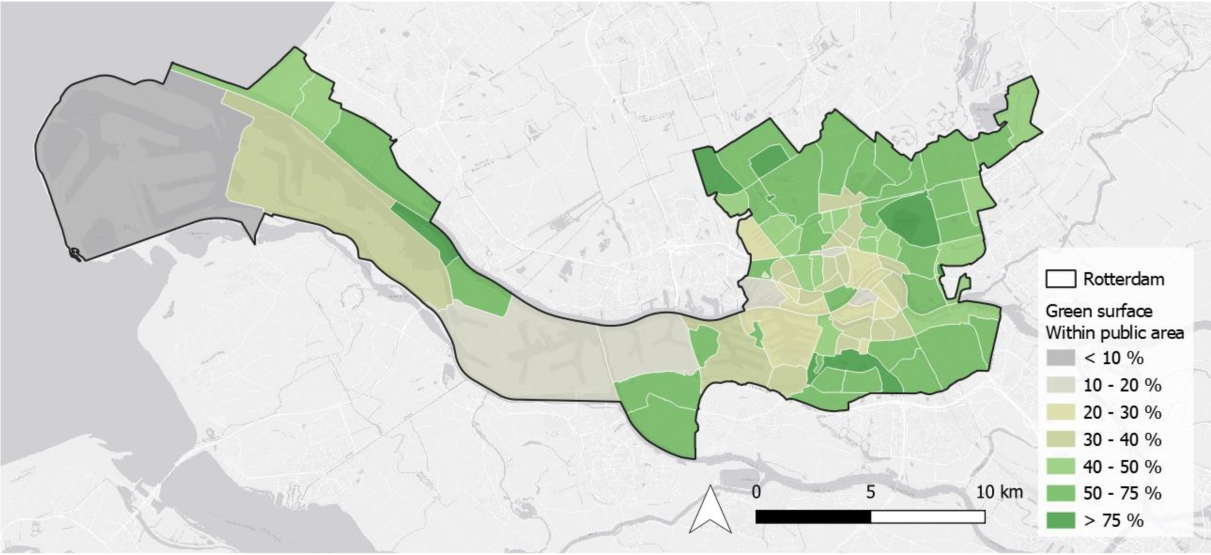

Figure 25 Percentage of green (greenery and trees) in the public area per neighbourhood in Rotterdam (Sc2)

3) Scenario 3

The most extreme scenario shows the effect of transforming 20 percent of the current road surface area and 25 percent of public parking spaces to greenery in the city of Rotterdam. As can be seen in Figure 26, this could drastically increase the amount of green public area in almost every neighbourhood. Except for the highly industrialized western part of the harbour (The Maasvlakte), there will be no neighbourhoods with less than 10% green public surface area. On average over the whole municipality the amount of green public area increases with 5%, compared to the current situation, to 47% in total.

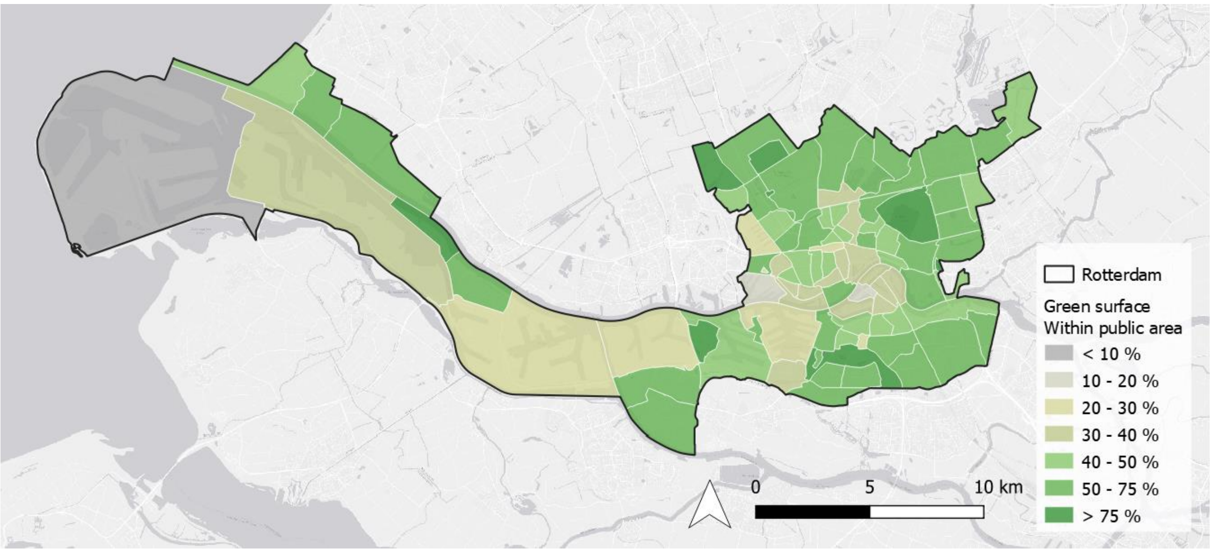

Figure 26 Percentage of green (greenery and trees) in the public area per neighbourhood in Rotterdam (Sc3)

Additional remarks

The Rotterdam case shows a distinct difference to the case of Utrecht especially in way of formulating the municipal policy documents. The mobility vision of Utrecht clearly expresses the intention to remove a certain amount of parking spaces, on the contrary the mobility vision of Rotterdam does not mention a policy on the removal of parking spots at all. During the reconstructions of the city centre car traffic has been prioritized and shifting from this paradigm, towards a higher priority for bikes and pedestrians, is sometimes met with resistance from the public opinion.

Rotterdam focuses on a few major infrastructural projects (Stadsprojecten). These projects combine mobility and climate adaptation and are quite costly. Total expenses were estimated to be 233 million Euros in 2020, which will be spent in the next 10 years[11]. Two years later the project costs were already estimated to be 80 million Euros higher[12]. The high costs makes the realization of these projects extra difficult.

Nonetheless, they show the potential for climate adaptation because of a change in mobility. For example, the new Hofplein plan, which will change from a traffic square into a green public area. This plan imposes an average reduction of sensible heat of 7 °C on hot days and creates an extra water storage capacity of 1200 m^2.


Visualizations of the new Hofplein, from above (Source: Gemeente Rotterdam)

[11] Source: https://www.nrc.nl/nieuws/2020/06/17/college-wil-233-mln-euro-investeren-in-zeven-grote-stadsprojecten-met-groen-a4003169 Accessed August 2023

[12] Source: https://www.rijnmond.nl/nieuws/1456290/grote-groene-stadsprojecten-gaan-rotterdam-bijna-80-miljoen-extra-kosten Accessed August 2023

4.2. Neighbourhood scale

In order to give a more detailed understanding of the potential for BGI because of a change in mobility, two case studies are performed on a neighbourhood scale. Conversations with experts suggested that different dynamics can be expected in a neighbourhood in a city centre or in a residential area. Therefore, two neighbourhoods with different typologies were chosen for this analysis. For each case the amount of green space in the current situation, the proposed design and possible other mobility scenarios are assessed. More greenery and trees improve the thermal comfort in a neighbourhood and is therefore an important climate adaptation measure.

4.2.1. Het Stadspark van Apeldoorn, Apeldoorn

The idea of a City Park for the centre of Apeldoorn has several motivations, including vacant retail premises in the city centre, a shifting focus towards residential function, a cluttered streetscape and heat stress on warm days due to excessive pavement (shown in Figure 27).

Figure 27 Heat stress map in the city centre of Apeldoorn (Source: Gemeente Apeldoorn, 2022)

To address these issues and respond to future challenges, a radical decision has been made to transform the city centre, with a central focus on green spaces. To achieve this, a different approach to mobility is required, reallocating the space currently used for cars to other purposes. To execute this ambitious plan and transform the whole city centre of Apeldoorn into a city park by adding more green, a phased approach is needed. The preliminary designs of the first three streets of the city centre are now ready and shown in Figure 28. This case study analysis focuses on these three streets as a part of the city centre of Apeldoorn.

The interview survey gave insight into the approaches used and the decisions made in the design process. The design will be made in accordance with the nature-inclusive and climate-adaptive (NIKA) guidelines as far as possible. This guideline prescribes, for example, that at least 40% shade should be provided in the planning area, preferably by means of tree crowns (Meijaard *et al*, 2022). Concrete climate adaptation requirements are not yet in place, but efforts are underway to establish a set of criteria for new construction and renovation projects regarding green spaces and climate adaptation. The goal is to achieve a minimum of 15% less pavement and work towards a minimum of 40% green area in redevelopment projects. Additionally, the public spaces should be able to withstand an extreme rainfall event of 60 mm in one hour.

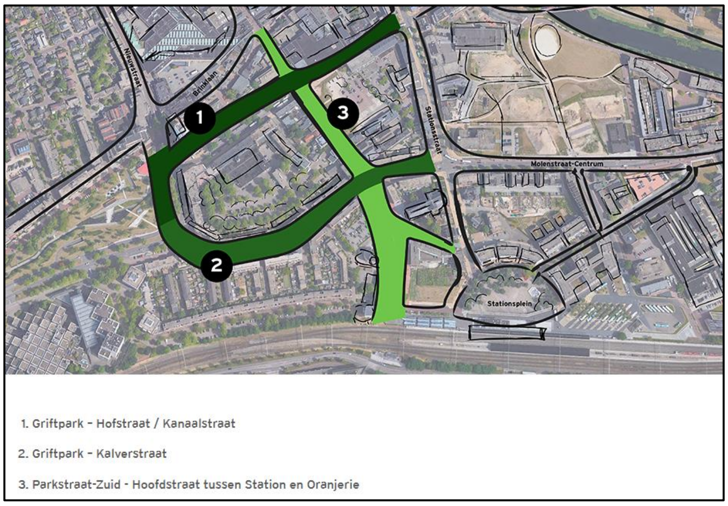

Figure 28 Outline of the first three streets of the city park of Apeldoorn for which a preliminary design has been made. (Source: Stadspark van Apeldoorn, 2023)

Information from policy documents

The preliminary designs of the first three streets of the new city centre are used in this case study. The amount of green space, which can be seen as an indicator of climate adaption, of the new spatial plans are assed. Next to the new designs other policy documents applicable to the case study area have been analysed. An overview of the applicable policy documents for the case of Apeldoorn that have been reviewed and applicable information found is given in Tabel 30 in appendix A.

The most important findings in terms of mobility expectations, goals and ambitions are:

- Create a car free city centre
- Redirect car and bus routes in the new city park
- Remove on street parking places and stimulate the use of the available car parks on the edge of the city centre

The most important findings in terms of goals and ambitions for climate adaptation are:

- Realize more greenery and trees in the new city park
- Realize at least 40 percent green area in aerial view, to mitigate heat stress.
- Create a water resilient urban space able to cope with rainfall with an intensity of 60 mm in one hour.

Scenarios and results

0) The existing situation

Currently the city centre of Apeldoorn is highly paved and does not have much greenery or green area as seen from above. This can be seen In the three streets selected in this case study in Figure 29. The total study area currently gives place to 66 parking spots. All streets are currently two way streets and are used mostly by through traffic. The total surface area of the study area is almost 3 hectares. The Hofstraat-Kanaalstraat is currently the street with the largest green area, about 19 percent of the area is green in aerial view. Parkstraat-Zuid, which is currently named Hoofdstraat, is the least green street in the area with only 6 percent of its surface according to Tabel 5.

Figure 29 Shows a satellite image of the existing situation (Sc0) of the study area in Apeldoorn outlined in red (Left) and indicates the current green areas (Right)

Tabel 5 Shows the characteristics of the streets in the study area in Apeldoorn in the existing situation (Sc0)

Street	Surface area (Public) (m²)	Parking spots (#)	Green area[13] (m²)	Unpaved area (m²)	Green (%)
Hofstraat - Kanaalstraat	9000	6	1700	270	19
Kalverstraat	9500	25	1350	1100	14
Parkstraat-Zuid	10000	36	550	550	6
Total	*28500*	*66*	*3600*	*1920*	*13*

[13] Green area in an aerial view

2) Preliminary design

The first visualizations of the Parkstraat-zuid. (Illustrator: Buro Sant en Co)

After months of intensive cooperation between urban planners, inhabitants, entrepreneurs and others the first designs for the city park of Apeldoorn have been made. In September and October 2022 research has been done to the preferences of stakeholders. This led to a few design criteria, most importantly was the addition of extra green (Gemeente Apeldoorn, 2023).
Subsequently these design criteria have been translated into a spatial plan the result can be seen in Figure 30. In this plan the Hofstraat-Kanaalstraat will turn in to a cycling street were only local or access traffic is allowed and a guest. Currently busses use this street, but they will be diverted to the Kalverstraat. The Kalverstraat will still provide room for cars driving both ways. The maximum allowed speed will be lowered to 30 km/h, which allows for a smaller road design. The new Parkstraat-Zuid will become totally car free maximum possible space to pedestrians, cyclist and greenery. The amount of green area increases to an average of 40%, this is equal to the equal to the climate adaptation goal, stated in the development outlook for the city park, in order to reduce heat stress.

Figure 30 Shows the preliminary spatial designs (Sc2) of the study area in Apeldoorn outlined in red (Left) and indicates the amount of green areas in the design plans (Right)

Tabel 6 Shows the characteristics of the streets in the study area in Apeldoorn in the preliminary design (Sc2)

Street	Surface area (Public) (m²)	Green area[14] (m²)	Unpaved area (m²)	Green (%)
Hofstraat – Kanaalstraat	9000	3100	2600	34
Kalverstraat	9500	4100	3700	43
Parkstraat-Zuid	10000	4300	3300	43
Total	*28500*	*11500*	*9600*	*40*

1) Preliminary design without parking place removal

Finally a scenario is analysed for which the lane width reduction is maintained, as suggested in the preliminary design, but the amount of parking spots available in the existing situation are brought back in the spatial design. This means that the 66 currently available on-streets parking spots have to be incorporated in the design of this scenario. Knowing that the Hofstraat - Kanaalstraat currently only provides room for 6 on-street parking spaces and because the street will be turned into a one-way street with a reduced road width, the proposed street profile does not provide enough space to add a large amount of parking places. The choice is therefore made to add 66 parking spots to the road design of the Kalverstraat. The space needed for this will come at the expense of greenery and trees on both sides of the road, which can be seen in Figure 31. This leads to a significant reduction of the percentage of green area in the street and almost 10 percent less green in the whole case study area according to Tabel 7.

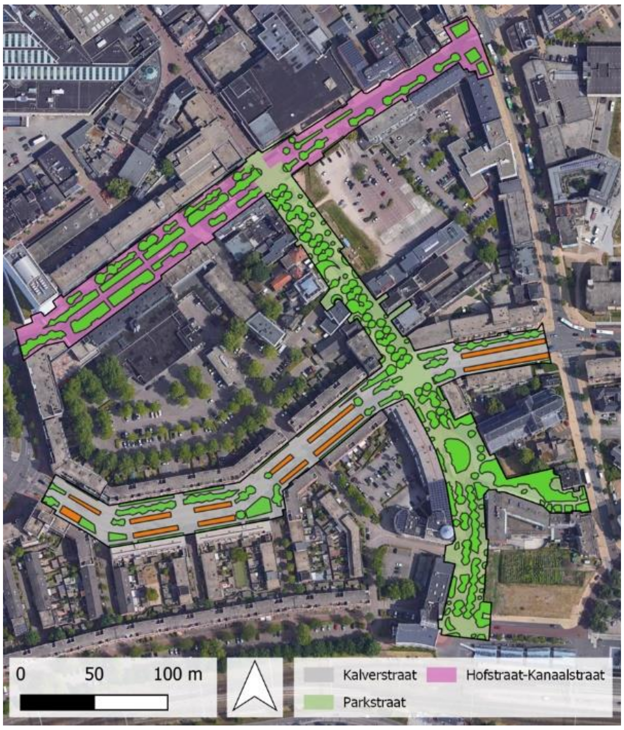

Figure 31 Indicates the amount of green areas in a scenario retaining the current amount of parking spaces (Sc1) in the study area in Apeldoorn. Parking lots are indicated - Brown, greenery and tree canopies - Green

[14] Green in an aerial view

Tabel 7 Shows the characteristics of the streets in the study area in Apeldoorn in the scenario of retained parking spaces (Sc1)

Street	**Surface area (Public) (m²)**	**Parking spots (#)**	**Green area[15] (m²)**	**Unpaved area (m²)**	**Green (%)**
Hofstraat – Kanaalstraat	9000	*0*	3100	2600	34
Kalverstraat	9500	*66*	2200	1800	23
Parkstraat-Zuid	10000	*0*	4300	3300	43
Total	*28500*	*66*	*9600*	*7700*	*33*

Additional remarks

Through an interview survey multiple barriers, which were encountered in the process of developing the plan for a new city centre, could be identified. The most important are summed up below.

Adding green space is not prioritized in the spatial planning process and is often seen as secondary to urban design visions. Therefore spatial planners usually incorporate elements needed for mobility, climate adaptation and green spaces in a primarily paved plan area. Secondly, the additional cost of greenery is sometimes overlooked and may lead to resistance from departments within the municipality responsible for maintenance. It is often unclear how maintenance expenses are to be covered and shared. Removing parking places may lead to resistance from car owners in the city centre and retailers who fear a loss of turnover due to the absence of a parking option right on their doorstep.

Lastly, organic shapes and greenery in street designs could make the street structure less clear and thus less accessible. Therefore it is important to take this in account during the planning process to ensure a social inclusive street design which is accessible and accommodating to people of all ages and abilities. Consider, for example, ensuring that streets remain accessible to people with disabilities, including wheelchair users and individuals with visual impairments, even if this is at the expense of the amount of green space.

The Apeldoorn case shows a major opportunity for adding more green spaces and BGI by banning car traffic, narrowing roads and moving parking facilities to the outskirts of the city. Lastly, it is worth noting that there are many areas within the city that are currently paved without a clear purpose. These "unused spaces" offer potential for green spaces and climate adaptation without compromising the area available for mobility purposes.

[15] Green in an aerial view

4.2.2. Taagdreef, Utrecht

The municipality of Utrecht has decided that the public spaces in the Utrecht neighbourhoods Kanaleneiland and Overvecht are in need of a quality improvement. The project in the Taagdreef neighbourhood functions as a pilot for the rest of the neighbourhoods and possibly the entire municipality. The project integrally improves public space and addresses several spatial tasks simultaneously. Lessons learned in terms of contracting, participation, design and realization will be used to develop other projects in the public space. The stated objectives for this project are a quality improvement in traffic safety, liveability and climate adaptation. A variant study was done in 2018 to determine how these goals can be achieved best. An optimal variant was chosen and, after participation of local residents, this variant was further developed into a preliminary design. This design was presented in early 2023. Tendering will soon be done and construction works are expected to start in 2024 and completed within two years.

The plan area is divided in three different types of streets; Molenwieken (Mill wings), Velden (Fields) and Randen (Edges). An overview of the redesigned public area can be seen in Figure 32. Each part has its own characteristics, the fields will be redesigned as a 15 km/h area, the rest of the neighbourhood will get a 30 km/h speed limit.

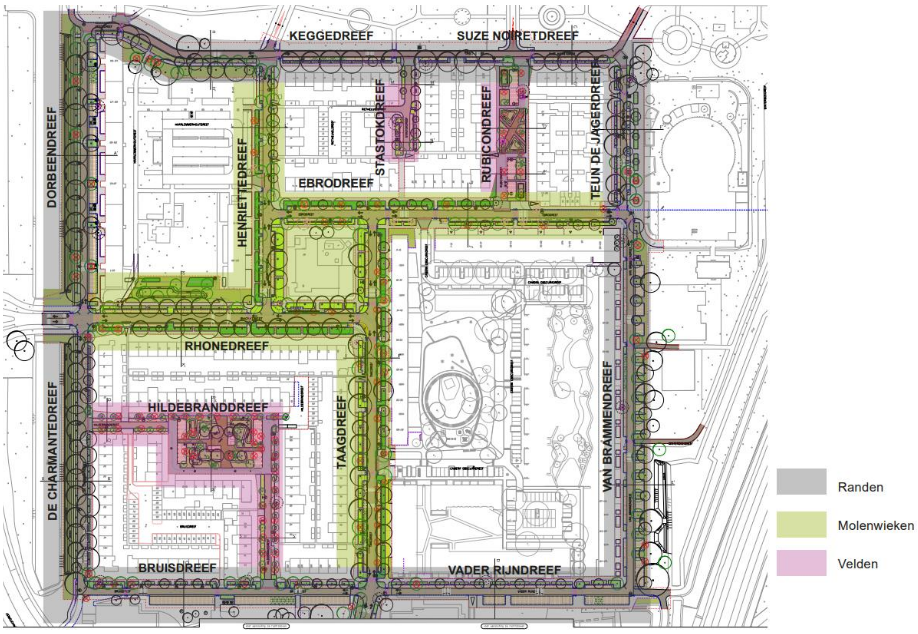

Figure 32 Outline of the Taagdreef neighbourhood area for which a preliminary redesign has been made. (Source: Gemeente Utecht, 2023)

Information from policy documents

A number of policy documents were analysed to identify the most important requirements and goals regarding mobility and climate adaptation. This includes the variant study, reactions from residents and a description of the preliminary design. A more detailed summary of the policy documents that were reviewed can be found in Tabel 32 in Appendix A. Additionally, the main climate adaptation goals within the municipality of Utrecht, based on subsection 4.1.1, are listed.

The most important findings in terms of mobility expectations, goals and ambitions are:

- Improve traffic safety; narrow roads and implement a speed limit of 15 km/h in the fields and 30 km/h in the rest of the neighbourhood.
- Currently a large amount of cars are parked unregulated on undefined parking places. Make sure that cars can be parked on official parking places after the neighbourhood is renovated.
- A parking pressure of up to 90 percent is accepted. This means that about 647 parking places must be realized in the area.
- Decrease the amount of paved area and asphalt in the neighbourhood.
- Roads are reconstructed of baked clinker bricks.
- Make the area accessible to everyone; wide enough sidewalks to ensure accessibility for people with disabilities and clear street layout for easy accessibility for emergency services.

The most important findings in terms of goals and ambitions for climate adaptation are:

- Realize more greenery and trees. Replace paved surfaces; wide roads and sidewalks and parking spaces with greenery unless pavement is needed.
- Infiltrate most of the stormwater through; less paved area and increased greenery, permeable pavements and applying infiltration sewers where possible.
- Realize at least 40 percent green area in aerial view, to mitigate heat stress.
- Maintain the sewage system and replace with a separated sanitary sewer and stormwater sewer (SSO).
- At least 40% green area, seen from above, for both public areas and private terrain.
- Water resilient public space, by providing enough water storage capacity, to prevent damage in case of an extreme precipitation event of 80 mm in one hour.

Scenarios and results

0) Existing situation

The residential area Taagdreef is designed in the 1950's and 60's as a car oriented neighbourhood, with plenty of space for standing and moving car traffic. Roads are constructed out of asphalt and about 9 meters wide. This gives a 50 km/h speed limit appearance and causes regular speeding and unsafe traffic situations in the area. There are about 730 formal and informal parking places in the area. Due to unmaintained and undefined street layouts, a lot of unregulated and incorrect parking is taking place, on the sidewalks for example. Due to the wide roads and abundance of parking spaces the amount of paved surface in the area is relatively large and the amount of greenery limited.
The amount of green area, as seen from above, is below the municipal ambition of 40%. About 26% of the Taagdreef is currently green, according to Figure 33 and Tabel 8. The low amount of green area leads to increased temperatures on warm days. The excessive pavement limits the infiltration capacity in the area, which leads to water shortages for trees in dry periods. As a result, a large number of the trees present are in poor condition.

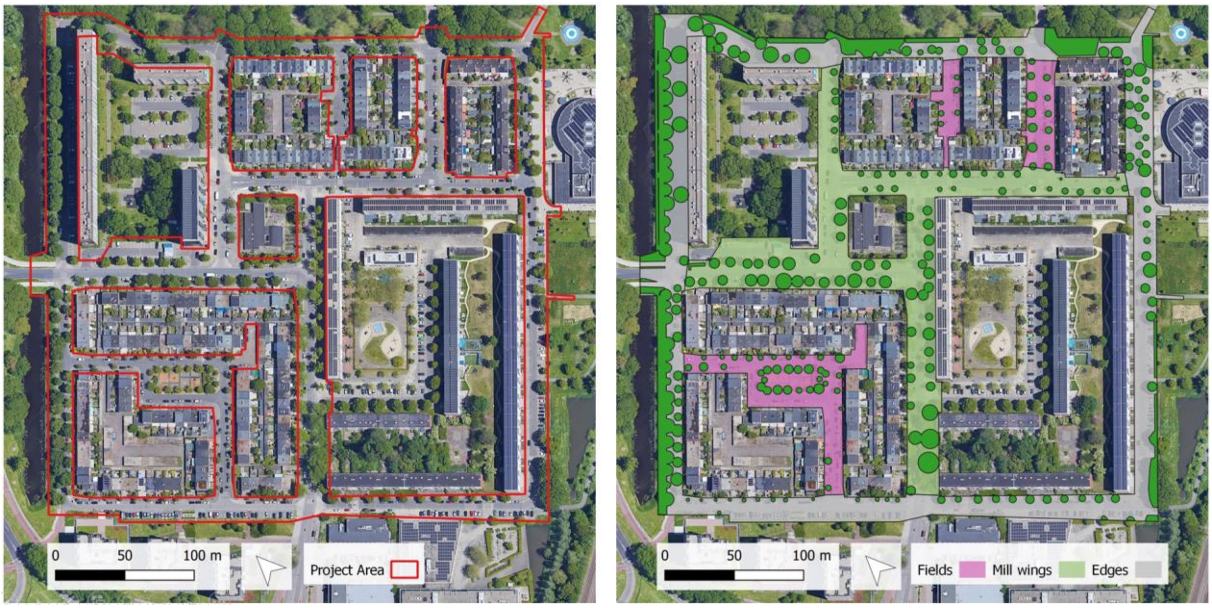

Figure 33 Shows a satellite image of the existing situation (Sc0) of the Taagdreef study area in Utrecht, outlined in red (Left) and indicates the current green areas (Right)

Tabel 8 Shows the characteristics of the sections in the Taagdreef study area in Utrecht in the existing situation (Sc0)

Section	Surface area (Public) (m²)	Parking spots (#)	Green area[16] (m²)	Unpaved area (m²)	Green (%)
Edges (Randen)	25400	377	8670	900	34
Mill wings (Molenwieken)	15200	179	2860	250	19
Fields (Velden)	7000	68	1000	200	14
Total	*47600*	*624*	*12530*	*1450*	*26*

2) Preliminary design

Since the Taagdreef redesign is a pilot project for the whole city, the design method and process has been well documented. First the main goals have been defined which are stated in the case description. Multiple design variants have been proposed of which the most effective one, to reach the design goals has been further developed into a functional design. The participation of residents was included in the design process, has been well documented and is openly available. In particular, the decision to increase greenery by reducing the number of parking spaces encountered resistance from neighbourhood residents.

In order to reach the predefined goals of the project; improve traffic safety and liveability and climate adaptation, the street layout has to be changed. The currently broad (9 meters wide) asphalted road takes up a large part of the study area. A new more suitable street

[16] Green area in an aerial view

design for residential 30 km/h roads is proposed. This is according to the CROW guidelines for bicycle streets (as mentioned in section 2.2.2. Policy documents explaining the mobility transition in the Netherlands). Roads are about 5 meters wide, cyclist bike on the same road as cars and pedestrians walk on an elevated sidewalk. To ensure accessibility for wheelchair users and visually impaired people these sidewalks must have a minimum width of 1.80 meters.

According to municipal policy and in order to create a better distribution of space utilization the total amounts of parking spots will be reduces. Additionally parking will be formalized, currently parking happens often at places not intended for parking purposes. A parking research has been performed and it was fund that at peak times a maximum amount of 564 cars were parked in the study area. Taking the maximum acceptable parking pressure in the municipality into account, it was decided that 569 parking spaces will be included in the redesign. This means a reduction of 55 parking spaces (9%). This allows for the removal of an obsolete car park on the Rhônedreef of 48 parking spaces.
The additional space that is created by this change can be used to add greenery and reduce the amount of paved surface in the study area. Rainwater will be stored and infiltrated though greenery at the parking strip on the side of the road and a few small scale bioswales or raingardens are included in the design of the study area. Part of the parking spaces will be constructed of permeable paving (grass concrete grid pavers) on the north west side of the edges of the project area. This is chosen so that water permeability is optimal and existing trees can be maintained. Throughout the entire area, 78 additional trees will be allocated. As a result of the design choses made in the proposed plan the total amount of permeable surface and greenery will quintuplicate from 1450 m^2 to 7250 m^2. The total green area from an aerial view will on average be more than 40%, according to Tabel 9, which in accordance with the ambition of the municipality.

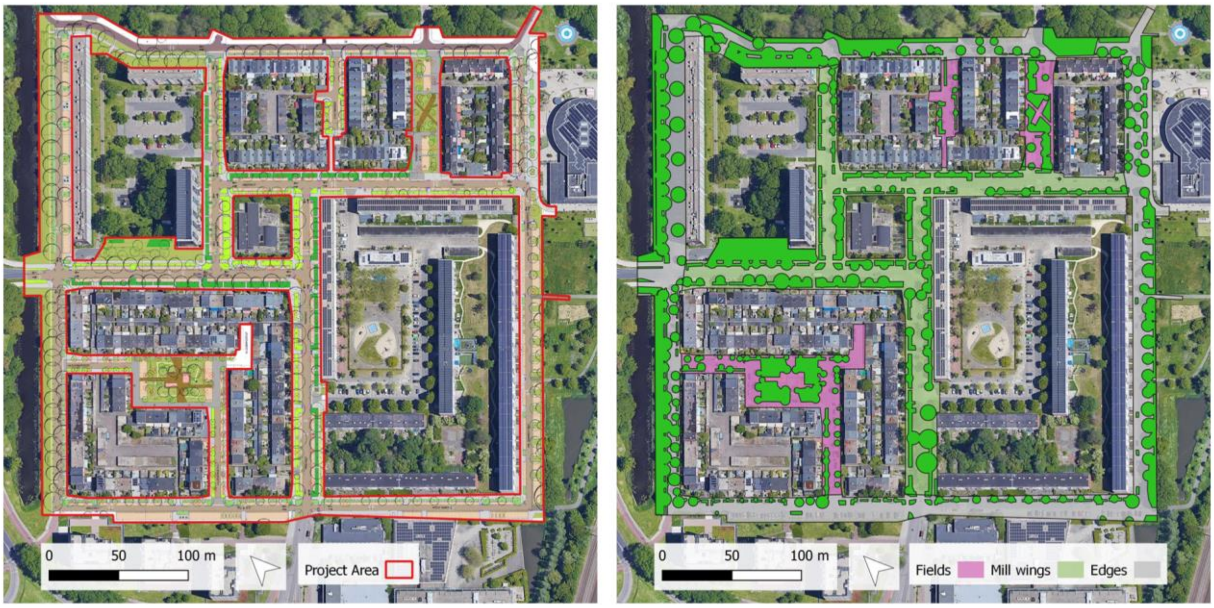

Figure 34 Shows the preliminary spatial design (Sc2) of the Taagdreef study area in Utrecht outlined in red (Left) and indicates the amount of green areas in the design plan (Right)

Tabel 9 Shows the characteristics of the sections in the Taagdreef study area in Utrecht in the preliminary design (Sc2)

Section	**Surface area (Public) (m²)**	**Parking spots (#)**	**Green area[17] (m²)**	**Unpaved area (m²)**	**Green (%)**
Edges (Randen)	25400	333	11570	2100	46
Mill wings (Molenwieken)	15200	170	6090	3300	40
Fields (Velden)	7000	66	2630	1850	38
Total	*47600*	*569*	*20290*	*7250*	*43*

1) Preliminary design without parking place removal

Lastly, a scenario in which the amount of parking places will remain the same as in the current situation and street layout is according to the proposed redesign, will be examined. This means that the preliminary design will be adjusted such that enough space will be available for a total of 624 parking spots. Therefore the car park on the Rhônedreef that gives space to 48 parking spots is maintained. Furthermore, 7 parking spots on the south east side of the study area will be added. The addition of these 55 parking spots is at the expense of the available space for greenery and trees. Figure 35 shows a decreased amount of green, that can be seen from above, compared to the proposed design. This also has the consequence that the municipal target of 40 per cent green space in public areas will be slightly underachieved in the study area according to Tabel 10.

Figure 35 Indicates the amount of green areas in a scenario retaining the current amount of parking spaces (Sc1) in the Taagdreef study area in Utrecht. Greenery and tree canopies are indicated in Green.

[17] Green area in an aerial view

Tabel 10 Shows the characteristics of the stections in the Taagdreef study area in Utrecht in a scenario with retained parking spaces (Sc1)

Section	**Surface area (Public) (m^2)**	**Parking spaces (#)**	**Green area[18] (m^2)**	**Unpaved area (m^2)**	**Green (%)**
Edges (Randen)	25400	340	11120	1960	44
Mill wings (Molenwieken)	15200	218	5030	2240	33
Fields (Velden)	7000	66	2630	1850	38
Total	*47600*	*624*	*18780*	*6050*	*39*

Additional remarks

From the case study in the Taagdreef neighbourhood several barriers can be identified. One of the main challenges found in the case study is the resistance encountered from neighbourhood residents, particularly regarding the decision to increase greenery by reducing the number of parking spaces. Secondly, residents expressed expected concerns about adding more greenery. These range from the expectation that it will be difficult to maintain, more clutter on the street and incorrect parking on green spaces.

Moreover, the case study gives more insight in how project objectives can be achieved. To integrally improve the neighbourhoods' public space, a number of key objectives have been identified, this helps in the discussion of the redesign. In order to finance the projects multiple funding sources are available. Combining municipal budgets of major maintenance, urban development, disconnection of hardened surface and traffic makes it possible to achieve the set objectives. Lastly, the Taagdreef project is designated as a pilot project, which presents an opportunity to apply the lessons learned from this pilot, including effective project management, community engagement and design in other projects. Properly documenting the process and examining different variants and solution options can help substantiate choices made.

[18] Green area in an aerial view

4.3. Street scale

To show the potential for BGI because of a change in mobility and how this could help to make cities climate adaptive, two detailed case studies on a street scale were conducted. Similar to the case studies on neighbourhood scale, study areas in both a residential neighbourhood and city centre are selected.

4.3.1. Kanaalstraat, Utrecht

The Kanaalstraat is the main street of the Lombok neighbourhood in Utrecht. It is a city street with many local stores and relatively busy traffic. A redesign of the street was desirable for several reasons. Cluttered streetscape, street harassment and traffic congestion were among the main causes mentioned. Traffic accident concentration in the street is high and chaotic situations often arise due to speeding and incorrect parking. Goals for the new street design include lowering the speed limit, more space for pedestrians and cyclists and more space for greenery. This offers opportunities for climate adaptation. The case study will discuss the current situation, the proposed design and two fictitious street layouts.

Information from policy documents

To develop a new street design, a number of policy documents were drawn up, these were analysed to identify the most important requirements and wishes regarding mobility and climate adaptation. A more detailed summary of the policy documents reviewed can be found in the Appendix A. In addition, the main climate adaptation goals within the municipality of Utrecht, based on subsection 4.1.1 and applicable to this case, are mentioned.

The most important findings in terms of mobility expectations, goals and ambitions are:

- One-way bicycle street with a 30 km/h speed limit and a combined with of 4.10 meter
- 15% to 30% of the parking spaces will be removed
- New parking lots will be on permeable pavement
- The "function strip" (Parking and greenery) will be 2.50 meters wide

The most important findings in terms of goals and ambitions for climate adaptation are:

- The street will be fitted with a sanitary sewer and stormwater sewer (SSO)
- At least 40% green area, seen from above, for both public areas and private terrain.
- Water resilient public space, by providing enough water storage capacity, to prevent damage in case of an extreme precipitation event of 80 mm in one hour.

Scenarios and results

A small area of approximately 3500 m^2 has been selected in the Kanaalstraat to perform a scenario based case study, an aerial view of the selected study area is shown in Figure 36. Because this study only focuses on the public space, gardens and roofs are excluded from the case study area. The total public part of the selected area is 2259 m^2. Four spatial designs are made and described below, the current situation, proposed redesign, a more far reaching mobility transition scenario and a scenario with additional climate adaptation measures. This was done according to the method presented in section 3.2.5.

Figure 36 Shows an aerial view of the case study area of the Kanaalstraat (outlined in red). (Source: Google Maps)

0) The existing situation

Figure 37, shows a street view of the Kanaalstraat. It can be seen that a large part of the street is paved. The road and parking spots are covered with asphalt, the sidewalks are made of concrete tiles. At the time this picture was taken the trees were already removed in preparation for street renovation. Due to the large amount of impervious (dark) surfaces and the little amount of greenery, the need for climate adaptation is high.

Figure 37 Street view of the Kanaalstraat, current situation. (Author's own picture)

A layout of the street, indicating each type of surface has been made using QGIS. This can be found in the Appendix B. From this the area and percentage of surface type has been calculated and presented in Tabel 11.

Tabel 11 Area per surface type in the Kanaalstraat - existing situation (Sc0)

Surface type	Area (m^2)	Percentage of total surface area (%)	Characteristics
Paved (Road)	670	29.7	Asphalt
Low	*475*		
Elevated	*195*		
Paved (Cycling path)	285	12.6	Asphalt
Low	*265*		
Elevated	*20*		
Paved (Parking)	235	10.4	Asphalt
Paved (Sidewalk)	1038	45.9	Pavers
Unpaved	31	1.4	Limited permeability
Green (aerial view)	*438*	*19.4*	
Total	*2259*	*100*	

A cross sectional representation of the current situation in the Kanaalstraat is given in Figure 38 Cross section of the Kanaalstraat – existing situation (Sc0). The street is about 18 meters wide, of which 6.80 meters are used for cars and cyclist on a separate bicycle lane on both sides of the road. Limited space is available for greenery and trees. A combined sewer is located under the road and cables and pipelines are situated under the sidewalks.

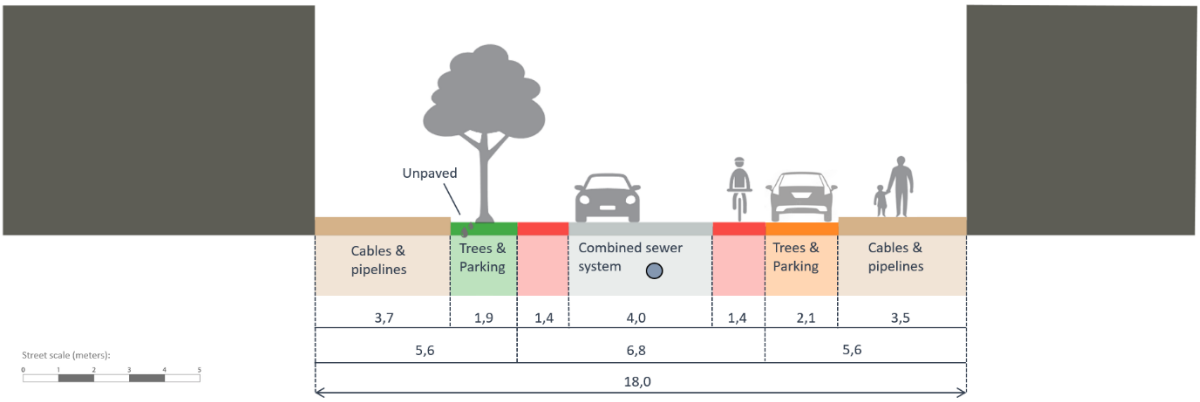

Figure 38 Cross section of the Kanaalstraat – existing situation (Sc0)

Calculated surface type areas and assumptions made, based the literature study, are used in a water balance. According to the method describe in section 3.2.6. For the municipality of Utrecht 70 mm/h rainfall is the normative storm intensity to test climate adaptation to pluvial flooding. This storm event is used in the hydraulic calculation to test whether the current storage capacity is sufficient. The results are presented in Tabel 12, this shows that in the existing situation a storage deficit of 83 m^3 or 36,7 mm occurs in the study area.

Tabel 12 Storage capacity of the Kanaalstraat - existing situation (Sc0)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 2259 m^2 + 22 mm/h * 2259 m^2 = 67,77 m^3
Street	V_{street} = 30 mm * 740 m^2 + 30 mm * 235 m^2 = 29,35 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 31 m^2 + 15 mm/h * 31 m^2 = 0,78 m^3
Total storage	V_{tot} = 67,77 m^3 + 22,2 m^3 + 0,78 m^3 + 5,28 m^3 = 97,8 m^3
Required storage	V_{req} = 80 mm/h * 2259 m^2 = 180,72 m^3
Storage deficit	180,72 m^3 – 97,8 m^3 = 82,9 m^3 = 36,7 mm

1) Proposed redesign

The reconstruction works of the Kanaalstraat have already begun and in the fall of 2023 the specific area considered in this case study, will be rebuild. Figure 39 shows a part of the new Kanaalstraat which has already been finished. The type of surface has been changed, asphalt is no longer used and the parking spot is made of permeable pavement. Space for greenery is very limited.

Figure 39 Street view of a renovated part of the Kanaalstraat. (Author's own picture)

A layout of the new street design, indicating each type of surface has been made using QGIS. This can be found in the Appendix B. From this, the area and percentage of surface type has been calculated and presented in Tabel 13.

Tabel 13 Area per surface type in the Kanaalstraat – proposed design (Sc1)

Surface type	Area (m²)	Percentage of total surface area (%)	Characteristics
Paved (Road)	686	30.4	Pavers
Low	*484*		
Elevated	*202*		
Paved (Parking)	222	9.8	Permeable pavement
Paved (Sidewalk)	1286	56.9	Pavers
Unpaved	65	*2.9*	Limited permeability
Green (aerial view)	*376*	*16.6*	
Total	*2259*	*100*	

A cross sectional representation of the proposed design of the Kanaalstraat is given in Figure 40. The road is transformed into a bicycle street, without a separate bicycle lane. The total width available for cars an cyclist is 4.10 meters. The parking space and greenery with is larger, 2.50 meters. Limited space is available for greenery and trees and at the cross sectional location no greenery is visible. A separated sanitary sewer and stormwater sewer located under the road and cables and pipelines are situated under the sidewalks.

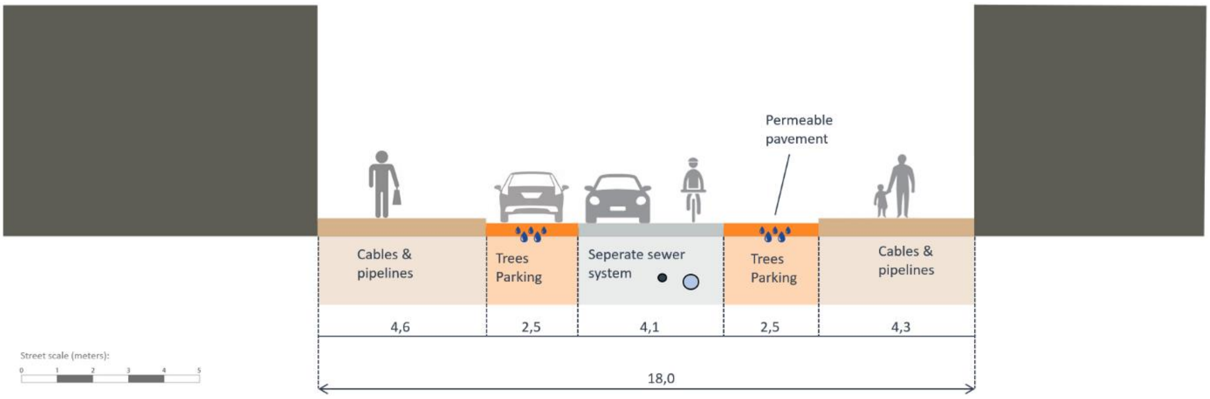

Figure 40 Cross section of the Kanaalstraat – proposed design (Sc1)

The water storage capacity of the proposed design of the Kanaalstraat is calculated and presented in Tabel 14. According to the assumptions made based on literature study and equations presented in this section, the storage deficit of the renovated street is 57 m^3 or 25 mm. Thus, more climate adaptation measures are needed in order to meet municipal climate adaptation targets. This will be discussed in scenario 2 and 3.

Tabel 14 Storage capacity of the Kanaalstraat – proposed design (Sc1)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 2259 m^2 + 22 mm/h * 2259 m^2 = 67,77 m^3
Street	V_{street} = 30 mm * 484 m^2 + 30 mm * 222 m^2 = 21,18 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 65 m^2 + 15 mm/h * 65 m^2 = 1,63 m^3
Permeable pavement	$V_{permeable}$ = 180 mm/h * 222 = 39,96 m^3
Total storage	V_{tot} = 67,77 m^3 + 14,52 m^3 + 1,63 m^3 + 39,96 m^3 = 130,54 m^3
Required storage	V_{req} = 80 mm/h * 2259 m^2 = 180,72 m^3
Storage deficit	180,72 m^3 – 130,54 m^3 = 50,19 m^3 = 22,2 mm

2) Proposed design + parking place reduction + raingardens

This scenario examines whether more space can be freed up for greenery by applying a more extreme mobility scenario. In the current situation, 12 parking spaces are present in the plan area, the redesign will include 10 parking spaces and in this scenario, half of the parking spaces will be removed (6 will be realized). The road width will stay the same as in the proposed street design. Extra removal of parking places gives the opportunity for more green space. The space freed up will be utilized by BGI, namely raingardens. Four additional trees will also be placed which will provide more shade and hence cooling.

A layout of the street design of this scenario, indicating each type of surface has been made using QGIS. This can be found in the Appendix B. From this, the area and percentage of surface type has been calculated and presented in Tabel 15.

Tabel 15 Area per surface type in the Kanaalstraat – proposed design + parking space reduction + raingardens (Sc2)

Surface type	**Area (m^2)**	**Percentage of total surface area (%)**	**Characteristics**
Paved (Road)	686	30.4	Pavers
Low	*484*		
Elevated	*202*		
Paved (Parking)	153	6.8	Permeable pavement
Paved (Sidewalk)	1286	56.9	Pavers
Unpaved	134	5.9	Rain gardens
Green (aerial view)	*605*	*26.8*	
Total	*2259*	*100*	

A cross sectional representation of design scenario 2 of the Kanaalstraat is given in Figure 41. According to the figure, the width of the bicycle street stays the same and for the parking places permeable pavement will be used. More tress and green are added and small raingardens are made (with a surface area of about 5 – 18 m^2) to better infiltrate and store stormwater.

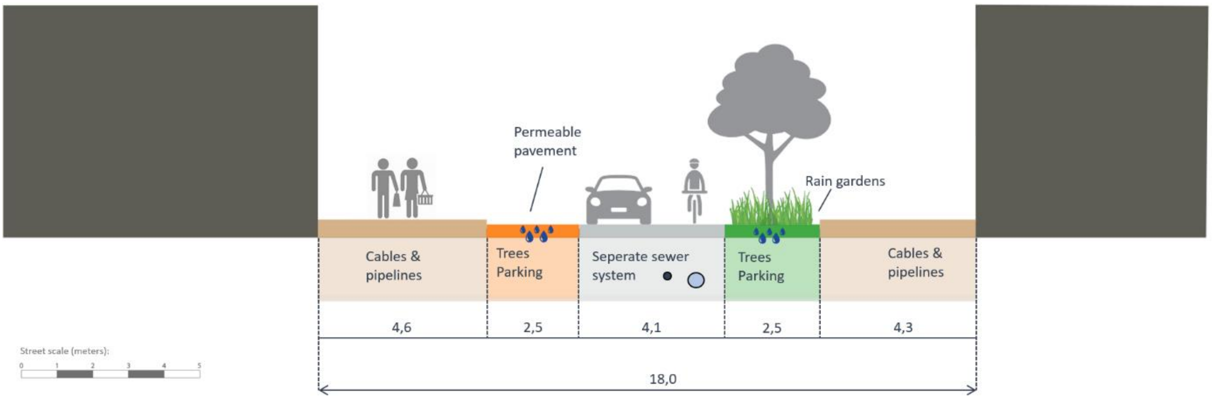

Figure 41 Cross section of the Kanaalstraat – proposed design + parking space reduction + raingardens (Sc2)

The water storage capacity of the scenario 2 design of the Kanaalstraat is calculated and presented in Tabel 16. According to the assumptions made based on literature study and equations presented in this section. The storage deficit of the proposed street design with additional removal of parking spots and added climate adaptation measures is 57,4 m^3 or 16,4 mm. The storge capacity of this street design approaches meeting the climate adaptation targets considerably better than the proposed redesign. Nonetheless, even with these extra measures there is still a storage deficit. In the next scenario it will be tested whether or not the climate adaptation goals can be met if additional measures in the private space are taken.

Tabel 16 Storage capacity of the Kanaalstraat – proposed design + parking space reduction + raingardens (Sc2)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 2259 m^2 + 22 mm/h * 2259 m^2 = 67,77 m^3
Street	V_{street} = 30 mm * 484 m^2 + 30 mm * 153 m^2 = 19,11 m^3
Raingarden	V_{SUDS} = 150 mm * 134 m^2 + 250 mm/h * 134 m^2 = 53,6 m^3
Permeable pavement	$V_{permeable}$ = 180 mm/h * 153 = 27,54 m^3
Total storage	V_{tot} = 67,77 m^3 + 14,52 m^3 + 53,6 m^3 + 27,54 m^3 = 168,02 m^3
Required storage	V_{req} = 80 mm/h * 2259 m^2 = 180,72 m^3
Storage deficit	180,72 m^3 – 168,02 m^3 = 12,7 m^3 = 5,6 mm

3) Proposed design + no on-street parking + added raingardens

As scenario 2, in which additional climate adaptation measures are taken, proves to be insufficient, this scenario examines whether completely omitting on-street parking spaces can ensure that the goals are met. A layout of the street design of this scenario, indicating each type of surface has been made using QGIS. This can be found in the Appendix B. From this, the area and percentage of surface type has been calculated and presented in Tabel 17.

Tabel 17 Area per surface type in the Kanaalstraat – proposed design + no on-street parking + added raingardens (Sc3)

Surface type	Area (m²)	Percentage of total surface area (%)	Characteristics
Paved (Road)	686	30.4	Pavers
Low	*484*		
Elevated	*202*		
Paved (Sidewalk)	1286	56.9	Pavers
Unpaved	287	12.7	Rain gardens
Green (aerial view)	*834*	*36.9*	
Total	*2259*	*100*	

A cross sectional representation of design scenario 3 of the Kanaalstraat is given in Figure 42. According to the figure, raingardens will be realized on both sides of the road. This will provide additional storm water storage and increase the infiltration capacity.

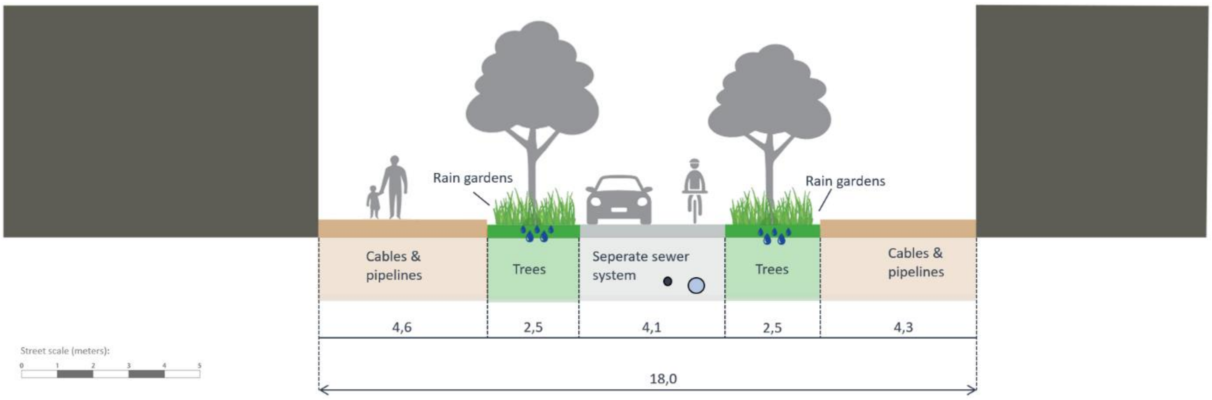

Figure 42 Cross section of the Kanaalstraat – proposed design + no on-street parking + raingardens (Sc3)

The water storage capacity of the 3th scenario design of the Kanaalstraat is calculated and presented in Tabel 18. According to the assumptions made based on literature study and equations presented in this section. The water balance indicates that the storage capacity of the study area will be sufficient to meet the municipal climate adaptation goals for pluvial flooding.

Tabel 18 Storage capacity of the Kanaalstraat – proposed design + no on-street parking + raingardens (Sc3)

Storage type	Equation
Sewer	V_{sewer} = 8 mm * 2259 m^2 + 22 mm/h * 2259 m^2 = 67,77 m^3
Street	V_{street} = 30 mm * 484 m^2 = 14,52 m^3
Raingarden	V_{SUDS} = 150 mm * 287 m^2 + 250 mm/h * 287 m^2 = 114,8 m^3
Total storage	V_{tot} = 67,77 m^3 + 14,52 m^3 + 114,8 m^3 = 197,09 m^3
Required storage	V_{req} = 80 mm/h * 2259 m^2 = 180,72 m^3
Storage surplus	197,09 m^3 - 180,72 m^3 = 16,37 m^3 = 7,25 mm

Additional remarks

The scenarios provide insights into some of the opportunities and challenges for the implementation of BGI. In addition, the case was discussed with an urban water professional from the municipality of Utrecht. From this, the following understandings followed.

The case study shows that the mobility transition can significantly alter urban land use. Areas previously occupied by cars are reused. For example, in the redesign of the Kanaalstraat, the extra space gained from reducing car usage allows for a wider sidewalks, improving walkability and accessibility. However, the incorporation of greenery and climate adaptation measures is not immediately evident in the new design. The study shows that with relatively minor adjustments, such as adding trees and implementing climate-adaptive features, there would be sufficient space to make the street climate adaptive. For this, a road narrowing and reduction of parking spaces is essential in this dense urban area.

One of the challenges encountered in the project is financing. The budget allocated for municipal water tasks alone is inadequate to cover the costs of increasing greenery and implementing climate adaptative measures. By integrating climate adaptation into other urban planning projects, costs can be reduced and synergies can be created. Clear goals and ambitions are crucial in making these endeavours feasible and implementable.

The dense underground infrastructure poses difficulties for incorporating greenery, rainwater infiltration, and adding trees. The presence of cables, pipes, and sewer systems in sidewalks and roadways often leaves only the strip with parking spaces available for trees. In urban planning projects, resident participation is essential, but it can sometimes hinder climate adaptation efforts. For instance, opposition from some residents or shop owners to the removal of parking spaces can hinder progress, even if the majority supports the changes. Furthermore, the higher maintenance costs associated with green infrastructure compared to paved surfaces presents a barrier to climate adaptation. Additionally, substantial water usage is required for irrigation during summers, adding to the challenges. Lastly, it is to be mentioned that there are still areas with excessive, unused pavement that could be utilized for climate adaptation without limiting space for other functions.

4.3.2. Edeseweg, Ede

Ede is a medium sized municipality in the east of the Netherlands. Similar to the other municipalities covered in the case studies, the municipality of Ede is taking action to encourage a mobility change. This goes in the following steps: "reduce, change and clean up mobility" ("verminderen, veranderen en verschonen van mobiliteit"). Car use is discouraged and the focus shifts to clean forms of mobility. Additionally, the municipality needs to adapt to a changing climate. Dealing with heat and extreme rainfall are the biggest challenges within the built-up area. In order to anticipate, the municipality focuses on processing rainwater above the surface and applying BGI.
The Edeseweg is located in Bennekom, a village which is part of the municipality of Ede. The renovation of the street is part of a larger infrastructural cycling project. The goal of this project is creating a better cycling connection between Ede and Wageningen. By doing so, the municipality tries to stimulate bicycle traffic and discourage car usage, and is therefore an example fitting the mobility transition. The case study will discuss the current situation, the proposed design and one fictitious street layout, In which efforts will be made to meet stated climate adaptation ambitions.

Information from policy documents
A number of policy documents were analysed to identify the most important requirements and wishes regarding mobility and climate adaptation, for the project and in the municipality. A more detailed summary of the policy documents reviewed regarding this case study, can be found in Tabel 33 in the Appendix A. The information was verified and supplemented by an interview with an employee of the municipality. The most important findings are listed below.

The most important findings in terms of mobility expectations, goals and ambitions are:

- Stimulate healthy and clean forms of mobility such as public transport, walking and cycling
- Give less space to cars in renovation projects, lower on-street parking when possible
- The Edeseweg will be a both-way bicycle street with a 30 km/h speed limit and a width of 5.80 meters, constructed in red asphalt (+ two ditches of each 35 cm)
- Less parking spaces will return to the project area after the reconstruction, the new parking spaces will be 2.20 meters wide
- Sidewalks will remain unchanged

The most important findings in terms of goals and ambitions for climate adaptation are:

- Provide at least 40% shade on important cycling connections, preferably by threes
- Water resilient public space, by providing enough water storage capacity, to prevent damage in case of an extreme precipitation event of 70 mm/h
- Treat stormwater as much as possible above the surface, preferably by storing and infiltrating through greenery and BGI
- Current trees in the Edeseweg will be cut down and replaced
- Additional space will be used for greenery (unpaved surface)

Scenarios and results

A small part of the Edeseweg, with an area of approximately 3600 m^2, has been selected to perform a scenario based case study. A satellite view of the study area is shown in Figure 43. Because this study only focuses on the public space, gardens, lawns and roofs are excluded from the case study area. The total public part of the selected area is 1895 m^2. Three spatial designs were made and described below, the current situation, proposed redesign and a scenario with additional climate adaptation measures. This was done according to the method presented in section 3.2.5.

Figure 43 Shows an aerial view of the case study area of the Edeseweg (outlined in red), (Source: Google Maps)

0) The existing situation

Figure 44, shows a street view image of the current layout of the Edeseweg. On both sides of the street there are two separated bicycle lanes, between the main road and bicycle lane a small strip is used for greenery and about 2 meter wide parking spaces. In total, 22 on-street parking sports area present in the study area. It is a residential street and most houses have private parking areas and a driveway or lawn, therefore part of the public space is reserved to serve to provide access to the private terrains. The road, parking spaces, sidewalks and bicycle lanes are paved with concrete tiles or bricks.

Figure 44 Street view of the Edeseweg, current situation. (Source: Google maps)

A layout of the street, indicating each type of surface was made with QGIS. This can be found in the Appendix B. From this the area and percentage of surface type has been calculated and presented in Tabel 19.

Tabel 19 Area per surface type in the Edeseweg - existing situation (Sc0)

Surface type	Area (m^2)	Percentage of total surface area (%)	Characteristics
Paved (Road)	544	28.7	Concrete pavers
Paved (Cycling path)	371	19.6	Concrete tiles
Paved (Parking)	264	13.9	Concrete pavers
Paved (Sidewalk)	330	17.4	Concrete tiles
Paved (Driveway)	223	11.8	Concrete pavers
Unpaved	163	8.6	Limited permeability
Green (aerial view)	*217*	*11.5*	
Total	*1895*	*100*	

A cross sectional representation of the current situation in the Edeseweg is given in Figure 45. The street is about 18.40 meters wide in total. The sidewalks, bicycle lane, greenery parking spaces and main road have a width of 1.65, 1.80, 1.25, 1.75 and 5.50, respectively. A combined sewer system is located under the main road and cables and pipelines are present under the sidewalks.

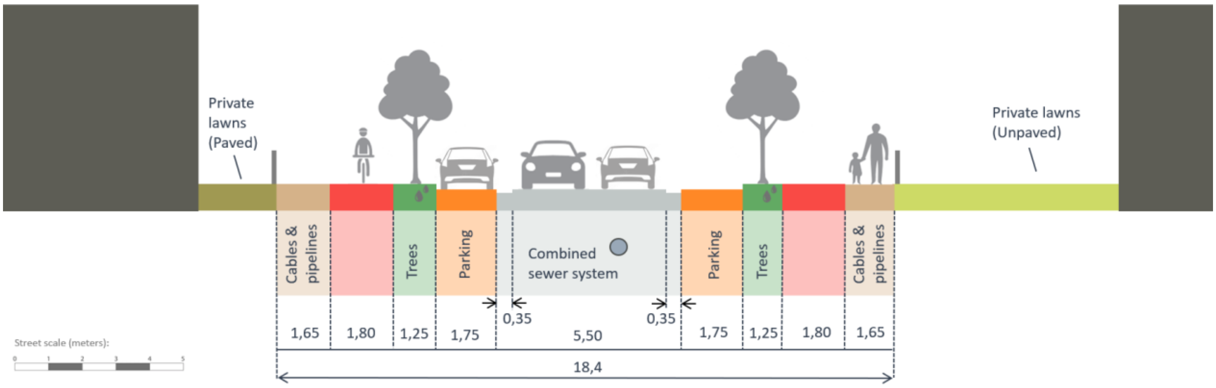

Figure 45 Cross section of the Edeseweg – existing situation (Sc0)

Calculated surface type areas and assumptions made, based the literature study, are used in a water balance. According to the method describe in section 3.2.6. For the municipality of Ede 70 mm/h rainfall is the normative storm intensity to test climate adaptation to pluvial flooding. This storm event is used in the hydraulic calculation to test whether the current storage capacity is sufficient. The results are presented in Tabel 20, this shows that in the existing situation a storage deficit of 47 m^3 or 25,1 mm occurs in the study area.

Tabel 20 Storage capacity of the Edeseweg - existing situation (Sc0)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 1895 m^2 + 22 mm/h * 1895 m^2 = 56,85 m^3
Street	V_{street} = 30 mm * 544 m^2 + 30 mm * 264 m^2 = 24,24 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 163 m^2 + 15 mm/h * 163 m^2 = 4,075 m^3
Total storage	V_{tot} = 56,85 m^3 + 24,24 m^3 + 4,075 m^3 = 85,165 m^3
Required storage	V_{req} = 70 mm/h * 1895 m^2 = 132,65 m^3
Storage deficit	132,65 m^3 – 85,165 m^3 = 47,485 m^3 = 25,06 mm

2) Proposed redesign

The reconstruction works of the Edeseweg are planned to started next year (2024). The project is part of a larger infrastructural cycling project, which aims to promote cycling between Ede and Wageningen. A layout of the new street design, indicating each type of surface can be found in the Appendix B. From this, the area and percentage of each surface type has been calculated, using QGIS and is presented in Tabel 21. The amount of green area, as seen from above, increases significantly. This is due to the greatly increased amount of greenery and replacement of the current small trees with trees that can grow into trees with larger canopies. Since these newly planted trees are provided with more space and more water can infiltrate to the root zone due to the increased unpaved surface, healthy growth of the trees is plausible.

Tabel 21 Area per surface type in the Edeseweg – proposed design (Sc2)

Surface type	**Area (m^2)**	**Percentage of total surface area (%)**	**Characteristics**
Paved (Road)	659	34.8	Asphalt
Paved (Parking)	291	15.4	Street bricks
Paved (Sidewalk)	330	17.4	Street bricks
Paved (Driveway)	275	14.5	Street bricks
Unpaved	340	17.9	Limited permeability
Green (aerial view)	*575*	*30.3*	
Total	*1895*	*100*	

A cross sectional representation of the proposed redesign of the Edeseweg is given in Figure 46. The road is transformed into a bicycle street, without a separated bicycle lane. The total width available for cars an cyclist is 5.80 meters (plus a 35 centimetres gully on both sides of the road). The parking spaces have a much greater width than in the current situation of 2.20 meters. About 18 parking spaces will return in the study area, which is about 4 less than currently present (-18%). On the contrary, the total area used for parking does increase by about 25 m^2 (+10%), which is mainly due to the increased area of individual parking spots. Next to the parking spaces greenery will be planted, which will be about 2.10 meters wide. The sidewalks on both side of the street will be repaved but retain their current width. Investigations have to be carried out into the condition of the subsoil and the work required. It is also not yet clear what type of sewer will be installed. This will be determined in the next phase of the project.

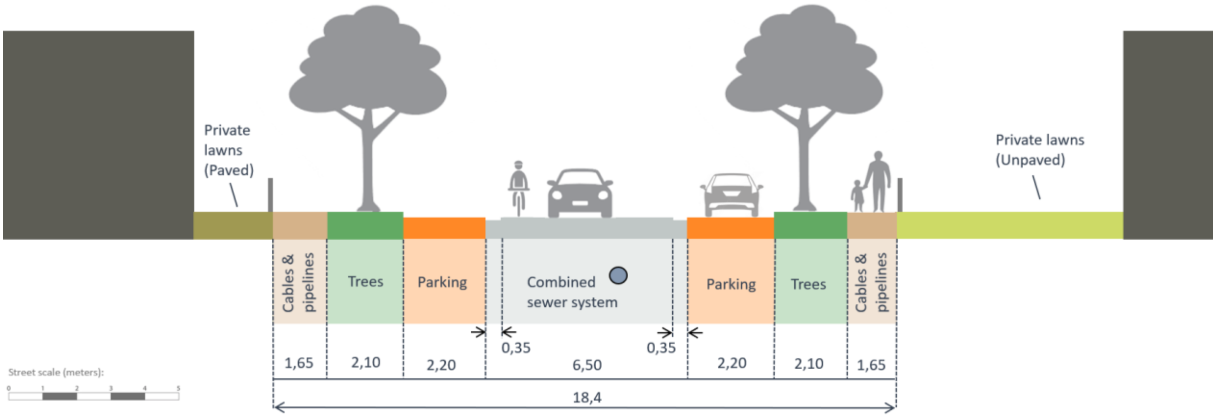

Figure 46 Cross section of the Edeseweg – proposed design (Sc2)

The water storage capacity of the proposed design of the Edeseweg is calculated and presented in Tabel 22. According water balance, the storage deficit of the renovated street is about 39 m^3 or 20 mm. Thus, additional climate adaptation measures are needed in order to meet municipal climate adaptation targets. This will be discussed in the next scenario description.

Tabel 22 Storage capacity of the Edeseweg - proposed design (Sc2)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 1895 m^2 + 22 mm/h * 1895 m^2 = 56,85 m^3
Street	V_{street} = 30 mm * 659 m^2 + 30 mm * 291 m^2 = 28,50 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 340 m^2 + 15 mm/h * 340 m^2 = 8,50 m^3
Total storage	V_{tot} = 56,85 m^3 + 28,50 m^3 + 8,50 m^3 = 93,85 m^3
Required storage	V_{req} = 70 mm/h * 1895 m^2 = 132,65 m^3
Storage deficit	132,65 m^3 – 93,85 m^3 = 38,80 m^3 = 20,47 mm

1) Parking space reduction

The proposed redesign of the Edeseweg involves a reduced number of parking spaces and a narrowed road. This scenario examines what the effect would be of only reducing the number of parking spaces without narrowing the road. The old street design remains the same with two separate bicycle lanes on either side of the road. Four present parking spaces will be changed to greenery to result in an equal number of parking spaces as in the proposed design (18).

A layout of the new street design, indicating each type of surface can be found in the Appendix B. From this, the area and percentage of each surface type has been calculated, using QGIS and is presented in Tabel 23.

Tabel 23 Area per surface type in the Edeseweg – parking space reduction (Sc1)

Surface type	**Area (m²)**	**Percentage of total surface area (%)**	**Characteristics**
Paved (Road)	544	28.7	Concrete pavers
Paved (Cycling path)	371	19.6	Concrete tiles
Paved (Parking)	213	11.3	Concrete pavers
Paved (Sidewalk)	330	17.4	Concrete tiles
Paved (Driveway)	211	11.1	Concrete pavers
Unpaved	226	11.9	Limited permeability
Green (aerial view)	*350*	*18.5*	
Total	*1895*	*100*	

A cross sectional representation this street design with reduced parking spaces (scenario 1) is given in Figure 47. Because more greenery is created (unpaved surface), more water can infiltrate in these places, this offers the possibility of replacing the existing trees with larger trees with a larger canopy area.

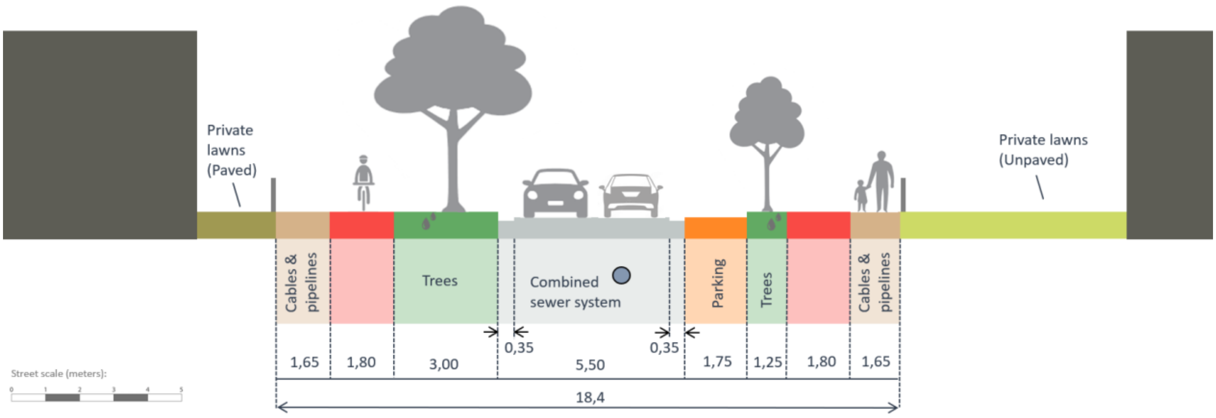

Figure 47 Cross section of the Edeseweg – parking space reduction (Sc1)

The water storage capacity of this design scenario of the Edeseweg is calculated and presented in Tabel 24. According to the assumptions made based on literature study and equations presented in section 3.2.6. The storage deficit is about 47 m^3 or 25 mm. The storge capacity of this street design is about the same as in the current situation. This is because the parking spaces being converted to greenery can be used as temporary water storage location during a storm. This is roughly equivalent to the storage and infiltration capacity of greenery in an hour. As a result, the water storage capacity of the study area during a 1-hour storm is almost the same. However, the infiltration capacity of the road does increase significantly and, in addition, the added greenery allows for more and larger trees and thus more shade.

Tabel 24 Storage capacity of the Edeseweg - parking space reduction (Sc1)

Storage type	Equation
Sewer	V_{sewer} = 8 mm * 1895 m^2 + 22 mm/h * 1895 m^2 = 56,85 m^3
Street	V_{street} = 30 mm * 544 m^2 + 30 mm * 213 m^2 = 22,71 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 226 m^2 + 15 mm/h * 226 m^2 = 5,65 m^3
Total storage	V_{tot} = 56,85 m^3 + 22,71 m^3 + 5,65 m^3 = 85,21 m^3
Required storage	V_{req} = 70 mm/h * 1895 m^2 = 132,65 m^3
Storage deficit	132,65 m^3 – 85,21 m^3 = 47,44 m^3 = 25,03 mm

3) Proposed design + added raingardens

The latter scenario will examine whether the municipality's climate adaptation goals can be achieved by applying BGI in the proposed redesign. This is in line with the municipal Strategy on Spatial Planning and the Environment (*Omgevingsvisie*) and the municipal sewerage plan (*Gemeentelijk Rioleeringsplan*). In the policy documents these technical solutions are mentioned and a wish to successfully implement them is expressed, but no standard guidelines have yet been developed.
Section 2.1.2. discusses rain gardens and their functioning. To select the most suitable location, the AHN 2 file was used (*Actueel Hoogtebestand Nederland*), in the most low-lying part of the study area, greenery is converted into rain gardens. The design will also include more trees to increase the percentage of green and amount of shade in the street, the large unpaved surface makes this plausible. Other than that, the parking spaces and road surface remain the same as in the redesign proposal (Scenario 2). An overhead view of this street design can be found in the appendix B. Using QGIS, the areas per surface type were calculated and this is presented in Tabel 25.

According to Tabel 25, this design scenario will result in meeting climate adaptation objectives of 40% green space and 30% shade on main bicycle routes.

Tabel 25 Area per surface type in the Edeseweg – proposed design + rain gardens (Sc3)

Surface type	Area (m²)	Percentage of total surface area (%)	Characteristics
Paved (Road)	659	34.8	Asphalt
Paved (Parking)	291	15.4	Street bricks
Paved (Sidewalk)	330	17.4	Street bricks
Paved (Driveway)	275	14.5	Street bricks
Unpaved (Greenery)	220	11.6	Limited permeability
Unpaved (Raingarden)	120	6.3	High permeability
Green (aerial view)	*850*	*44.9*	
Total	*1895*	*100*	

A cross sectional representation of design scenario 3 of the Edeseweg is given in Figure 48. According to the figure, at the cross section location, a raingarden is constructed on one side of the road, adjacent to the parking spaces and sidewalks. This will provide additional storm water storage and improve infiltration rates.

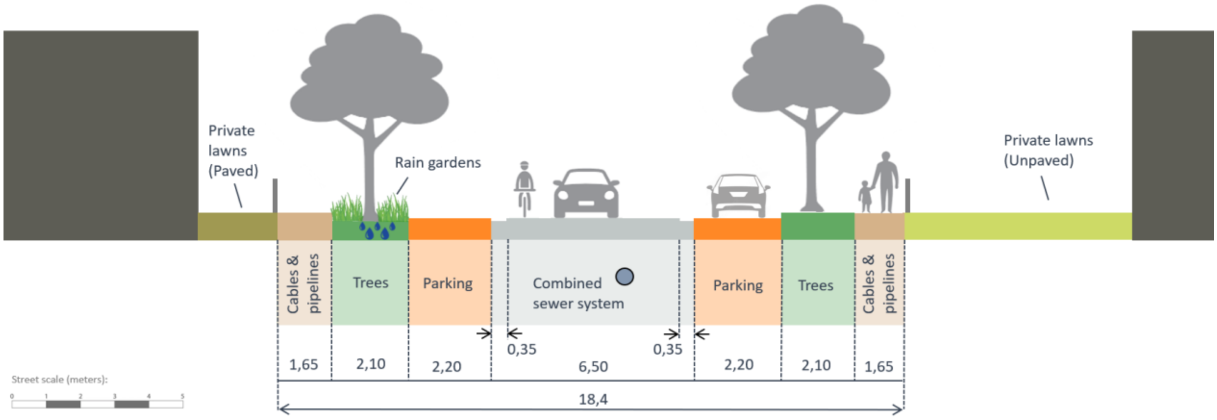

Figure 48 Cross section of the Edeseweg – proposed design + rain gardens (Sc3)

The effect of raingardens on the water balance (storage and infiltration) is described in case study method section 3.2.6. The water storage capacity of this scenarios design is calculated and presented in Tabel 26. Implementing raingardens as proposed in this design results in reaching the municipal climate adaptation goals for pluvial flooding, in the study area. A storage surplus of 3 mm can be realized with this.

Tabel 26 Storage capacity of the Edeseweg – proposed design + rain gardens (Sc3)

Storage type	**Equation**
Sewer	V_{sewer} = 8 mm * 1895 m^2 + 22 mm/h * 1895 m^2 = 56,85 m^3
Street	V_{street} = 30 mm * 659 m^2 + 30 mm * 291 m^2 = 28,50 m^3
Unpaved area	$V_{unpaved}$ = 10 mm * 220 m^2 + 15 mm/h * 220 m^2 = 5,50 m^3
Raingarden	V_{SUDS} = 150 mm * 120 m^2 + 250 mm/h * 120 m^2 = 48 m^3
Total storage	V_{tot} = 56,85 m^3 + 28,50 m^3 + 5,50 m^3 + 48 m^3 = 138,85 m^3
Required storage	V_{req} = 70 mm/h * 1895 m^2 = 132,65 m^3
Storage surplus	138,85 m^3 - 132,65 m^3 = 6,2 m^3 = 3,3 mm

Additional remarks

This case study provides insights into some of the opportunities and challenges for the implementation of BGI. In addition, the case was discussed with an urban water professional from the Ede municipality. From this, the following understandings followed.

The case study in Ede shows a contrast to larger cities such as Utrecht and Rotterdam. Resources and capabilities to prioritize climate adaptation are fewer within the municipality. A climate adaptation strategy is being developed (at the time of writing), but clear goals are not yet in place. Reasons for this include a lack of awareness about the necessity of climate adaptation by policy makers. Additionally, concerns are often raised by residents, urban planners and execution and maintenance departments about the use of climate adaptive solutions, citing reasons like high cost, uncertainties in usability and functioning and high maintenance requirements.

The lack of prioritization of climate adaptation is reflected in the plan for a redevelopment of Edeseweg. Mobility goals are strongly addressed in this plan, moving away from car-oriented mobility, but climate adaptation remains underexposed.

The case study shows combining functions in a street design and prioritizing bicycle traffic, instead of car oriented streets, could result in a significant amount of added green space. Integrating climate adaptation into mobility projects can help achieving climate adaptation goals. The third scenario complies with national climate adaptation and water resilience ambitions; more than 40% green area and a water storage large enough to cope with a 70 mm per hour rainfall intensity. Moreover, an integrated approach can raise awareness among different municipal departments.

5. Synthesis & Discussion

Chapter 5 presents, discusses and interprets the main findings of the research. The chapter is subdivided into four sections. In section 5.1, the main findings of the case-study and scenario designs per case are presented and interpreted, next a synthesis of the results is discussed. Section 5.2 presents the main findings of the interview survey. Section 5.3 discusses the theoretical implications of the findings and compares some of the results with existing literature on the barriers to climate adaptation. It reflects on how this research can contribute to the discussion. The last section, 5.4, reflects on the limitations of the research.

5.1. Findings from the case study

In this subsection the main findings from all six cases are presented individually. Each section reflects on the (design) scenarios and whether climate adaptation goals can be met. The final part compares the findings from the cases and syntheses the results in order to find answers to research questions four and five.

Findings from the Utrecht case (City scale)

The goal of this case study is to show the potential for BGI on a city scale because of a change in mobility. This was done by estimating the amount of public space, currently used by cars, that could be transformed due to multiple mobility scenarios based on the municipality's mobility plans. This resulted in an increased amount and percentage of green public area, assuming that all freed up space is used for BGI. The municipality's ambition is to realize 40% public green space in all neighbourhoods. Currently about 51 out of the 111 neighbourhoods in Utrecht have more than 40% green public surface area. The municipality tries to adapt to a changing climate and combat the UHI effect by increasing the amount of greenery. On Figure 49 it can be seen which parts of the city experience the severest UHI effect. In these neighbourhoods the need for climate adaptation is the highest.

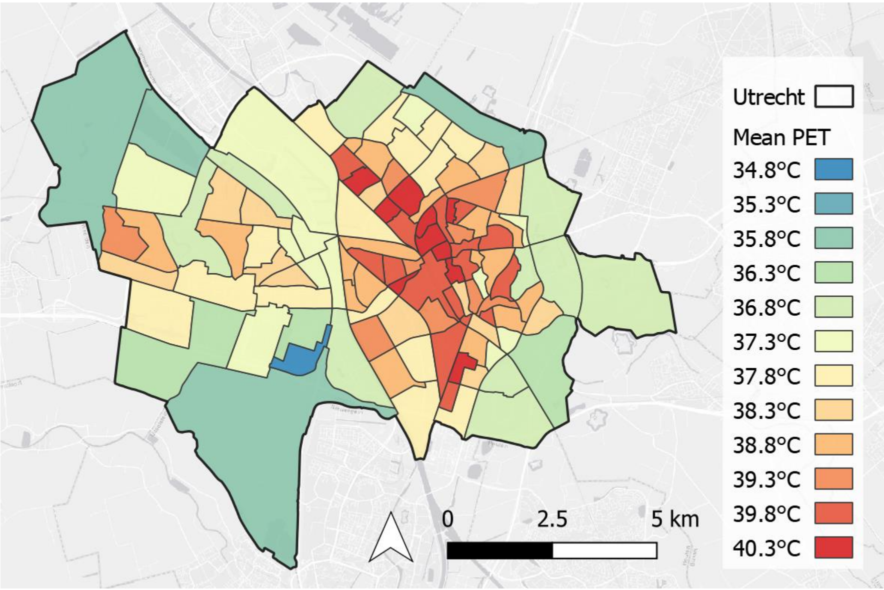

Figure 49 Heat stress map of Utrecht. Mean Physiological Equivalent Temperature (PET) per neighbourhood on a warm summers day, 1st of July 2015. (Source: Klimaateffectenatlas, 2023)

By transforming 12% of the public parking spaces (Sc1), an increase in the amount of green public surface area can be achieved. This will not be enough to meet the municipal goal of 40% green in every neighbourhood, but could help to make the most urbanized and paved areas of the city more climate adaptive. In a scenario which estimates the effects of both on-street parking space removal and a reduction of road surfaces (Sc3), the number of neighbourhoods with more than 40% green in the public space rises to about 80 out of 111. The design scenarios suggest that transforming part of the road surfaces seems to have a higher potential for realising more green than transforming parking spaces. This is probably due to the fact that road surfaces occupy more space than parking surfaces. Area-specific conditions, such as the size and location of roads and parking lots, determine which mobility measure brings about the greatest potential impact for greening. The municipal aim to realize 40% of green area in every neighbourhood will most likely not be achieved by a change in mobility alone. To meet this specific climate adaptation target, more efforts will be required. It could also be that this objective is too ambitious, and possibly very unlikely to be able to realise 40% green space in highly urbanised areas.

All three scenarios show a clear decrease in the percentage of paved surfaces. This is especially apparent in the currently least green parts of the city, which correspond to the areas where, according to the heat stress map, the need for climate adaptation is the highest. The increased green areas per neighbourhood in the most extreme scenario (Sc3), compared to the current situation is shown in Figure 50. The most significant gains in green area correspond, in general, to the areas experiencing the most severe UHI effect, according to Figure 49.

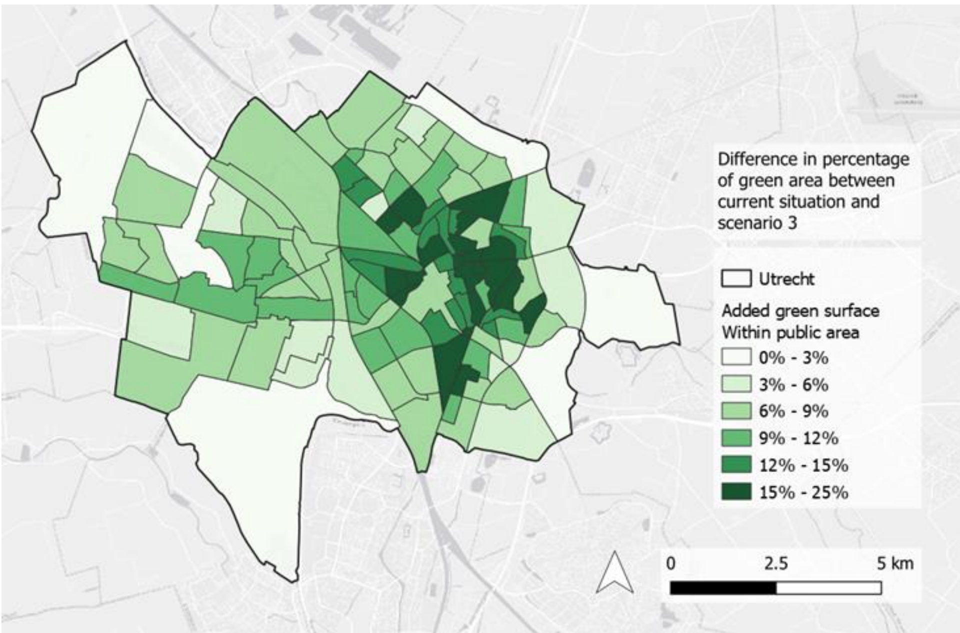

Figure 50 Shows the added percentage of green in the public area per neighbourhood in scenario 3, compared to the current situation (Utrecht).

Findings from the Rotterdam case (City scale)

A clear trend can be noticed in the city of Rotterdam; the municipality actively tries to reshape the city, and by doing so stimulate more active and healthy forms of mobility such as cycling or walking. Due to the city's history, cars have claimed a prominent place in the public urban area. Given that urban space is scarce, the municipality is trying to give some space back to the people by taking it away from cars (Mingardo, 2020). This can be seen in the recent restructuring of a main arterial road, the Coolsingel, for example. A four lane road in the city centre has been turned into a two lane road. The freed-up space can now be used by pedestrians and cyclists, alongside of the street more trees have been planted.

Furthermore, in recent years a considerable number of on-street parking places have been removed in the inner city. Planned mobility projects in the city show Rotterdam's ambition. These "city projects" (Stadsprojecten) are transforming mostly car-dominated places into more climate-adaptive urban areas.

The case study results show that different mobility scenarios offer significant potential for climate adaptation, especially in the parts of the city where the need is highest. Figure 51 shows the heat stress map of Rotterdam. Mainly in the city centre heat stress is high. In these neighbourhoods the Physiological Equivalent Temperature (PET) can rise above 41 °C on a hot summers day, which corresponds with the physiological stress level of extreme heat stress (Goede, 2021).

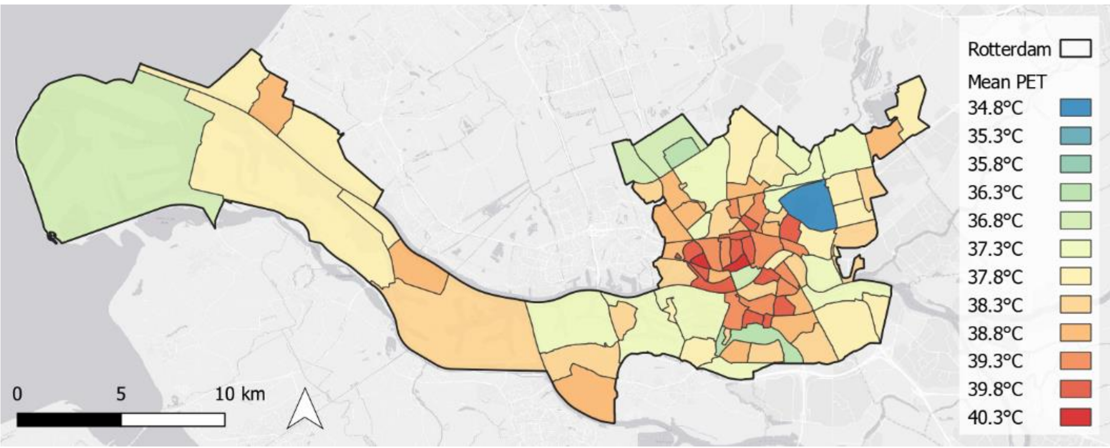

Figure 51 Heat stress map of Rotterdam. Mean Physiological Equivalent Temperature (PET) per neighbourhood on a warm summers day, 1st of July 2015. (Source: Klimaateffectenatlas, 2023)

The most extreme mobility scenario; removal of 25% of on-street parking spaces and reduction of 20% of the road area (Sc3), could result in a substantial increase in the percentage of green space (seen from above) in many neighbourhoods. The difference in the percentage of green area between the current situation and the most extreme design scenario is shown in Figure 52. It is interesting to note that the neighbourhoods with the highest heat stress almost all show an increase of at least 9 per cent green area.

Climate adaptation goals regarding the reduction of heat stress and realisation of green area, in Rotterdam and Utrecht, are formulated completely different. Unlike Utrecht, the municipality of Rotterdam has not defined a clear climate adaptation target in terms of green area per neighbourhood. On the other hand, the municipality has the ambition to realize 20 hectares extra greenery, this can be achieved by transforming less than 12% of the on-street parking spaces (Sc1), which could result in 30 hectares added green area. The latter demonstrates that it is challenging to determine whether climate adaptation targets will be met if they are not formulated uniformly.

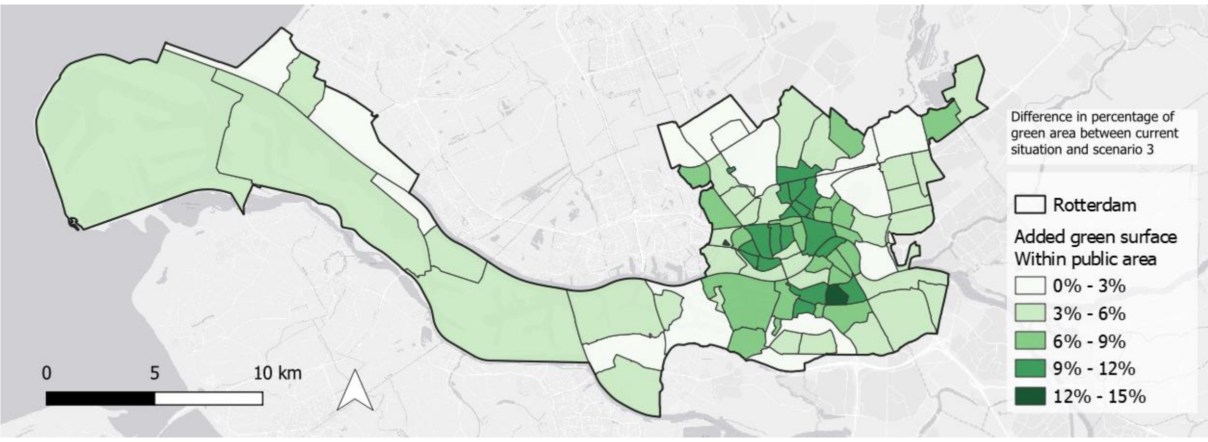

Figure 52 Shows the added percentage of green in the public area per neighbourhood in scenario 3, compared to the current situation (Rotterdam).

Findings from the Stadspark Apeldoorn case (Neighbourhood scale)

In summary, the Apeldoorn case showed that a decision for a radical change in mobility presents a great potential for climate adaptation. Reasons to transform a car-oriented neighbourhood to a city park include; vacant retail space, shift towards residential function, cluttered streetscape and heat stress. The proposed new spatial design for the city centre of Apeldoorn decreases the available space for cars and turns the area into an almost car free, green park.

A new mobility plan has been drawn-up to create a car-free city centre, reroute car and bus traffic within the new city park, and remove on-street parking to encourage usage of off-street parking space. Climate adaptation objectives aimed at increasing greenery and tree coverage, achieving a minimum of 40% green space, seen from above, to combat heat stress.

The new spatial design (Sc2) increases the amount of unpaved (permeable) area with 400%. The amount of green space (mostly tree cover) rises from 13% to 40%. According to literature as described in section 2.1.2 Blue Green Infrastructure (BGI), this could impose a temperature reduction of about 3 °C, on a summers day. The case also shows the impact of reducing parking spaces and using this area for greenery. In a scenario where the currently existing 66 parking spaces are maintained (Sc1), green area was reduced with nearly 10% across the entire case study area. This shows that transforming roads has a greater impact in this specific example, yet it is necessary to additionally replace on-street parking spaces in order to meet climate adaptation targets.

From the Apeldoorn case several challenge could be identified, including; a lack of prioritization for green spaces in spatial planning, resistance from maintenance departments due to increased costs, opposition from car owners and retailers concerned about on-street parking removal, and the challenge of ensuring accessibility in streets with organic shapes and greenery. Despite these challenges, the Apeldoorn case is a good example of how liveability can be improved and green area can be increased by eliminating car traffic, narrowing roads, and relocating parking facilities to the edges of the city centre.

Findings from the Taagdreef Utrecht case (Neighbourhood scale)
The Taagdreef neighbourhood in Utrecht serves as a pilot project to enhance the quality of public spaces. The project aims to improve traffic safety, liveability, and climate adaptation in the area. The new spatial plan involves narrowing roads (by implementing bicycle streets), regulating parking and reducing paved surfaces. Climate adaptation efforts focus on increasing greenery, increasing stormwater infiltration, mitigating heat stress (objective: 40% green in aerial view), and creating a water-resilient urban space.
Three scenarios were evaluated: the existing situation (Sc0) features 26% green area, a preliminary design with reduced parking availability and reduced road area (Sc2) shows 43% green area, and a spatial design maintaining current on-street parking availability (Sc1) results in results in slightly less than 40% green area. Based on these findings, it appears that the greatest space gains can be achieved by narrowing existing roads. Transforming a small portion of the existing on-street parking spaces has a minor impact, in this case. This can probably be explained by the fact that a large portion of parking spaces return in the new spatial design. Thus, the surface area of the removed parking spaces is small compared to the reduced road area.
Challenges in this case include resident resistance to reduced parking spaces and concerns regarding greenery maintenance. Nonetheless, the project presents opportunities for effective project management, community involvement, and integrated urban planning. Funding from various municipal budgets is used to achieve combined policy objectives. As a pilot project, the Taagdreef neighbourhood redevelopment provides a blueprint for future urban transformations, integrating mobility and climate adaptation.

Findings from the Kanaalstraat Utrecht case (Street scale)
This case study showed that new spatial development plans not always lead to increased greenery in streetscapes and not always impose a climate adaptive street design. In this specific case a reduced road width and removal of all on-street parking spaces could result in a climate adaptive and water resilient street design, meeting municipal goals and ambitions.
The municipality of Utrecht wants to make urban areas water resilient, which means being able to cope with a storm event of 80 mm of rainfall in one hour. The proposed design of the street includes a separated sanitary and stormwater sewer, most rainwater can be discharged to the surface water by this system. A normal stormwater sewer only has a limited discharge capacity of about 22 mm/h, therefore additional storage will need to be created to cope with precipitation of 80 mm in one hour. The case study showed that this can almost be achieved by narrowing the road, constructing parking lots on permeable pavement and adding rain gardens instead of traditional greenery (Sc2). Figure 53 shows the water storage volumes and the storage deficit (or surplus) per scenario. It has to be noted that the objective of water resilience, or no damage to properties in case of 80 mm of rainfall in one hour, could also be achieved in other ways, such as constructing a higher door step, so that water can temporarily be stored on the street without causing damage.

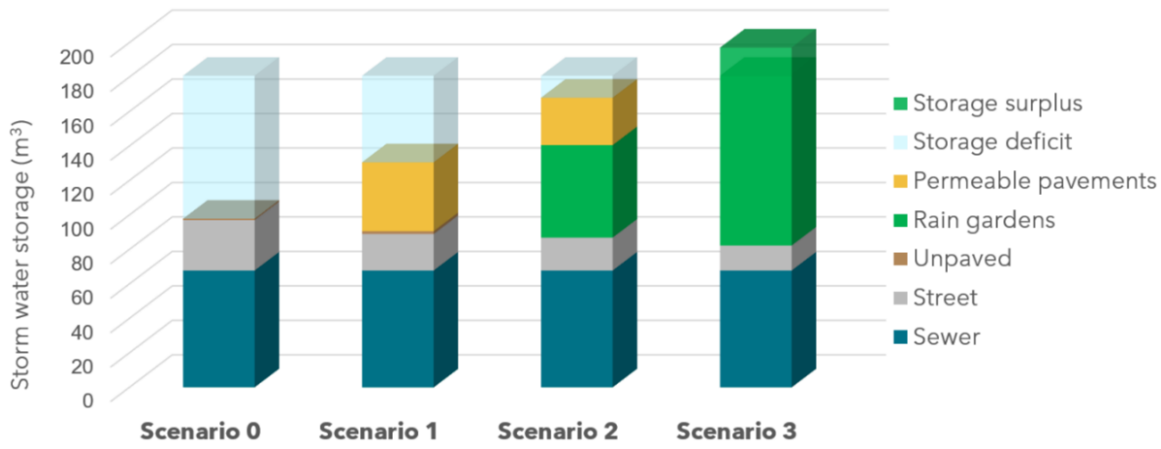

Figure 53 Shows the water storage volumes and storage deficit per scenario in the Kanaalstraat

Findings from the Edeseweg Ede case (Street scale)

The renovation of the Edeseweg is part of a bigger project aimed at improving the cycling connection between Ede and Wageningen. The project promotes bicycle traffic while discouraging car usage; an approach in line with the mobility transition, as discussed in this research. The case study area will be transformed into a both-way bicycle-friendly street with a 30 km/h speed limit, accompanied by less, but larger, parking spaces. Next to the existing situation (Sc0) and the proposed design (Sc2), the case study examines two more scenarios; reduced parking spaces solely (Sc1) and a scenario with additional climate adaptation measures (Rain gardens) to the proposed design (Sc3).

Reducing the amount of parking spaces can lead to increased greenery in the streetscape. Although the proposed redevelopment will significantly increase the amount of green space and water storage capacity of the studied area, additional climate adaptation measures (within the convention of the case study design 3.2.6) will be required to achieve climate adaptation targets. The third case study scenario, which adds raingardens to the proposed street design, instead of traditional greenery, is the most effective in meeting climate adaptation objectives by providing a storm water storage surplus, according to Figure 54. This approach aligns with the municipality's ambitions to encourage sustainable mobility and climate adaptation.

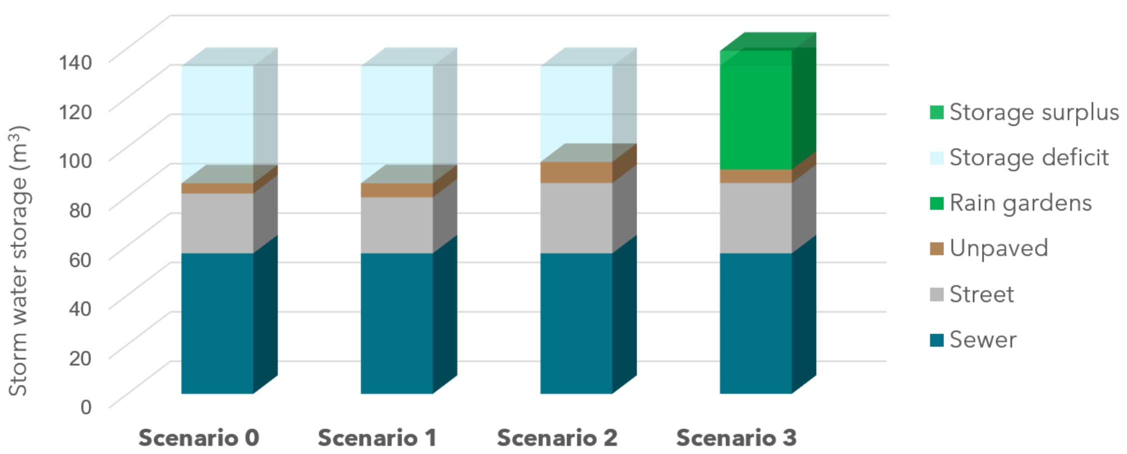

Figure 54 Shows the water storage volumes and storage deficit per scenario in the Edeseweg

Synthesis of the case study findings

The six cases in Utrecht, Rotterdam, Apeldoorn, and Ede, covering three different spatial scales, provide valuable insights into the potential for implementing BGI and promoting climate adaptation through changes in urban mobility. This section synthesises the findings of all six case studies and addresses sub-research questions 4 and 5.

Research Question 4: How much green space could potentially be added in urban areas because of a change in mobility?

All case studies indicate that green space can be substantially increased in various mobility (design) scenarios compared to the current situation. The city scale case studies reveal a slight overall increase in the percentage of green space when some of the on-street parking spaces are transformed into green space (Sc 1). In particular, the scenarios that include the effect of road surface reduction (Sc 2 and 3) show a sharp increase in public green space, as shown in Tabel 27. Hence, it appears that measures such as the removal of double lane roads or imposing lower speed limits to decrease road widths are more effective than transforming part of the public parking spaces. The neighbourhood- and street-scale cases show that the effectiveness of measures depends on site-specific characteristics.
It appears that the potential increase in green space in Utrecht is comparatively larger than in Rotterdam. This may be due to Utrecht's explicit mobility goals, such as the goal of removing 0.5% to 1.0% of on-street parking spaces per year, which results in a greater change in the modal split. Nevertheless, Rotterdam city authorities are also committed to reducing car use in the city centre. A considerable shift in modal split is expected in the coming years.
Furthermore, the two city-scale studies indicate that a strong increase in the amount of green space can be achieved especially in those neighbourhoods where heat stress (and thus climate adaptation needs) are highest, as shown in the case study results presented earlier in section 5.1. This is likely due to the abundance of roads and parking spaces that lead to a large amount of paved surface, which results in a stronger UHI effect and large disturbances to the natural water balance. Therefore, the need for climate adaptation is greatest in the neighbourhoods where motorised traffic predominates. Modifying the existing paved surfaces can provide the necessary space for this.

*Tabel 27 Percentage of green area for multiple mobility scenarios shown per case. The current situation is Sc0. Proposed designs in **Bold**. Due to the level of detail, city-scale cases are difficult to compare with the other cases.*

Nr	Case	Spatial scale	Green space in aerial view			
			Sc 0 [%]	*Sc 1 [%]*	*Sc 2 [%]*	*Sc 3 [%]*
1	Utrecht	City[19]	47	48	52	55
2	Rotterdam	City	42	43	44	47
3	Stadspark – Apeldoorn	Neighbourhood[20]	13	33	**40**	x
4	Taagdreef – Utrecht	Neighbourhood	26	39	**43**	x
5	Kanaalstraat – Utrecht	Street	19	**17**	27	37
6	Edeseweg – Ede	Street	12	19	**30**	45

[19] Green space in aerial view, in the total municipalities public space. *(City scale).*
[20] Green space in aerial view, in the public space within the study area. *(Neighbourhood and street scale).*

The case studies on a smaller spatial scale show that in urban areas with a lot of paved surfaces, climate adaptation goals can be met by implementing a less car-oriented street design. For each of the four study areas on a neighbourhood and street scale, a redesign was presented by the municipality. It is remarkable that in three of the four projects, the amount of green space increases significantly (shown in bold in Tabel 27), except for case number 4 (Kanaalstraat). In the Kanaalstraat in Utrecht, the redesign indicates a lower percentage of green space than present in the current street. This is because in the redesigned study area, less trees will return than currently present, in addition, the sidewalks will be widened and larger parking spaces will be constructed. The redesign is therefore not as green as the current street, despite using less space for roads.
The results seem to indicate that scenarios where road surfaces are reduced lead to the greatest increase in green space. This suggests that modifying roads is a more effective mobility measure to create space for climate adaptation than converting a proportion of parking spaces. The case studies at neighbourhood and street scale show that climate adaptation objectives related to urban heat can be met by converting space taken up by cars into green space and room for trees.

Research Question 5: How could this area be used to make urban areas more climate adaptive and water resilient?

The literature study in Section 2.1.2 focused on three commonly used types of BGI; Rain gardens, permeable pavement, trees & vegetation. These infrastructures help adapting to a changing climate and weather extremes. The design scenarios, at a street scale, look at the effect of applying rain gardens instead of traditional greenery and parking spaces on permeable pavement, also known as green parking or park positive (Park positive, 2023).
Being climate adaptative means, limiting heat stress, withstanding extreme rainfall and prolonged periods of drought. The case studies show that by applying a non-car oriented street design, it is possible to reduce the urban heat island effect by adding sufficient greenery and planting trees, to provide shade. The cases also demonstrate that it is possible to make public areas water resilient by creating enough water storage capacity through rain gardens and permeable pavements. Adapting to the increasing threat of drought has been less thoroughly researched due to various reasons, including difficulties in quantification and lack of guidelines for determining when an area has achieved its drought prevention goals. Greenery and BGI's help restore the natural water balance by increasing the infiltration capacity of urban areas. As a result, groundwater levels are recharged more effectively and the likelihood of droughts is reduced. However, it must be taken into account that water is needed to irrigate the additional vegetation or planted vegetation must be chosen in such a way that it is able to withstand droughts.
The research suggest that the most effective measure to combat heat stress is by planting trees and creating enough canopy area to provide natural shade.
The results also show that it will take more than traditional greenery and permeable pavement under parking lots to withstand extreme rainfall in a changing climate. To cope with extreme precipitation of 60 or 80 mm in an hour, additional storm water storage will have to be created in streets, for example by constructing rain gardens.

5.2. Findings from the interviews

In order to gain insight in perspectives of professionals involved in the mobility transition, climate adaptation and urban planning and to provide background information for the case studies, in-depth interviews were conducted with seven professionals, with different fields of expertise, working at four different municipalities. Activities of the interviewees within municipalities were in the field of; mobility, urban planning, water management and climate adaptation. All had their own views on the mobility transition, climate adaptation and the relationship between the two transitions. Many of these views were similar, some opinions differed. This section provides a summary of the results from all seven interviews, addressing research question 6.

Research Question 6: How do professionals view the relation between the mobility transition and climate adaptation?

All interviewees recognize the potential for climate adaptation through a change in mobility. It was suggested that a shift away from car orientated urban planning might be essential to meet climate adaptation goals and make urban areas climate resilient by 2050, as agreed in the Delta Plan on Spatial Adaptation.

The need for climate adaptation

Interviewed water managers and climate adaptation advisors emphasised the need to make urban areas resilient to heat stress, pluvial flooding and drought. Opinions differed on which of these three effects of climate change will pose the greatest challenges to the urban area. The prevailing climate adaptation goals were different for each municipality. For instance; the municipality of Utrecht's ambition is to be able to withstand 80 mm of rain in an hour, Rotterdam, on the other hand, aims to avoid damage to buildings in the event of 70 mm of precipitation in an hour. Some smaller municipalities have not (yet) formulated or quantified climate adaptation goals. Although smaller municipalities may have less staff capacity, their ambitions are not necessarily lower. Local climate adaptation policy often adopts the same objectives as defined by larger municipality. The majority of interviewees suggested that formulating clear goals will be helpful to promote climate adaptative urban planning and integrate climate adaptation into mobility projects. Clear objectives help to address the challenges, promote discussion and increase the urgency for climate adaptation.

BGI challenges

Implementing BGI and greenery often meets resistance. Among other things, objections are raised by the municipality's maintenance department because they are unable to cope with the extra maintenance work. Greenery requires more irrigation in summer and usually has higher construction and maintenance costs than paved surfaces. Moreover, climate adaptation measures initiated by the urban planning or water management department in the design phase results in increased pressure on other departments, such as city maintenance, in the operating phase.

The congestion in the underground infrastructure makes it challenging to add greenery, implement rainwater infiltration, and plant trees. Cables, pipes, and sewers often occupy the space beneath sidewalks and road lanes, leaving the strip where parking spaces are located as the only available area for planting trees.

Mobility transition challenges

Several mobility experts and urban planners indicated that reduction of parking spaces and less space for cars often evokes resistance from residents and business owners, in many projects. The reason for this may be that the car has long been prioritized in urban design practise, as a result a more equal distribution of space can therefore feel like inequality for motorists. This complicates the introduction of car-free neighbourhoods. Views on how to overcome this challenge vary. Some interviewees argued that residents' resistance can be reduced by providing good examples. Demonstrating the benefits of greenery and reduced car dependency can help overcome resistance. Other experts suggested that these challenges can be addressed by allowing less resident participation in the decision-making process and by imposing stricter requirements in redevelopment projects. For example, by introducing a greening norm in projects where parking spaces should be reduced.

Municipal cooperation practice

The interviews underscore a divide between mobility and climate adaptation within urban planning. Mobility professionals often have limited awareness of climate adaptation objectives and their urgency. Mobility and climate adaptation are generally perceived as operating in separate domains. This is reflected in the organisational structure of municipalities, where a clear division is noticeable between the departments responsible for these tasks. There appears to be a little collaboration between the departments, creating a barrier to the integration of climate adaptation and mobility practices.

Integrated approach

Most professionals recognise that mobility projects offer opportunities for climate adaptation. By incorporating greenery and BGI into mobility designs, they believe both goals can be achieved simultaneously and a potential synergy arises. All interviewees agreed on the importance of an integrated approach to mobility and climate adaptation projects. This would have several advantages according to the interviewees, namely: reduced costs, more efficient execution of operations and increased awareness of the need for climate adaptation. Moreover, it could accelerate both the mobility and climate adaptation transition.

5.3. Theoretical implications

This section presents the research findings derived from case studies and interviews, and compares them with relevant scientific literature previously published. Based on the case study findings, it can be argued that the integration of climate adaptation and mobility can significantly contribute to climate proofing urban areas. This section explores whether this link between climate adaptation and mobility has already been discussed in scientific literature. Multiple challenges and opportunities for climate adaptation were identified in the case studies and interview survey. This section will compare some of the most relevant barriers identified to those mentioned in scientific literature. It will also discuss how the research can contribute to overcoming these barriers.

Space for climate adaptation

The multiple case-study analysis show that the space needed for climate adaptation can largely be provided by a change in mobility and reduction of space for cars. The interview survey confirms this observation. Some interviewees also mentioned that because of the existing urban infrastructure above and below ground, the possible locations for BGI are limited. Underground infrastructure, such as cables and pipelines, often limit the suitable location for greenery or SUDS to the on-street parking strip. Zhang *et al*. (2017) suggest that the biggest challenge for the implementation of BGI in highly urbanized areas, is the lack of available space. To the author's knowledge, the spatial relationship between mobility and climate adaptation has not previously been described in scientific literature.

Lack of uniform and clear climate adaptation goals and urgency

During the case studies and interviews, a lack of uniform and clear climate adaptation goals in national and local policies was identified as a challenge to effectively implement BGI. There is no consensus on how to determine whether a specific area is resilient to pluvial floods, heat stress and droughts. Previous research argued that the lack of clear goals hinders the widespread implementation of urban water innovations, such as green parking (van Horn, 2023). The absence of policy frameworks with clear norms and agreements on adaptation was described as an 'institutional void' by Van den Ende *et al*. (2022). In scientific literature this challenge is rarely mentioned, according to the authors knowledge. Based on the findings of the interview survey it can be argued that the lack of clear goals contributes to the absence of a sense of urgency among urban planning and mobility practitioners. The lack of urgency to adapt to the effects of climate change in urban areas (Runhaar *et al,* 2012; Mees *et al,* 2018; Almaaitah *et al,* 2021) has often been mentioned as a key barrier to climate adaptation.

Concerns about greenery and BGI

The study identified concerns about the finding, maintenance, lack of resources and irrigation needs of climate adaptation measures. There is a discrepancy in responsibility for financing, constructing and maintaining greenery. The construction of BGI is regularly funded through water management budgets, however, this may cause unexpectedly high maintenance costs, which must be financed with green facility maintenance budgets. Matthews *et al*. (2015) describe budgetary and maintenance challenges as a management issue and a socio-political factor in the implementation of climate adaptation measures. *Suleiman* (2021) describes the lack of maintenance organisation and the entrenchment of traditional practices as an operational and financial barrier to BGI. The reduction of socio-political uncertainties and concerns is essential for the widespread implementation of BGI (Thorne *et al*, 2018).

Concerns about non-car orientated urban planning

The case study research and interview survey mentioned some challenges concerning the implementation of car free or low car developments, thus obstructing the green mobility transition. Some of the mentioned concerns were resistance from residents and retailers when parking spaces are removed or car accessibility is reduced. This barrier to the implementation of car free cities was mentioned by Nieuwenhuijsen *et al*. (2018) retailers expected revenue loss when car access is limited. However, it seems that this is not the case in practice (Mingardo *et al,* 2015). A strong car dependency or habit is hard to be broken and therefore changes, such as reduction of parking spaces, may seem radical and will take time. It requires people to adjust their travel patterns (Nieuwenhuijsen *et al*, 2018).

Another challenge, apparent from the case studies, which was not found in scientific literature is the reduction of paid parking revenues. Mingardo *et al*. (2018) mentions that one of the inexplicit parking policy aims of municipalities is to raise revenue. It is unclear whether reducing parking spaces is hampered by municipalities because it would impose a revenue reduction, in paid parking areas.

Lack of cooperation between municipal departments

In particular, the interview survey showed that despite increasing integration at a policy level, cooperation between municipal departments (e.g. mobility and water management) is, in practice, still often limited. For example, climate adaptation is not commonly considered when developing mobility plans. Additionally, problems may arise between different stages of the development cycle (design phase, construction phase and maintenance phase), for instance, when there are ambiguities about who is responsible for maintaining and financing greenery. The lack of cooperation is closely related to previously mentioned challenges, such as concerns about BGI and the lack of urgency and clear climate adaptation goals. The research pointed out that a lack of attention to climate adaptation among mobility experts and uncertainties about responsibilities, financing and maintaining greenery might limit cooperation.

The review of policy plans confirmed that climate adaptation is not (yet) well embedded in mobility policies. According to Uittenbroek *et al*. (2013), the focus has been on developing a separate policy domain for climate adaptation in literature. Integrating adaptation in other policy domains, (such as urban planning and mobility), can be more effective and increase the efficiency of resources by combining objectives. This process of integrating climate adaption is also known in literature as; "mainstreaming climate adaptation" (Runhaar *et al,* 2018). An integrated and collaborative planning approach is needed for BGI to become a mainstream component of management practices (Suleiman, 2021). The Dutch climate adaptation governance structure is quite complex and relies on integration and mainstreaming adaptation in various other sectoral policies (Mees *et al,* 2023). Nieuwenhuis *et al*. (2022) concluded that Dutch urban water practitioners recognize that sustainability challenges should be addressed with cooperation beyond sectoral boundaries.

5.4. Limitations of the research

This section discusses the limitations of the thesis research. It provides a non-exhaustive list points of discussion concerning the scope, methodology and findings of the research.

The geographical *scope* of this thesis research is on Dutch urban areas. Six case studies in four Dutch municipalities on three spatial scales have been conducted. It was sought to select several cases with various characteristics (city centres and residential areas). Other types of cities within, and cities outside the Netherlands should be studied, to give a more comprehensive view. General urban transport policy has undergone similar development in cities across Europe (Mingardo *et al*, 2015), this might suggest comparable results in other urban areas in Europe.
The 'mobility transition' is a freely interpretable concept with no general definition. This study assumes that the mobility transition will lead to less spatial claim of mobility on the public space. It does not consider the specific effects of, for example, shared transportation, mobility hubs and electric vehicles.
The study solely focused on the impacts of climate change on pluvial flooding, heat and, to a lesser extent, drought. Biodiversity restoration and other climatic concerns have not been taken into account; thus, the effects of BGI on these issues have also not been examined.

The *methodology* applied in this research is an exploratory, multiple case-study for which multiple data gathering methods were used; review of policy documents, semi-structured interviews and scenario based modelling or research through design. These diverse types of data gathering offer multiple perspectives to approach the topic, giving a comprehensive view. On the downside, also due to time constraints, a limited number of cases and interviews could be conducted. Focusing on one data collection method would potentially provide a more in-depth assessment, and conducting more case studies could increase the validity of generalized results.

The semi-structured interview survey method allowed for in-depth exploration of experts' views on the mobility transition and climate adaptation, however also this method has some limitations. The interviews required preparation and evaluation and were time consuming. This allowed for a limited amount of interviews, possibly excluding certain perspectives. Interviewees were mostly selected by convenience sampling, all interviewees are employees of municipalities and worked as policy makers or project leaders. Thus, excluding views from other stakeholders in the mobility and climate adaptation transition, such as employees at maintenance department of municipalities, companies involved and motorist. This might have led to a narrow perspective.

The study was significantly affected by numerous assumptions made in the scenario design and water storage calculations, leading to a considerable impact on certain outcomes. In the case studies conducted on a city scale, assumptions were made regarding reductions in parking space and road width. In the case studies conducted on a street scale, assumptions were made regarding hydraulic parameters of surface types and BGI characteristics, in order to calculate stormwater storage capacity. Furthermore, only two types of BGI were considered in the water balance, excluding the potential of, for example, storage crates under roads and green tram tracks. These assumptions and decisions naturally influenced the outcomes of the case study calculations. Nonetheless, the calculations provided an indication of the potential for climate adaptation through a shift in mobility.

The study focuses solely on the potential effects of the mobility transition on climate adaptation, excluding the impacts of other transitions that play an important role in the spatial domain of urban areas, such as the energy transition, the transition to a circular economy and the current housing challenge. Additionally, the costs for renovation works, alternative modes of transportation, and the implementation of BGI have hardly been considered. Financial constraints may significantly limit the potential of BGI.

Lastly, I as a researcher might have personal biases which influence the made assumptions, selected cases, interpretation of the interviews and more, which could have had an effect on the study results. In order to mitigate this bias explorative research methods were applied and efforts were made to provide as much justification as possible for the decisions taken.

6. Conclusion

This master's thesis explored the potential impact of the transition to green mobility on the implementation of Blue Green Infrastructure (BGI) in urban areas in the Netherlands. The potential was examined through an explanatory, multiple-case study of six cases at three spatial scales and interviews with experts in the fields of urban planning, mobility and climate adaptation.

There is a need for climate adaptation due to the increased likelihood of extreme heat, pluvial floods and droughts in urban areas. In response, Dutch governmental organizations have expressed the ambition for a climate adaptive and water resilient country by 2050, outlined in the Delta Plan on Spatial Adaptation (DPSA). The implementation of Blue Green Infrastructures (BGI) in urban areas can mitigate the effects of increased heat, drought and pluvial flooding, help restore the natural water balance, store and infiltrate rainwater and have a cooling effect on their surroundings.
In parallel with the ambition to adapt to the effects of climate change, there is a noticeable shift in transport modes in urban areas. Government organisations are actively steering policy towards more sustainable, active and healthy forms of mobility and a reduction in car dependency.

In densely populated areas, public space is scarce, the need for climate adaptation is high, and many people will be affected by extreme weather conditions. Municipalities want to improve liveability and accessibility in these highly urbanised areas by facilitating sustainable forms of mobility and reducing car traffic. An additional benefit is that the transition to green mobility could potentially provide the space needed for BGI. Therefore, this study examines how the transition to green mobility could contribute to adapting urban areas to a changing climate. This chapter presents the conclusions of the research and attempts to answer the main research question.

Main Research Question: What is the potential impact of the transition to **green mobility** on the implementation of **Blue-Green Infrastructure (BGI)** in urban areas in the Netherlands?

Case studies conducted in Utrecht, Rotterdam, Apeldoorn and Ede showed that a shift towards green mobility can indeed have a substantial impact on urban climate adaptation through the implementation of BGI. The analysis of municipal policy documents revealed an increasing focus on sustainable forms of mobility and a decreasing priority for privately owned cars in urban areas. The case studies examined different mobility and BGI scenarios, such as the reduction of parking spaces, the narrowing of roads, and the incorporation of climate adaptation measures such as rain gardens and permeable pavements, to show the potential for climate adaptation on three spatial scales.

Interviews with experts in the field and a review of policy documents revealed that there is a general recognition of the potential for climate adaptation through a shift towards green mobility. However, it was noted that there is a lack of clear and consistent climate adaptation objectives, a lack of sense of urgency and a lack of cooperation between municipal departments. These challenges make it difficult to effectively integrate climate adaptation into mobility projects. Furthermore, resistance to mobility changes, especially when it comes to reducing parking space, was identified as a common barrier.

The findings of this study can be summarised under three main headings, which clarify the climate adaptation potential of the mobility transition:

Increase in Green Space (spatial relation)

The case studies showed that the amount of green space can be increased in different mobility (design) scenarios compared to the current situation, as discussed in section 5.1. The two city scale case studies, Utrecht and Rotterdam, showed that especially in places where the need for climate adaptation is highest (highly urbanised areas; neighbourhoods with the highest UHI-effect), space for BGI can be created by reallocating public space and utilizing previously claimed space for motorized traffic (roads and parking spaces). The conversion of parking spaces alone will most likely not be sufficient to achieve climate adaptation goals at a city level. It should be noted that meeting climate adaptation goals varies from one municipality to another, and it requires a more detailed, city-specific assessments for accurate determination.

Increased greenery and BGIs have the potential to mitigate the urban heat island effect, pluvial floods and droughts. The spatial relationship between mobility and climate adaptation has not (yet) been extensively explored in existing literature.

Climate Adaptation Potential

The case studies on a neighbourhood and, especially, street scale showed that by redesigning urban spaces to be less car-oriented and by incorporating BGI in urban planning, climate adaptation goals related to heat and pluvial flooding can be met. The two case studies on a neighbourhood scale in Utrecht and Apeldoorn showed that it is possible to significantly increase the amount of green space in both a city centre and a residential area. The two case studies on a street scale in Utrecht and Ede showed that the climate adaptation goals related to pluvial flooding can be achieved by creating sufficient water storage capacity, through the adoption of the mobility transition.

The results of the study suggest that the implementation of rain gardens or other forms of SUDS, in addition to traditional greenery and permeable pavement, is necessary and effective to create sufficient water storage capacity to meet climate adaptation objectives related to pluvial flooding. A specific determination on whether a design meets the defined policy objectives will always need to be made on a case-by-case basis.

The interview survey confirmed the recognition of this potential by experts. A change in mobility, less space for cars, is often essential to provide the space needed for climate adaptation in densely built-up urban areas.

Challenges

However, several challenges to the implementation of BGI and to harnessing the potential of the mobility transition were identified in the case-study and confirmed or elaborated by the interview survey. The challenges can be categorised in three observations, following from the discussion in section 5.2 and 5.3:

Lack of uniform policy goals and urgency A policy framework with clear climate adaptation goals and norms is lacking at both a national and local level. For example, the goals of the municipality of Utrecht, related to urban heat, were more ambitious and explicit than those of the other municipalities. Unclear and freely interpretable climate adaptation ambitions make it difficult to prioritise climate adaptation measures in urban planning and may contribute to a lack of urgency. As a result, there is a risk that, for example, parking spaces will be preserved at the expense of green spaces.

Concerns about BGI and the mobility transition Concerns related to financing, maintenance, and irrigation needs of climate-adaptive measures and unclear responsibilities were identified. These practical challenges align with management issues mentioned in the literature as socio-political factors affecting the implementation of climate adaptation measures. Other concerns include resistance from car owners and retailers regarding parking space reduction and reduced car accessibility. Furthermore, the limited space available in the urban underground was identified as a challenge that complicates the implementation of greenery and BGI.

Integration of climate adaptation (in mobility policy): The study showed that mainstreaming climate adaptation into other policy domains, such as mobility, could contribute to achieving combined objectives. It was argued that cooperation between municipal departments (e.g. mobility and water management) and between different stages of the development cycle (design phase, construction phase and maintenance phase) is often still limited. Collaboration beyond sectoral boundaries could accelerate climate adaptation efforts.

In conclusion, this research demonstrates the significant potential of the transition to green mobility to improve climate adaptation and water resilience in urban areas in the Netherlands. Space currently used for motorised transport can be reallocated to increase stormwater storage capacity to prevent flooding, provide shade to reduce urban heat and improve infiltration to reduce droughts. The study showed that sustainable mobility and climate adaptation can go hand in hand. With an integrated approach to both transitions, combined goals can be achieved. By transforming urban mobility and reallocating space from cars to green spaces and BGI, cities can make important progress towards creating more sustainable, liveable, healthy, climate adaptive and water resilient urban environments.

7. Recommendations

This chapter will formulate policy recommendations (section 7.1) and recommendations for further research (section 7.2), based on the findings and conclusions of this study.

7.1. How to harness the potential

Based on the discussion and conclusions, the following policy recommendations are proposed, to enhance the transition to green mobility and exploit its potential for climate adaptation and BGI.

Establish clear and uniform climate adaptation goals

One of the identified barriers mentioned in section 5.3 was the lack of uniform and clear climate adaptation goals. To improve effective BGI implementation, it is crucial to address the diverse and ambiguous climate adaptation objectives identified during the study. Therefore it is recommended to define clear climate adaptation goals both on a national and local level. The national government should take the lead by defining objectives which can be translated by local governments to their specific context. The first import steps for this have already been taken with the Delta Plan on Spatial Adaptation (DPSA), by committing to achieve climate resilience and water robustness by 2050. Stress tests have already been carried out as part of the DPSA, the next step would be to set concrete targets that are measurable, make climate adaptation less non-committal and possibly mandatory. Goals can be established by further specifying and quantifying current climate adaptation policy documents such as the 'Maatlat groene klimaatadaptieve gebouwde omgeving'[21], formulating a guideline for the number of trees or implementing a greenery norm required in urban planning projects and renovations. Strict policies could prevent green spaces from eventually being squandered for parking spaces, for example, after resident participation. However, a more mandatory approach to climate adaptation would also involve a political choice between resident participation and achieving climate adaptation objectives.

Establish clear mobility transition goals

Make active and steering mobility policy. Promote active forms of mobility (walking and cycling) and reduce car dependence. Include future expectations in urban planning. The emergence of shared transport and expansion of the paid parking area allows for lower parking standards. Facilitate parking spaces possibly at the edge of the city and re-evaluate how space is currently distributed, the ratio between space for motorised transport and other urban functions. The current trend in mobility policy in the Netherlands is shifting from a (private car) mobility-oriented to a socially-oriented approach (KiM, 2023). This should be promoted.

---

[21] Source: https://klimaatadaptatienederland.nl/hulpmiddelen/overzicht/maatlat-groene-klimaatadaptieve-gebouwde-omgeving/ Accessed in September 2023

Integrated approach to climate adaptation

Approach adaptation in the public space holistically. The case study showed that it is possible to achieve mobility and climate adaptation goals simultaneously by adopting an integrated approach in urban planning projects. The following recommendations are made to better exploit the linkage opportunities offered by the mobility transition:

- *Collaboration between municipal departments*
  Promote collaboration between municipal departments responsible for mobility, urban planning, and climate adaptation.

- *Collaboration between actors in different stages of the development cycle*
  Integrating previously separately functioning domains together with applying innovative climate adaptive solutions, requires a different management approach. It is important that newly established policy can actually be implemented. Therefore, it must be ensured that actors in different stages of the development cycle (the design phase, construction phase and maintenance phase) are involved in establishing new policies and practices.

- *'Mainstream' climate adaptation in mobility policy*
  Emphasize the importance of greenery and BGI in urban planning policies and guidelines. Encourage the incorporation of green infrastructure, such as rain gardens, permeable pavements, and tree planting, into mobility policy. Prioritize green mobility solutions that not only promote sustainable transportation but also enhance climate adaptation and liveability. This can, for instance, be done by updating and elaborating on the already available climate adaptive roads guideline (Handreiking Klimaatadaptieve én Natuurinclusieve Wegen[22]).

- *Combine funding resources*
  Make use of multiple financing options for projects in the public space with diverse objectives (e.g. climate adaptation and sustainable mobility). For example, use a variety of funding possibilities such as the national road safety investment impulse[23] and municipal rainwater drainage disconnection budgets, in addition to traditional budgets from urban development, maintenance and sewer replacement.

Conduct a case-specific test on meeting policy goals

As mentioned earlier, climate adaptation and other policy objectives can vary from one municipality to another, in addition, their attainment is influenced by site-specific characteristics. It is therefore recommended to determine for each urban planning design whether it is in line with the municipalities spatial planning and environmental vision, and if prevailing policy goals are met.

[22] Source: https://klimaatadaptatienederland.nl/hulpmiddelen/overzicht/handreiking-wegen-klimaatadaptief-natuurinclusief/ Accessed in September 2023

[23] Source: https://investeringsimpulsspv.nl/ Accessed in September 2023.

These case-specific tests should include comprehensive assessments of applicable policy goals and physical conditions. In some cases, transforming a few parking lots into green space might be sufficient to meet climate adaptation targets, in other cases more drastic interventions may be needed.
In addition, the effectiveness of many adaptation measures depends on site-specific, physical conditions. For example, the infiltration capacity of rain gardens is largely dependent on subsurface permeability. This will have to be measured on-site to determine the storm water storage and infiltration capacity of urban drainage infrastructures. Consequently, climate adaptation measures need to be assessed on a case-by-case basis to determine their effectiveness.

Share experiences and involve residents
Finally, it is recommended to promote knowledge exchange and cooperation to share experiences, challenges and successful strategies for achieving climate adaptation and mobility goals. The case studies provide an opportunity to identify the most effective design scenarios from which lessons can be learnt and applied to other cases. Create a database of examples of integrated mobility and climate adaptation projects. This will facilitate knowledge sharing. Also report on negative outcomes so that lessons can be learnt from them.

Show residents the benefits of other forms of mobility, a different distribution of public space, less space for cars and the advantages of climate adaptation. Consider initiatives such as the moving forest in Dordrecht[24]. In this pilot project temporary greenery is placed on parking spaces to enthuse residents and show how less space for cars can improve the quality of public space in streets. In addition, neighbourhood initiatives could, for example, contribute to the management and community-maintenance of greenery. This could alleviate concerns about maintenance and financing of BGI.

---

[24] Source: https://cms.dordrecht.nl/Onze_stad/Overzicht_Onze_stad/Bewegend_bos Accessed in September 2023

7.2. Future research

From the results and limitations of this research multiple suggestions for further research can be formulated. Some are listed below:

- Take the cost of BGI and different forms of mobility into account. Investigate how this can influence the potential for climate adaptation through a change in mobility.
- Include a more diverse group of stakeholders in a follow-up study. As indicated in section 5.4, this study only conducted interviews with policy makers and project leaders from municipalities. Additionally, explore the perspectives of maintenance workers, businesses and residents, for example.
- Include other spatial tasks (e.g. the energy transition, transition towards a circular economy and housing challenge) and their influence on climate adaptation and claim on urban space.
- Conduct more case studies in different types of cities and neighbourhoods, possibly beyond the country's borders, to build a more general and probable theory.
- Perform a sensitivity analysis and show the effect of different assumptions on the results of this research.
- Conduct research on concerns related to BGI and the mobility transition, as indicated in section 5.3. Examine, for example, the irrigation needs of green space and how this can be managed, or whether reduced availability of car parking spaces will lead to a loss of revenue for retailers.
- Create a tool that links mobility and climate adaptation. For example by showing how many parking spaces need to be removed to make a specific area climate adaptive. This tool could be added to the Knowledge Portal Climate Adaptation (https://klimaatadaptatienederland.nl).

References

Adams, W. C. (2015). Conducting Semi-Structured Interviews. *Handbook of Practical Program Evaluation: Fourth Edition*, 492–505. https://doi.org/10.1002/9781119171386.CH19

Almaaitah, T., Appleby, M., Rosenblat, H., Drake, J., & Joksimovic, D. (2021). The potential of Blue-Green infrastructure as a climate change adaptation strategy: a systematic literature review. *Blue-Green Systems*, *3*(1), 223–248. https://doi.org/10.2166/BGS.2021.016

Anastasiadou, K., & Gavanas, N. (2023). Enhancing urban public space through appropriate sustainable mobility policies. A multi-criteria analysis approach. *Land Use Policy*, *132*, 106765. https://doi.org/10.1016/j.landusepol.2023.106765

Arias-Molinares, D., & García-Palomares, J. C. (2020). The Ws of MaaS: Understanding mobility as a service fromaliterature review. *IATSS Research*, *44*(3), 253–263. https://doi.org/10.1016/J.IATSSR.2020.02.001

Aram, F., Higueras García, E., Solgi, E., & Mansournia, S. (2019). Urban green space cooling effect in cities. *Heliyon*, *5*(4), e01339. https://doi.org/10.1016/J.HELIYON.2019.E01339

Armson, D., Stringer, P., & Ennos, A. R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening*, *11*, 245–255. https://doi.org/10.1016/j.ufug.2012.05.002

Autoweek. (2021, November 24). *Utrecht gaat jaarlijks 750 tot 1.500 parkeerplaatsen schrappen.* Retrieved from https://www.autoweek.nl/autonieuws/artikel/utrecht-gaat-jaarlijks-750-tot-1-500-parkeerplaatsen-schrappen/

Bakker, N. (2017, June). *ROTTERDAM: VAN STAD VOOR DE AUTO NAAR CITY LOUNGE AAN DE RIVIER - Lukt het op de Coolsingel, dan lukt het overal.* Langzaam verkeer. https://www.mobiliteitsplatform.nl/sites/default/files/LukthetopdeCoolsingel%2Cd anlukthetov eral.pdf

Ballard, W., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T., Ashley, R., & Kellagher, R. (2007). The SUDS manual. *CIRIA*. ISBN: 978-0-86017-759-3

Bean, E. Z., Hunt, W. F., & Bidelspach, D. A. (2007). Field Survey of Permeable Pavement Surface Infiltration Rates. *Journal of Irrigation and Drainage Engineering*, *133*(3), 249–255. https://doi.org/10.1061

Bella, F. (2013). Driver perception of roadside configurations on two-lane rural roads: Effects on speed and lateral placement. *Accident; Analysis and Prevention*, *50*, 251–262. https://doi.org/10.1016/J.AAP.2012.04.015

Bernatzky, A. (1982). The Contribution of Trees and Green Spaces to a Town Climate. *Energy and Buildings*, *5*, 1–10.

Boogaard, F., Lucke, T., & Beecham, S. (2014). Effect of Age of Permeable Pavements on Their Infiltration Function. *CLEAN – Soil, Air, Water*, *42*(2), 146–152. https://doi.org/10.1002/CLEN.201300113

Boogaard, F., & Lucke, T. (2019). Long-Term Infiltration Performance Evaluation of Dutch Permeable Pavements Using the Full-Scale Infiltration Method. *Water 2019, Vol. 11, Page 320*, *11*(2), 320. https://doi.org/10.3390/W11020320

Bouwmeester, H. (2023). Waterdoorlatende verharding vraagt om bijzondere aandacht bij ontwerp, aanleg en beheer. https://www.kanbouwen.nl/2023/04/14/waterdoorlatende-verharding-vraagt-om-bijzondere-aandacht-bij-ontwerp-aanleg-en-beheer/

Brouwer, M. (2021). Klimaat adaptatie strategieën vergeleken. klimaatadaptie.nl.

Brunner, H., Hirz, M., Hirschberg, W., & Fallast, K. (2018). Evaluation of various means of transport for urban areas. Energy, Sustainability and Society, 8(1), 1–11. https://doi.org/10.1186/S13705-018-0149-0/FIGURES/10

Central Bureau for Statistics. (2023, April 26). *Bevolkingsontwikkeling; regio per maand* [Data file]. Retrieved from Https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37230ned/table?ts=1684311881148

Central Bureau for Statistics. (2014, January 6). *Oppervlakte per gemeente, 1 januari 2014* [Data file]. Retrieved from https://www.cbs.nl/nl-nl/maatwerk/2014/02/oppervlakte-per-gemeente-1-januari-2014

Christiansen, P., Engebretsen, Ø., Fearnley, N., & Usterud Hanssen, J. (2017). Parking facilities and the built environment: Impacts on travel behaviour. Transportation Research Part A: Policy and Practice, 95, 198–206. https://doi.org/10.1016/J.TRA.2016.10.025

CROW, & het Fietsberaad. (2005). *Fietsstraten in hoofdfietsroutes Toepassingen in de praktijk*.

CROW. (2021). *Toepassen STOMP Voor duurzame gebiedsontwikkeling*.

Davis, A. P., Hunt, W. F., Traver, R. G., & Clar, M. (2009). Bioretention Technology: Overview of Current Practice and Future Needs. *Journal of Environmental Engineering*, *135*(3), 109–117. https://doi.org/10.1061/(ASCE)0733-9372(2009)135:3(109)/ASSET/2D2F4FBA-809E-44A1-BE99-F0A8B5F77E7C/ASSETS/IMAGES/LARGE/2.JPG

de Graaf Van Dinther, R., Leskens, A., Veldkamp, T., Kluck, J., & Boogaard, F. (2021). From pilot projects to transformative infrastructures, exploring market receptivity for permeable pavement in the netherlands. *Sustainability (Switzerland)*, *13*(9), 4925. https://doi.org/10.3390/SU13094925/S1

de Vos, J. (2015). The influence of land use and mobility policy on travel behavior: A comparative case study of flanders and the netherlands. *Journal of Transport and Land Use*, *8*(1), 171–190. https://doi.org/10.5198/JTLU.2015.709

de Vries, S., Kamphorst, D., & Langers, F. (2022). Beleidsdenken over stedelijk groen en gezondheid : en de mate waarin dit zich laat onderbouwen vanuit het onderzoek.

Delta Programme Commissioner. (2017, September 20). Delta programme 2018, continuing the work on a sustainable and safe delta. Ministry of Infrastructure, Water Management, Ministry of Agriculture, Nature, Food Quality, Ministry of the Interior, and Kingdom Relations.

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. G., Mittal, N., Feliu, E., & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, *146*, 107–115. https://doi.org/10.1016/J.JENVMAN.2014.07.025

Dong, T., Jiao, L., Xu, G., Yang, L., & Liu, J. (2019). Towards sustainability? Analyzing changing urban form patterns in the United States, Europe, and China. *Science of The Total Environment*, *671*, 632–643. https://doi.org/10.1016/J.SCITOTENV.2019.03.269

Ekka, S. A., Rujner, H., Leonhardt, G., Blecken, G. T., Viklander, M., & Hunt, W. F. (2021). Next generation swale design for stormwater runoff treatment: A comprehensive approach. *Journal of Environmental Management*, *279*, 111756. https://doi.org/10.1016/J.JENVMAN.2020.111756

European Commission. (2017). *Sustainable & Smart Mobility Strategy - Putting European transport on track for the future #MobilityStrategy*.

Faber, R., & Hamersma, M. (2021). De effecten van COVID-19 op mobiliteit: een analyse van de (wetenschappelijke) literatuur.

Fenner, R. (2017). Spatial evaluation of multiple benefits to encourage multi-functional design of sustainable drainage in Blue-Green cities. Water (Switzerland), 9(12). https://doi.org/10.3390/W9120953

Foletta, N., & Field, S. (2011). *Europe's Vibrant New Low Car(bon) Communities*. Institute for transportation & development policy (ITDP).

Graça, M., Cruz, S., Monteiro, A., & Neset, T. S. (2022). Designing urban green spaces for climate adaptation: A critical review of research outputs. *Urban Climate*, *42*, 101126. https://doi.org/10.1016/J.UCLIM.2022.101126

Gemeente Utrecht (2021). *Mobiliteitsplan 2040 Jouw straat en onze stad gezond, aantrekkelijk en bereikbaar voor iedereen.*

Gemeente Rotterdam. (2020). *Rotterdamse Mobiliteits Aanpak*.

Gemeentewerken Rotterdam, Nijhuis, E. W. J. T., & Kennis voor Klimaat. (2011). *Hittestress in Rotterdam*. www.kennisvoorklimaat.nl

Gemeente Rotterdam (2016). Parkeren in Beweging - Parkeerplan Rotterdam 2016 - 2018.

Gemeente Rotterdam (2017). Slimme bereikbaarheid voor een gezond, economisch sterk en aantrekkelijk Rotterdam Stedelijk Verkeersplan Rotterdam

Gemeente Apeldoorn (2023). Het stadspark van Apeldoorn - Resultaten enquête - Hart van de Stad. https://www.apeldoorn.nl/fl-resultaten-openstad-enquete

Global Designing Cities Initiative. (2023). *Green Infrastructure Design Guidance*. https://globaldesigningcities.org/publication/global-street-design-guide/utilities-and-infrastructure/green-infrastructure-stormwater-management/green-infrastructure-design-guidance/

Goede, A. (2021). *Landelijke hittekaart gevoelstemperatuur - Technische toelichting - inclusief klimaatscenario WH 2050 - Stichting Climate Adaptation Services*. www.witteveenbos.com

Guo, Z. (2013). Does residential parking supply affect household car ownership? The case of New York City. Journal of Transport Geography, 26, 18–28. https://doi.org/10.1016/J.JTRANGEO.2012.08.006

Hamilton-Baillie, B. (2008). Shared Space: Reconciling People, Places and Traffic. *Built Environment*, *34*(2).

Hammond, M. J., Chen, A. S., Djordjević, S., Butler, D., & Mark, O. (2014). Urban flood impact assessment: A state-of-the-art review. *Https://Doi-Org.Tudelft.Idm.Oclc.Org/10.1080/1573062X.2013.857421*, *12*(1), 14–29. https://doi.org/10.1080/1573062X.2013.857421

He, C., Zhou, L., Ma, W., & Wang, Y. (n.d.). *Spatial Assessment of Urban Climate Change Vulnerability during Different Urbanization Phases*. https://doi.org/10.3390/su11082406

Heusinkveld, B. G., Steeneveld, G. J., van Hove, L. W. A., Jacobs, C. M. J., & Holtslag, A. A. M. (2014). Spatial variability of the rotterdam urban heat island as influenced by urban land use. *Journal of Geophysical Research*, *119*(2), 677–692. https://doi.org/10.1002/2012JD019399

Hurlimann, A., Moosavi, S., & Browne, G. R. (2021). Urban planning policy must do more to integrate climate change adaptation and mitigation actions. *Land Use Policy*, *101*, 105188. https://doi.org/10.1016/j.landusepol.2020.105188

Jayakody, R. R. J. C., Keraminiyage, K., Alston, M., & Dias, N. (2018). Design factors for a successful shared space street (SSS) design. *International Journal of Strategic Property Management*, *22*(4), 278–289. https://doi.org/10.3846/IJSPM.2018.3685

Jorritsma, P., Arendsen, K., Faber, R. (2023). *Autoluw beleid gemeenten. Doelen, effecten en rollen.* Kennisinstituut voor Mobiliteitsbeleid (KiM).

Ka, F., Chan, S., Griffiths, J. A., Higgitt, D., Xu, S., Zhu, F., Tang, Y.-T., Xu, Y., & Thorne, C. R. (2018). *"Sponge City" in China-A breakthrough of planning and flood risk management in the urban context*. https://doi.org/10.1016/j.landusepol.2018.03.005

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954–2965. https://doi.org/10.1111/JAN.13031

KiM. (2019). *Mobiliteitsbeeld 2019 | Publicatie | Kennisinstituut voor Mobiliteitsbeleid*. https://www.kimnet.nl/mobiliteitsbeeld/publicaties/rapporten/2019/11/12/mobiliteitsbeeld-2019-vooral-het-gebruik-van-de-trein-neemt-toe

KiM. (2021). *Mobiliteitsbeeld 2021 | Publicatie | Kennisinstituut voor Mobiliteitsbeleid*. https://www.kimnet.nl/mobiliteitsbeeld/publicaties/publicaties/2021/11/18/mobiliteitsbeeld-2021

Kirschner, F., & Lanzendorf, M. (2020). Parking management for promoting sustainable transport in urban neighbourhoods. A review of existing policies and challenges from a German perspective. *Transport Reviews*, *40*(1), 54–75. https://doi.org/10.1080/01441647.2019.1666929

Klemm, W., Heusinkveld, B. G., Lenzholzer, S., & van Hove, B. (2015). Street greenery and its physical and psychological impact on thermal comfort. *Landscape and Urban Planning*, *138*, 87–98. https://doi.org/10.1016/J.LANDURBPLAN.2015.02.009

Klok, L., Jeroen, J. (, & Kluck,). (2016). Reasons to adapt to urban heat (in the Netherlands). *Urban Climate*. https://doi.org/10.1016/j.uclim.2016.10.005

KNMI. (2021). KNMI Klimaatsignaal '21 - Hoe het klimaat in Nederland snel verandert. *De Bilt*.

Kraemer, R., & Kabisch, N. (2022). Parks Under Stress: Air Temperature Regulation of Urban Green Spaces Under Conditions of Drought and Summer Heat. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/FENVS.2022.849965

Kumar, H., Singh, M. K., Gupta, M. P., & Madaan, J. (2020). Moving towards smart cities: Solutions that lead to the Smart City Transformation Framework. *Technological Forecasting and Social Change*, *153*. https://doi.org/10.1016/J.TECHFORE.2018.04.024

Langeveld, J. G. (2019). *AFKOPPELEN KANSEN EN RISICO'S VAN ANDERS OMGAAN MET HEMELWATER IN DE STAD*. STOWA. www.stowa.nl

Langergraber, G., Castellar, J. A. C., Pucher, B., Baganz, G. F. M., Milosevic, D., Andreucci, M. B., Kearney, K., Pineda-Martos, R., & Atanasova, N. (2021). A Framework for Addressing Circularity Challenges in Cities with Nature-Based Solutions. *Water 2021, Vol. 13, Page 2355*, *13*(17), 2355. https://doi.org/10.3390/W13172355

Lenzholzer, S., Duchhart, I., & Koh, J. (2013). Perspective essay "Research through designing" in landscape architecture. *Landscape and Urban Planning*, *113*, 120–127. https://doi.org/10.1016/j.landurbplan.2013.02.003

Lucke, T., Boogaard, F., & Ven, F. van de. (2014). Evaluation of a new experimental test procedure to more accurately determine the surface infiltration rate of permeable pavement systems. *Urban, Planning and Transport Research: An Open Access Journal*, *2*(1), 22–35. https://doi.org/10.1080/21650020.2014.893200

Machairas, I., Frans, ·, & van de Ven, H. M. (2023). An urban drought categorization framework and the vulnerability of a lowland city to groundwater urban droughts. *Natural Hazards*, *116*, 1403–1431. https://doi.org/10.1007/s11069-022-05767-0

Matthews, T., Lo, A. Y., & Byrne, J. A. (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning*, *138*, 155–163. https://doi.org/10.1016/j.landurbplan.2015.02.010

McGrane, S. J., Acreman, M. C., & Rozos, E. (2016). Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. https://doi.org/10.1080/02626667.2015.1128084

Mees, H., Tijhuis, N., & Dieperink, C. (2018). The effectiveness of communicative tools in addressing barriers to municipal climate change adaptation: lessons from the Netherlands. *Climate Policy*, *18*(10), 1313–1326. https://doi.org/10.1080/14693062.2018.1434477

Mees, H., & Surian, J. (2023). Dutch national climate change adaptation policy through a securitization lens: Variations of securitization. Frontiers in Climate, 5, 1080754. https://doi.org/10.3389/FCLIM.2023.1080754/BIBTEX

Meijaard, S., van Hamel, A., Dekker, G., & Handgraaf, S. (2022). Handreiking decentrale regelgeving – klimaatadaptief en natuurinclusief bouwen, inrichten en beheren. *Ministerie van Binnenlandse Zaken En Koninkrijksrelaties*.

Melia, S. (2010). *Carfree, low car - what's the difference?* https://uwe-repository.worktribe.com/output/974666/carfree-low-car-whats-the-difference

Miller, J. D., & Hutchins, M. (2017). The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *Journal of Hydrology: Regional Studies*, *12*, 345–362. https://doi.org/10.1016/J.EJRH.2017.06.006

Mills, G. (2008). Luke Howard and The Climate of London. *Weather*, *63*(6), 153–157. https://doi.org/10.1002/WEA.195

Mingardo, G., van Wee, B., & Rye, T. (2015). Urban parking policy in Europe: A conceptualization of past and possible future trends. *Transportation Research Part A*. https://doi.org/10.1016/j.tra.2015.02.005

Mingardo, G. (2020). Parking - An International Perspective - Rotterdam, The Netherlands. https://doi.org/10.1016/B978-0-12-815265-2.00008-X

Ministry of the Interior and Kingdom Relations (2020). National Strategy on Spatial Planning and the Environment - A sustainable perspective for our living environment

Mullaney, J., & Lucke, T. (2014). Practical Review of Pervious Pavement Designs. *CLEAN – Soil, Air, Water*, *42*(2), 111–124. https://doi.org/10.1002/CLEN.201300118

NAS. (2016). “Nationale klimaatadaptatiestrategie (NAS),” in Kennisportaal klimaatadaptatie (Ministerie van Infrastructuur en Milieu). Available online at: https://klimaatadaptatienederland.nl/overheden/nas

NEN. (2013, March 1). *NEN 2443: Parkeren en stallen van personenauto's op terreinen en in garages.* Retrieved from: https://www.nen.nl/nen-2443-2013-nl-175451

Nicolaisen, J. (2017). Citation Analysis. *Royal School of Library and Information Science, Copenhagen*.

Nieuwenhuijsen, M., Bastiaanssen, J., Sersli, S., Waygood, E. O. D., & Khreis, H. (2018). Implementing car-free cities: Rationale, requirements, barriers and facilitators. *Integrating Human Health into Urban and Transport Planning: A Framework*, 199–219. https://doi.org/10.1007/978-3-319-74983-9_11

Nieuwenhuijsen, M. J. (2020). Urban and transport planning pathways to carbon neutral, liveable and healthy cities; A review of the current evidence. *Environment International*. https://doi.org/10.1016/j.envint.2020.105661

Nieuwenhuis, E., Cuppen, E., Langeveld, J., & de Bruijn, H. (2021). Towards the integrated management of urban water systems: Conceptualizing integration and its uncertainties. Journal of Cleaner Production, 280. https://doi.org/10.1016/J.JCLEPRO.2020.124977

Nieuwenhuis, E., Cuppen, E., & Langeveld, J. (2022). The role of integration for future urban water systems: Identifying Dutch urban water practitioners’ perspectives using Q methodology. Cities: The International Journal of Urban Policy and Planning, 126. https://doi.org/10.1016/J.CITIES.2022.103659

NWK KBS. (2020). Handreiking Slim Koppelen Klimaatadaptatie - Klimaatadaptatie. https://klimaatadaptatienederland.nl/hulpmiddelen/overzicht/handreiking-slim-koppelen/

OCW. (2008). *Waterdoorlatende verhardingen met betonstraatstenen*.

Optigrün. (2023). *Economisch Groendak - Systeemopbouw*. https://www.optigruen.nl/systemen/standaard-groendak/systeemopbouw

Orimoloye IR, Belle JA, Olusola AO, Busayo ET, Ololade OO (2021) Spatial assessment of drought disasters, vulnerability, severity and water shortages: a potential drought disaster mitigation strategy. Nat Hazards 105(3):2735–2754. https://doi.org/10.1007/s11069-020-04421-x

Park Positive. (2023). *Home - Groen Parkeren met Duurzame Grastegels - Park Positive*. https://parkpositive.nl/

Parker, C., Scott, S., & Geddes, A. (2019). *Snowball Sampling*. http://methods.sagepub.com/foundations/snowball-sampling

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the

Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001.

Pochodyła, E., Glińska-Lewczuk, K., & Jaszczak, A. (2021). Blue-green infrastructure as a new trend and an effective tool for water management in urban areas. *Landscape Online*, *92*, 92–92. https://doi.org/10.3097/LO.202192

Priya, A. (2021). Case Study Methodology of Qualitative Research: Key Attributes and Navigating the Conundrums in Its Application. *Sociological Bulletin*, *70*(1), 94–110. https://doi.org/10.1177/0038022920970318

QGIS. (2023). *Discover QGIS*. https://www.qgis.org/en/site/about/index.html

Raimondi, A., & Becciu, G. (2021). Performance of Green Roofs for Rainwater Control. *Water Resources Management*, *35*(1), 99–111. https://doi.org/10.1007/S11269-020-02712-3/FIGURES/4

Renalds, A., Smith, T. H., & Hale, P. J. (2010). A systematic review of built environment and health. *Family and Community Health*, *33*(1), 68–78. https://doi.org/10.1097/FCH.0B013E3181C4E2E5

Runhaar, H., Mees, H., Wardekker, A., van der Sluijs, J., & Driessen, P. P. J. (2012). Adaptation to climate change-related risks in Dutch urban areas: Stimuli and barriers. *Regional Environmental Change*, *12*(4), 777–790. https://doi.org/10.1007/S10113-012-0292-7/TABLES/4

Runhaar, H., Wilk, B., Persson, Å., Uittenbroek, C., & Wamsler, C. (2018). Mainstreaming climate adaptation: taking stock about "what works" from empirical research worldwide. Regional Environmental Change, 18(4), 1201–1210. https://doi.org/10.1007/S10113-017-1259-5/TABLES/1

Scoones, I., Stirling, A., Abrol, D., Atela, J., Charli-Joseph, L., Eakin, H., Ely, A., Olsson, P., Pereira, L., Priya, R., van Zwanenberg, P., & Yang, L. (2020). Transformations to sustainability: combining structural, systemic and enabling approaches. *Current Opinion in Environmental Sustainability*, *42*, 65–75. https://doi.org/10.1016/J.COSUST.2019.12.004

Shashua-Bar, L., Tsiros, I. X., & Hoffman, M. (2012). Passive cooling design options to ameliorate thermal comfort in urban streets of a Mediterranean climate (Athens) under hot summer conditions. *Building and Environment*, *57*, 110–119. https://doi.org/10.1016/J.BUILDENV.2012.04.019

Shen, T., Hong, Y., Thompson, M. M., Liu, J., Huo, X., & Wu, L. (2020). *How does parking availability interplay with the land use and affect traffic congestion in urban areas? The case study of Xi'an, China*. https://doi.org/10.1016/j.scs.2020.102126

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A., Baas, P., & Mackie, H. (2017). Systematic literature review of built environment effects on physical activity and active transport - an update and new findings on health equity.

International Journal of Behavioral Nutrition and Physical Activity, *14*(1), 1–27. https://doi.org/10.1186/S12966-017-0613-9/TABLES/3

Snep. R.P.H. & C.M. Goossen, (2022). Groennormen in de stad en omgeving; Een verkenning vanuit de wetenschap. Wageningen, *Wageningen Environmental Research*, Rapport 3219. 42 blz.; 1 fig.; 9 tab.; 68 ref.

Siwiec, E., Erlandsen, A. M., & Vennemo, H. (2018). City Greening by Rain Gardens - Costs and Benefits. *Ochrona Srodowiska i Zasobow Naturalnych*, *29*(1), 1–5. https://doi.org/10.2478/OSZN-2018-0001

Steeneveld, G. J., S. Koopmans, B. G. Heusinkveld, L. W. A. van Hove, and A. A. M. Holtslag (2011), Quantifyingurban heat island effects and human comfort for cities of variable size and urban morphology in the Netherlands,J. Geophys. Res.,116, D20129, doi:10.1029/2011JD015988

Stichting RIONED. (2019). Defaultwaarden inloopparameters inloopmodellen - RIONED. https://www-riool-net.tudelft.idm.oclc.org/defaultwaarden-inloopparameters-inloopmodellen

Suleiman, L. (2021). Blue green infrastructure, from niche to mainstream: Challenges and opportunities for planning in Stockholm. *Technological Forecasting and Social Change*, *166*, 120528. https://doi.org/10.1016/J.TECHFORE.2020.120528

Thorne, C. R., Lawson, E. C., Ozawa, C., Hamlin, S. L., & Smith, L. A. (2018). Overcoming uncertainty and barriers to adoption of Blue-Green Infrastructure for urban flood risk management. *Journal of Flood Risk Management*, *11*, S960–S972. https://doi.org/10.1111/JFR3.12218

TUlib. Making a search plan, 2023. URL https://tulib.tudelft.nl/searching-resources/making-a-search- plan/

Uittenbroek, C. J., Janssen-Jansen, L. B., & Runhaar, H. A. C. (2013). Mainstreaming climate adaptation into urban planning: Overcoming barriers, seizing opportunities and evaluating the results in two Dutch case studies. *Regional Environmental Change*, *13*(2), 399–411. https://doi.org/10.1007/S10113-012-0348-8/TABLES/4

Ungvarai, A. (2019). Modal Split-Different Approaches to a Common Term. *IOP Conference Series: Materials Science and Engineering*, *603*(4). https://doi.org/10.1088/1757-899X/603/4/042091

van Boggelen, O., & Hulshof, R. (2019). Fietsberaadnotitie aanbevelingen fietsstraten binnen de kom.

van den Ende, M. A., Mees, H. L. P., Hegger, D. L. T., & Driessen, P. P. J. (2022). Mechanisms influencing mainstreaming of adaptation in spatial development: case studies in three Dutch municipalities. Journal of Environmental Planning and Management. https://doi.org/10.1080/09640568.2022.2092724

van der Hoeven, F. (2013). Deconstructing Rotterdam's modern city centre. *Vostoksibacademcenter*, 60–71.

van Horn, D. (2023). Paving the Way - Exploring the Potential of Green Parking and Collaborative Information Sharing between Municipalities and Companies. *MSc Thesis, Delft University of Technology*. Delft, the Netherlands.

Veldkamp, T., Schoenmaker, T., & Klück, J. (2020). WP2: FUNCTIONEREN VAN INFILTRERENDE VERHARDING IN DE PRAKTIJK RAAK MKB project: De Infiltrerende Stad. *Hogeschool Amsterdam*.

Venter, Z. S., Barton, D. N., Gundersen, V., Figari, H., & Nowell, M. (2020). Urban nature in a time of crisis: recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway. Environmental Research Letters, 15(10), 104075. https://doi.org/10.1088/1748-9326/ABB396

Venvik, G., & Boogaard, F. C. (2020). Infiltration Capacity of Rain Gardens Using Full-Scale Test Method: Effect of Infiltration System on Groundwater Levels in Bergen, Norway. 9, 520. https://doi.org/10.3390/land9120520

Versini, P.-A., Kotelnikova, N., Poulhes, A., Tchiguirinskaia, I., Schertzer, D., & Leurent, F. (2018). A distributed modelling approach to assess the use of Blue and Green Infrastructures to fulfil stormwater management requirements. https://doi.org/10.1016/j.landurbplan.2018.02.001

Wegman, F., Zhang, F., & Dijkstra, A. (2012). How to make more cycling good for road safety? *Accident Analysis and Prevention*, *44*, 19–29. https://doi.org/10.1016/j.aap.2010.11.010

Weustenenk, A. G., & Mingardo, G. (2023). Towards a typology of mobility hubs. *Journal of Transport Geography*, *106*, 103514. https://doi.org/10.1016/J.JTRANGEO.2022.103514

Woo, H. (2020). Nature-based solutions and similar concepts on water management. *IOP Conference Series: Earth and Environmental Science*, *599*(1). https://doi.org/10.1088/1755-1315/599/1/012094

Yin, R. K. (2003). Case study methodology R.K. Yin (2003, 3rd edition). Case Study Research design and methods. Sage, Thousand Oaks (CA)..pdf. Case Study Research: Design and Methods, 19–39; 96–106. https://books.google.com/books/about/Case_Study_Research.html?hl=nl&id=BWea_9ZGQMwC

Zhang, K., Fong, T., & Chui, M. (2017). *A comprehensive review of spatial allocation of LID-BMP-GI practices: Strategies and optimization tools*. https://doi.org/10.1016/j.scitotenv.2017.11.281

Appendices

A. Review of policy documents

Tabel 28 Review of policy documents, municipality of Utrecht

Document	Policy domain	Document type	Applicable information	Quantifiable information
Coalitieakkoord 2022-2026 "Investeren in Utrecht" (2022)	General	Guiding policy document	Political choices made by the governing parties in the municipality	-More space for pedestrians -30 km/h becomes the standard for most roads -Transform 0.5-1% of the public on-street parking space yearly
Ruimtelijke Strategie Utrecht (RSU) "Utrecht dichtbij: de tien-minutenstad" (2021)	Urban planning	Strategical environmental and urban planning vision	Overarching document on the strategical vision of the municipalities public space	-40% green in every neighbourhood. -Store 90% of the yearly precipitation -Integrated approach to mobility and climate adaptation
Mobiliteitsplan 2040 "Jouw straat en onze stad gezond, aantrekkelijk en bereikbaar voor iedereen" (2021)	Mobility	Guideline for new traffic projects	Shows how mobility is changing and gives a prediction for the future. Gives additional measure to stimulate other forms of mobility.	Reduce the available parking space on streets with 0.5 to 1% yearly. Mobility shift from cars to public transport and bikes in 2040. Even more extreme with measures from mobility plan.
Parkeervisie "Fiets- en autoparkeren in een groeiend Utrecht" (2021)	Mobility	Part of the mobility policy and mobility plan	Instrument and guiding document to steer towards less space for cars and more other forms of mobility	-Map of different zones in the municipality with accompanying parking policy. -Fewer parking spaces improves liveability. -Revenue loss often an obstacle. -Goal: transform 1% of parking space to other functions yearly.
Aanpak parkeren openbare ruimte (2021)	Mobility	Detailed elaboration of the parking vision.	Shows the approach to removing parking spaces. Focusses on exciting urban areas.	-Creating space by moving cars to parking spots at the edge of the city and stimulating alternatives for private owned cars. -Use this space for green, bicycles and playgrounds.
Parkeernormen fiets en auto (2021)	Mobility	Detailed elaboration of the parking vision.	General information on parking space requirements for newly build areas	Municipality is divided in different areas, with accompanying rules. Focusing on distant parking and shared mobility.
Parkeernormentabellen Bijlage bij module Parkeernormen (2021)	Mobility	Normative parking space	Minimum number of car and bicycle parking space needed in newly build areas	Number of parking spots per type of building per area type

Actualisatie Groenstructuurplan 2017-2030 (2018)	Climate adaptation	Guideline for green and ecology in the municipality	-One of the primary goals is climate adaptation. -BGI to cope with the negative effects of climate change: Floods, droughts and heat	-50% of the surface area in Utrecht is paved - An indicator for climate adaptation and greening is the amount of public green space (m2) per household
Plan Gemeentelijke Watertaken Utrecht 2016-2019 (April 2015)	Water	Municipal sewage plan	Description of the obligations of the municipality on waste water, precipitation and ground water.	-Municipality sewer system must be able to store process 20mm water per hour -change paved surfaces to BGI -permeable pavements only in areas where traffic intensity is low -Expected: 2Ha permeable pavements and 4ha BGI each year.
Visie Klimaatadaptatie Utrecht (2022)	Climate adaptation	Guideline on how to fulfil DPRA goals. Interconnected with other themes and tasks of the municipality.	Without taking action the cost of damages, due to climate change, rise significantly to 1.6 billion euros and more. By 2050, the Utrecht wants to be climate-proof and thus have addressed their vulnerabilities. Important to combine climate adaptation with other activities such as mobility change.	-Store and use at least 90% of the precipitation -30% shade on walking and cycling paths -40% green surface in each neighbourhood -Able to cope with rainfall extremes of 80 mm in one hour. -Storage capacity of at least 15mm, to cope with droughts -Limit the heat island effect to a maximum difference of 5 degrees Celsius -Utrecht stress test risk maps for floods, droughts and heat
Visie Water en Riolering Utrecht (2022)	Water	Municipal sewage plan	Gives a detailed explanation on the policy choices the municipality takes in order to fulfil the targets of climate adaptivity and legal water obligations	-Store and use at least 90% of the precipitation -Able to cope with rainfall extremes of 80 mm in an hour -Storage capacity of at least 15mm -20mm/h rainfall: no water on the streets -80mm/h rainfall: Max 20 mm of water in front of doorsteps, 7.5 cm on 50 km/h roads and 20 cm on other roads. Normal use of space within 3 hours.

Tabel 29 Review of policy documents, municipality of Rotterdam

Document	Policy domain	Document type	Applicable information	Quantifiable information
Coalitieakkoord 2022-2026 “Een Stad Rotterdam” (2022)	General	Guiding policy document	Political choices made by the governing parties in the municipality	-20 extra hectare of urban green -30 km/h becomes the standard when possible -Work towards a car free city centre, by creating one way streets, sperate cycle paths, 30km streets and possible removing parking space.
Omgevingsvisie Rotterdam “De Veranderstad” (2021)	Urban planning	Strategical environmental and urban planning vision	Guiding spatial vision, guiding for spatial plan and programs. Uses information of multiple policy documents.	-More green with 7 city projects -No traversing car traffic in the city centre. Car traffic outside the centres -Speed limit all roads within residential areas to 30 km/h -More space for bikes and pedestrians less for cars. -especially in old city residential districts more need for green and water.
Visie Openbare Ruimte 2019-2029 Rotterdam “Een gezond en groen Rotterdam voor iedereen” (2019)	Urban planning	Strategical urban planning vision	Overarching document on the strategical vision of the municipalities public space	-More green spaces where need is highest (city centre and city neighbourhoods) -Transform pavement into green. In streets squares and between tram tracks. -More space for bikes and pedestrians.
Rotterdamse Mobiliteits Aanpak (2020)	Mobility	Guideline for new traffic projects	Shows how mobility is changing and gives a prediction for the future. Gives additional measure to stimulate other forms of mobility.	-Link with climate adaptation -Different division of space for traffic needed -Lower the maximum speed and car intensity on main streets (Stadsstraten)
Gemeentelijk Rioleringsplan Rotterdam 2021-2025 ”Van buis naar buitenruimte” (2020)	Water	Municipal sewage plan	Gives a detailed explanation on the policy choices the municipality takes in order to fulfil the targets of climate adaptivity and legal water obligations	Combine programs and investments with i.a. the mobility transition Different requirements per rainfall intensity: -T=2, 20 mm/h, no water on streets -T=10-25, 48 mm/h, little water on streets accepted -T=100, 70mm/h, water on streets accepted for a few hours, no structural damage

Tabel 30 Review of policy documents, municipality of Apeldoorn, stadspark

Document	**Policy domain**	**Document type**	**Applicable information**	**Quantifiable information**
Omgevingsvisie Apeldoorn "WOEST AANTREKKELIJK APELDOORN" (2022)	General	Strategical environmental and urban planning vision	Guiding spatial vision, guiding for spatial plan and programs. Uses information of multiple policy documents.	-City centre will become car free. Parking facilities will be concentrated on the edge of the centre. Focus on active forms of mobility, walking and cycling - Critical spots in public spaces have been identified for which heat stress occurs. Goal to realize a spatial planning that counteracts heat stress by 2030. - The water system has to become more circular, by retaining and using more of the rainwater.
Verkeersvisie 2016 - 2030 (2016)	Mobility	Guideline for new traffic projects in the municipality	Describes challenges concerning mobility and the measures that are planned to be taken	- Ambition to promote Apeldoorn as cycling city -Creating a car free city centre is NOT mentioned.
Gemeentelijk Water- en Rioleringsplan Apeldoorn 2022-2026 "Water in Balans" (2021)	Water	Municipal sewage plan	Gives a detailed explanation on the policy choices the municipality takes in order to fulfil the targets of climate adaptivity and legal water obligations	-Goal to limit the amount of paved area by implementing green forms of mobility, for example by creating a car free city centre, stimulate car sharing, MaaS and reducing the maximum speed. - Realize more green in the city centre and minimize the paved area. - New city centre design must prevent water on the street during a rainfall event with a return period of 5 years.
Visie op Mobiliteit in het Stadspark van Apeldoorn (2021)	Mobility	Mobility plan for the city centre	Detailed document reflecting on the mobility challenges and suggesting solutions	-Give more space to pedestrians and cyclist. Redirect car an bus routes around the city centre. -Remove the parking fields in the centre, make more use of the indoor car parks by improving the accessibility.
Ontwikkelperspectief binnenstad Apeldoorn – Het stadspark van Apeldoorn (2020)	General urban planning	Development outlook on the city centre	First urban planning document with suggested designs for the new city centre	-To mitigate heat stress: Realize a minimal of 40% green -To mitigate pluvial flooding: infiltrate and store rainwater create a resilient urban space able to cope with a rainfall intensity of 60 mm in one hour

Tabel 31 Review of policy documents, municipality of Utrecht - Taagdreef

Document	**Document type**	**Applicable information**	**Quantifiable information**
Raadsbrief Pilot inrichting openbare ruimte Taagdreef en omgeving (March 2018)	Council letter to city council on the redevelopment of public space in Taagdreef and surroundings	Explanatory note on variant study conducted for the redesign. One preferred design has been chosen.	-Main goals are; climate adaptation and traffic safety -Expected start of renovation works is in the middle of 2019.
Variantenstudie openbare ruimte Taagdreef en omgeving (March 2018)	Variant study on multiple redesigns for Taagdreef.	Taagdreef is a pilot for integrated approach to public space redevelopment in residential areas in Utrecht. Important; Road safety, Liveability, Climate adaptation and Parking	-Speed limit on main roads of 30 km/h. Rest of the neighbourhood a 15 km/h speed limit is applied -Current road width is about 9 meters, this leads to speeding. -Reduce parking spaces (+- 50) (total now +- 700) -Disconnecting paved surfaces to cope with 80 mm of rainfall in one hour
Integraal programma van eisen (IPvE) en Functioneel ontwerp (FO) - Openbare ruimte Taagdreef (May 2021)	Detailed description of the proposed street design. With the integral list of requirements because of municipal policy.	Describes the background of the goals for this project and how the provisional design plans to reach these goals. Main goals are; improving traffic safety and climate adaptation	-Speed limit is reduced from 50 km/h to 30 or 15 km/h -Minimal side walk width: 1.80 meter, to ensure accessibility for wheelchair users and visually impaired people. -Road width will be reduced to about 5 meters. -Parking spaces must have a width of about 2 meters. -Rainwater will be stored and infiltrated though green at the parking strip on the side of the road -114 trees are cut down. 170 new trees will be planted. -New street designs are according to CROW guidelines for 30km/h street. All roads are accessible to emergency services. -Current about 700 in(formal) parking sport are situated in the area. In the new design 616 parking sport will be constructed. -Rainwater is stored and infiltrated as much as possible via green spaces and parking areas with permeable paving.
Reactienota voorlopig ontwerp Herinrichting Taagdreef (Novemver 2022)	Reaction from 31 residents and 2 stakeholder organizations on the proposed redesign and answers from project managers	Shows the issues residents think are important in a new design and especially which decisions residents disagree with. This is responded to by the project team and they explain what decision will be made or adjusted.	-Most of the concerns were about bus stops, parking places and the layout of the Taagdreef and Rhônedreef -Despite concerns, parking spaces in the area will be reduced as indicated in the design. -113 trees will be cut down, 191 will be added, which leads to a total increase of 78 trees.

Voorlopig ontwerp - Openbare ruimte Taagdreef (March 2023)	Description of the provisional design which an adjusted version of the proposed design. (Including technical drawings)	Gives a detailed overview of the design choices in the final design. Most important design principles; (Add trees, "Green, unless..", streets of pavers, less parking space)	-Expect construction to start in 2024. -Some adjustments are made in the road designs and location in order to create more space for greenery and trees. -One important street in the cycling structure is turned in to a bicycle street, constructed of red asphalt -Greenery in the design has a total surface of 7250 m^2, which is 5 time as much as the unpaved surface now. -Residents are asked to add climate adaptation measures in the private space with help of the municipality, during construction works. -Final design gives room to 645 parking spaces, this is 83 less than the current 728 parking spaces -Parking pressure is expected to decrease in the future, due to developments in the field of shared mobility and implementation of paid parking.

Tabel 32 Review of policy documents, municipality of Utrecht - Kanaalstraat

Document	**Document type**	**Applicable information**	**Quantifiable information**
Buurtvisie (neighborhood vision) Kanaalstraat/ Damstraat (2017)	Presents key findings following consultations with residents, visitors and business owners on the desired future appearance of the Kanaaltraat/ Damstraat, the desired changes and the focal points	Wishes to create more space for pedestrians cyclist and green. Ensure more and healthier trees. Traffic safety should be improved and traffic congestion reduced.	-General: Kanaalstraat 700 meters long and has a width of about 18 meters. - Create a one-way bicycle street about 4 meters wide and reduce the speed limit to 30 km/h -Double the available space for pedestrians -Reduce parking congestion
Consument, locatie en leefstijlen analyse van het winkelgebied Kanaalstraat – Damstraat (2019)	Generic study of the current situation in the plan area commissioned by the municipality	Number of residents in the area will increase. The study area can be classified as shopping area with over 100 stores.	
Herinrichting Kanaalstraat – Damstraat (2019)	Neighbourhood meeting and presentation of the preliminary functional design of the redesign.	A neighbourhood survey shows that speeding and incorrect parking are the biggest concerns. Objective of the redevelopment: Improve liveability, improve traffic safety, replace the sewer system and climate adaptation.	-Maximum speed will be reduced to 30 km/h -Some parking spots will be removed -At least the same number of trees
Herinrichting Kanaalstraat - Damstraat Integraal Programma van Eisen & Functioneel Ontwerp (2020)	Detailed description of the proposed street design. With the integral list of requirements.	The neighbourhood is green-poor and the Kanaalstraat has relatively the most space available for greenery. The aim is to make the new street climate-adaptive. By paving as little as possible, planting as much greenery as possible and infiltrating rainwater.	-Currently 64 parking places -5 to 10 parking places can be removed to facilitate space for waste containers. Removing more parking spaces is undesirable. -New road lane will be 4.10 meters wide -The "function strip" (parking and greenery) will be 2.50 meters wide -Goal to store and use 90% of yearly precipitation -Able to cope with a rainfall event of 80 mm in an hour -Sewer system will be replaced, Applicability of an infiltration sewer (IT) being investigated
Kanaalstraat - Damstraat Ontwerptoelichting Voorlopig Ontwerp (2021)	Detailed description of the provisional street design.	Shows the final street design, which can be used in the case study. Provides information on the street design and the type of climate adaptation measures applied, such as types of trees, application of permeable pavement and sewerage design.	-Total number parking places in the Kanaalstraat are being reduced from 64 to 55 (14%). In the whole project area parking spots are reduced with 30%. (After shopping hours, parking spots added) -The street will be fitted with a sanitary sewer and stormwater sewer (SSO) -Parking spots will be on permeable pavement.

Tabel 33 Review of policy documents, Ede municipality - Edeseweg

Document	**Document type**	**Applicable information**	**Quantifiable information**
Bestuursakkoord Ede 2022-2026 "Samen werken aan de toekomst" (2022)	Strategical vision of the political administration on plans for the next four years	-Take action towards a climate adaptive municipality -Steer towards sustainable and green mobility -Reduce on street car parking through clustering and underground parking lots	-Add green and adapt to increasing droughts heat and extreme precipitation -Stimulate walking, cycling, public transport and shared mobility -Decrease car parking standards when possible
Omgevingsvisie Ede 2040 "Dierbaar Duurzaam Dynamisch" (May 2022)	Strategical long term vision for the physical environment of the municipality, no plan or design for the public area	Mobility; -Parked cars put pressure on the quality of the limited available public space -Some roads are designed for cars, leaving insufficient space for pedestrians, cyclists and greenery -It is expected that the use of shared mobility will increase in residential areas and in the city centre car ownership will transform in to car usage -Sustainable mobility = "reduce, change and make clean" Climate adaptation; -Climate change stress test must show the consequences of climate change in the municipality -Green-blue structures suffer from high parking demand	Mobility; -On roads where mobility types can't be separated speed is reduced through street design measures, such as bicycle streets. -Stimulate healthy and clean forms of mobility such as public transport, walking and cycling. - To redesign public space and give less space to cars, parking standards are adjusted Climate adaptation; -Retain and store rainwater and reduce heat stress -Add green, especially in the most paved areas
Verkeersvisie Bennekom 2030-2040 (February 2022)	Future mobility vision established by the people of Bennekom and not a defined policy of the municipality of Ede	Describes how traffic and mobility in the village can become safer and more sustainable. Elaborates on the policy choices that will be made in order to reach this goal. Shortly mentions the mobility transition and climate adaptation.	-30 km/h speed limit will be the standard on most roads -Prioritize cyclist and pedestrians -Construct a bicycle street on the Edeseweg
Gemeentelijk Rioleringsplan Ede 2018-2022 "Verbindend water" (2021)	Legally required plan on water and sewage management. Describes how the municipal legal obligations because of the water act will be fulfilled.	Gives a detailed explanation on the policy choices the municipality takes on water management. Focusses on climate adaptation, sustainability and a healthy environment, next to the regular sewage obligations. Integrated approach needed between water system and other urban spatial systems.	-Water resilient and climate adaptive by 2050: -treat stormwater above the surface: Store and infiltrate through parking spaces and greenery -Use blue green infrastructure (BGI) as smart multifunctional use of space.
Fietsroute Ede-Wageningen (2023)	General description of the plan for new cycle infrastructure between Ede and Wageningen	The Edeseweg is part of a larger infrastructural project called "pico bello pad". This part of the new cycle infrastructure will be constructed mid-2024. Goal is to promote cycling and discourage car usage	-The Edeseweg will be turned into a bicycle street, cars and cyclist combined, narrow road, 30 km/h speed limit. -Trees will be cut down and replaced

B. Aerial views and street designs from QGIS analysis

B.1. Kanaalstraat, Utrecht

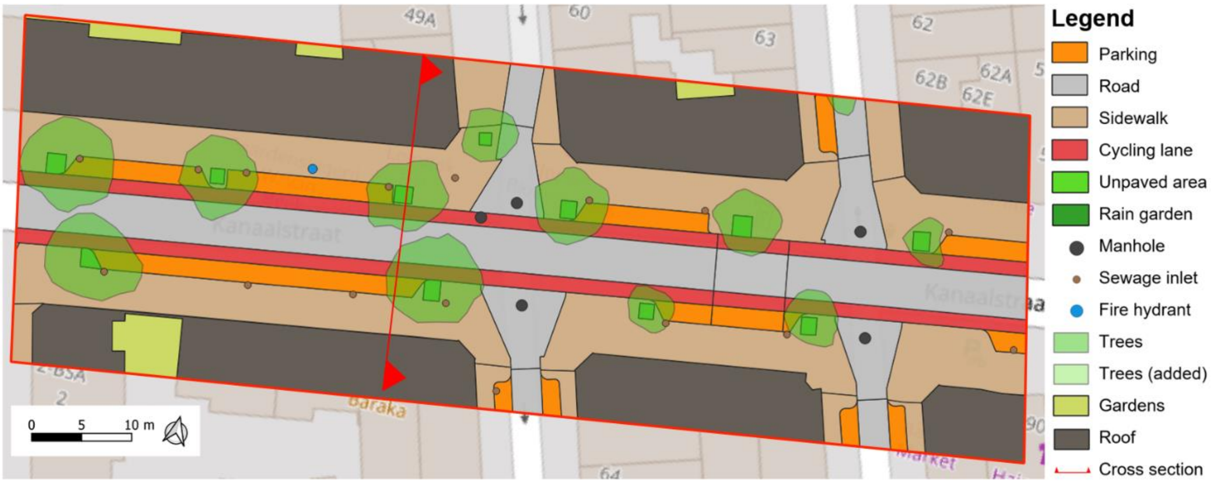

Figure 55 Aerial map (indicating land cover types) - Kanaalstraat – existing situation (Sc0)

Figure 56 Aerial map (indicating land cover types) - Kanaalstraat – proposed design (Sc1)

Figure 57 Aerial map (indicating land cover types) - Kanaalstraat – proposed design + parking space reduction + rain gardens (Sc2)

Figure 58 Aerial map (indicating land cover types) - Kanaalstraat – proposed design + no on-street parking + rain gardens (Sc3)

B.2. Edeseweg, Ede

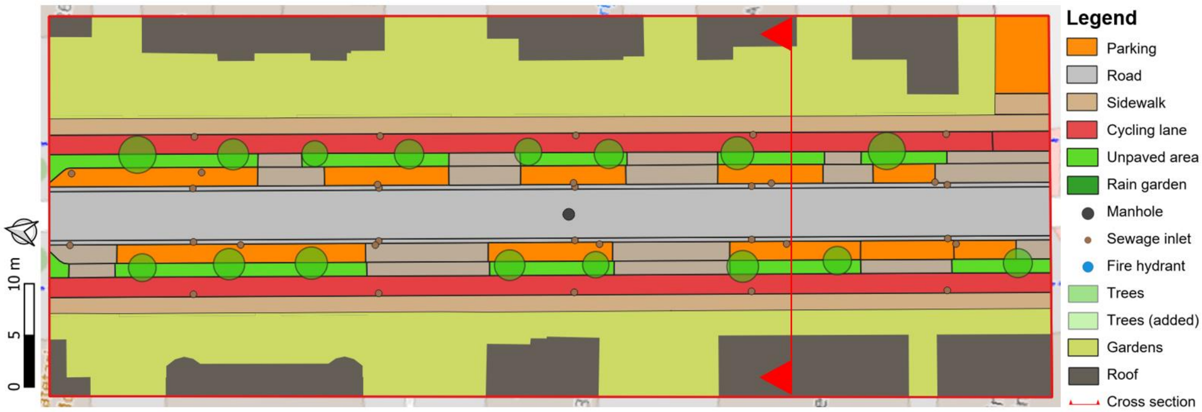

Figure 59 Aerial map (indicating land cover types) - Edeseweg – existing situation (Sc0)

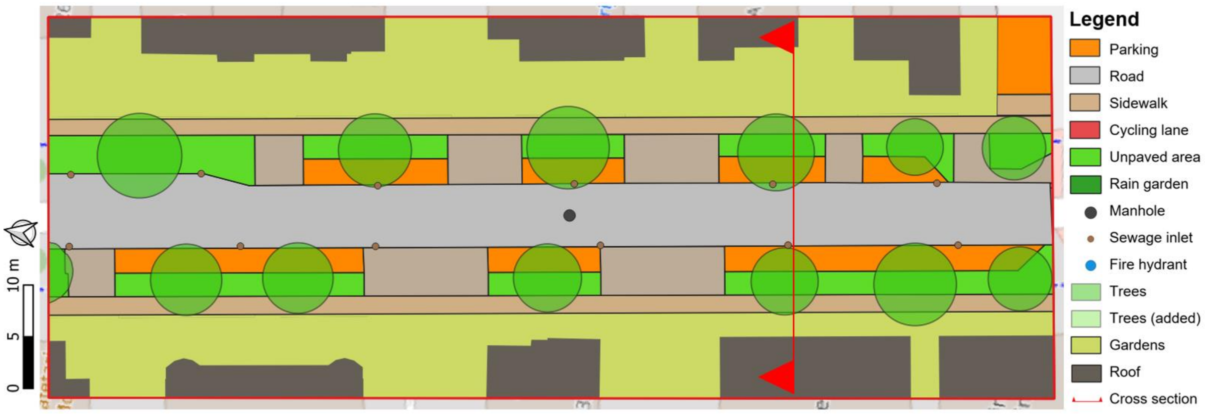

Figure 60 Aerial map (indicating land cover types) - Edeseweg – proposed design (Sc2)

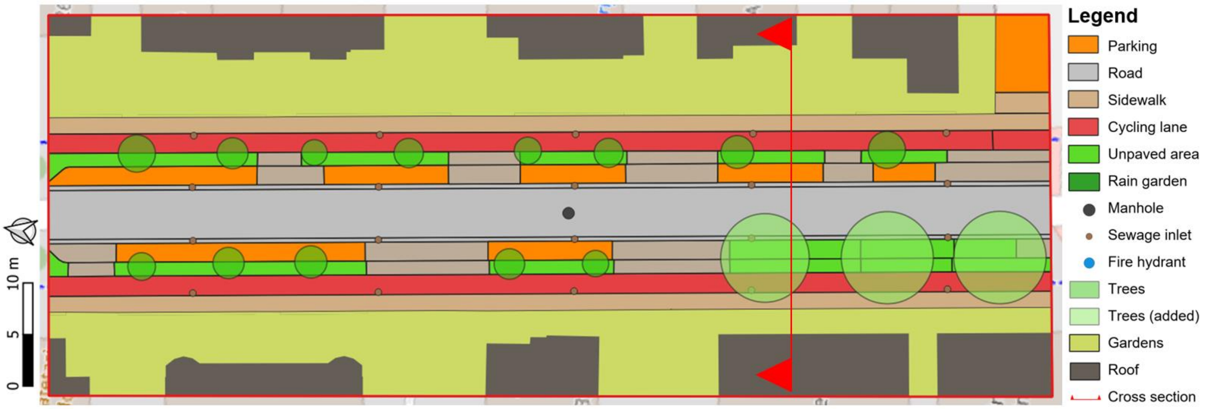

Figure 61 Aerial map (indicating land cover types) - Edeseweg – existing situation + parking space reduction (Sc1)

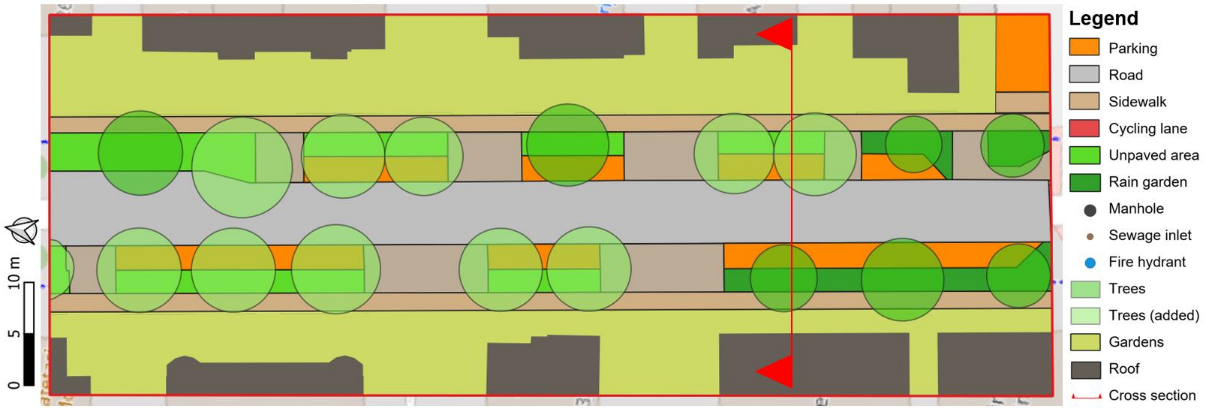

Figure 62 Aerial map (indicating land cover types) - Edeseweg – proposed design + rain gardens (Sc3)

C. Interview guide

Tabel 34 Interview guide. Containing general questions.

Procedure	Before the interview: Informed consent form After the interview: Paraphrased summary of the conversation based on hand written notes will be shared with the interviewee, after permission the results are used in the study
Introduction	Urban mobility is changing, and to make cities cleaner, healthier and more accessible, municipalities are now prioritizing public transport, cycling and walking over car use (the green mobility transition). Fewer cars in urban areas can offer great potential for climate adaptation (dealing with heat, drought and flooding) by providing space for BGI (blue and green infrastructure).
Objective	Find out how mobility plans and ambitions are translated into spatial plans. What future scenarios are likely? Will the space currently used for roads and parking spaces be used for BGI in the future? Or is it more likely that the change in mobility will mainly result in wider pedestrian and bicycle lanes? What could the changing mobility bring to urban climate adaptation? Additionally the interview could provide information for the case study
General information	What is the purpose of your department/organization? What does your work involve?
Mobility	What does the expected future urban mobility look like? And what is the ideal picture? What impact will this have on road use? The number of parking spaces? The width of roads? Number of lanes? In what places in the city will roads or parking spaces be transformed?
Climate adaptation	What is the ideal image for climate adaptive city? Where in the city is climate adaptation most needed? What forms of climate adaptation are typically applied?
Relation	Do some interests from mobility and climate adaptation conflict? If a choice has to be made between mobility (space for parking and roads) or climate adaptation (green, water, infiltration) which is (usually) preferred? What does this choice depend on?