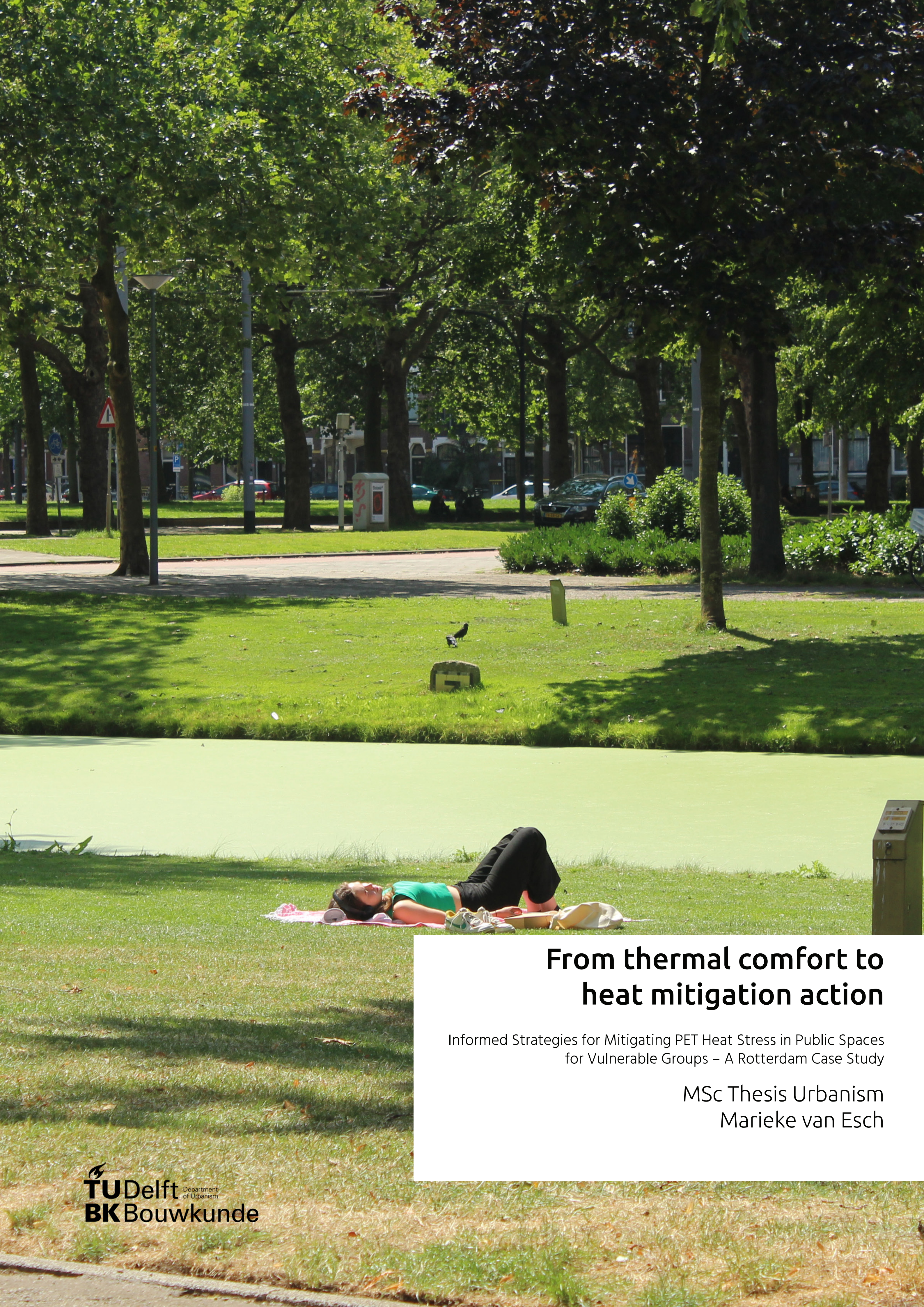

From thermal comfort to heat mitigation action

Informed Strategies for Mitigating PET Heat Stress in Public Spaces for Vulnerable Groups – A Rotterdam Case Study

MSc Thesis Urbanism

Marieke van Esch

TU Delft Department of Urbanism
BK Bouwkunde

COLOPHON

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MSc Graduation Thesis Urbanism and Geomatics
April, 2024
Keywords: Physiological Equivalent Temperature, Thermal Accessibility, Liveability, heat mitigation

Delft University of Technology
Faculty of Architecture and the Built Environment
Studio Design of the Urban Fabric

Author
Marieke van Esch
Student number: 4545508

Mentors:

1st mentor/2nd mentor	Dr. Ir. S.C. van de Spek	Design of the Urban Fabric/ Geomatics
2nd mentor	Dr. Ir. Marjolein van Esch	Metropolitan Ecologies Planning
External mentor	Dr. S. Koopmans	Metereological department Wageningen

Delegate from the Board of Examinors

Examinator	S. Khademi	ABE department

Abstract

In the summer of 2023 heatwaves became quite prominent in the south of Europe. The Netherlands Meteorological Institute predicts that heat waves will increase from 26 to a maximum of 47 days by 2050, affecting also the Netherlands in the future. The main research question focused on proposing a strategy for a livable environment by designing public spaces to mitigate heat stress for vulnerable groups in Bospolder Tussendijken, Rotterdam, the Netherlands. The research involved a literature review, expert consultations, mapping of heat stress, scenario planning, and modelling of the urban environment.
The research aimed to assess the livability of Bospolder Tussendijken in terms of physical and social liveability conditions. The research identified vulnerable groups as the elderly and young children. Vulnerable groups were assessed for their accessibility to public spaces on a summer day, despite the range restriction caused by heat stress, and this information was used to inform design strategies. The application of the reproducible PET tool helped to identify the temporal vulnerability to heat stress. The urban design was tested and evaluated on the heat mitigation effect.
The research emphasized the importance of identifying heat stress in public spaces and the need for urgent action to maintain the quality of life in the future. This research explores the thermal accessibility of humans in public space networks and could have various applications, including modelling the urban heat island and health effects at night. This research should prompt discussions for health organizations to investigate the thermal endurance acceptability of different target groups. Ultimately, the research concluded that urban planning should prioritize durable and readable interventions for citizens to function in the urban environment, while not being the only option to maximize heat mitigation.

KEYWORDS: Physiological Equivalent Temperature, Thermal Accessibility, Liveability, heat mitigation

Fig 0.1 The summer isn't that bad, is it? Delfshaven. Photo taken by Author

Prologue

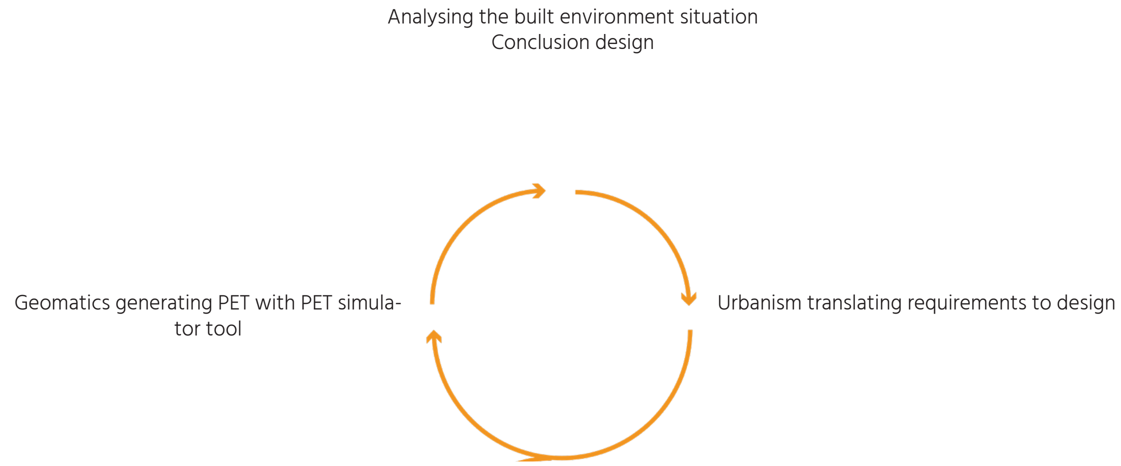
The past summer has shown signs of changing climate variability. In Spain, people are already feeling the effects of heat at the beginning of spring, according to The Guardian (2023). Due to carbon emissions over the past decades, the heat will continue to linger in the atmosphere. The government has warned people to take precautions due to drought and temperatures 7-11 degrees Celsius above the average for this time of year. They have also highlighted behavioral thermoregulation strategies to cope with the heat (Millyard, Layden, Pyne, Edwards & Bloxham, 2020). If emissions continue at the current rate, heat events are likely to occur more frequently in the future, affecting not only the southern part of Europe but also other regions. It is important to take action in the built environment to address climate change, which requires a new approach to how we design our surroundings.
Speculative design is necessary to sketch future scenarios with different stakeholders by creating scenarios and testing them to develop comprehensive designs (Dunne & Raby, 2013). Climate modeling requires consideration of the complexity of meteorological and physical factors. The synergy of the social aspect of public space usage is a key driver for adapting to climate adaptation in the built environment.
This report is part of the joint degree between the studies Geomatics and Urbanism, in which speculative design can be tested. The title of the Geomatics report is: “From thermal comfort to heat mitigation action: A reproducable QGIS plugin for calculating the physiological equivalent temperature in Dutch cities”.

Spain braced for record April temperature of 39C as extreme heat causes misery

Government warns people to take precautions amid drought and heat 7C-11C above average for time of year

A woman gives water from a fountain to her dog in Seville as Spain experiences unseasonal temperatures. Photograph: Jorge Guerrero/AFP/Getty Images

Fig. 0.2 Retrieved from https://www.theguardian.com/world/2023/apr/27/spain-braced-for-record-april-temperature-of-39c-as-heatwave-causes-misery



Acknowledgements

I would like to thank my supervisors Edward Verbree, Stefan van der Spek and Marjolein van Esch. Also the external supervisor Sytse Koopmans and Gertjan Steeneveld from Wageningen University.

Next to that I would like to thank external parties like Niels van der Vaart for providing the links towards Rotterdam. Martijn Meijers for his time sharing information how to use API's from KNMI. Merel Scheltema as urban designer of the municipality of Rotterdam for sharing her knowledge about the heat plan of Rotterdam and Andre de Wit as Mobility expert of municipality of Rotterdam.
Laurens Versluis sharing his knowledge of Witteveen and Bos.

Most of all I would like to thank my family for being supportive throughout the whole graduation year. Also the graduation group with who I studied with. I would also like to thank Diego Sieglevulda for the guidance in the first quarter of the master orientation process.

Images

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Glossary

Svf	Sky view factor
Bb	Bowen ratio
PET	Physiological Equivalent Temperature
PMV	Predicted Mean Vote
Mrt	Mean radiant temperature
WBGT	Wet bulb globe temperature
MEMI	Munich Energy-balance Model for Individuals
UTCI	Universal Thermal Climate Index
GSI	Ground Space Index
FSI	Floor Space Index
OSR	Open Space ratio

Definitions

Acces	Access simply refers to the ability or permission to enter or use something. It is more broadly applied and is not specific to the context of disabilities. It can be about reaching or using something without barriers.
Accessibility	Refers to the design and creation of an environments that can be used by people with disabilities. The goal of accessibility is to ensure that everyone, regardless of their abilities or disabilities, has equal access to information, technology, and physical spaces.
Heatwave:	summer days (maximum temperature 25.0°C or higher) in De Bilt, of which at least three are tropical (maximum temperature 30.0°C or higher). This can only be detected afterwards
Isochrone:	In geography and urban planning, an isochrone map illustrates the region accessible from a given position within a certain time frame
Warm day :	20 degrees Celsius or higher air temperature (KNMI, nd)
Summerish day:	25 degrees Celsius or higher day air temperature (KNMI, nd)
Social mobility:	Interactions and destinations that are of social importance
Spatial mobility:	Geographical displacement by several modes: in this case we look into the walkability of a place

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‘‘Chapter 1 Introduction‘‘

Fig 1.1. Schiedamseweg , Bospolder Tussendijken. Photo taken by Author

1.1 Problem field

Global climate change

Stated by the Intergovernmental Panel on Climate Change constituted by the Intergovernmental Panel on Climate Change (IPCC) the 2023 report, human activities with the involvement of production of emissions of greenhouse gases, have caused global warming. This was already visible in temperature trends 1.1 °C of difference in temperature above 1850-1900 in the time period of 2011-2020. Global greenhouse gas emissions have continued to increase from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumptions across regions, countries and among individuals (IPCC, 2023a). This has implications in the fields this has implications, namely: water availability, health and well-being, cities settlements and infrastructures as well as biodiversity and ecosystems. Which is virtually certain are the increase in hot extremes due to attributed human influence.

The past decades and future projections for (2021-2100) are shown in fig 1.2 Four projections of global surface temperatures are used, based on the predicted continuation of GHG emissions very low (SSP1-1.9), low (SSP1-2.6), intermediate (SSP2-4.5), high (SSP3-7.0) and very high (SSP5-8.5). Those annual global surface temperature changes are marked in the fig 1.2 as 'climate stripes'. Clearly our future depend on the actions we take nowadays.

These IPCC predictions are also developed for the Netherlands. The Dutch Meteorological Institute (KNMI) does indicate the scenarios of high (Gl, Gh, Wl, Wh).Those predictions there is a difference between Gscenario's G moderate global temperature exceedence most probably 1 degree exceedance and 2 degrees in heat temperature in 2050. In 2085 it will vary between 1.5 and 3.5 degree celsius. Next to this the difference between high wind pressure areas and low wind pressure areas. In summertime high

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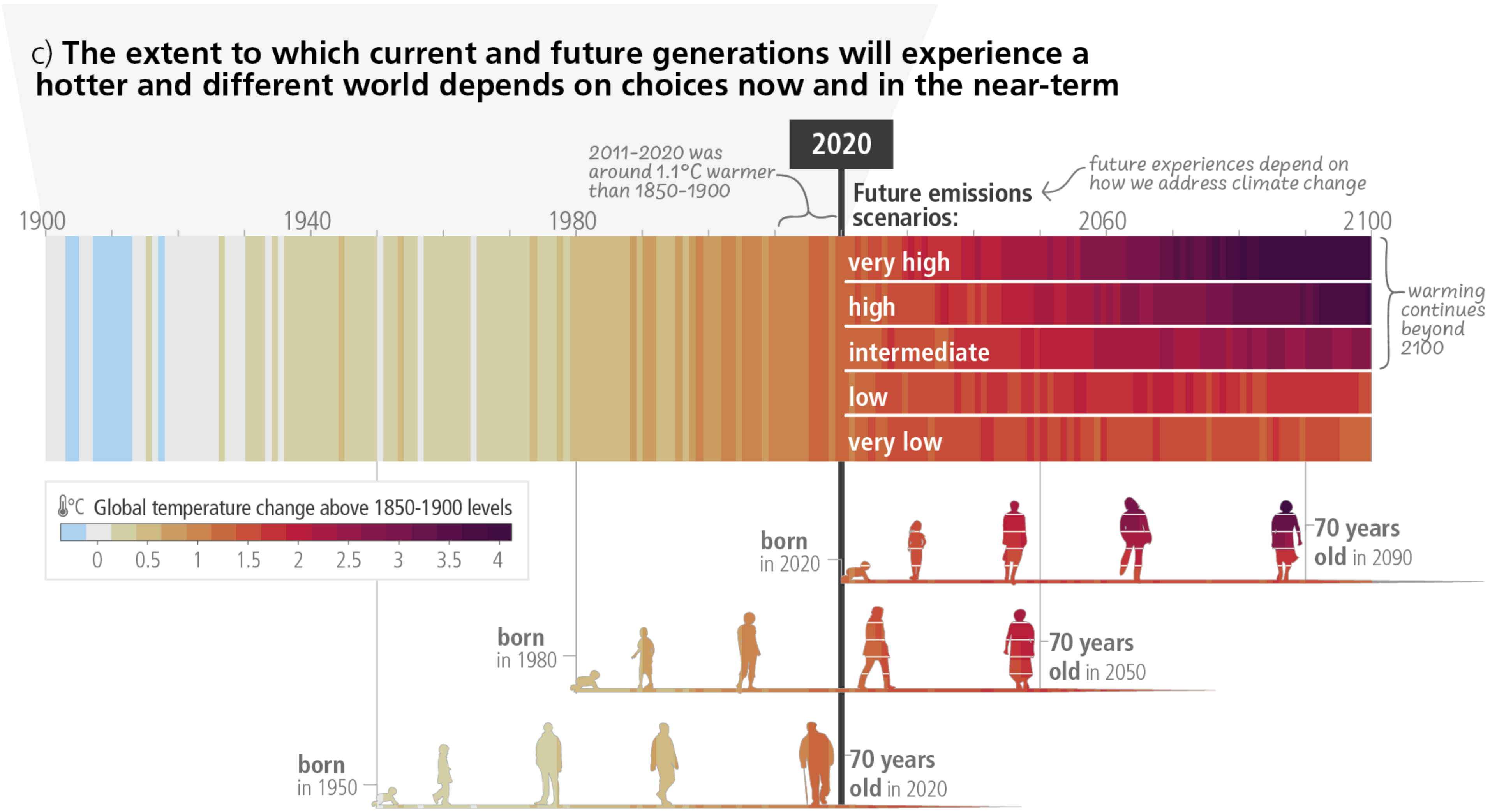

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wind air pressure cause warmer and drought. The climate change in terms of heat do cause problems for the health of humans and the natural system. The thermal complex is one of the contributors to the health status of people (Matzarakis & Amelung, 2008).

Additionally, the Urbanity element indicates the release of temperature. Most of the time this term is indicated by Urban Heat Island. effect causes greater diurnal temperature fluctuations.

Health problems considering heat

Extreme heat can lead to various health issues such as heat syncope, heat exhaustion, and heat stroke. Heat syncope causes a temporary loss of consciousness due to a drop in blood pressure (Bernard, Kenney, 1989). Heat exhaustion occurs when the core body temperature is between 38 and 40 degrees and can lead to dehydration, muscle dysfunction, dizziness, and headache. Heat stroke happens when the core temperature exceeds 40 degrees Celsius and can result in failure of the body's cooling system, muscle damage, and inflammation of the heart (Robbins, 1989. The lack of adaptation to heat waves can increase the risk of mortality, see Figure 1.4. Inadequate environmental adaptation can lead to more deaths in the future, see Figure 1.3 (Bernard, Kenney, 1989; Unicef, nd; Robbins, 1989; Daanen, 2023).

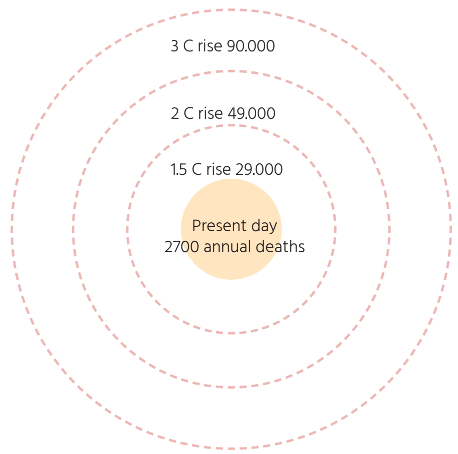


Fig 1.3. Projected annual deaths in Europe due to extreme heat in 2100 without adaptation (Nauman et al. 2020).

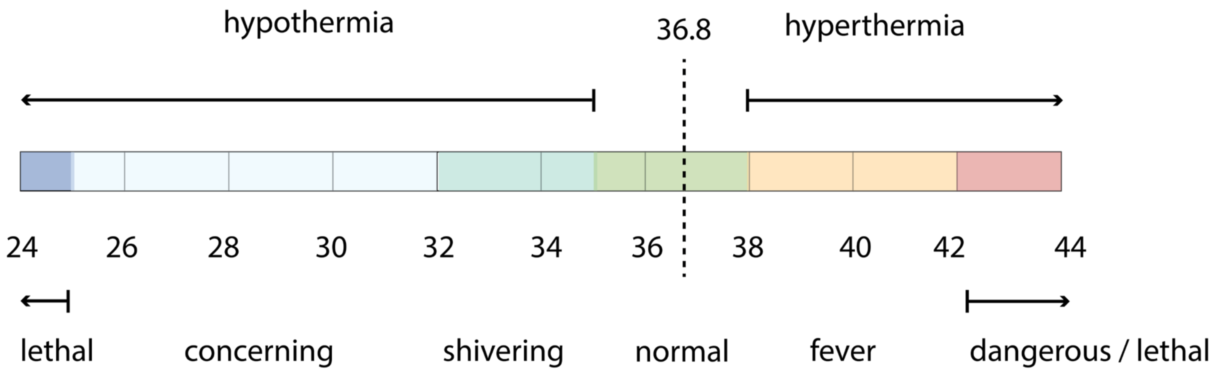


Fig 1.4. derived from (Martin et al., 2017)

Pressure space in population growth cities

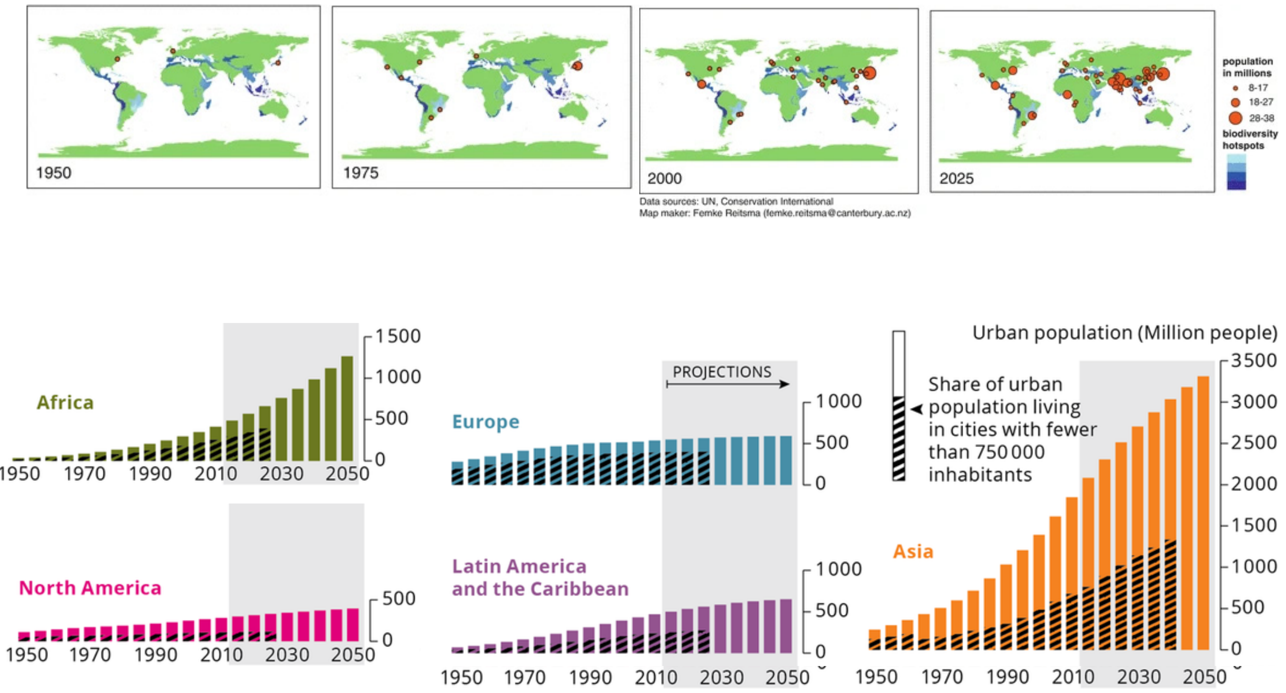


Fig. 1.5 Growth of population throughout the years Retrieved from https://link.springer.com/cha

"In 2018, 55% of the global population resides in urban regions, with projections indicating an increase to 68% by the year 2050" (United Nations, 2018). Prospects are showing that there is a gradual shift in residence of human population from rural to urban areas, in combination with the growth of population, see Figure 1.5.

1.2 Problem statement

Cities formed by fast traffic and urbanization face, from today onwards, the effects of increased temperatures due to climate change. This influences the microclimate in different pedestrian public spaces networks within the city and therefore influences the daily life of its inhabitants.
In the upcoming years, the vulnerability in terms of socio-groups and environmental morphology will increase due to heat.
In these urban environments, it seems there is an inequity in the sustainable, liveable environment. The vulnerability of humans and environments is under pressure, and urban design can affect it by adequate possible solutions in the public domain.

1.3 Research gap

There are two main research gaps. One is the lack of an open tool that helps discovering the knowledge towards a action based approach see Figure 1.6. Next to this is that there is no strategy developed yet how to target down the most important public spaces to transform.

Lack of one open platform with knowledge for multiple parties/ stakeholders

The PET published there is designed to represent the average conditions from 10:00 UTC to 16:00 UTC on the first of July. However, it doesn't take into account the spatial-temporal variations throughout the day, nor does it offer a baseline for typical daily conditions in cities. As a result, it is not possible to test any interventions based on this data. To address this, the research opts to model the PET using the calculation model developed by Koopmans (2024) in line with the reproducability guidelines advocated by the Agile conference. We will need to provide a more detailed explanation of the PET calculation method using Python for the next steps in the process.

Strategy approach missing for intervening in public space

Currently, several municipalities are addressing this issue in their own way. There are no established guidelines for how municipalities should approach this problem, and their strategies vary widely. During the symposium at the University of Applied Sciences "Hot issues" organized by HVA (2023), the differences became evident. However, there is no standardized approach to the strategic implementation of interventions in public space design to make cities more heat-resistant.

1.4 Research aim

The research aim is to combine a tool that involves multiple stakeholders to make use of a general code for indicating the perceived temperature by humans.
Also a strategic way will be developed to create a heat resistant neighbourhood scale for pedestrian movement.

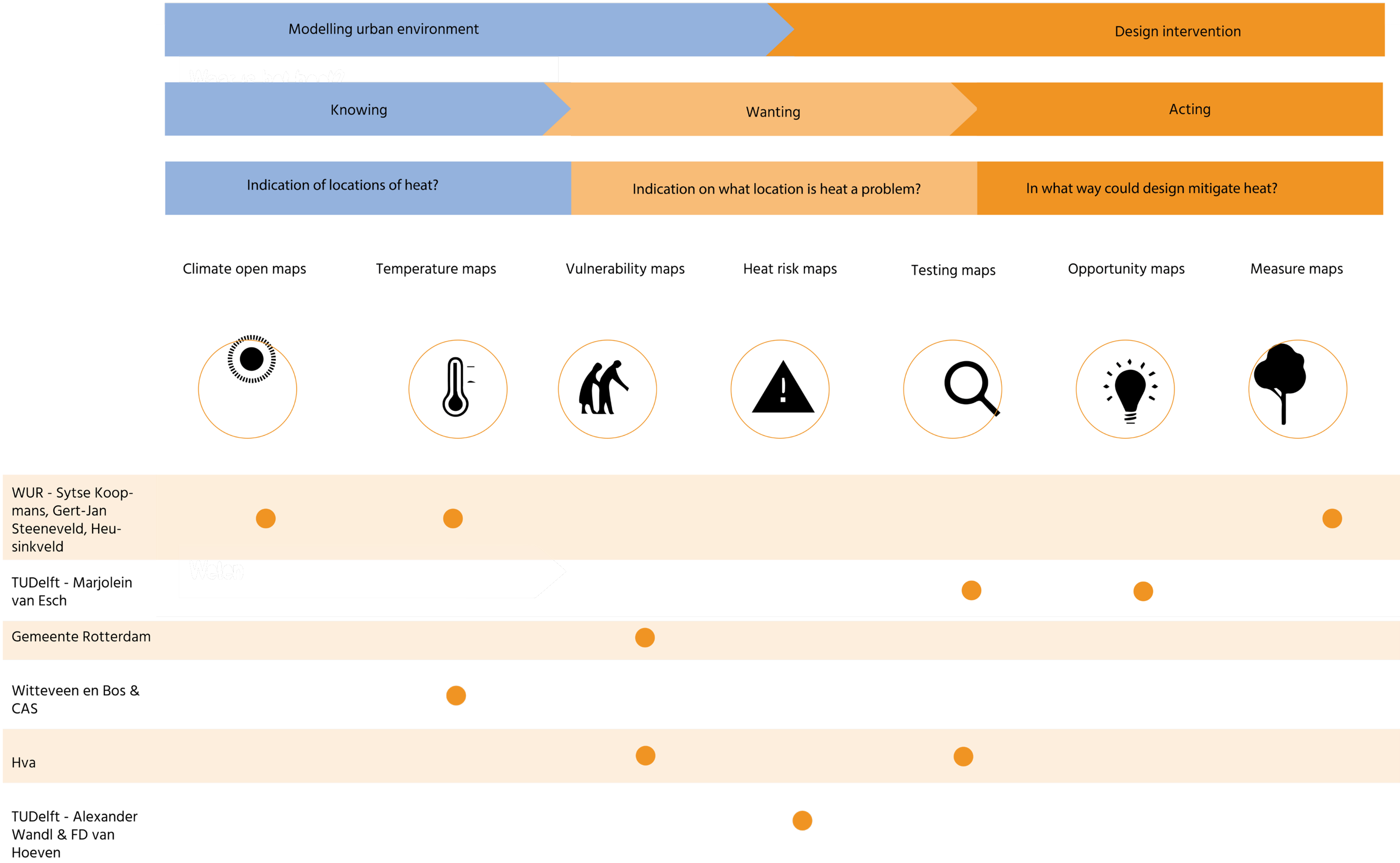


Fig. 1.6 Placement of this research within the field of knowledge and action. Put in the framework of Deltaprogramme (2018)

1.5 Site location

This case study looks into the municipality of Rotterdam in the province of South Holland in the Netherlands, which is divided into 22 districts (see figure 1.7 and 1.9). Rotterdam is one of the most populated cities in the Netherlands. Furthermore, the imbalance between natural elements and the urban landscape is quite prominent (Palmboom, 1995) .
If we want to stimulate local movement in cities we have to focus on the modelling of pedestrian friendliness in the urban areas. Right now the mobility split in the Netherlands is still dominated by fast mobility supported network and pavement. If we want a heat resilient city for pedestrian movement, so we need to have urban design that can facilitate that.

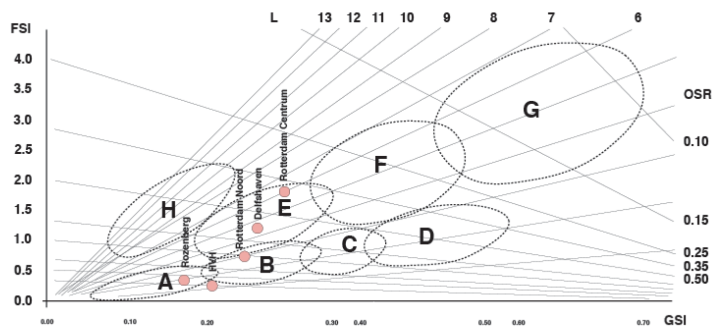


Fig 1.8. PBL (2022)

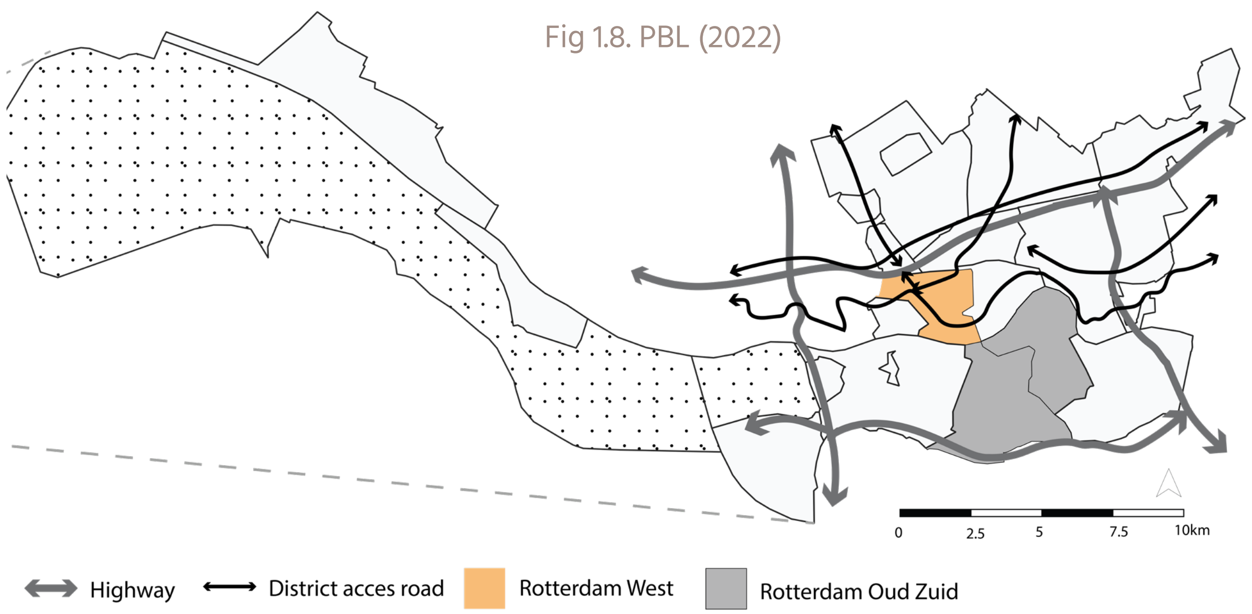
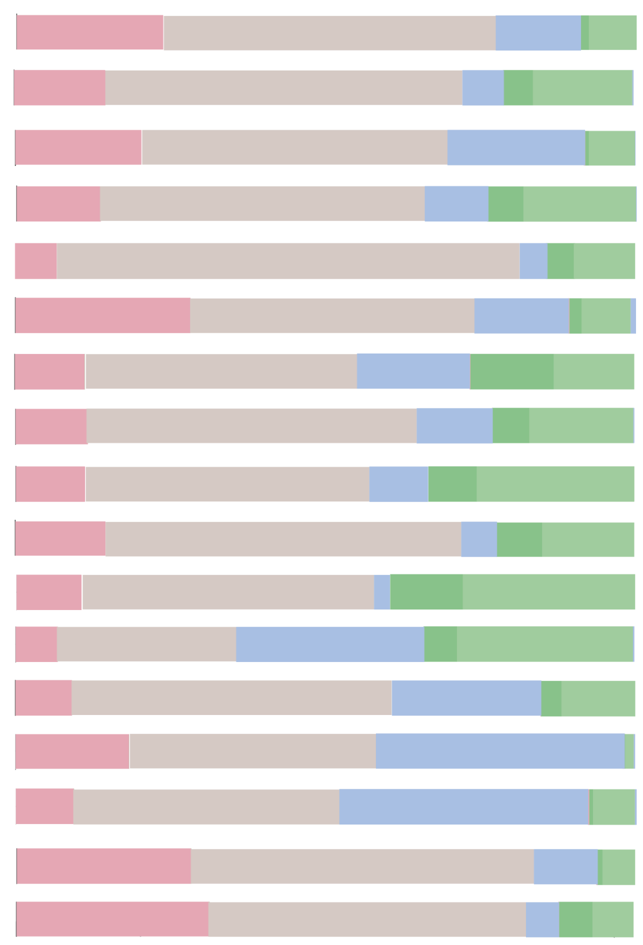


Fig 1.7. Rotterdam and highlighted Delfshaven neighbourhood.

District name	Amount of 65+ / ha Density/ha	Building typology
Delfshaven	148	B/C
Prins Alexander	55	A
Feijenoord	117	B
Ijselmonde	52	A
Rotterdam Noord	101	E
Rotterdam centrum	93	E
Kralingen krooswijk	52	A
Hilligersberg schiebroek	38	A
Hoogvliet	38	A
Charlois	62	A
Rozenberg	27	A
Hoek van Holland	7	B
Overschie	11	A
Rotterdam Noord West	0	A
Nieuwe Mathenesse	0	E
Spaanse polder	0	E
Waalhaven Eemshaven	0	A

Percentage landuse



Legend
- building
- forest
- grass
- water
- else

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Fig. 1.9 demographic inventory of CBS neighbourhood (2022) and Rudifun classification for building typology (PBL,2022)

A closer look at the neighborhoods reveals the stressing areas for intervention in public design. The conditional statement of high GSI and FSI and low OSR reveals the lack of public space in the area. Next to this, in several urban areas, there is a higher density of people inhabiting the place.

If there is a distinction that needs to be made of the intervention in the public design, there is more chance in the neighborhoods with the Urban prewar classification (see Fig 1.10 and Fig 1.11). Within the Delfshaven district, the neighborhoods Bospolder and Tussendijken will be chosen.

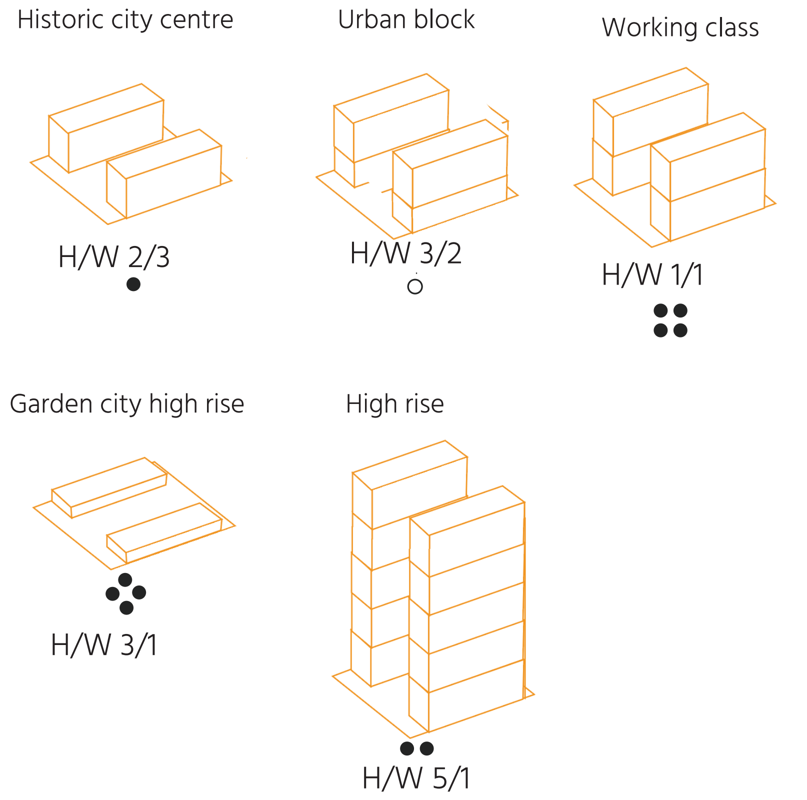

Fig. 1.10 H/W ratio of certain urban morphology typologies (HvA, 2022)

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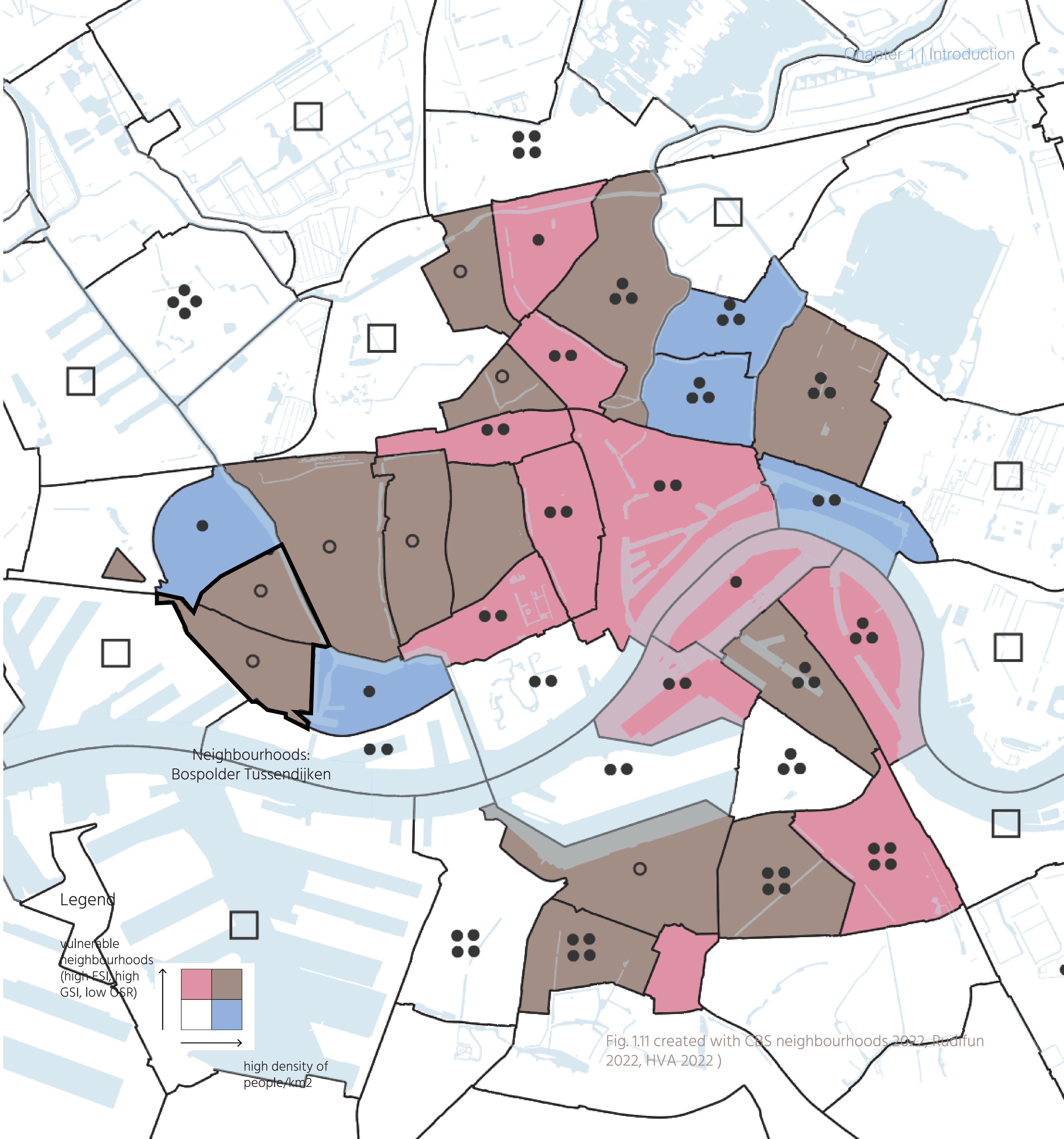

Fig. 1.11 created with CBS neighbourhoods 2022, Rudifun 2022, HVA 2022)

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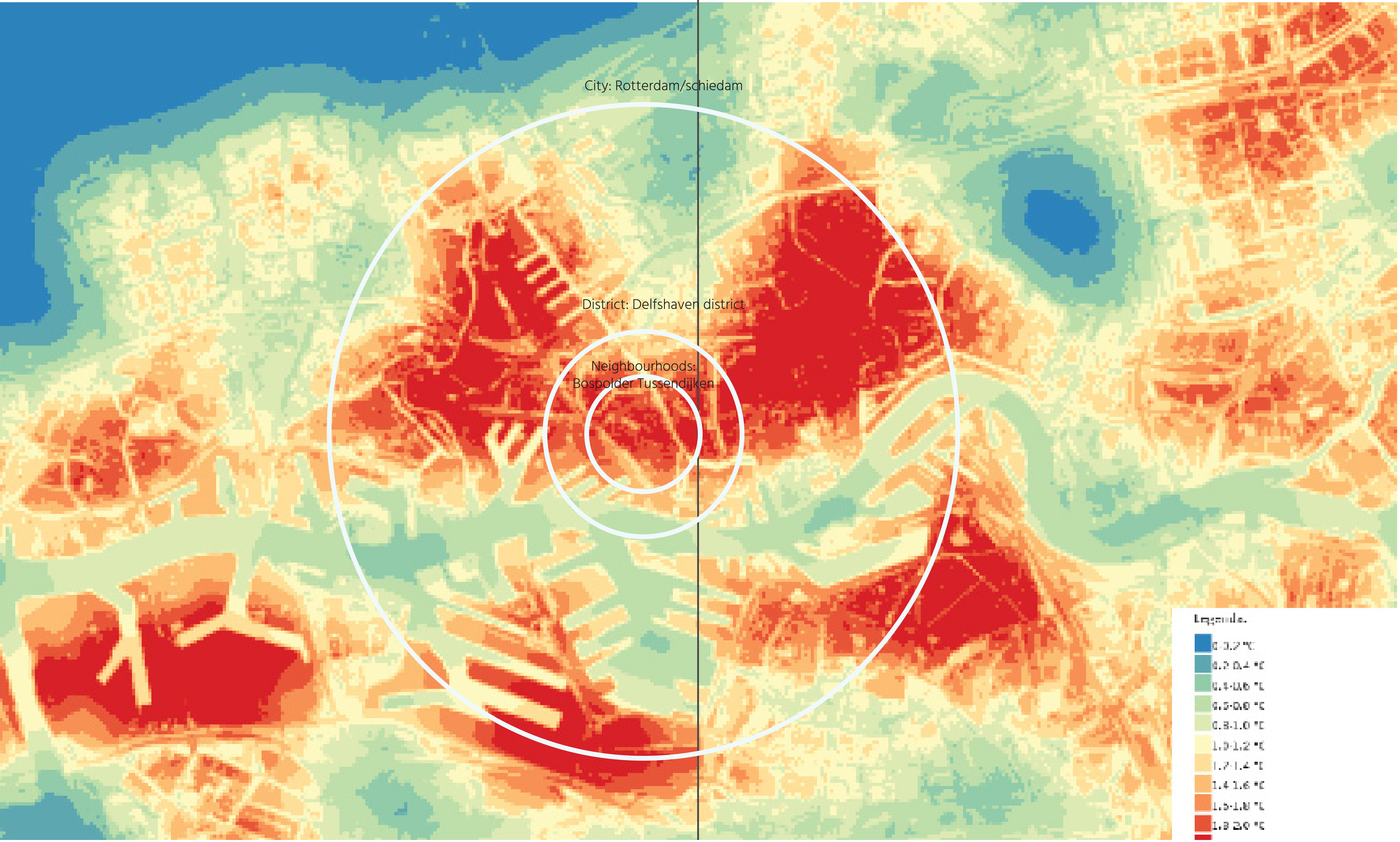

Fig. 1.12 Urban heat island contribution Klimaateffectenatlas (CAS, nd)

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,, Chapter 2 Methodology

1. Research approach
2. Theoretical framework
3. Research questions
4. Structure of reports
5. Methodological framework
6. Research methods of acquiring data

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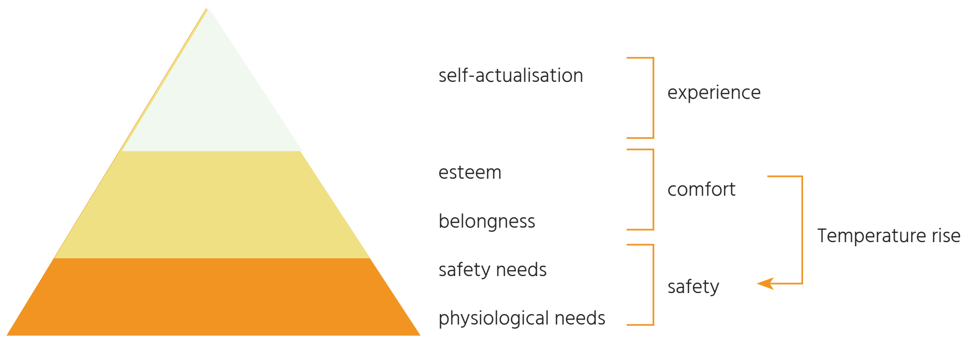
Fig 2.0. Dakpark, Bospolder. Picture taken by Author

2.1 Research approach



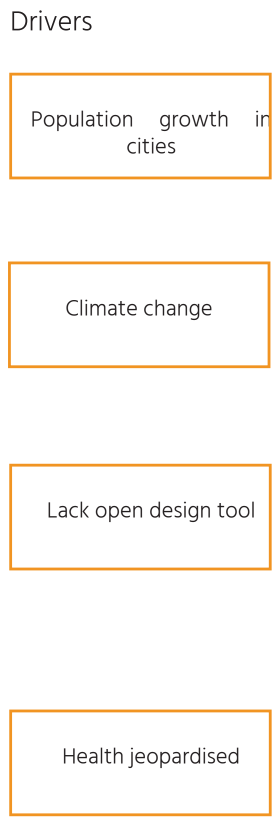


Fig. 2.1 Thermal comfort to climate safety adapted Maslow Piramide (1943) by Author

This research delves into the concept of liveability, examining how the social liveability and the physical liveability within a neighborhood interact with each other.

The primary motivation behind this research is the understanding that if thermal comfort ceases to be just a comfort and becomes a necessity, it will jeopardize the universal needs of humans. Therefore, thermal comfort is a fundamental requirement, preceding essential aspects such as social interactions and self-actualization (Maslow, 1943)(see figure 2.1).
The significance of this research lies in recognizing that a liveable neighborhood is one where the built environment complements the social fabric, creating a harmonious and enriching experience for its residents (Pacione, 2013). By exploring the dynamics at both the micro level of individual experiences and social interactions, and the macro level of environmental climate conditions, this study aims to unveil the synergies that contribute to a holistic perception of liveability.

On one hand, the physical liveability of a neighborhood is equally critical in determining its liveability. This research will investigate thermal comfort model and its components (Koopmans et al., 2020). Acknowledging the interconnectedness between the natural and built environment, the aim is to uncover how the synergy of these elements contributes to a liveable environment.
On the other hand, the human-scale social experience significantly shapes the character and vitality of a neighborhood. The quality of public spaces influence the well-being of individuals. Embracing an inclusive design perspective (Hanson, 2005), this research will also examine vulnerable groups to gain a better understanding of the neighborhood dynamics. An in-depth exploration of the intricate connections between individuals, the built environment, and the cultural nuances that define the social identity of a

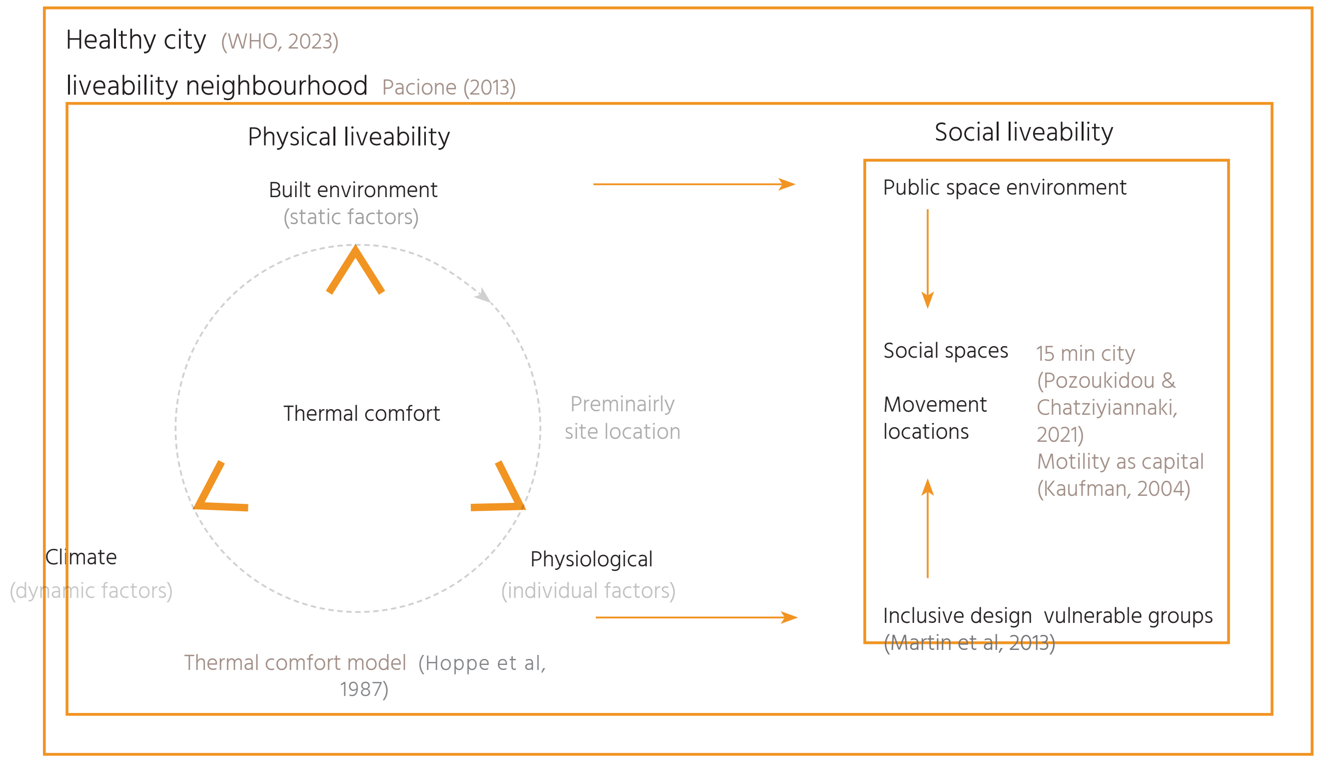


Fig 2.2 Conceptual framework made by author

place is necessary. Therefore, social conditions, which are dependent on the mobility of people of the place (Pozoukidou, & Chatziyiannaki, 2021; Kaufman, 2004), need to be investigated.
By adopting a methodological approach that bridges the human-scale social experience and the environmental climate, this research aims to provide valuable insights for urban planners, policymakers, and designers for future neighborhood developments (see figure 2.2). The goal is to understand the intricacies of creating liveable neighborhoods that not only meet the functional needs of residents but also enrich their lives on a profound and meaningful level. As we navigate the challenges of urbanization and environmental sustainability, this research supports a more holistic and integrated approach to shaping the future of our cities.
This climate public space design research methodology draws on the expertise of both the master Geomatics and the master Urbanism. The Urbanism aspect of this research focuses on the principles of good design, such as implementing the design in a strategic order. To accomplish this, the research utilizes the PET model of Wageningen, which is made more publicly available by leveraging the knowledge from the Geomatics master.
Finally, the effectiveness of the design solution in mitigating heat-related issues will be validated by the PET model again (see figure 2.3).

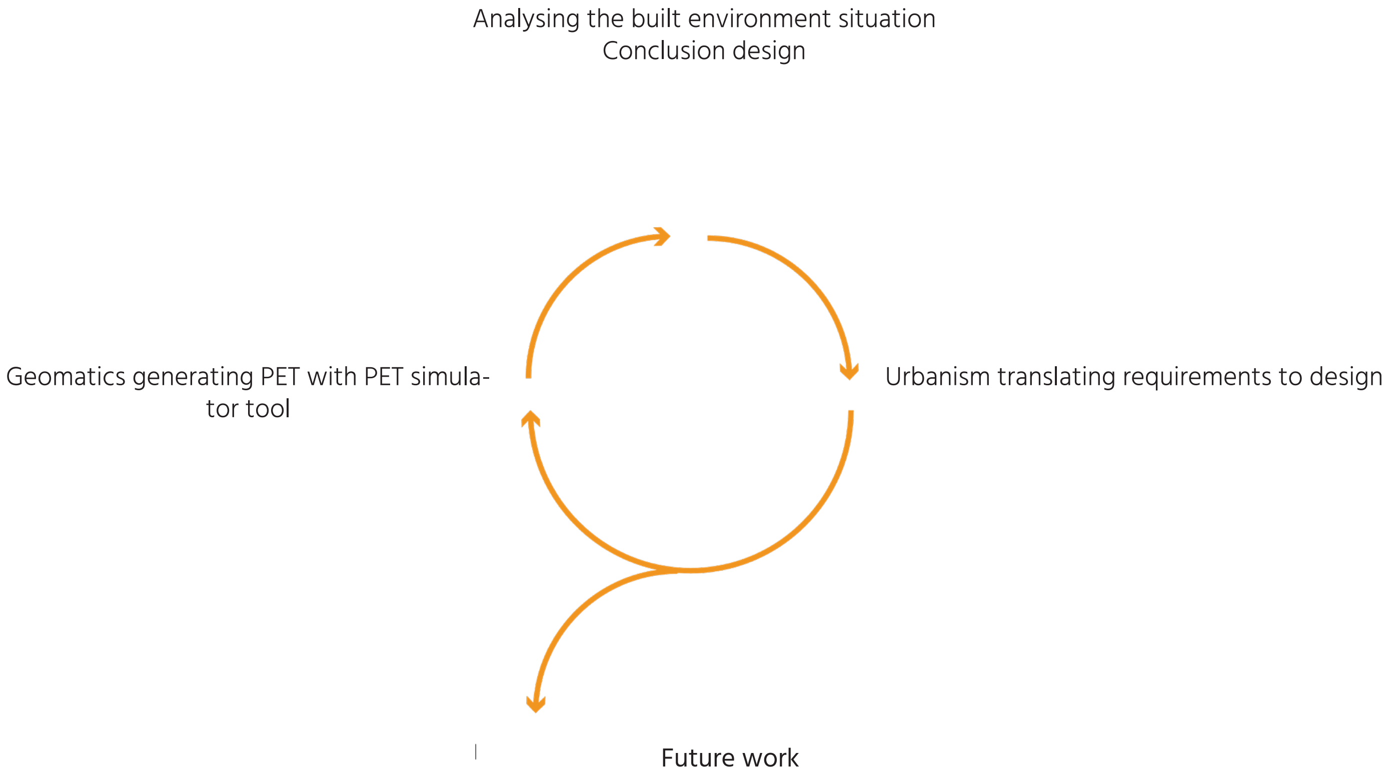


Fig 2.3. Relationship between Geomatics and Urbanism

2.2 Theoretical framework

Healthy cities

A healthy city prioritises investment in people and ensures access to shared goods and services for all. It considers multiple perspectives: prosperity, planet, place, participation and peace. It moves towards an asset-based approach, integrating health equity and sustainability into urban development and planning. The combination of environmental and social injustice, together with climate change, poses a significant threat to the health of cities and their citizens in the 21st century (WHO, 2023; Friel et al. 2011; Hancock et al. 2015)(see figure 2.4).

Fig. 2.4 retrieved from https://www.uwe.ac.uk/research/centres-and-groups/who/healthy-cities

Maslow piramide & Gromule et al. piramide

Maslow's theory of human motivation comprises five levels: biological needs, safety needs, love/belonging, esteem, and self-actualization. These levels can be categorized into basic physiological needs and self-actualization. As a result of climate change, increasing temperatures pose a threat to people's safety which will influence the higher levels. Consequently, thermal comfort is poised to become a safety requirement and integral to the mobility hierarchy (Maslow, 1943), see figure 2.5.

Human thermal comfort

Human thermal comfort is influenced by three elements.
The physical built environment. The dynamic climate and the physiological factors of individuals (Hoppe et al, 1987). More of this in the upcoming geomatics chapter. For the determination of vulnerable groups and the right urban environment to research this elements should be taken into account, see figure 2.6.

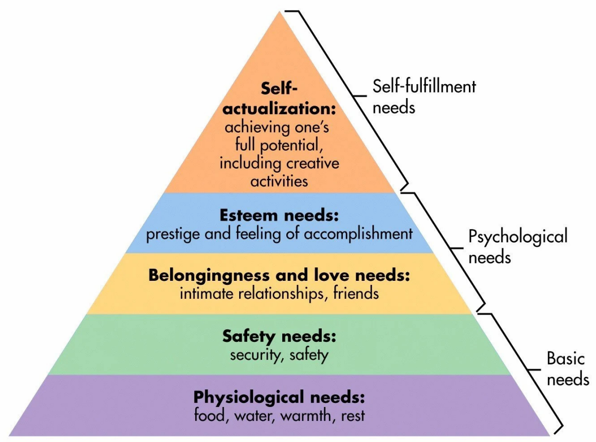


Fig. 2.5 Maslows piramide, retrieved from Mcleod, S., PhD. (2024). Maslow's hierarchy of needs. Simply Psychology. https://www.simplypsychology.org/maslow.html

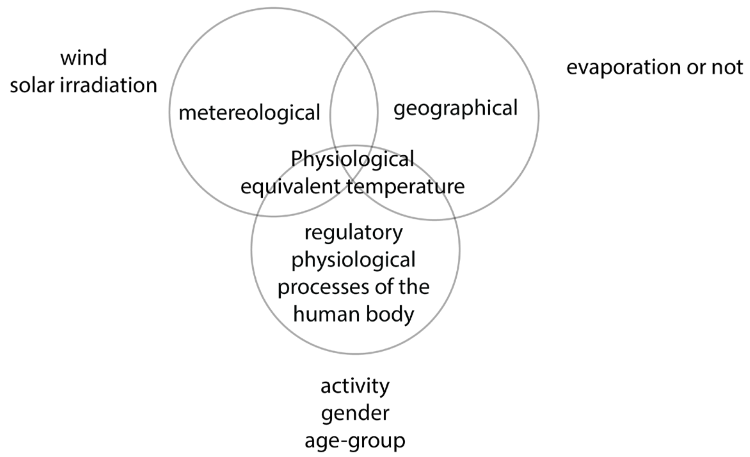


Fig. 2.6 own scheme based on Hoppe et al. (1987)

Inclusive cities

To cater to the needs of all social demographics, Lawton (1974) examined how the design of the built environment may restrict options for older individuals, introducing the concept of 'environmental pressure' to illustrate the negative effects of poorly designed spaces on people's lives. Improving the physical environment for them can achieve improvements for all. Recognizing equity as complementary to environmental justice can help reconcile conflicts between social and environmental priorities (Martin et al., 2013), see figure 2.7.

15 Minute city concept

The neighbourhood unit is the fundamental point of the urban system. Clarence Petty introduced in 1920 the hierarchical system of urban amenities, beginning with the neighborhood unit, which comprised larger subdivisions that collectively formed the city. The concept emphasizes having key accessible functions within the city, including parks, schools, and other local amenities within a 15-minute distance. The three primary pillars underlying this concept are security, integration, and health, fostering a lasting sense of ownership and connection to the space (Pozoukidou, G., & Chatziyiannaki, Z., 2021), see figure 2.8.

Motility: mobility as capital

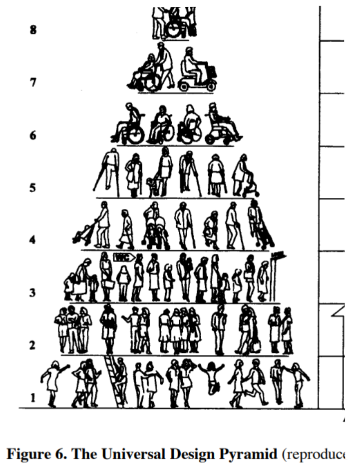


Fig. 2.7 Inclusivity ladder, design for the most vulnerable in order to meet the requirements of the rest (Hanson, 2005, page 19)

Fig. 2.8 Own scheme based on Pozoukidou, G., & Chatziyiannaki, Z.,2021).

Chapter 2 | Methodology

The concept of mobility can be divided into two different categories: spatial mobility and social mobility.
Spatial mobility refers the movement can influence the origin, transit, or destination of these entities, and can also lead to changes in their status.
Social mobility, expresses the social structure in the city. Where do people want to go. The collective social mobility over time is commonly referred to as social change.
Motility encompasses both spatial and social mobility, and motility refers to the interdependence between access to mobility, the ability to recognize and use it, and the appropriation of a particular choice (Kaufman, 2004).

Urban well being and liveability

Research into the relationship between people and their urban environment plays a central role in the growing interest in quality of life. Urban environmental quality and liveability are measured on both objective and subjective dimensions. Understanding the interplay between individuals and their surroundings is a common focus. It must be considered that scale, social demographics, composition, and theories do have an urban impact, see figure 2.9. For this research liveability is taken into account as physical liveability as the surroundings and the social liveability as the way people can in objective terms on the neighbourhood level of Bospolder Tussendijken with its own demographic (Pacione, 2013).

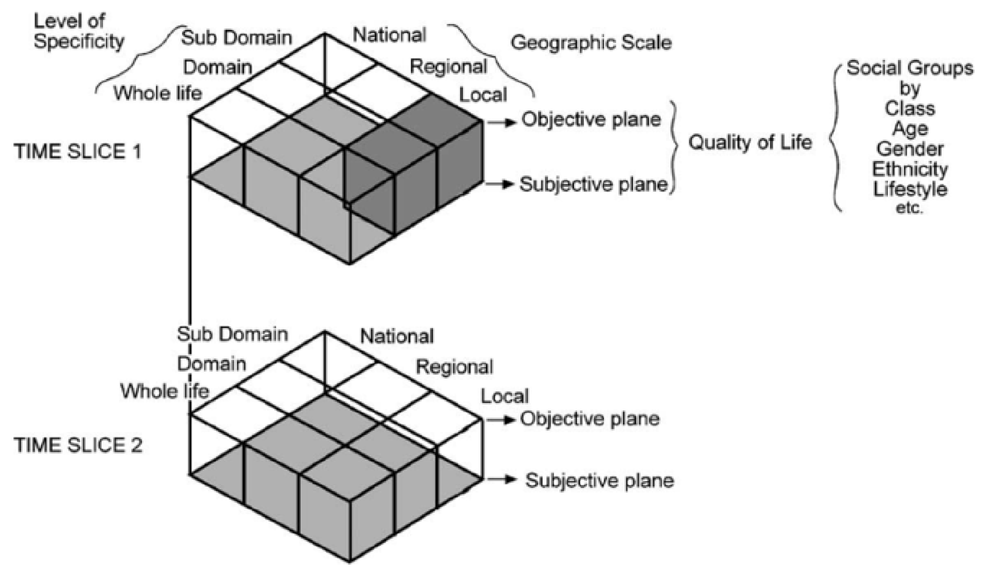


Fig. 2.9 A five-dimensional structure for quality of life research (fig. 1, Pacione, 2013)

2.3 Research questions

Main research question

"How can a strategy be developed for mitigating heat stress through the Physiological Equivalent Temperature model while ensuring a livable environment for vulnerable groups in Bospolder Tussendijken, Rotterdam, the Netherlands"

Sub research questions

SRQ 1. What are the liveability conditions?

This sets the conditions in which the end the design has to approve to. A destinction is made into climate environmental liveability and social liveability which has a main focus on the pedestrain mobility of citizens in the neighbourhood. Also this also give hints towards the toolbox solutions stated in chapter Interventions.

SRQ 2. What is the current state of liveability in Bospolder Tussendijken?

With mapping and modelling of the PET, and its contributing factors, the current liveability will be made visible. Eventually a SWOT will be produced to showcase the strenghts, weaknesses, opportunities and threats to the current environment.

SRQ 3. How could the current climate liveability be improved

This will be adressed through the creation of a vision map, scenario building of the liveability interpretation of climate environmental liveability and social liveability. The literature review of possible mitigation measures result in the toolbox and their choose of rearrangement decision making.

SRQ 4. How could the interventions be evaluated?

Liveability conditions assess both climatic and social liveability. Geomatics helps to assess the effectiveness of design interventions by modelling the new Physiological Equivalent Temperature (PET) and highlighting variations in PET to measure the impact of these interventions. In addition, by illustrating the cumulative temperature experienced by elderly citizens and the resulting expansion of service areas due to design interventions.

2.4 Structure of the reports

The urban design research will follow a structured approach with stages including methodology, conceptual framework, analysis, intervention, testing, and design. The analysis phase will utilize the conceptual framework to consider environmental and social quality in public space design, focusing on vulnerable groups. Techniques such as mapping, photography, and literature review will be used for comprehensive analysis. The intervention phase will use the pattern language approach and scenario planning, rigorously tested for optimal results. The final design phase involves implementing design interventions and conducting stakeholder analysis.

The geomatics aspect will focus on establishing reproducibility guidelines for the PET model, followed by developing the PET code and making it publicly available. Additionally, the accessibility of the public space network for different vulnerable user groups will be assessed. Overview of the reports are illustrated in figure 2.11 and figure 2.10.

Fig 2.10. a) Technical geomatics report & b) spatial urbanism report

2.5 Methodological framework

Figure 2.11 showchases the methodological framework is elaborated.

2.6 Research methods

LR
Literature study
Through theoretical knowledge lessons can be learned. Also lessons could be learned from reference projects, this is empirical knowledge.

EC
Expert consultation
WUR, Gemeente Rotterdam, Witteveen en Bos.
Through conversations of experts in the field, lessons can be learned and implemented.

MOP
Modelling urban environment
To quantify current heat stress areas and testing design interventions for their effectivity. This research enables to join design and design disciplines, modelling provides an engineering backing to proposed interventions. The PET model was already set up by Koopmans et al. (2020) but was not suitable for reproducibility yet and will be expanded in this thesis. In the analysis it will identify the vulnerable spaces.

Ob
Observation of public spaces
The qualitative perspective of a public space

MA
Mapping
The geographical outline of the city is visualised by creating maps. Varying through the scales to see the urban morphology effects on human health. For the quantifying method of measuring specific values by using grid data on spatial data the method of creating maps such as Van der Hoeven & Wandl (2015).

Dp
Design principles
With some variables the design principles will be created to showcase different implications of design decisions.

CS
Creating scenario's
To identify possible paths for the development of the city as a basis for interventions.

Sk
Sketching
Sketching can improve the research by design proces.

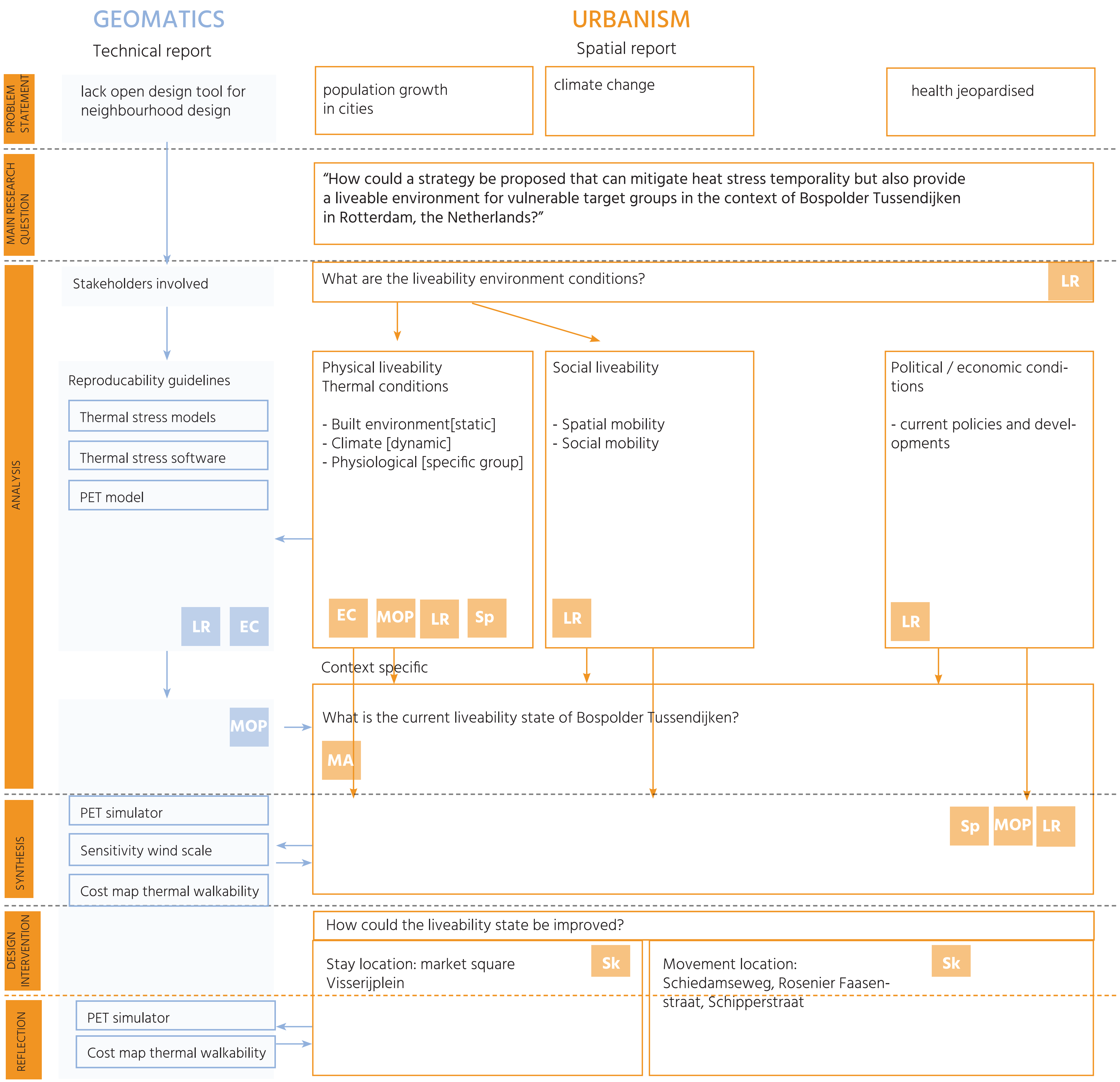


Fig 2.11 Methodological framework created by Author

Chapter 3 Thesis planning

3.1 Thesis planning

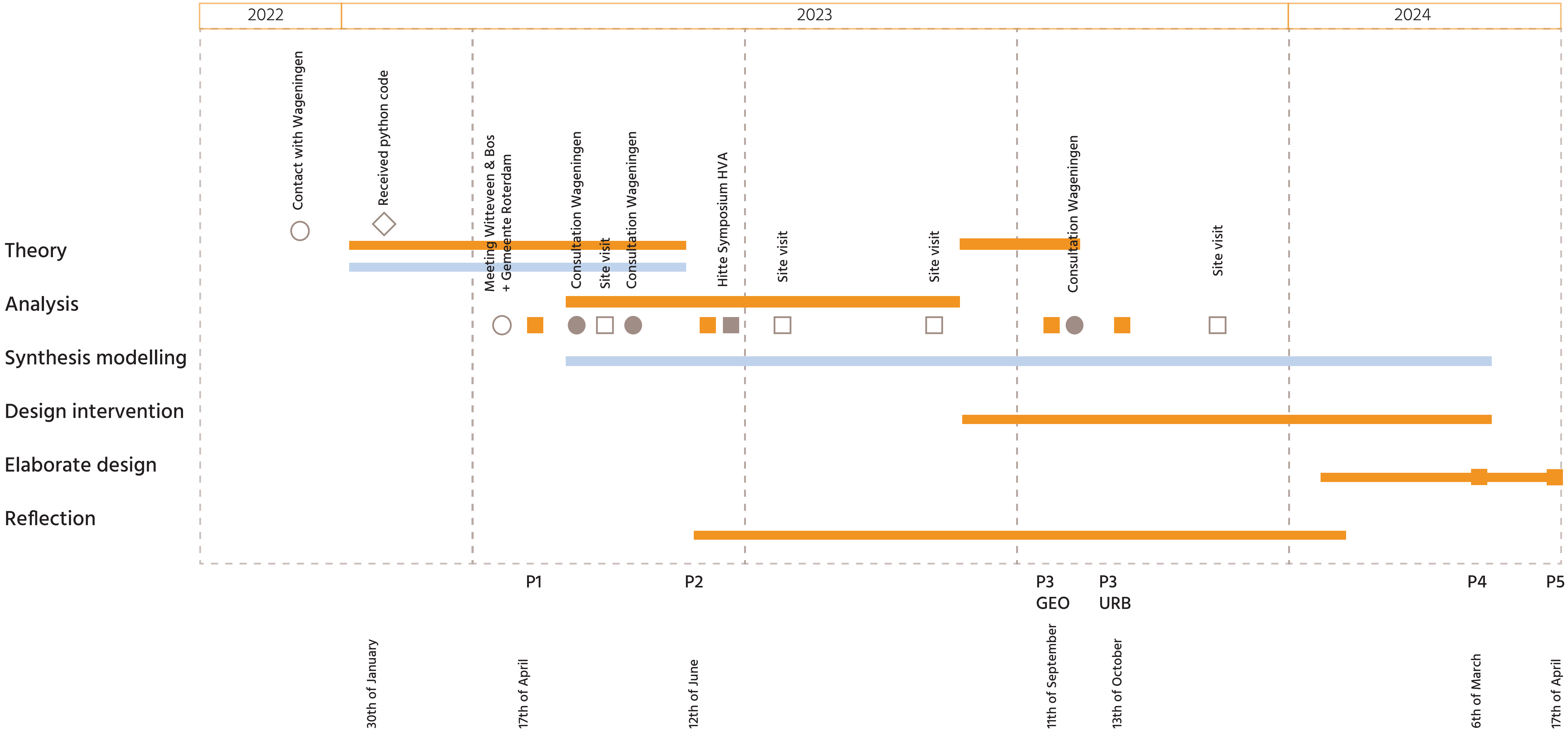


Fig 3.1 Thesis planning

‘‘Chapter 4 Liveability design guidelines

1. Thermal comfort Physiological factors
2. Physical liveability Climate and Built environment factors
3. Social liveability
4. Liveability conditions

Fig 4.0. Mathenesseweg, Tussendijken. Picture taken by Author

4.1 Physical liveability: thermal comfort

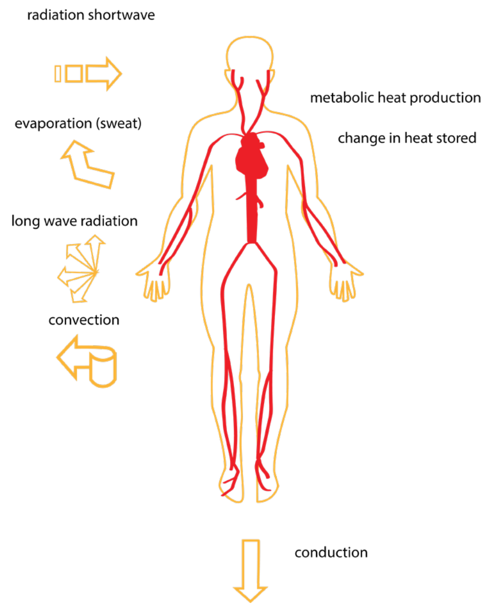


Fig 4.1. reproduced from Fiala (2012) fig 1

Thermal comfort

Humans are homeothermic beings, maintaining a stable body temperature of 36.1 to 37.8 degrees Celsius. This range is crucial for optimal bodily functions, including blood flow, oxygen release, and enzyme production. Humans can generate internal heat through muscle contractions and exchange heat with their surroundings through various means. Thermoregulation involves physiological and behavioral responses to heat (Campbell, 2018: GGD, 2023). Thermoregulation could be divided in physiological responses to heat and behavioural responses.

Physiological responses

Metabolic rate (M) denotes the pace at which the body produces internal heat. While at rest, the average metabolic rate typically stands at 70 W; however, during intense physical activity, it can escalate to 700 W. Net radiation (R) signifies the equilibrium between the radiation absorbed and emitted by the body. Mean radiant temperature (MRT) characterizes the radiation field. Convection (Cv) is the heat loss through the movement of air, which is bolstered by wind. Conduction (Cd) denotes the transmission of heat between materials in direct contact. Heat dissipation occurs through sweat evaporation and respiration, whereby exhaled air tends to be warmer and more humid compared to inhaled air (E). See the formula and figure 4.1.

$$\delta s = M + R + C_v + C_d - E$$

Changes in weather conditions impact the thermal balance. Increased net radiation typically leads to greater heat retention, whereas heat dissipation can be facilitated through perspiration or exposure to wind (Matzarakis, 2008; Hoppe, 1999). Several thermal indices have been developed to assess thermal comfort.

Next to this, it has to be said that the lack of adaptability response of the human body to a heatwave is an indicator of the mortality rates of people (see figure 4.3 and 4.4). Physiological factors like heart rate will take some days to adapt to a warmer environment. Another aspect is that people can dress more for colder situations in contrast to hotter days

Chapter 4 | Liveability conditions

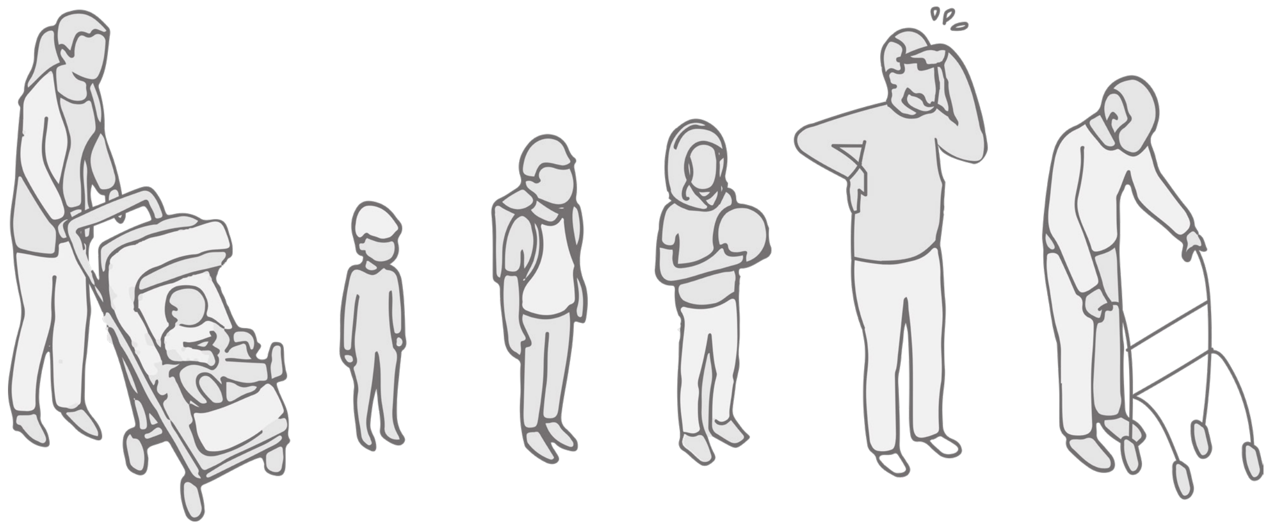


Fig. 4.2 target groups in this research (Young Children, from the year of 40 and above and elderly 65+) created by Author.

(Lenzholzer, 2018). These combinations lead to higher mortality rates with heat extreme like the occurrence of a summer day of 25 degrees (Daanen, 2023). This is a serious issue for the future to come if the amount of summer days will potentially be doubled in 2050 and increase in 2085 (see Fig. 4.6). Vulnerable groups are elderly, young children, people with obesity and vascular diseases (see figure 4.2).

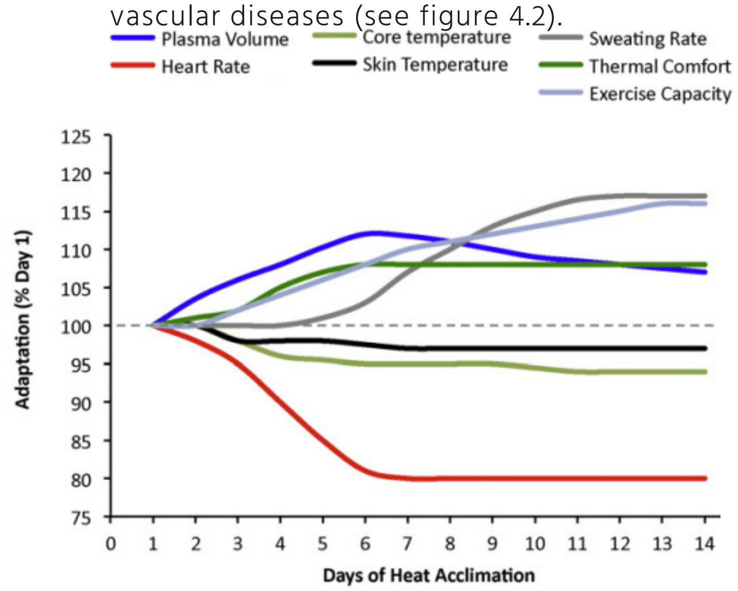


Fig. 4.3 Time course of acclamation of different physiological processes (Periard, 2015)

Elderly

Elderly individuals often experience a decline in thermoregulation efficiency due to factors such as diminished heat release, reduced sensory receptors, age-related skin changes, and decreased body water content. This can lead to challenges in temperature perception and increased risk of dehydration. Experimental conditions show limitations in thermoregulation from age 40, and epidemiological studies link it to a higher risk of heat-related illnesses from age 65 onwards. External measures are often necessary to maintain stable core body temperature in older adults (Sanders, 1996; Kenny, 2010; WHO, 2023; Hall et al., 2021; GGD). Especially on days with an atmospheric temperature of 25 degrees and higher, there is a higher correlation with mortality rates (Bhatia, 1997).

(Young) children

Children, especially newborns and

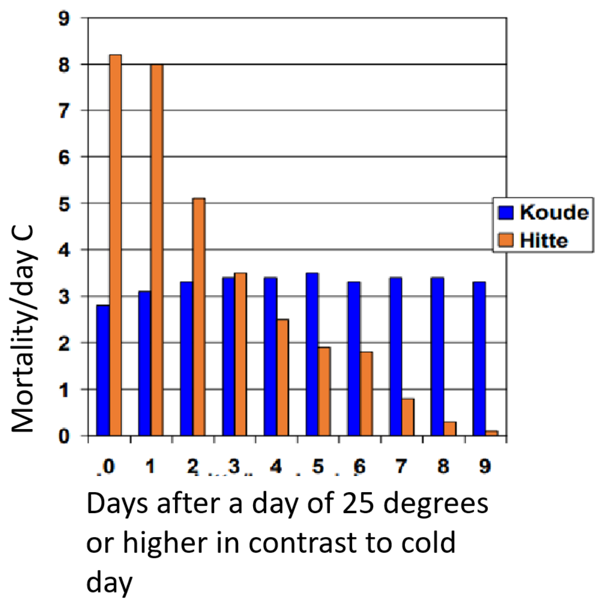


Fig 4.4. Mortality rate after a summer day (25 degrees or higher) derived from (Daanen, 2023)

infants, are at high risk of heat-related illness due to their slower temperature regulation and higher metabolic rates. Young children need adult care to prevent heatstroke. According to Unicef (2023), very young children are more susceptible to heat-related illness. The target group for CBS resources is young people, mostly aged 25 or younger.

Behavioural changes

are seeking for shelter in a colder climate instead of staying in a warmer climate. This could be by walking in the shade as searching for cool environments.

Personal factors do influence the physiological and behavioural changes. Age, gender, lifestyle, social group and metabolic rate are personal factors in the performance of the thermoregulation of the body (Calvin, 2012).

Some risk groups are spotted (GGD, nd). These are elderly, young childeren, people with vascular diseases and obesity. Due to the privacy conditions of people with underlying hyperthermia conditions, people with vascular diseases and obesity are left out of this research. This research will focus merely on children under 25 years and elderly above 65 years (GGD, 2023).

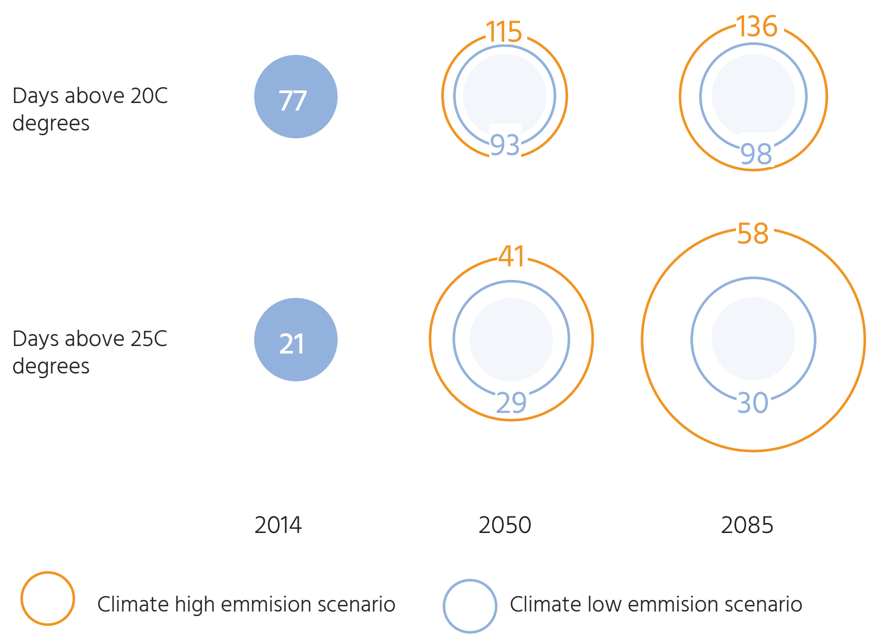


Fig 4.5. KNMI climate scenario's and predictability of amount of warm days and summer days adapted from KNMI (2015)

Design principles climate liveability: physiological factors

Human thermoregulation depends on the physiological responses and behavioural responses. The physiological response depends on the energy balance of thermal storage. People absorb heat due to long wave and short wave radiance and is the determing factor. Next to this evaporation due to wind is very effective.

The most heatgain is through short wave radiance and the most heat loss will be due to wind evaporation. Climatological requirement is that the humidity plays a role as well.

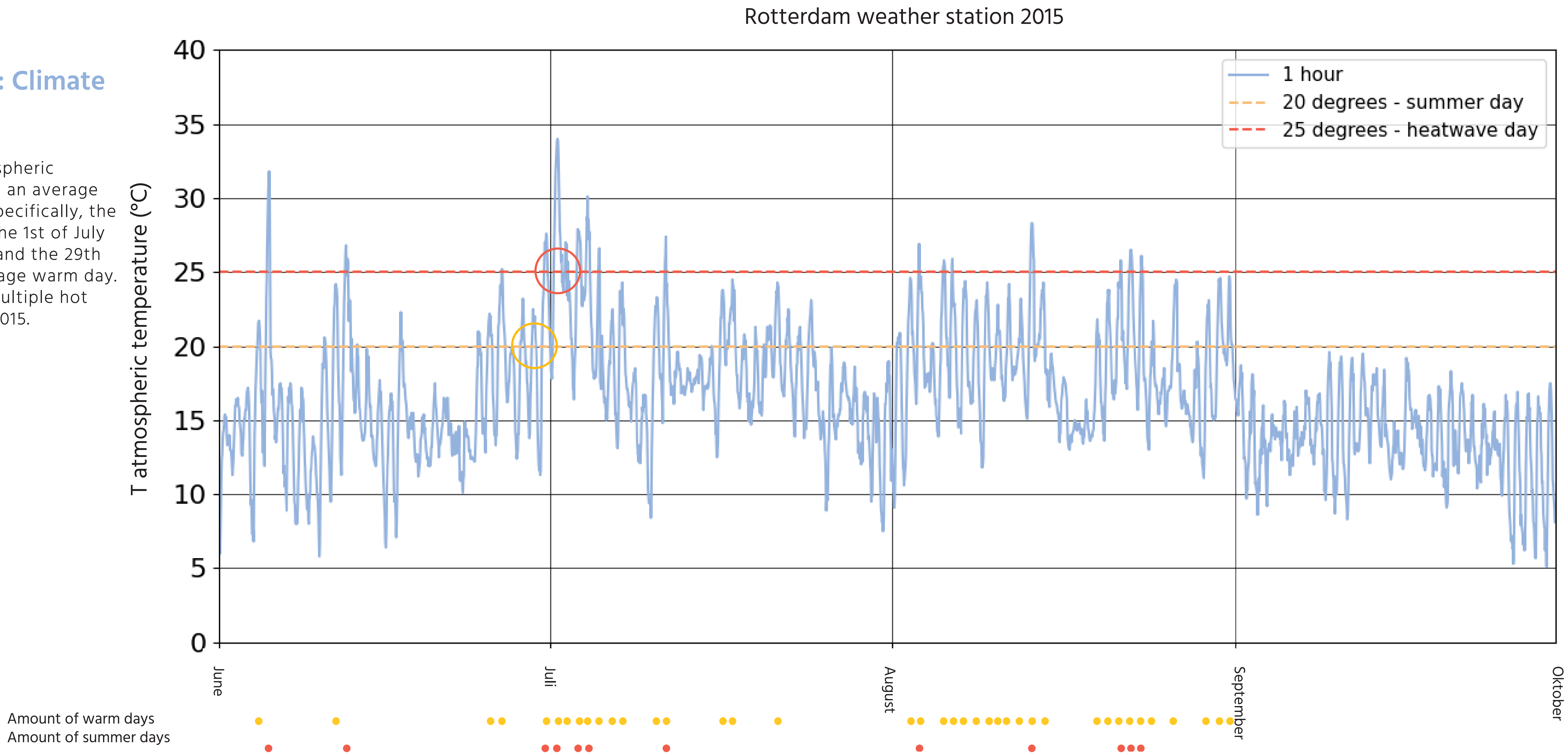
Also the vulnerable groups exposed to heat are (young) childeren, elderly, people with obesity and people with vascular diseases. Due to privacy health reasons, only young and elderly people will be taken into account. These groups have either a growth in development or decline in body functioning. Elderly do have less responses of their environment of being overheated. The immediate health effects are available in literature but not directly linked to the built environment requirements. They should be have thermal accessibility to the places they still want to go to [G1].
Behavioural changes are clothes or options to stay out of the sun or adding environmental cooling elments in the public space could help cool down the citizens. This can help the heat conscience.

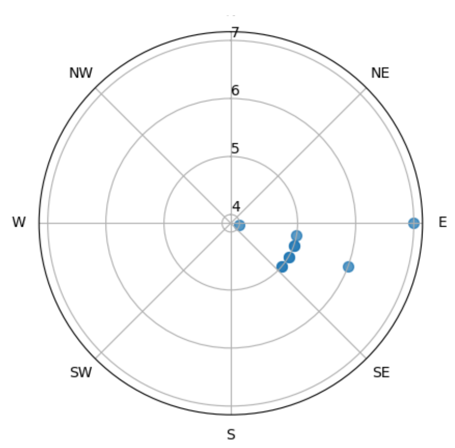
For the health of citizens it is important to look at a change of when a heatwave temperature will start. This will be 25 °C or higher. It is important to compare this with an average summer day of 20 °C. Also because this will most likely will occur more in the future see Fig. 4.5 [G1].

Chapter 5 | Current climate liveability of Bospolder Tussendijken|

4.2 Physical liveability: Climate

The mapping of days with atmospheric temperature involves comparing an average warm day with a summer day. Specifically, the analysis focuses on two dates: the 1st of July 2015, which was a summer day, and the 29th of June 2015, which was an average warm day. It was observed that 2023 has multiple hot summer days in comparison to 2015.





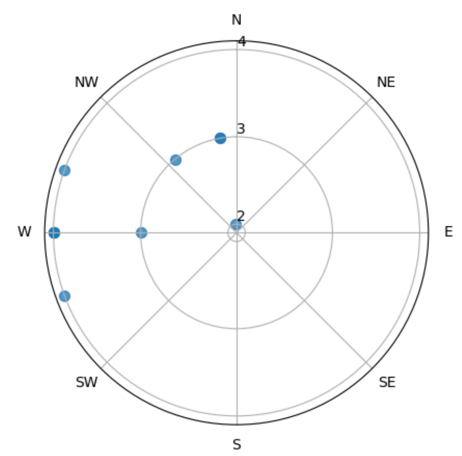


Fig. 4.6 from KNMI hourly data. Adapted by Author

4.2 Physical liveability: Climate and Built environment

Factors that determine the urban climate The urban climate is influenced by both dynamic and static factors. The dynamic weather factors vary from day to day, season to season and year to year. In addition, static factors such as the morphology of the urban environment influence the urban climate. Therefore, it is important for designers and planners to consider the fundamental processes of urban climate and to design with specific locations and their temporary climatic variations in mind (Lenzholzer, 2018).
In order to understand the relationship between the physical urban structure and meteorological factors, several elements come into play. The elements related to heat include (1) radiation such as (shortwave and longwave), (2) air temperature, and (3) wind in the urban environment. The factors influence the built environment at different scales and are determining the influence of the urban designer on the implementation on the urban fabric. Next up some mitigating measures are named (Marjolein van Esch, 2015) see figures 4.7 and 4.9 .

1. Radiation and heat

Radiation is fundamental to all thermal processes on Earth. This radiation comes from the Sun and reaches the Earth's

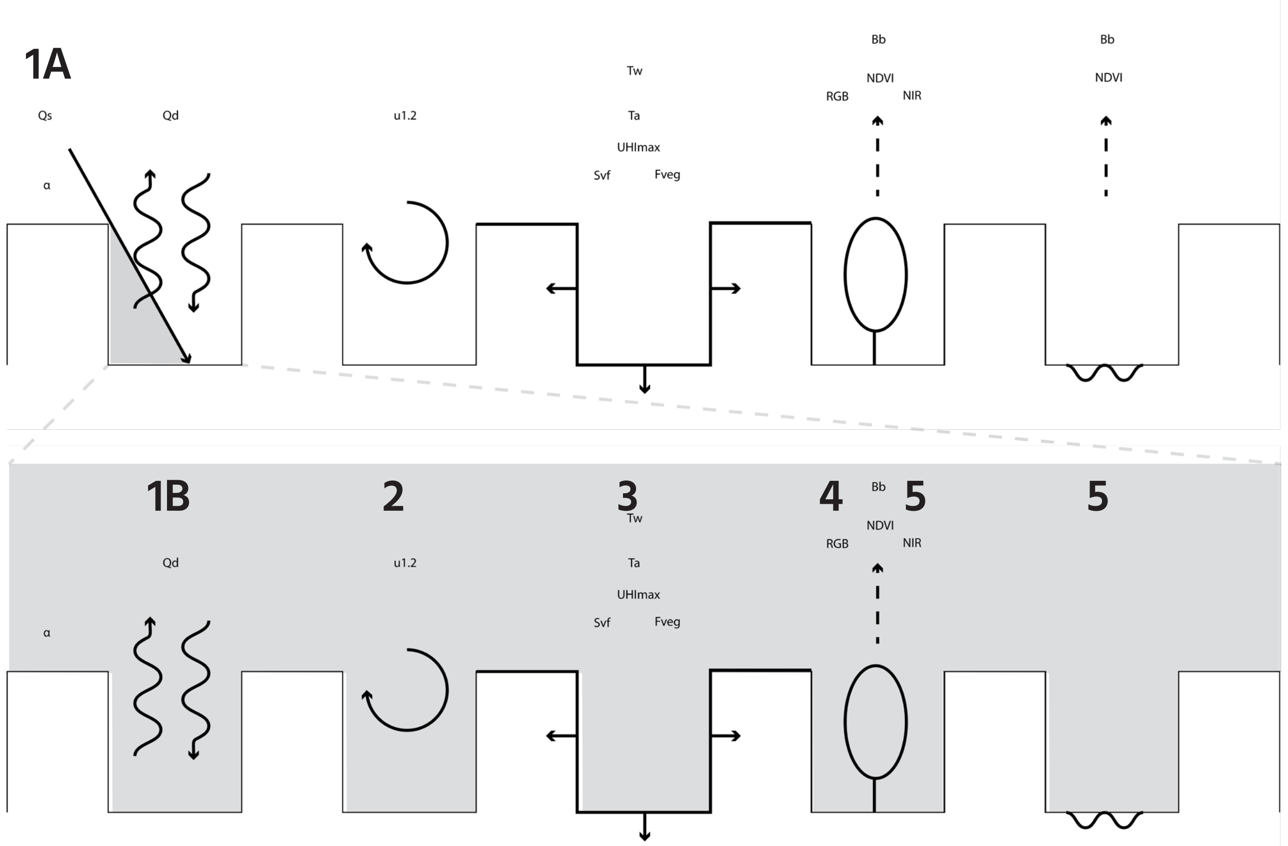


Fig. 4.7 a) day situation and influence on urban environment. b) night or shadow situation. Adapted from Marjolein van Esch and Koopmans et al. (2020) created by Author.

on the Earth's surface. Solar radiation can also be scattered by dust particles in the atmosphere and reflected by various surfaces. When the Earth's surface or materials absorb this shortwave radiation, it is later emitted as longwave heat radiation, with variations depending on the type of material, such as asphalt or greenery.

A. Direct shortwave radiation:

Shadows greatly affect the incoming radiation, depending on the characteristics of the objects casting those shadows. Buildings and other solid structures cast deep shadows, while transparent objects and trees provide varying degrees of shade. The altitude angle of solar rays also influences the intensity of incoming radiation, varying by location and time of year. For instance, on June 21st, the longest day, the sun takes a higher path and its rays have a longer duration.

B. Albedo, emissivity, thermal conductivity

Albedo relates to how much solar radiation a surface reflects. Next up emissivity relates to how efficiently a surface emits thermal radiation. Following up, thermal conductivity relates to how well a material conducts heat.

2. Wind in the urban environment

The movement of the wind is primarily caused by differences in temperature. Warm air typically rises, while cooler, denser air remains closer to the Earth's surface. Large-scale systems consider the direction and strength of the wind when predicting weather forecasts.

Throughout the day, landmasses and bodies of water experience varying temperature changes. Water generally takes a longer time to heat up than land, resulting in different airflow patterns. For instance, stronger winds may occur between densely populated city centers and large, open parks with cooler temperatures, while gentle breezes may happen between small parks and sparsely built residential areas. Allowing cool breezes to pass through can help ventilate warm areas within a city.

The roughness of the Earth's surface, also known as roughness length (z0), affects wind patterns around cities on a large scale. Land surfaces are more rugged due to plants and topographical features, while water surfaces tend to be relatively smooth. Cities, with their tall buildings and vegetation, act as obstacles that force the wind to flow around them. A city with many tall buildings presents a more significant obstacle than one with numerous low-rise structures.

On a smaller scale, distinct wind patterns emerge when buildings are clustered together due to flows around individual buildings' interactions. The building's geometry affects the flow pattern within its influence area. When a structure is thin and tall, most of the air passes through it sideways. If the building is tall and wide, the frontal cortex, downwash, and recirculation area are mentionable. A low and broad structure will have the most air travelling over it.

In urban canyons, three flow patterns can be distinguished, correlated to the wind direction at roof height: parallel, perpendicular, or at an angle to the canyon axis. The proportions of open spaces, such as streets and squares, significantly influence wind patterns, particularly the ratio between building height (H) and the width (W) of the spaces between buildings.

When the height-to-width ratios (h/w) fall within the range of 0.3 to 0.7, wake interference flow patterns are observed. For h/w ratios of 0.3 or smaller, buildings are far enough apart that the wind can almost return to its initial flow pattern and speed. This specific pattern is referred to as isolated roughness flow (Lenzholzer, 2018).

Street grids oriented in alignment with the dominant wind direction will feature perpendicular-facing streets (and other open areas) that offer a significant degree of shelter. Parallel-facing grids will experience higher wind speeds. Additionally, such grids may facilitate crosswise airflows in streets that intersect the wind direction, potentially leading to discomfort. On the other hand, grids set at oblique angles to the wind direction will result in a more uniform and consistent wind pattern. Square and relatively small enclosed spaces, such as courtyards and squares, offer the most shelter, as corner streams, frontal vortices, and transverse flows are prevented (Marjolein van Esch, 2015; Lenzholzer, 2018; Ilmer BWTinfo, nd)

3. Temperature

In densely built areas, this longwave radiation tends to be trapped as it bounces between buildings and a lack of open soil surfaces, water and plants. Therefore the heat phenomenon is therefore called the urban heat island effects. This is also related to the ratio of building height to street width (Marjolein van Esch, 2015). The radiation is mostly received and stored during the day, and released as longwave radiation at night.

Design principles mitigating heat in the public space level

4. Material surface properties

Reflection, absorption and re-emission of solar radiation. The amount of heat stored by a material exposed to radiation (direct, indirect or diffuse) is highly dependent on the thermal admittance and albedo of that material (Potz, 2016). Also influencing the albedo, emissivity and thermal conductivity.

5. Landscaping elements: water and vegetation

Vegetation impacts the microclimate not just through shading but also via evapotranspiration. Evapotranspiration encompasses the total process of water evaporation, including water that is intercepted by vegetation, soil, paved or building surfaces, as well as the evaporation of water from the soil and the transpiration by vegetation. The joint influence of evapotranspiration and shading results in reduced daytime air temperatures during the summer (Potz, 2016).

Scale dependence

By mentioning the climatic factors that contribute to the heat experience

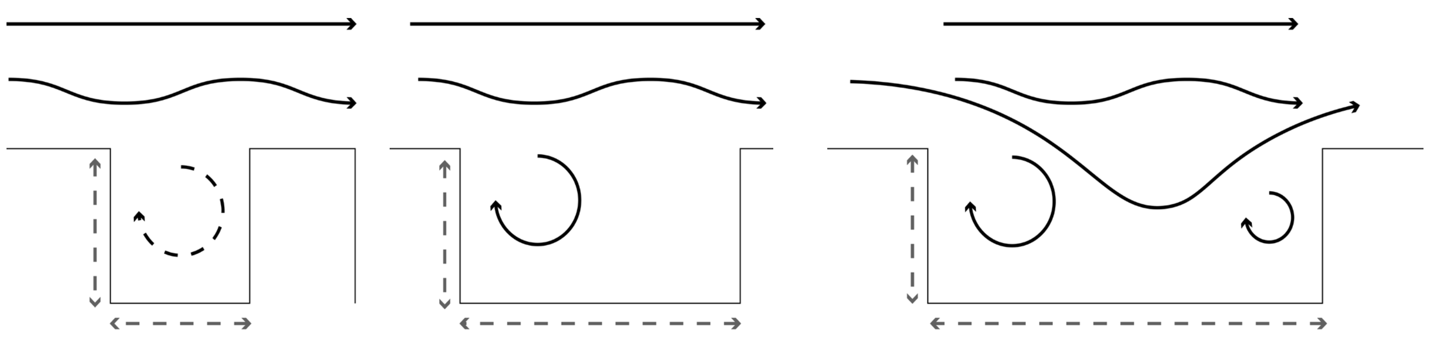


Fig. 4.8 a) Skimming flow, b) wake interference flow and c) isolated roughness flow Adapted from Lenzholzer (2018)

in urban environments, Marjolein van Esch (2015) relates the layered approach of Meyer & de Jong, Hoekstra (2012) to the influence of urban designers on heat mitigation in public spaces. It is stated that the long-term and higher scales are less changeable than the spatial functional organisation and the urban plan with the street pattern and street orientation. The public space is dependent on its closely related scales such as the urban plan and the architecture of the dwellings. For the preferred public space design and public space network, variations could be sought in changing the street profile while looking at the current orientation of the streets. As well as paving and landscaping. It is important to note that for solar radiation, wind and evaporation as a whole, it is helpful if they are implemented in a continous manner to reach higher scale of heat mitigation [G1] Next to this in order to make it a durable climate mitigation measures there needs to be looked into the permanence of the mitigating measures of the structures whereas it be greenery benefiting all year round or the ownership requirements for apply the mitigating structures in the network [G2].

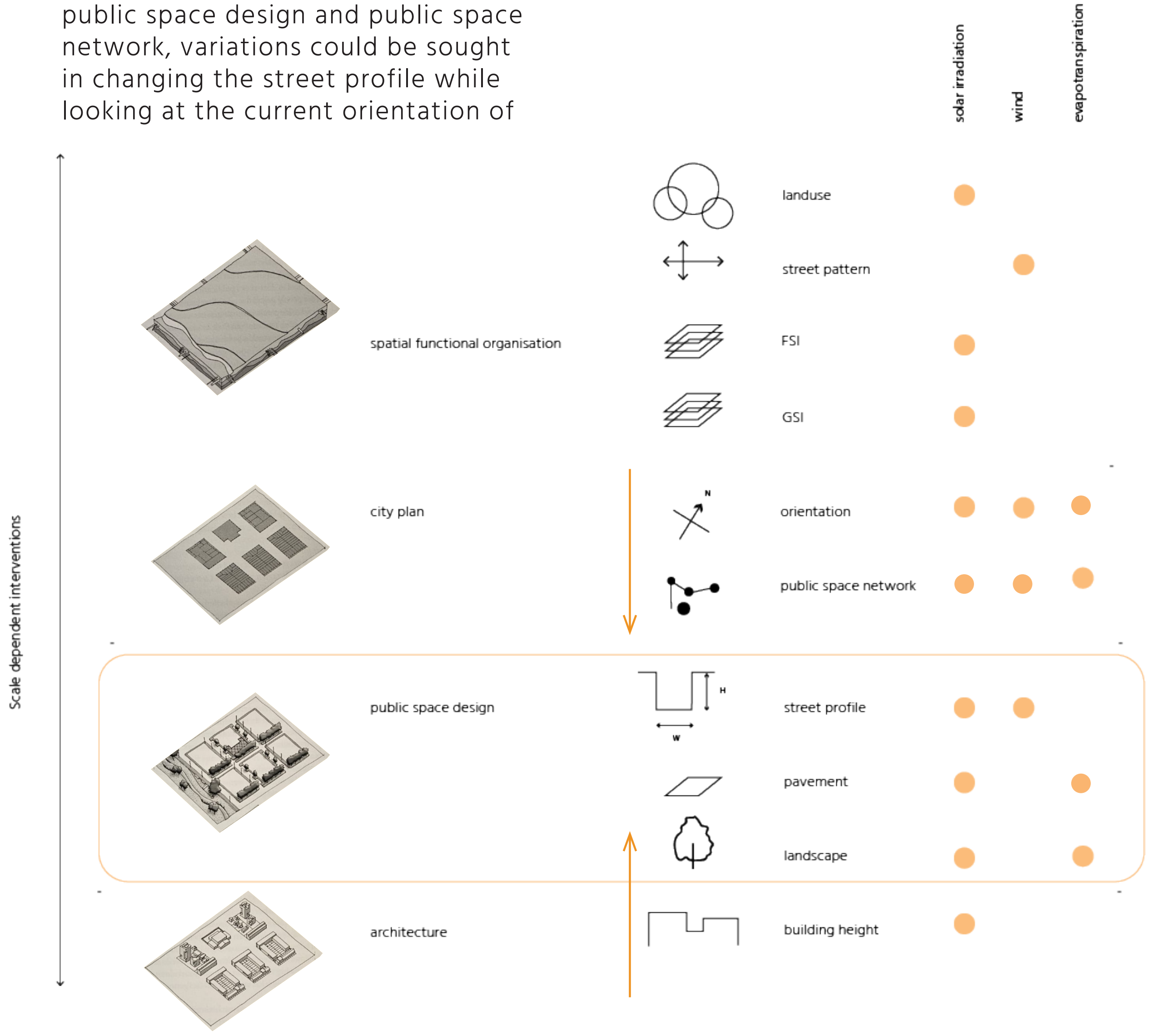


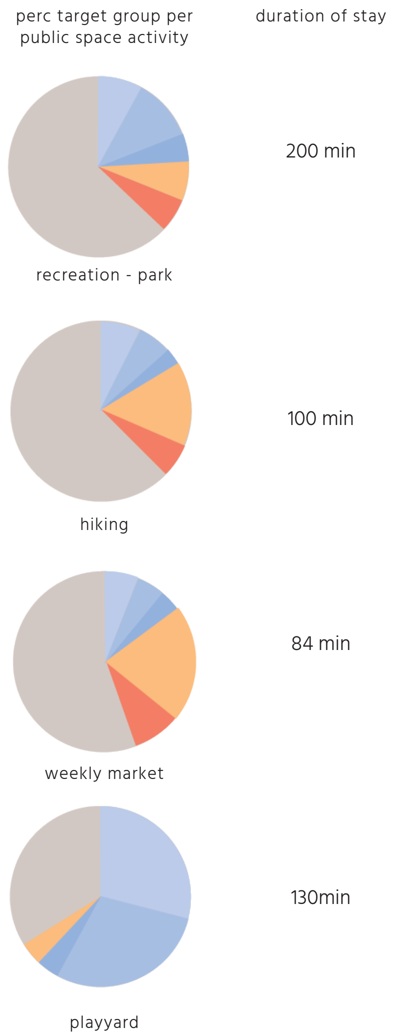
Fig. 4.9 Built environment scale dependencies of urban design principles for heat mitigation elements based on the main thermal comfort influences. Adapted from Marjolein van Esch and layer approach by Heeling Meyer & Westrik. Reprinted from Heeling et al. (2002). De kern van de stedebouw in het perspectief van de eenentwintigste eeuw. Dl. 1. Het ontwerp van de stadsplattegrond door Jan Heeling, Han

4.3 Social liveability

Investigating urban well-being and liveability involves delving into the nuanced connection between individuals and their daily urban surroundings (Maslow, 1943). This inquiry is fundamental to social geography, highlighting that the quality of urban environments and liveability are subjective concepts influenced by various factors such as location, time, scale of living space, and the particular social group in question. Quality, within this framework, is perceived as a function of behavior stemming from the interplay between environmental attributes and individual characteristics (Pacione, 2013).

Neighbourhood unit

For the social performance of liveability in the neighbourhood - the current socio-demographic context must be revealed (Pacione, 2013; WHO, 2023).
This research adopts the 15-minute city to consider the neighbourhood unit. Historically, the successes and failures in creating ideal cities suggest that neighbourhoods should be the spatial context in which residents meet their basic needs, interact and communicate with each other (Smith, 2020).



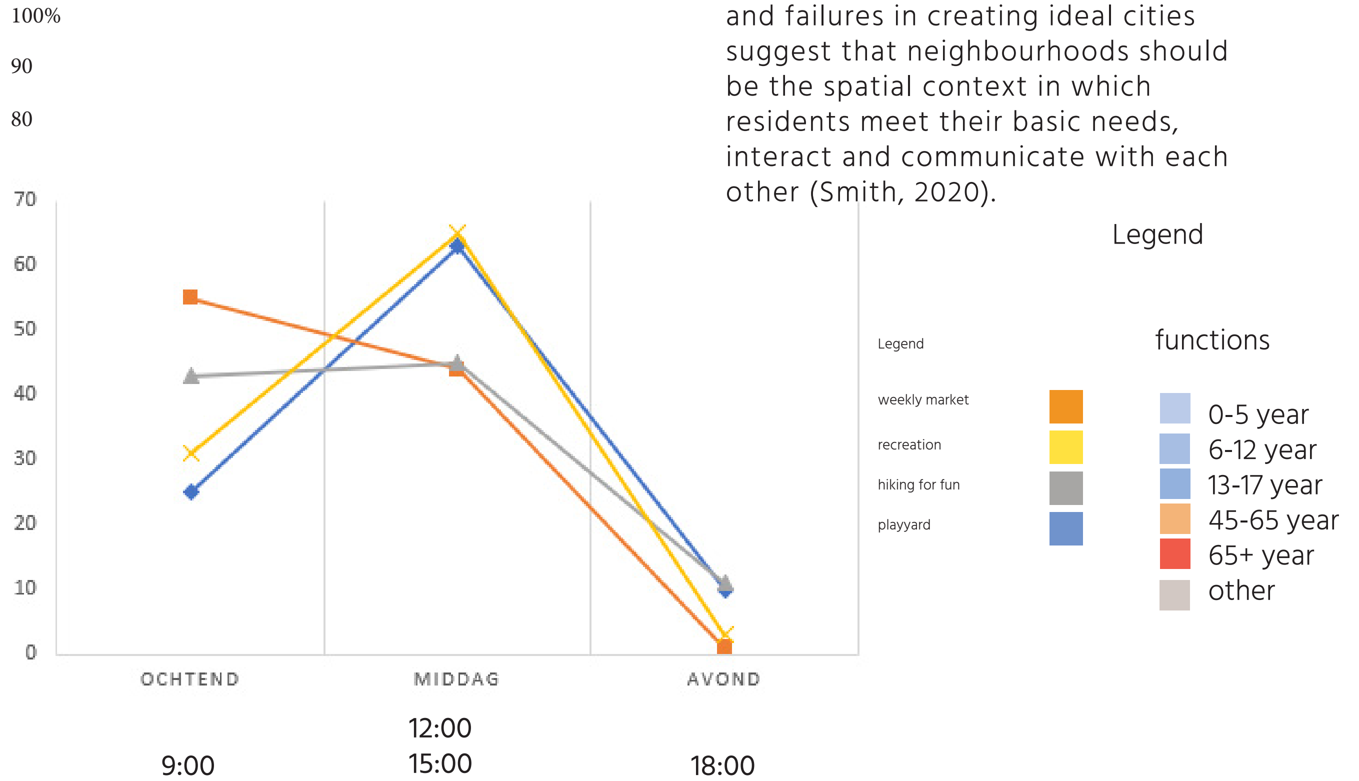


Fig. 4.10 Leisure activities and their demographic groups. Retrieved from CVTO 2018 vrijetijdsbestedingsonderzoek Nederland https://www.provincie-utrecht.nl/sites/default/files/2020-07/CVTO%20Basisrapport%20weekmetingen%202018%20-%20Utrecht.pdf

Simple local rules, motivations and goals create complex self-organising global behaviour. Friedman and Massey point out that neighbourhoods are the places where complex social relations and interactions can be publicly acknowledged and transform our learning about places (Friedman, 2008; Massey, 2005). Redefining neighbourhoods as carriers of social data, spaces of social production and reproduction [G4 +G5].

Social Mobility: Social places

Social mobility, refers to the changes in resources or social standing of individuals, families, or groups within a given social structure or network. Therefore it is important to look at the places were the interchange of social gatherings take place.

Julienne Hanson's concept of flexibility of daily needs and appropriateness is crucial for creating inclusive urban environments (2005). This involves providing varying degrees of public and private space throughout the day and over people's lifetimes, which should be continuously adjusted by residents and visitors. Giving residents some control over spatial structure, including a mix of land uses that promote continuous space utilization at different times of the day, is recommended for optimal city performance (Gehl, 2011), aligning with citizen-centered planning principles and recognizing public space as a common good.

Designing public spaces to accommodate diverse needs is essential for building the social capital of citizens (Gehl, 2011; Kaufman, 2004). Considering factors like environmental quality and mobility becomes pivotal, especially for vulnerable groups. Elderly individuals require natural, visually pleasing, legible, and diverse landscape elements, along with accessible and well-maintained infrastructure and amenities. Moreover, the significance of these preferences may be influenced by the interactions between individuals and their natural surroundings (Wen, 2018).

Identifying social need locations for vulnerable groups, such as the elderly and children, is crucial. For instance, in the Netherlands, the CVTO (2018) found that weekly markets are frequented by elderly individuals throughout the day, while parks and schoolyards are popular destinations for children, especially during school days and play hours [G5]. Overview of the occupation hours are visible in figure 4.10.

Spatial mobility: Movement places

Mentioning spatial mobility as a geographical displacement through the public space network. The mobility of slow traffic must therefore be considered, promoting accessibility, physical health, and community engagement at a pedestrian-friendly level. The 15-minute city concept emphasizes walkability as a requirement (Pozoukidou & Chatziyiannaki, 2021).

Since we are looking at inclusive design we are looking at the qualities of pedestrain traffic within the neighbourhood in contrast to fast traffic like cars. Whilst most of the trips are taken within 2.5km (Lucas, 2008) it is essential to focus on slow mobility like walking. This should fit in the 15 min approach of reaching your amenities in one kilometer radius.
Speed of movement reduced from 60 to 6 km/h will increase the number of people on the street. For elderly walkability measures are wide troittors for the slower pacements. They tend to walk 500m in 15min instead of 1000m because of their declined pace [G1]. They want to have safe crossings. More inmobile persons would like to have seatings of 200m distance (Molster,

4.4 Liveability conditions

Physical liveability

These external physical stimuli are determined by the built environment and the climate fluctuations. Concluded from research, the influence of the built environment has scale dependencies in mitigating heat possibilities. Therefore it is important to note that mitigation measures should be taken in a continuous manner for the best performance. Wind which has a great influence on mitigating heat in the city couldn't be modelled with such accuracy due to the roughness layer approximation of the Macdonald method (Macdonald et al., 1998). This is also seen by the wind computation method used for calculating the Physiological Equivalent Temperature as well. For health considerations it is important to qualify a day above 20 degrees and 25 degrees.

For designing the public space in cities you are dependent on the spatial functional situation as well as on the city structure as on the smaller scale of architecture. This research focuses on public space design and takes into account orientation of streets, height width ratio of streets and the architecture.

For heat mitigation measures it helps the best if they are on a higher level mitigating measures are possible like on the level of city or spatial organisation. Due to the unlikelihood of changing these long term formed urban fabric these are taken as static given factors. Also as mentioned before that it is important to is that the durability of the design interventions should be tested whetether it is on ownership or long term feasability.

Social liveability

The conclusion was that due to physiological factors the vulnerable groups are elderly, children, people with vascular diseases and obesity. This is due to their declined or underperformance of temperature regulation in the body. For the scope of this research elderly and childeren are the target groups for the research. There seems to be a correlation between health issues with 25 celsius degrees which is called a summer day, in comparison to the average 20 celsius degrees. The air temperature, wind, humidity and influence of long and shortwave radiation determine to a large extent

Design goals	Assesment (– to +)	Methods
Physical liveabilty		
G 1. Accesibility of places for elderly during summer days		cumulative thermal comfort accessibility of 500m
G 2. Continuous mitigating measures network of public spaces		line segments: shadows, orientation,
G 3. Durable application of mitigation measures		pattern flowchart: which mitigation elementsare there on which scale applicable
Social liveability		
G 4. Spatial mobility: investing in the environmental quality of walkable surfaces for elderly destination preferences		important streets for shortest paths (towards needs of vulnerable groups within the urban evnironment)
G 5. Social mobility: destinations as social spaces which are thermal inviting for vulnerable groups		layout of

Fig. 4.11 Design goals and ways to evaluate the state of liveability

the sensation of heat, this differentiates through the day due to the orientation of the sun in relation to the static built environment.
Because of the focus on spatial mobility and social mobility the locations to transform will include movement locations like streets and public space as stay locations for elderly and children.

Assesment

In order to evaluate the current liveability the previously literature is used as the framework how to asses the liveability requirements. The geomatics part focused on the assessment of the improvement of these liveability main goals, see figure 4.11.

"Chapter 5 Current liveability in Bospolder Tussendijken

Fig 5.1. Mathenesseweg, Tussendijken. Picture taken by Author

5.1 Context

History of Bospolder Tussendijken

Rotterdam, a city in the Netherlands, has a natural landscape that was originally characterised by both natural and man-made features (see figure 5.2). Polders were created to manage the freshwater uplands, while dikes were built to protect the city from flooding. The historic Delfshaven area served as a trading centre along the Maas River around 1500. As the area urbanised, housing regulations were introduced to improve the living conditions of the inhabitants. A.C. Burgdorfer established Bospolder in 1910, which provided a significant amount of social housing. However, his preferred monumental plan was hampered by the existing street plan, the historic Delfshaven and the harbour railway line to the west, resulting in a lack of public space, with the exception of Bospolderplein.

In contrast, Spangen and Tussendijken were designed with a monumental axis and a series of urban spaces, including sports grounds, a market square (Visserijplein) and a garden. J.P. Oud included blocks of social housing with gardens, the various blocks demonstrating Oud's development towards an anonymous, taut street elevation in which individual dwellings were subordinated to the unity of the streetscape, a point emphasised by the increasingly sculptural treatment of corners. In the wake of the housing market crisis, public spaces were built according to the original plan.

The contemporary M4H area, consisting of the Merwehavens, Keilehavens Lekhaven and Ijselhaven, has provided the city with a new labour market. However, Rotterdam's city centre was bombed in 1940 and Tussendijken was mistakenly bombed by the Allies in 1943, leading to a major reorganisation of the city. Inspired by the CIAM conferences, Witteveen and de Jongh implemented the 'Basisplan', which replaced building blocks with a rectangular composition of streets framing neighbourhoods and separating functions, with most functions planned for the city centre and adjacent neighbourhoods (Palmboom, 1995). De Jongh established a hierarchy of four types of street, with the Heemraadsingel being the first, followed by the 40m wide Mathenesserlaan, middle-class streets such as Hooidrift at around 25m, and the smallest streets, designed for dock workers, which were 11-15m wide. Gijzingsflats were also built in Tussendijken. In the field of mobility, there was a change from horse-drawn

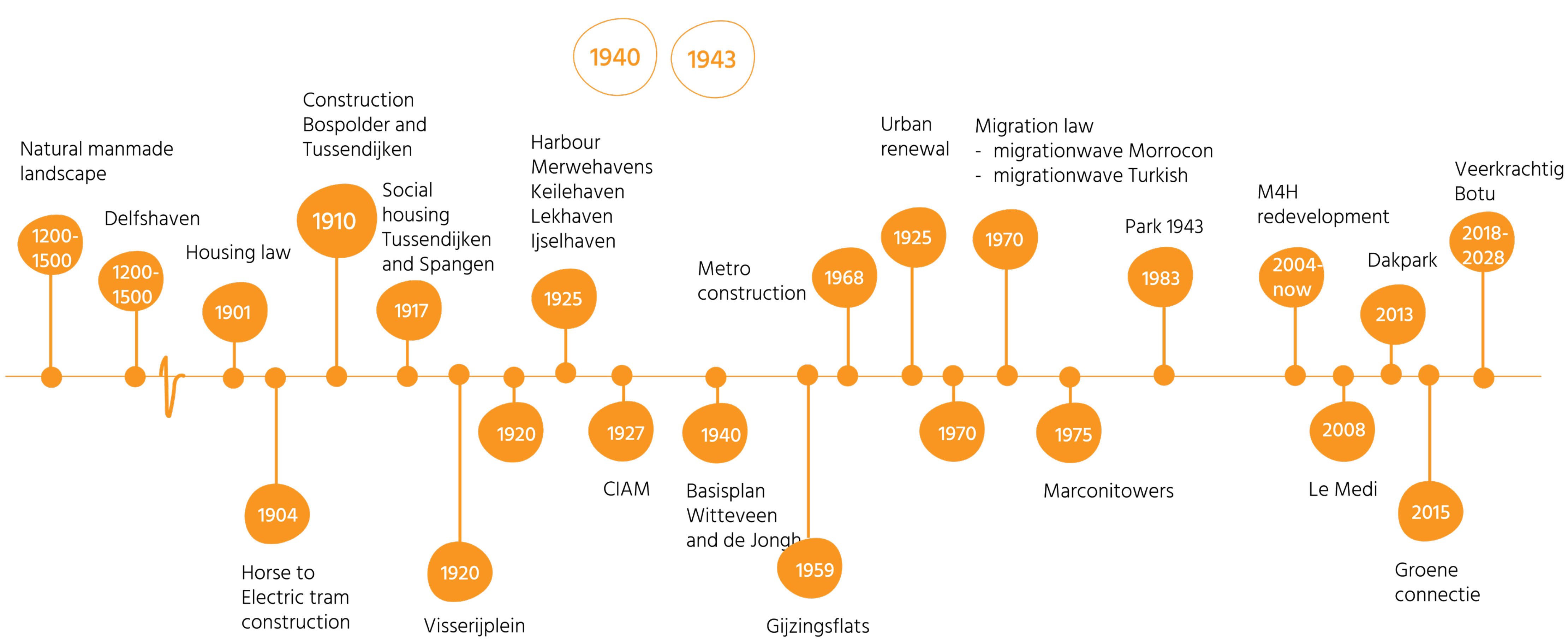


Fig 5.2 Time line Bospolder Tussendijken (Adapted from Veldacademie, 2020; Palmboom, 1995; Spek, 1986)

trams to electric trams, and a metro was dug, marking the underground division under the Bospolder and Tussendijken streets. In addition, the Migration Act was approved for additional labour activity in Rotterdam, with two significant waves of Moroccan and Turkish workers. The forthcoming law on family reunification made it possible to house this new population permanently.

Urban renewal took place in 1970, and Park 1943 was created after the bombing to provide additional green space. In the following decades, however, Bospolder and Tussendijken became one of the most deprived areas in the Netherlands. With the development of Maashaven I and II, port activities moved towards the sea entrance of the port, transforming the adjacent port activities. In 1986 the metro was prolonged to Marconiplein underneath Schiedamseweg (Spek, 1986). Since 2004, the M4H developments have taken place, with projects like the Le Medi social housing project and Dakpark. The Dakpark is a unit of the greening project of Rotterdam see Fig. 5.4. Despite the degraded state of the neighbourhood, several neighbourhood initiatives have been established to promote links between residents (Veldacademie, 2020).

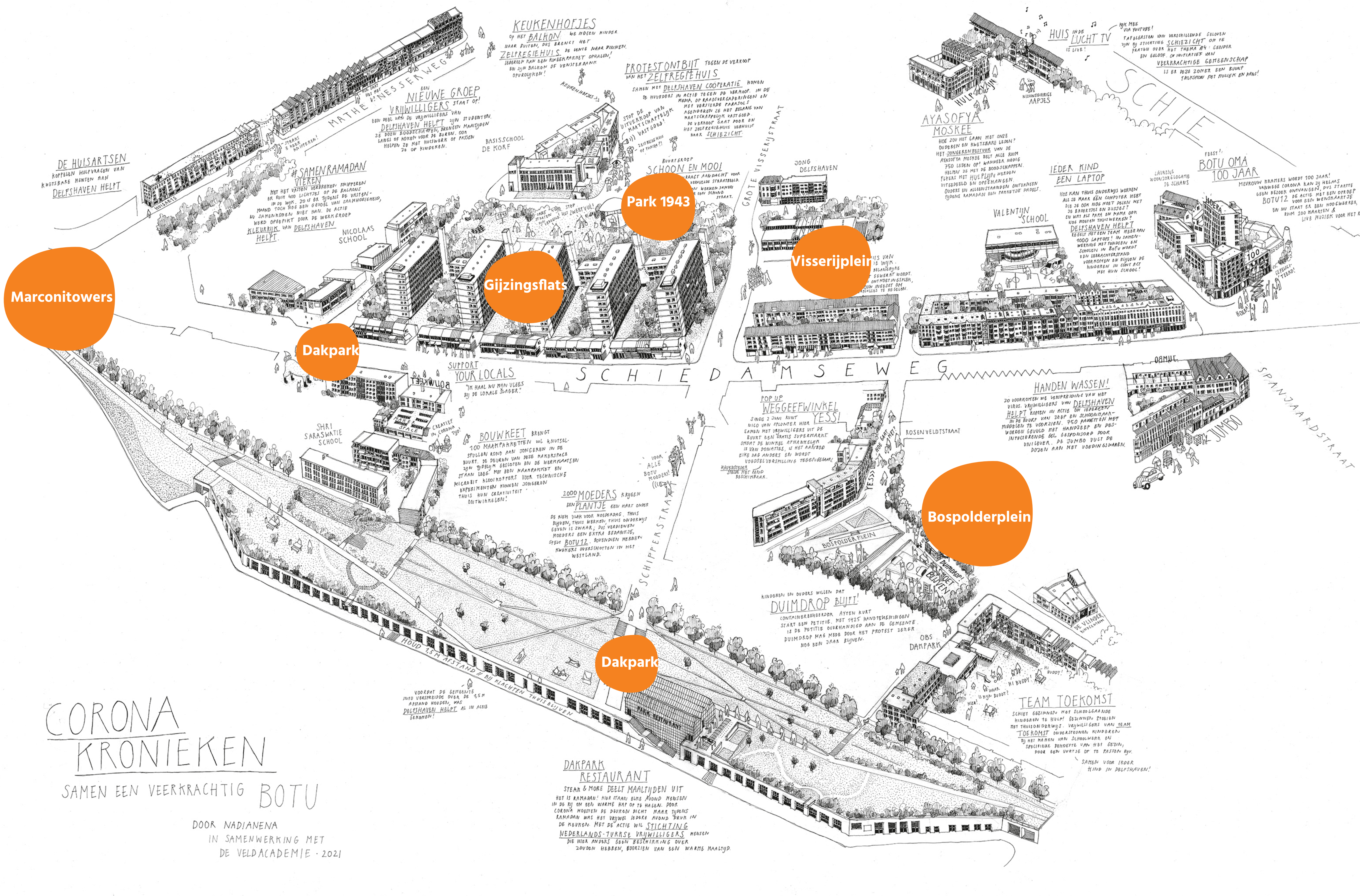


Fig. 5.3 Corona kronieken in Bospolder Tussendijken (BOTU) retrieved from Veldacademie with Studio Studio NadiaNena (2021) retrieved from https://www.veldacademie.nl/nieuws/2021/09/gemeenschapsveerkracht-in-rotterdamse-wijken-tijdens-de-coronacrisis

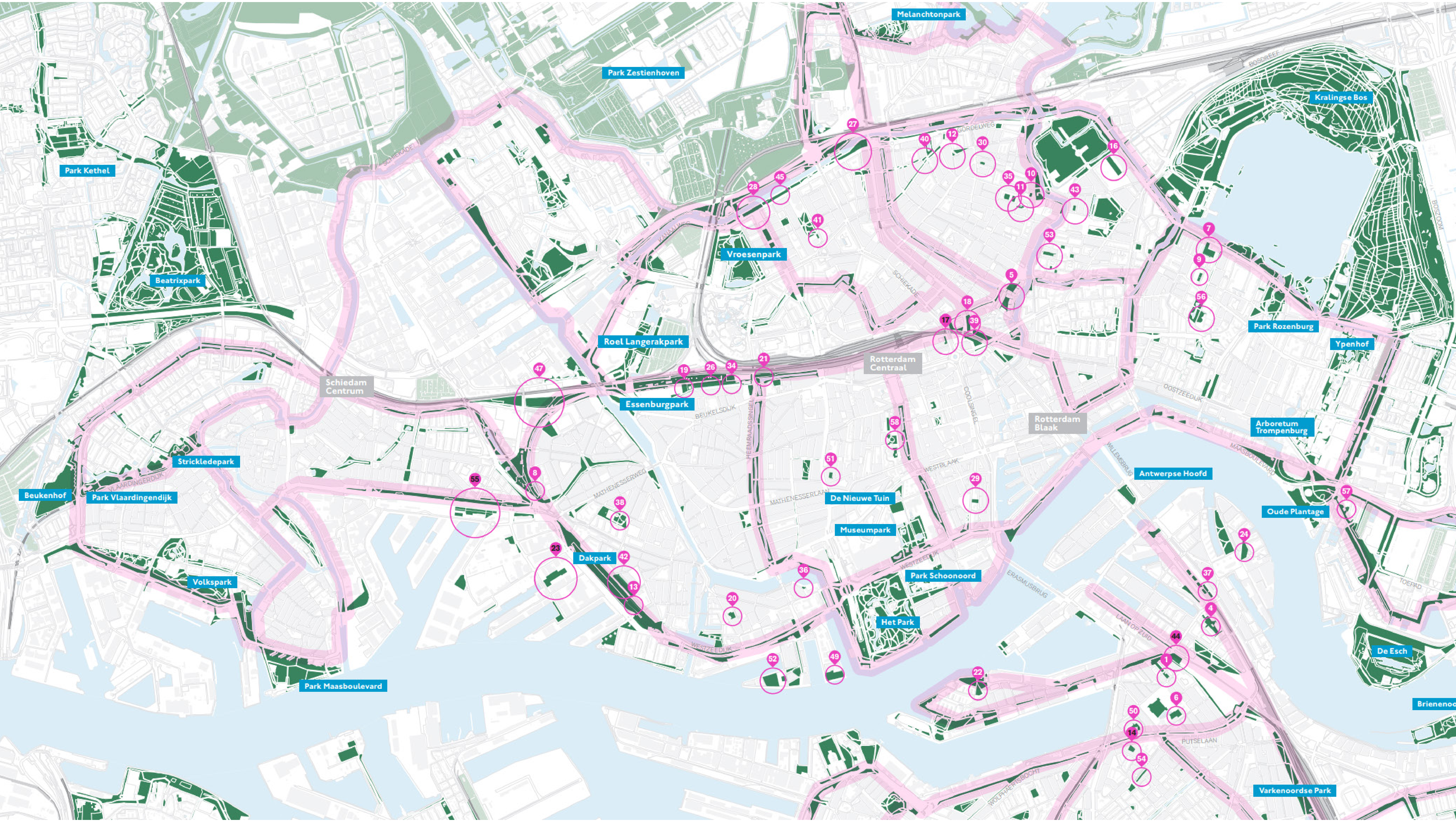


Fig. 5.4 Bospolder Tussendijken in their Rotterdam Context. Urban Nature map Rotterdam (Collaboration Deltametropool, Lola landscape architects, 2018)

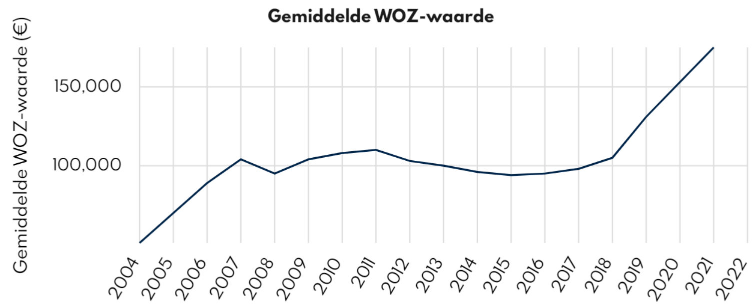
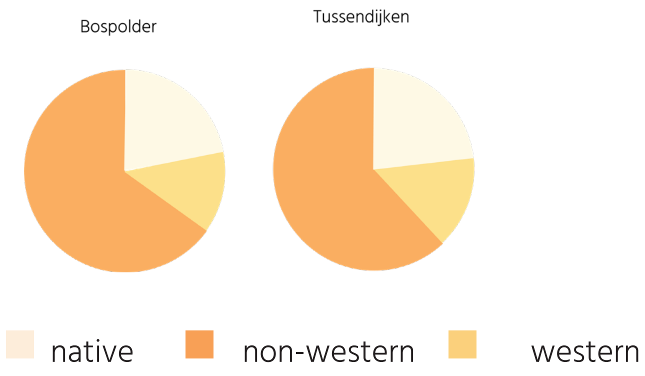


Fig 5.5 WOZ waarden dwellings Bospolder Tussendijken retrieved from Kadaster (2022)



Current social status

The peripheral regions of Bospolder and Tussendijken are becoming increasingly attractive due to their strategic location near the city centre for new urban development projects. Due to the accessibility to public transportation, and proximity to major roads, making them a popular choice for highly educated and affluent individuals and families. Areas such as Le Medi, Mathenesserdijk, and Mathenesserweg have already seen an influx of promising families. The introduction of new developments such as the Hudsons, Lee Towers, and the structures at the beginning and end of the Dakpark is expected to further drive this trend.

In contrast, the inner regions of the area are still struggling with a high level of vulnerability, particularly in residential areas. For example, over 60% of the available housing in Tussendijken consists of social rental properties within the lower income bracket and have a WOZ of 150.000 (figure 5.8 and 5.12). Despite ongoing urban renewal efforts, Bospolder still features several neighbourhoods with outdated housing options. Almost three-quarters of households in the BoTu area fall within the low-income bracket.

The physical index has slightly increased for Tussendijken, while it has remained unchanged for Bospolder. Interestingly, the overall perception of living in both neighbourhoods has declined. Despite that there are good amenities available, residents express dissatisfaction with their living conditions, including their homes and outdoor spaces (see figure 5.11, 5.8 and 5.7). Street clutter and trash near containers are significant sources of annoyance, along with aggressive and antisocial driving behavior (Gemeente Rotterdam, 2019).

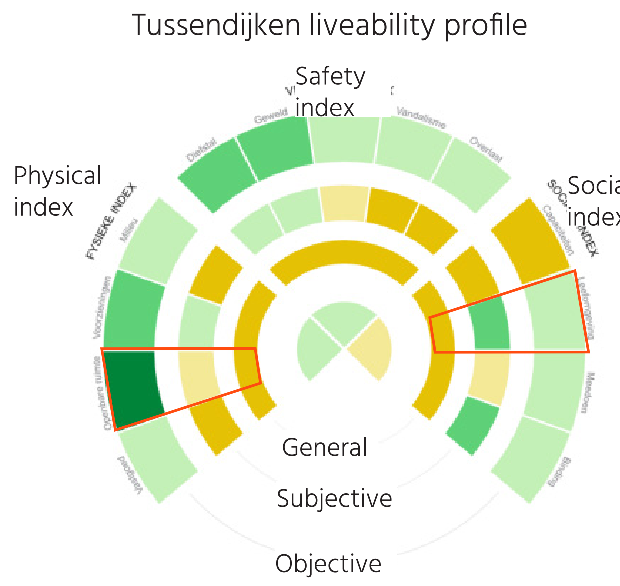


Fig 5.6 Ethical background (Allecijfers, 2024)

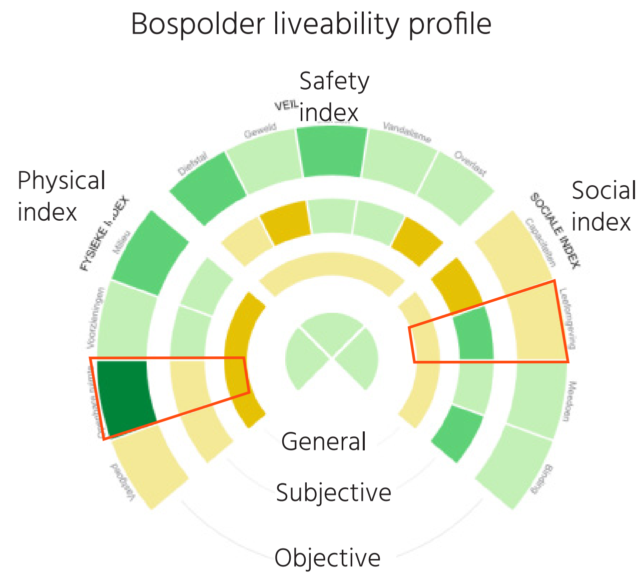


Fig 5.7 Liveability measured by safety, physical index and social index (2022) (retrieved from Gemeente Rotterdam, 2022). The classification is based on the objective measurments and the subjective experience of citizens

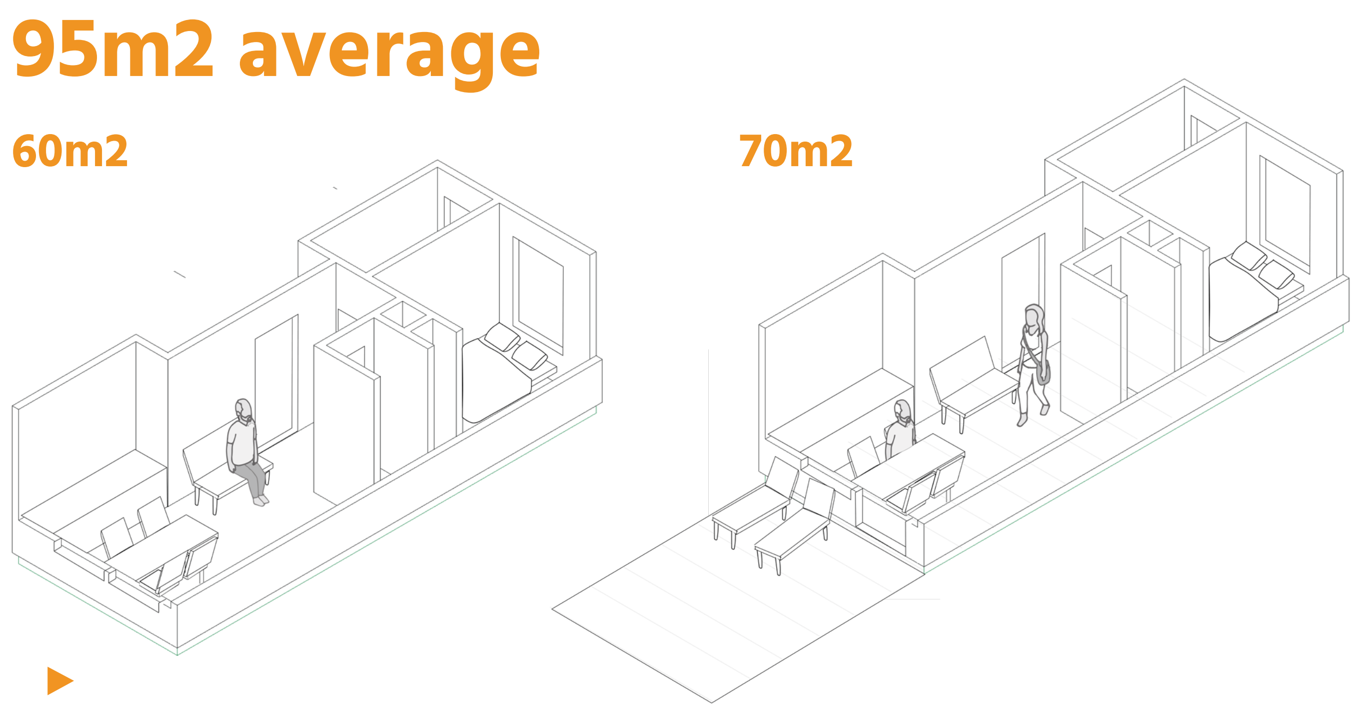
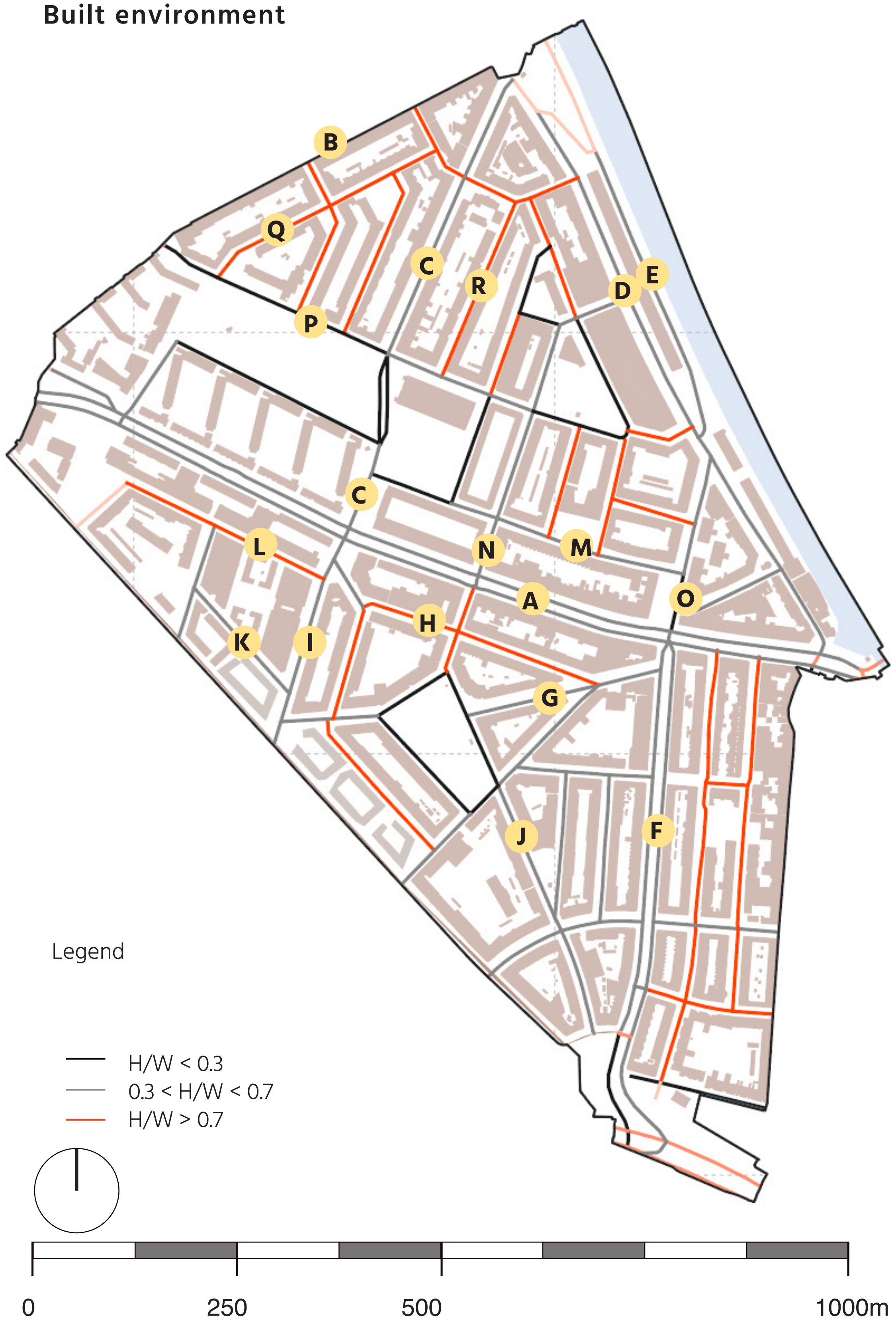


Fig. 5.8 appartement and ground floor apartement inspired from Funda Mathenesserdijk

5.2 Physical liveability

Built environment



Legend

A. Schiedamseweg
B. Mathenesseweg
C. Grote Visserijstraat
D. Mathenesselaan
E. Mathenessedijk
F. Spanjaardstraat
G. Rosier Faasenstraat
H. Rosenveldtstraat
I. Schipperstraat
J. Albert Engelmanstraat
K. Medinastraat
L. Blokmakerstraat
M. Gijzingstraat
N. Van Duylstraat
O. Jan Kuifstraat
P. Rosener Manzstraat
Q. Korfmakerstraat
R. Kleine Visserijstraat

Fig. 5.9 accessibility play yards (created by author)

Legend

percentage flat roof
- no data
- 0-20 no flat roof
- 20-40
- 40-60
- 60-80
- 80-100 flat roof

Fig. 5.10 Flat roof buildings (retrieved from https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/map)

Legend

energy label
- A+
- A
- B
- C
- D
- E
- F
- G

0 250 500 1000m

Fig. 5.11 Energy labels buildings (retrieved from https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/map)

Legend

- unknown
- housing association
- privately owned
- private rent

Fig. 5.12 Ownership (retrieved from veldacademie 2018)

Built environment: Orientation and height width of the streets

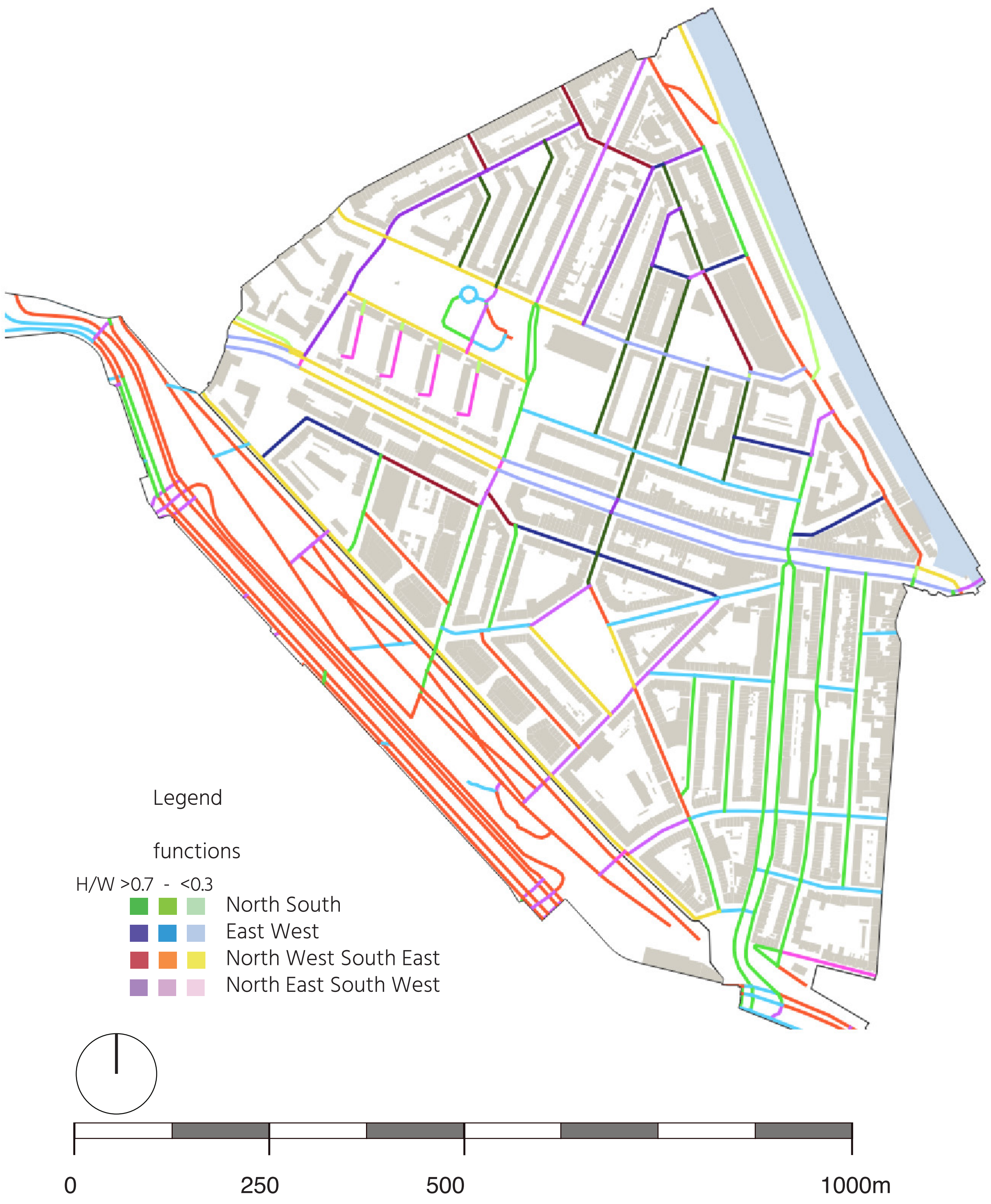


 Fig. 5.13 H/W ratio and orientation for Bospolder Tussendijken (created by Author and SQL queries)

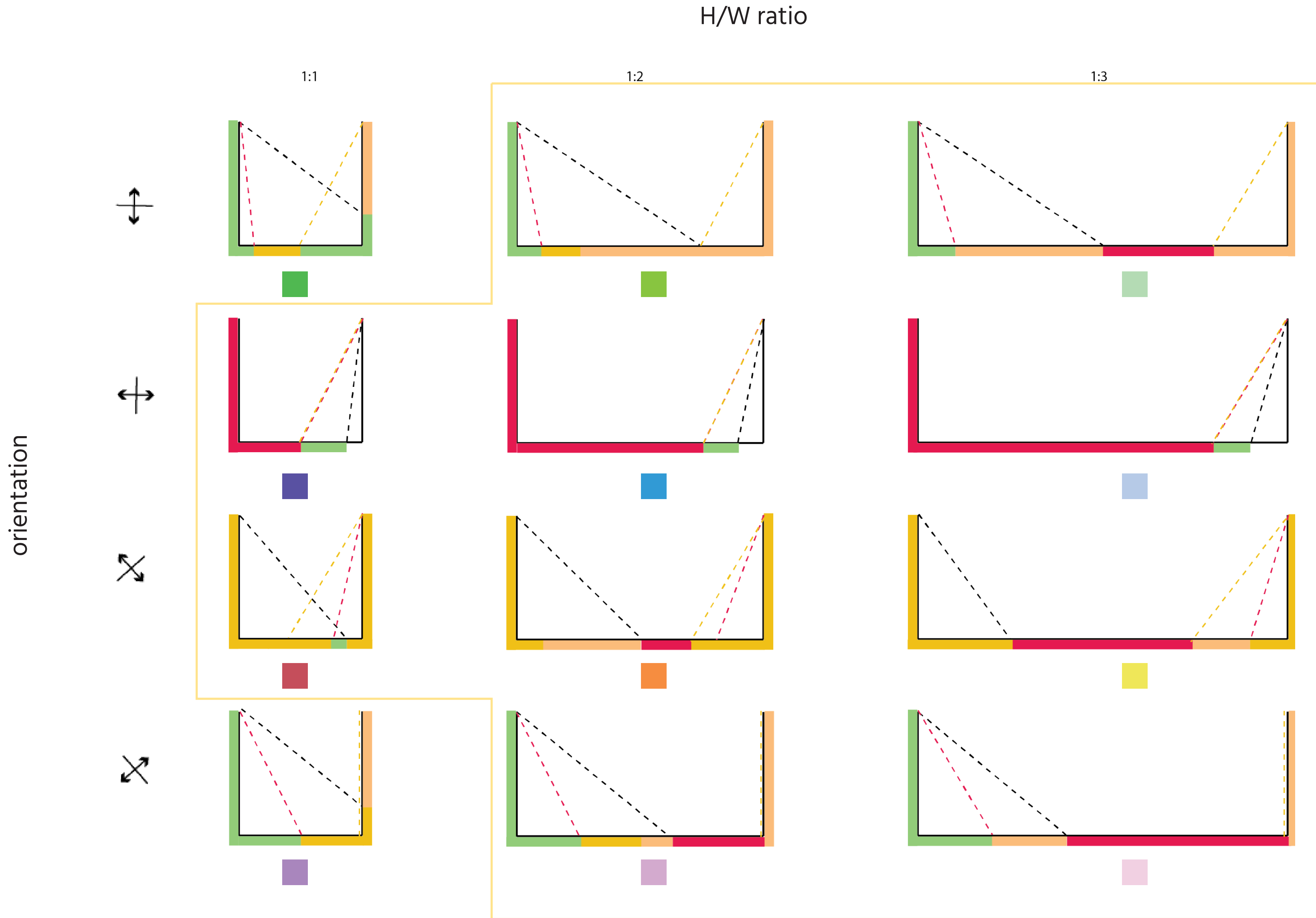


Fig. 5.14 solar exposure on street type H/W ratio and orientation from Lenzholzer (page 86)

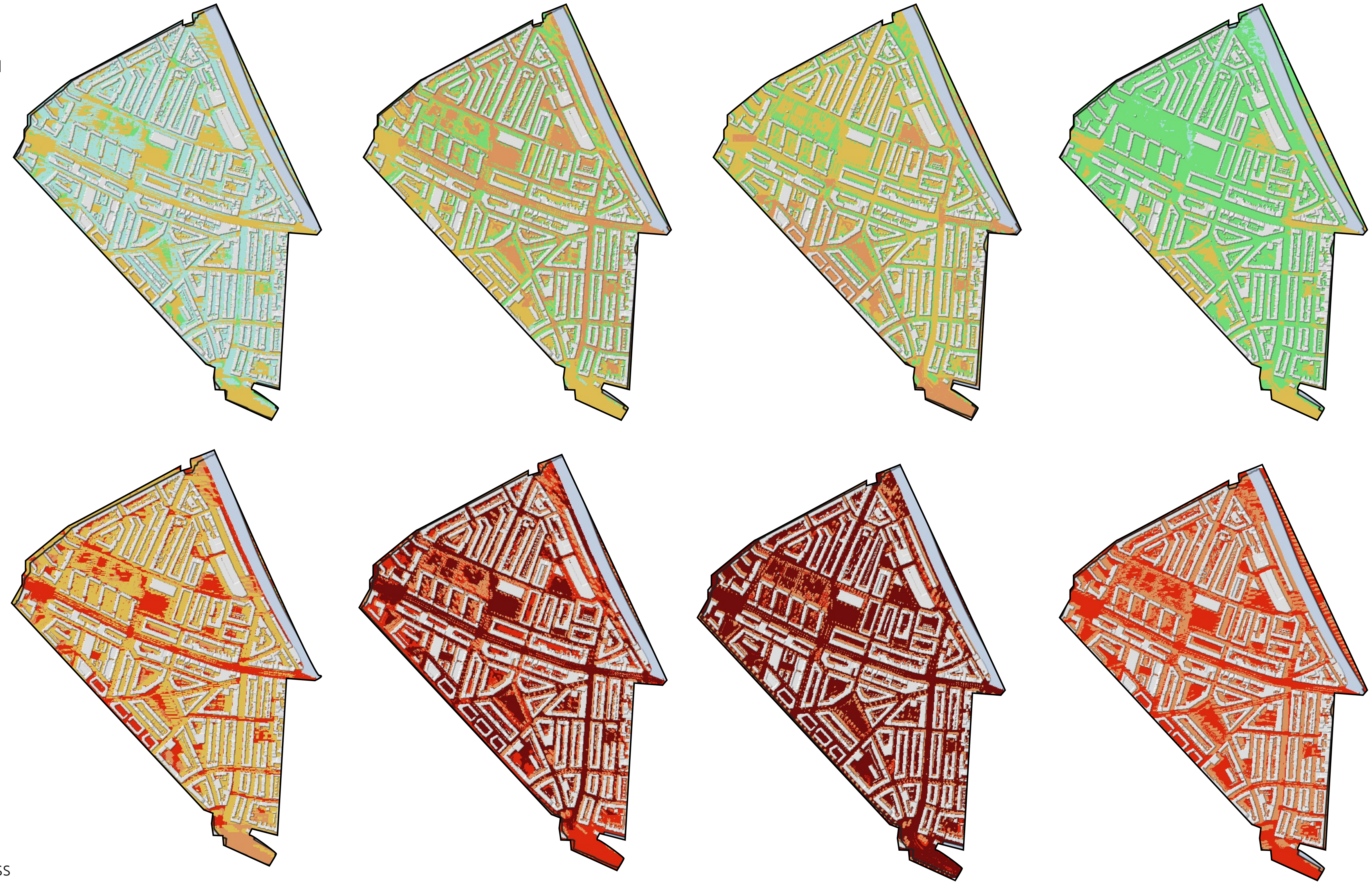
The orientation of streets and their Height-Width ratio are factors at the city scale that affect the thermal quality of public spaces in terms of solar radiation. Research indicates that streets with a west-east and northeast-southwest orientation receive longer exposure to the sun. However, for other streets, there is the option to choose a side that has shade for a longer period. The next image illustrates how the option of streets can be optimized to increase the H/W ratio. The color yellow represents interventions at the street level.

Fig. 5.15 Intervention conclusion

Thermal comfort: PET in Bospolder Tussendijken

The following images show the generated PET images of Bospolder Tussendijken by using the PET simulator tool. This showcases the warm day and the summer day differences.

PET 9:00 | PET 12:00 | PET 15:00 | PET 18:00



29st of June
(warm day > 20C)

1st of July
(summer day > 25C)

Legend
PET classification

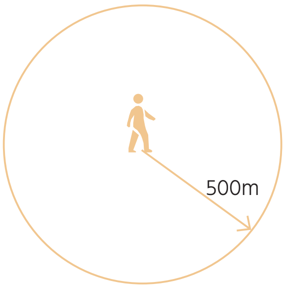
	13-18	slightly cold stress
	18-21	no thermal stress
	23-29	slight heat stress
	29-35	moderate heat stress
	35-41	strong heat stress
	>41	extreme heat stress

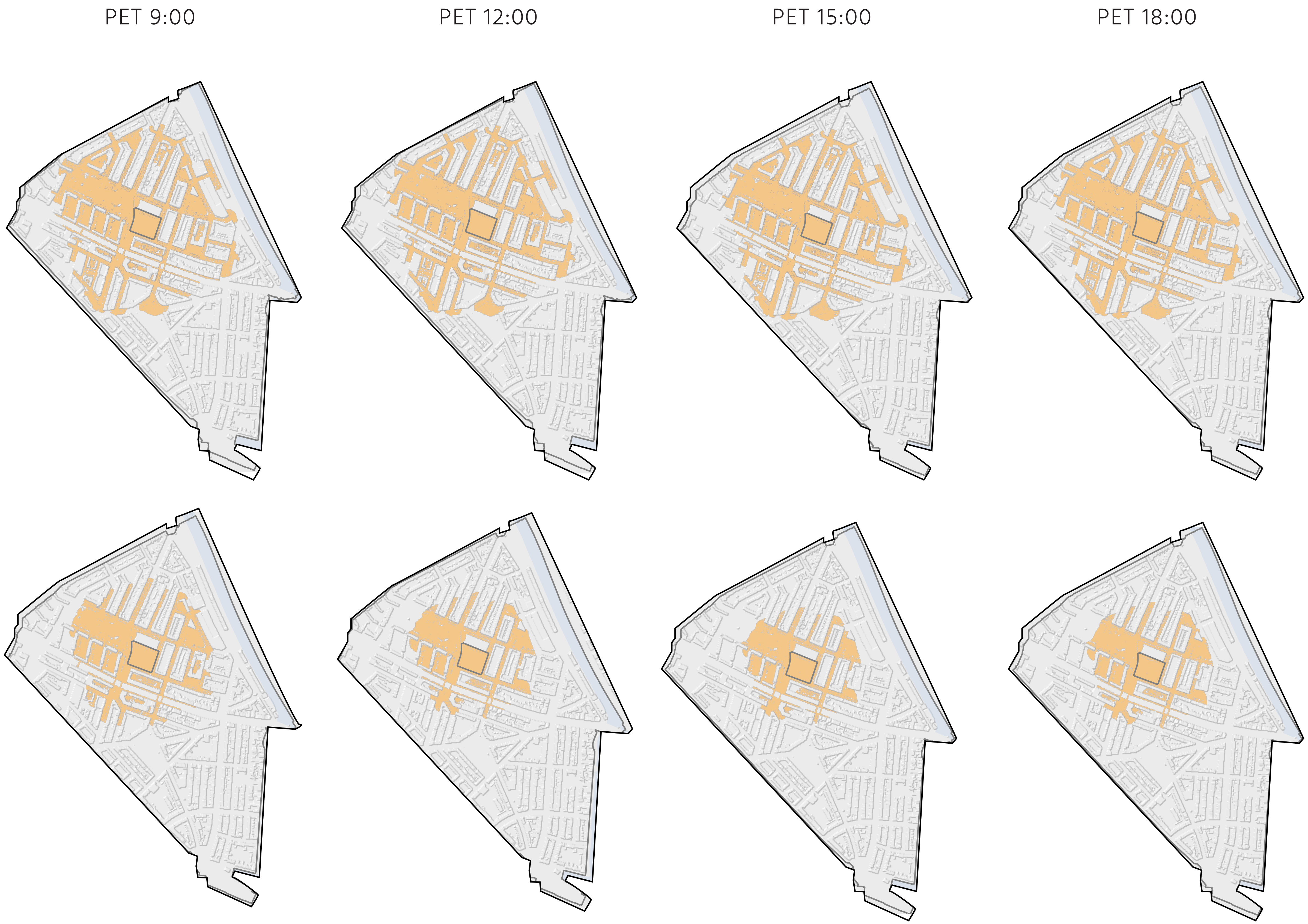
Fig. 5.16 PET on a warm day and a summer day. Created by PETs simulator tool

0 250 500 1000m

Thermal accessibility market

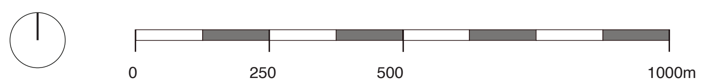
Legend





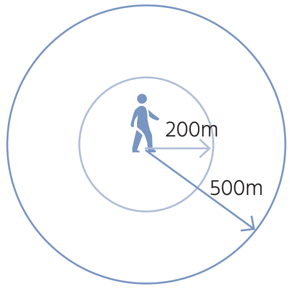
These images are generated by using the normalised friction costs of the PET maps on specific times of the day and used by the r.walk.cumsum tool by Grass. It can be seen that the thermal comfort range of the market is really degrading in service area.
(these maps could be improved in readability with Appendix G)

Fig. 5.17 Thermal accesibility of the Visserijplein. Created by PETs simulator tool and R.walk from Grass plugin in QGIS



Thermal accessibility playgrounds

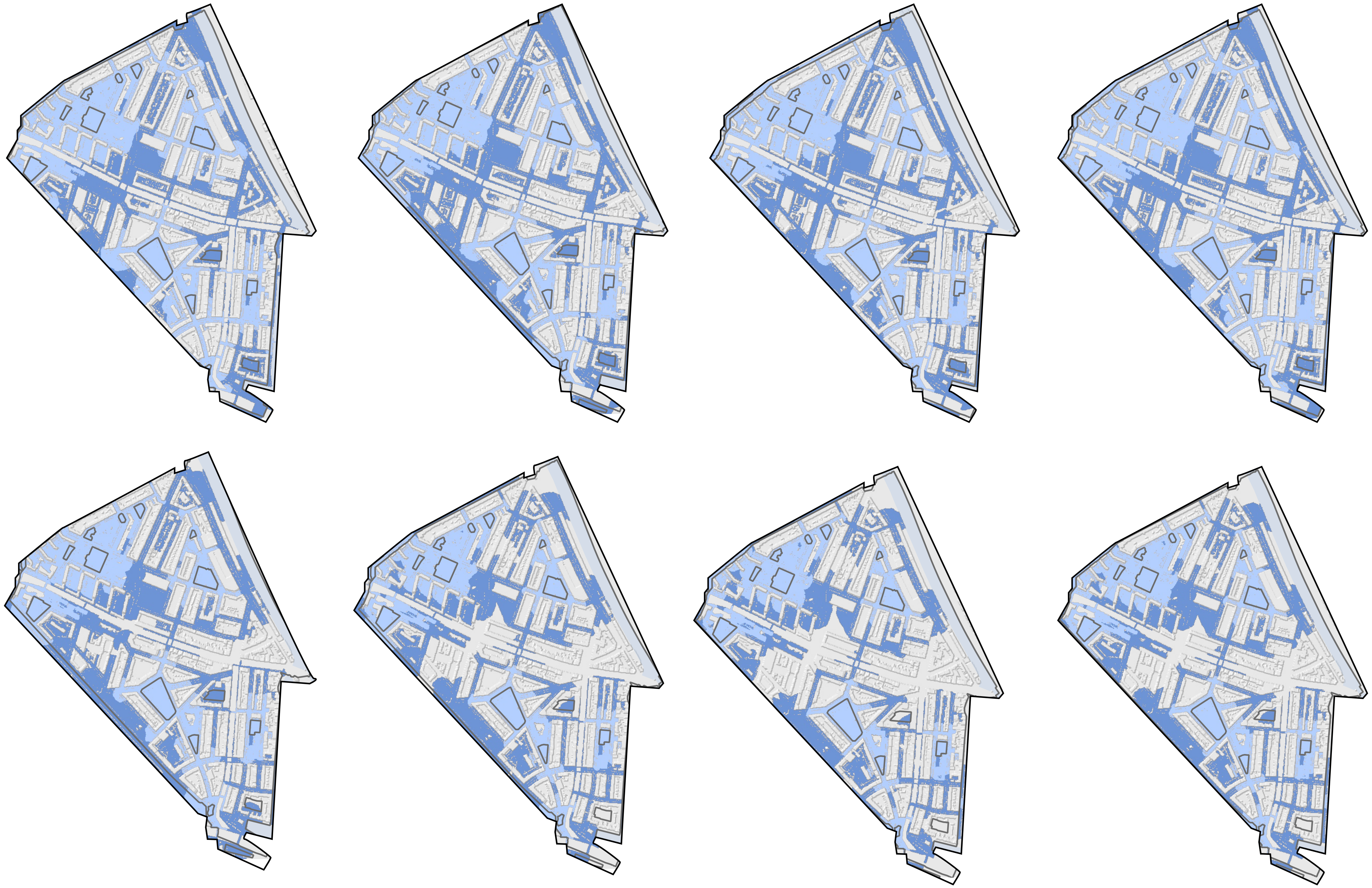
Legend



PET 9:00 PET 12:00 PET 15:00 PET 18:00

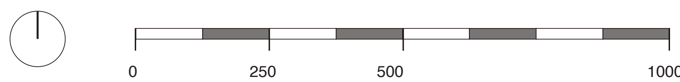
29st of June

1st of July



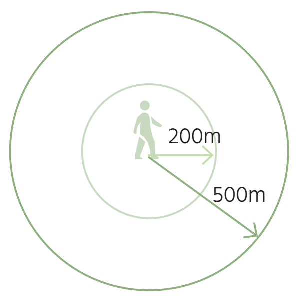
These images are generated by using the normalised friction costs of the PET maps on specific times of the day and used by the r.walk.cumsum tool by Grass. It can be concluded that the amount of playyards are sufficient enough to be reached on each time of the day. Only on the summer day at 12 and 15 o'clock some unreached areas are detected.
(these maps could be improved in readability with Appendix G)

Fig. 5.18 Thermal accesibility of the school yards. Created by PETs simulator tool and R.walk from Grass plugin in QGIS



Thermal accessibility parks

Legend

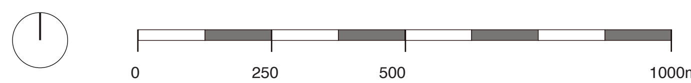


29st of June

1st of July

These images are generated by using the normalised friction costs of the PET maps on specific times of the day and used by the r.walk.cumsum tool by Grass. The connectivity between the two parks degrades when the temperatures rise. However the right areas remain unreached at all times, this is due to the distance limit.
(these maps could be improved in readability with Appendix G)

Fig. 5.19 Thermal accesibility of the Dakpark and park 1943. Created by PETs simulator tool and R.walk from Grass plugin in QGIS



5.3 Social liveability: spatial mobility and social mobility

The increased reliance on cars also influenced the development of parking infrastructure and the allocation of space for roads within urban areas. As a result, urban planning began to prioritize accommodating vehicular traffic over pedestrian and public transportation needs. This shift in focus had a profound impact on the overall design and functionality of urban spaces. Such as the utilisation of urban space for the different mobilities, see Fig 5.6 (Molster, 2020). This leads to a reevaluation of urban planning principles to address the growing dominance of cars in city landscapes (Palmboom, 1995).

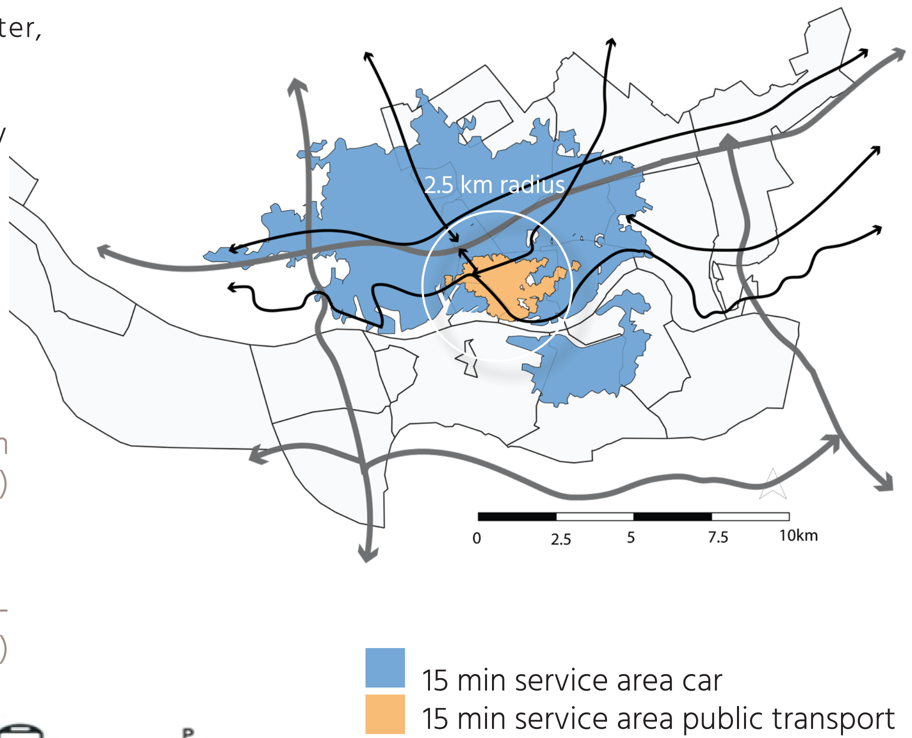


fig. 5.20 Traveltime app Rotterdam (nd)

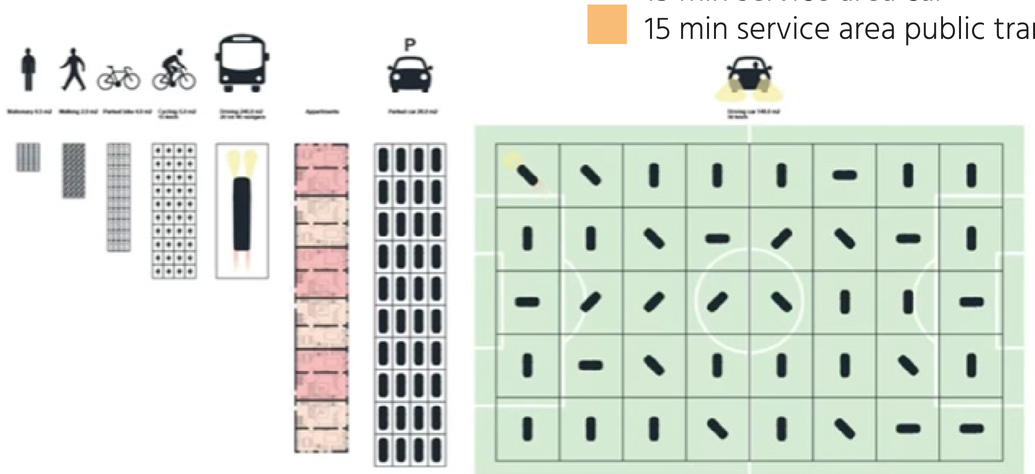


fig. 5.21 use of public space per mobility type (Molster, 2020)

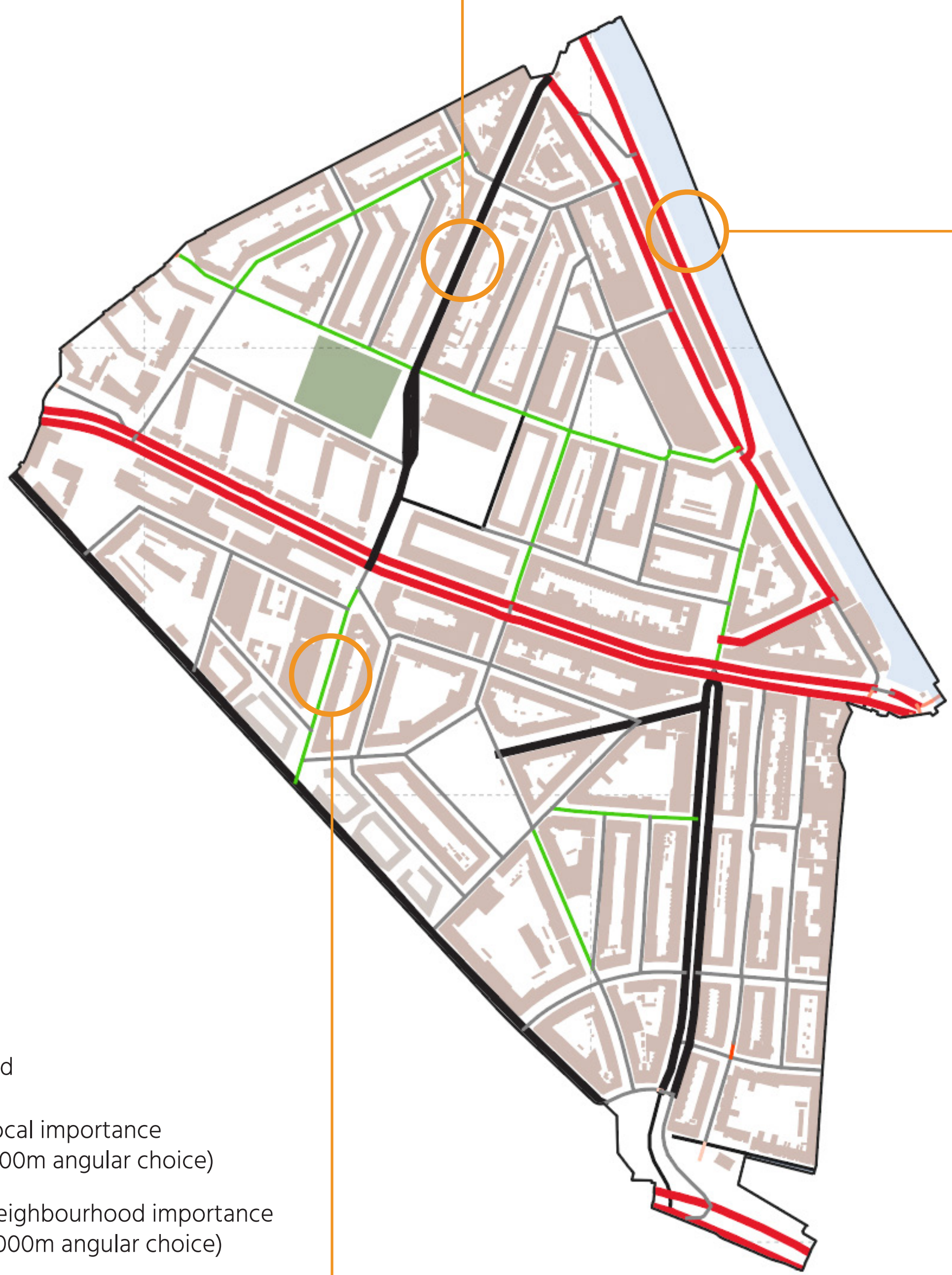
Fig. 5.22 percentage car occupation on streetlevel (parking+road)

Network betweeness: Spatial mobility

The hierarchy of the public space network can be analyzed using an assessed place syntax tool (PST). This open-source tool allows for spatial analyses that combine the space syntax description of the urban environment with conventional descriptions of attraction into a single accessibility analysis tool. Currently available as a plugin for both MapInfo Professional GIS and QGIS, PST is a valuable resource for anyone interested in understanding the accessibility of public spaces.

One of the unique features of PST is the angular choice, which is based on the geometry of the street and helps to assess whether it is commonly used or not. PST also allows users to differentiate between different travel distances, such as 500m, 1000m, and 2500m. These distances represent a 10-minute walking distance for an elderly person, a 10-minute walk for an average healthy person, and a 10-minute cycling distance on a city scale.

Using PST to assess several streets in a neighbourhood can reveal interesting trends in terms of usage. Some streets may decline in use over the travel distance, while others may increase in use. These assessments are based on the probability of the geometric representation of lines, making PST an invaluable tool for anyone interested in studying public space accessibility.



Legend

Local importance (500m angular choice)

Neighbourhood importance (1000m angular choice)

City importance (2500m angular choice)

Source fig 5.23 Angular choice 500m probability people will walk through a street

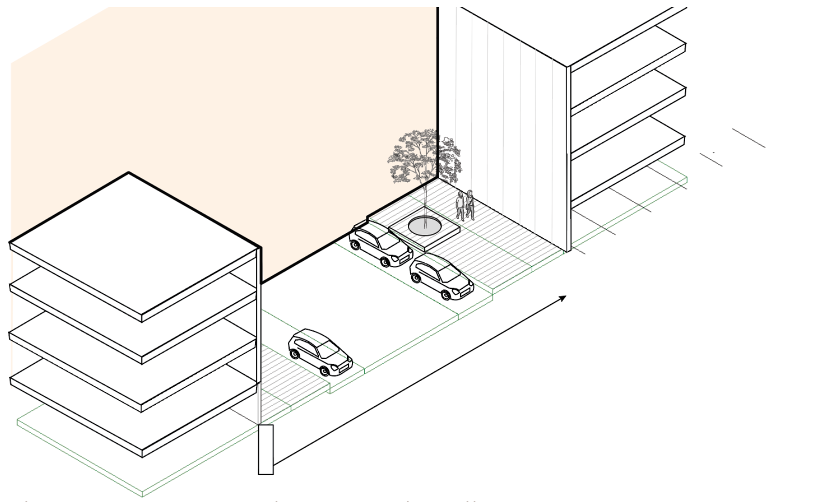


Fig. 5.24 Axonometric grote Visserijstraat

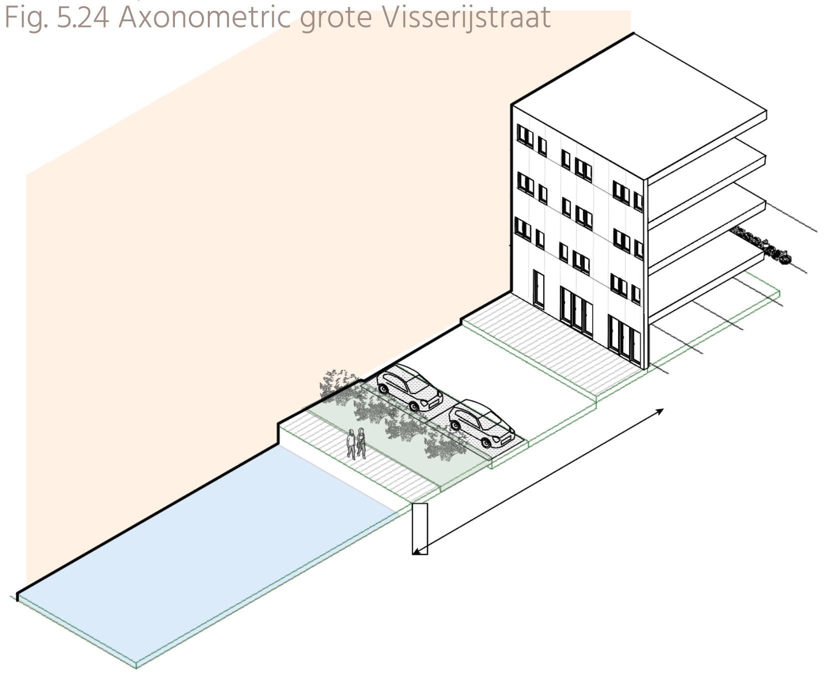


Fig. 5.25 Axonometric Spangeskade

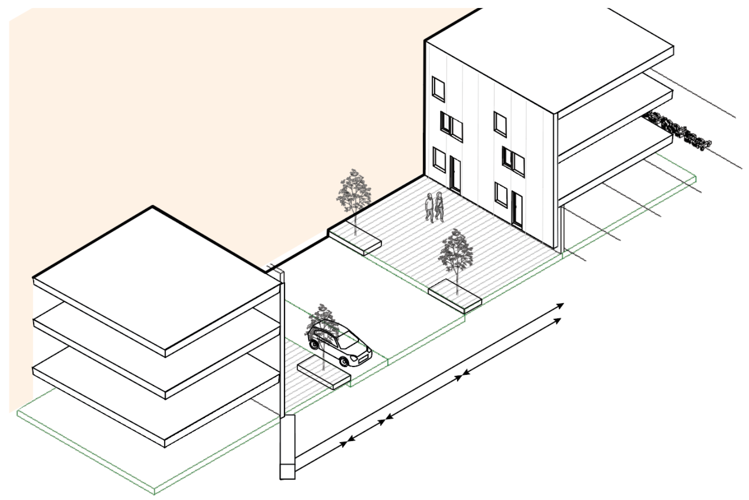


Fig. 5.26 Axonometric Schippersstraat

Social liveability with thermal comfort public spaces

Legend
PET classification

13-18	slightly cold stress
18-21	no thermal stress
23-29	slight heat stress
29-35	moderate heat stress
35-41	strong heat stress
>41	extreme heat stress
	in use
	less or not in use

Park 1943 offers a wide range of leisure activities for all ages.

At the weekly market on the Visserijplein on 9 September, with an air temperature of 26 degrees, it was clear that there was a high proportion of older people on the square throughout the day. The vibrancy of a market and the social interactions that come with it tend to extend beyond its immediate location and into the surrounding areas, resulting in the development of vibrant and economically thriving communities. This mutually beneficial relationship between the market and its surroundings underlines the inherent interdependence between economic and social activities in a given area.

The (young) children were found in several playgrounds such as Bospolderplein, Park 1943 and around several schools. The Dakpark also has a water element that could be used in the process.

Fig. 5.27 PET on public space use according to CVTO on a warm day and a summer day. Created by PETs simulator tool

Fig 5.28 Park 1943 Photo taken by Author

Fig 5.27 Visserijplein Photo taken by Author

Fig 5.28 Bospolderplein Photo taken by Author

Fig 5.29 Dakpark Photo taken by Author

Legend
Shadow percentage sidewalk

- 0.8-1.0
- 0.6-0.8
- 0.4-0.6
- <0.4

Shadow friendly and evaporative elements

Understanding how shadows affect urban microclimates is crucial as it impacts temperature distribution, energy consumption, and human comfort. Moreover, having knowledge about the performance of evaporative surfaces can help in designing sustainable urban landscapes that facilitate natural cooling processes, decrease surface temperatures, and improve air quality.fosters resilient, liveable cities adaptable to climate change challenges.

East wind

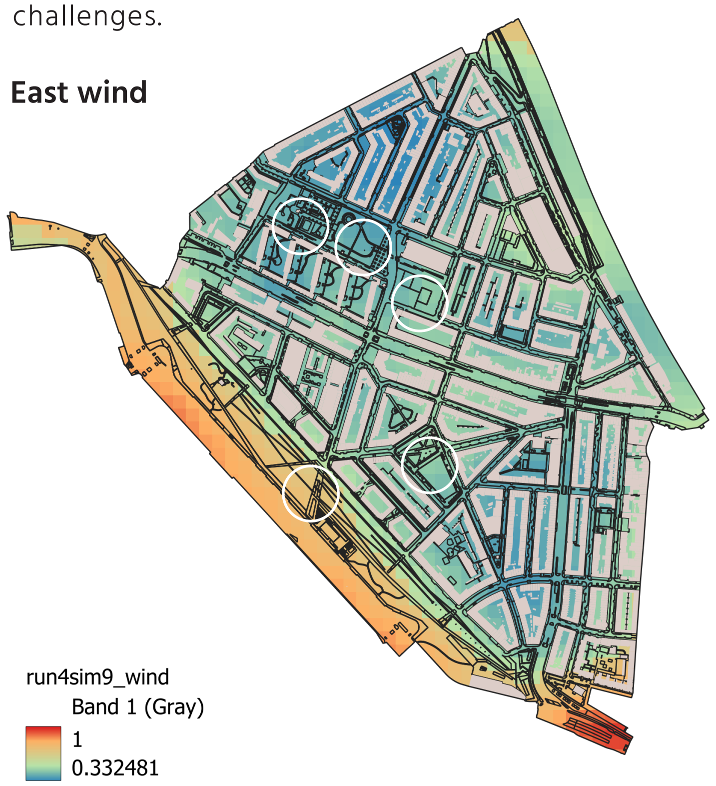


Fig. 5.30 East wind Bospolder Tussendijken

Zonal statistic analysis of shadow playgrounds, market and parcs

Fig. 5.31 Preffered shadow percentage on public space use according to CVTO on a warm day and a summer day. Created by PETs simulator tool

Average amount of trees per 30m

Health of public spaces plants

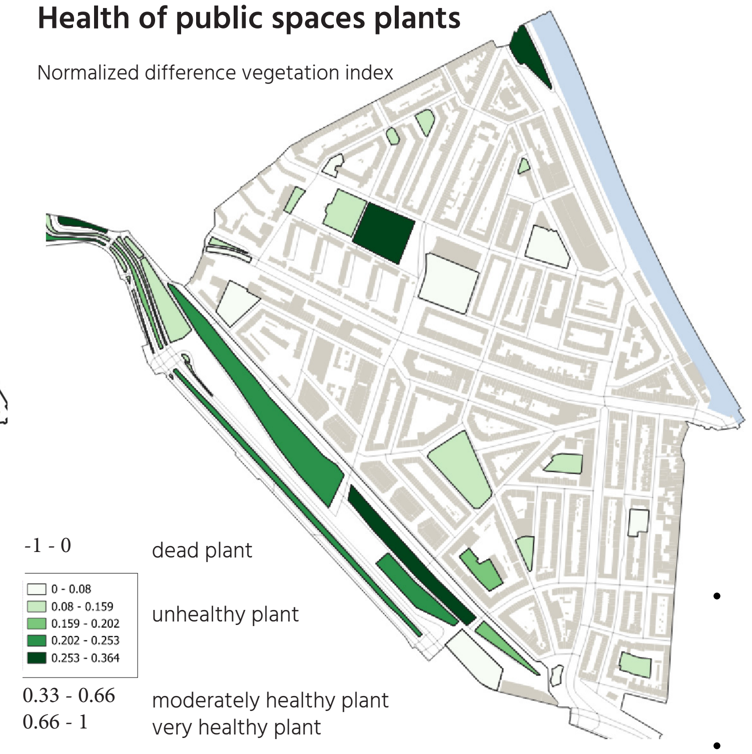


Fig. 5.32 trees averaged per 30 m line segment (SBI infra trees and TOP NL roads) & Fig 5.28 NDVI generated by PETs simulator tool and projected on polygon shapes

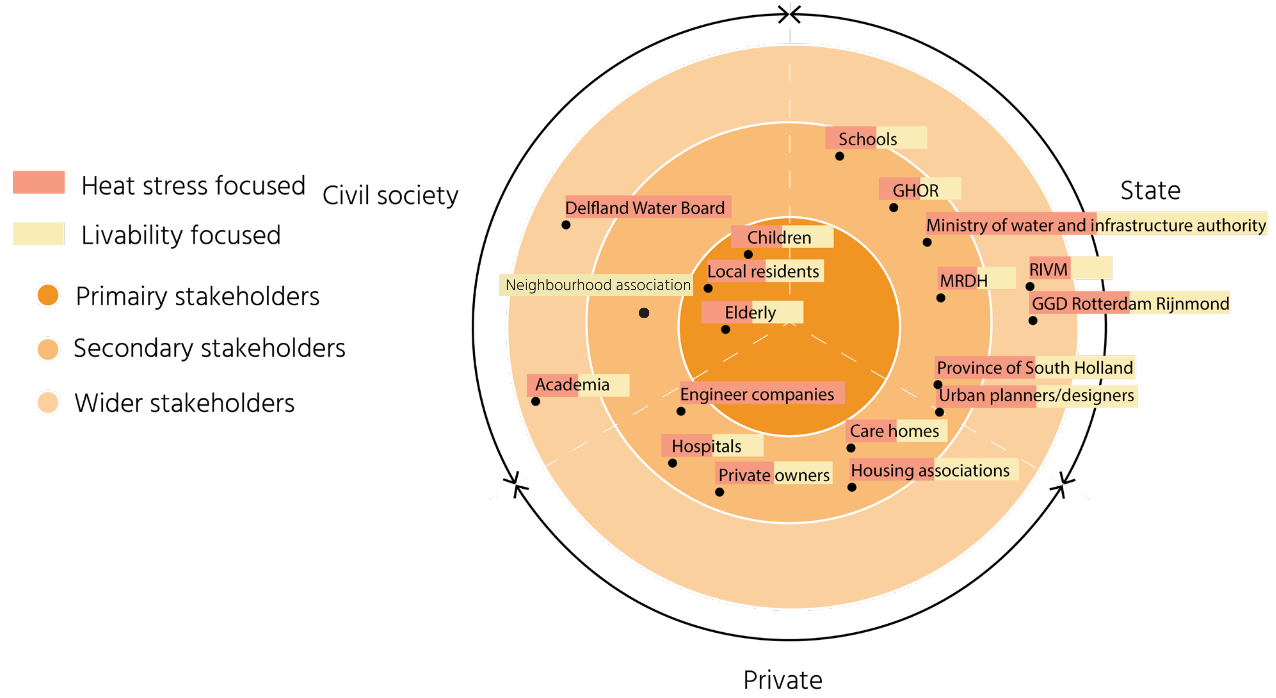
Fig. 5.18 Intervention conclusion

5.5 Policies considering heat and physical liveability improvement

When designing cities and urban areas, various stakeholders are involved, including civil society, state, and private parties. The state, at the local, provincial, or national levels, initiates the plans and sets the rules that urban designs must follow, although they are beginning to reduce their direct involvement. In addition, project developers and housing companies in the private sector have become significant clients for urban designers. Civil society, comprising individuals and interest groups, is also critical in providing feedback and occasionally participating in the design process. Finally, experts from various fields, such as consulting firms, law firms, research institutions, and government agencies, provide information on what is possible and what limitations exist. Urban design has become more complex and inclusive, covering a wide range of topics, which has resulted in more experts from different fields being involved (van Esch, 2015).

The National Climate Adaptation Strategy (NAS) and the Delta Plan for Spatial Adaptation, both integral components of the national Delta Program, form the framework for establishing a climate-resilient Netherlands (CAS, nd). Each municipality has devised its own heat plan, with Rotterdam, for instance, crafting a strategy to address acute heatwaves at the neighborhood or district level under the 'Rotterdam's Weather Response' climate adaptation program (2019-2026) (Gemeente Rotterdam, nd). Furthermore, the Rotterdam-Rijnmond Public Health Service (GGD) is devising preventive measures to mitigate the adverse health effects of heat.

In the initial phase of this initiative, activities are undertaken at both the neighborhood and city levels. These include conducting local assessments on factors like heat stress, residential comfort, amenities, and cool spots; establishing local networks; forging connections with relevant themes in Rotterdam; developing and utilizing communication tools; formulating, implementing, and refining the local heat plan; and sharing knowledge with other municipalities.



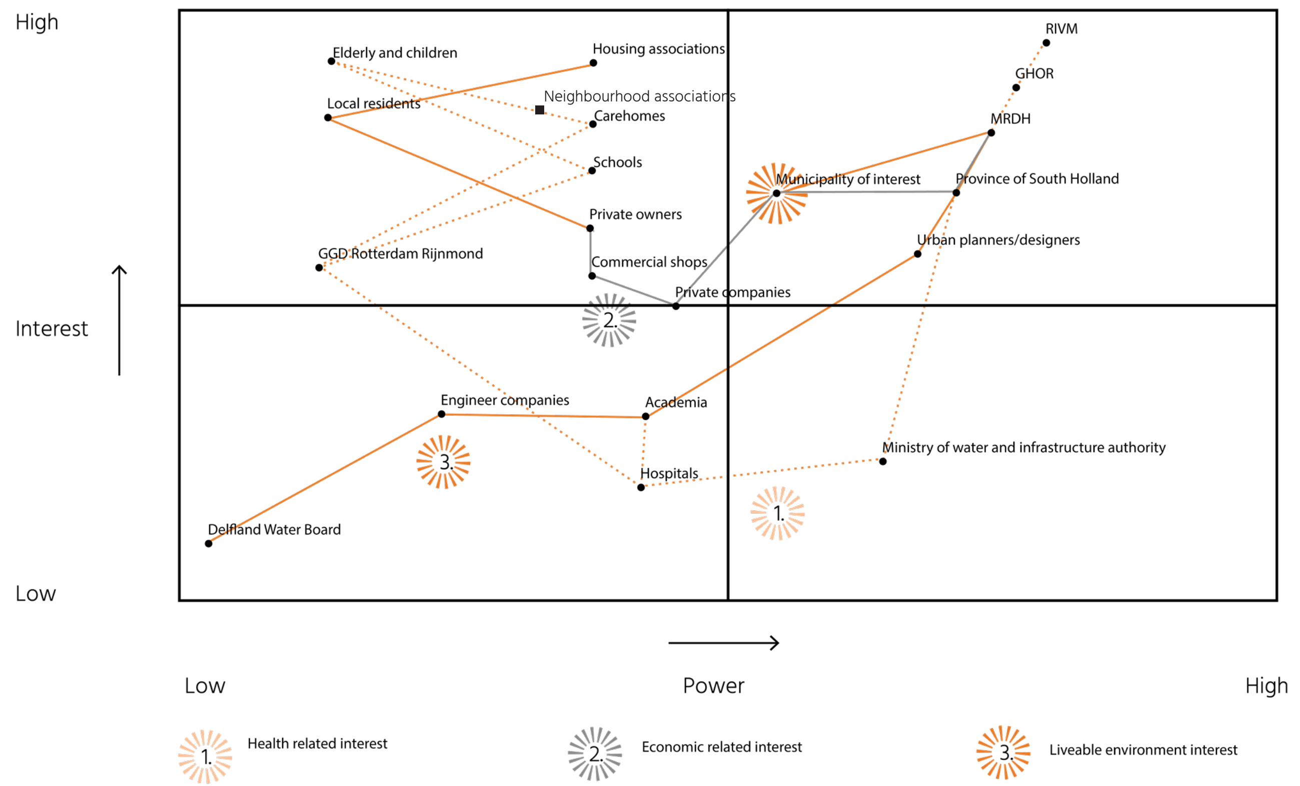


Fig. 5.33 Stakeholder analysis (Adapted by Author from Hofman 2022)

Planning process and the involvement of the urban designer

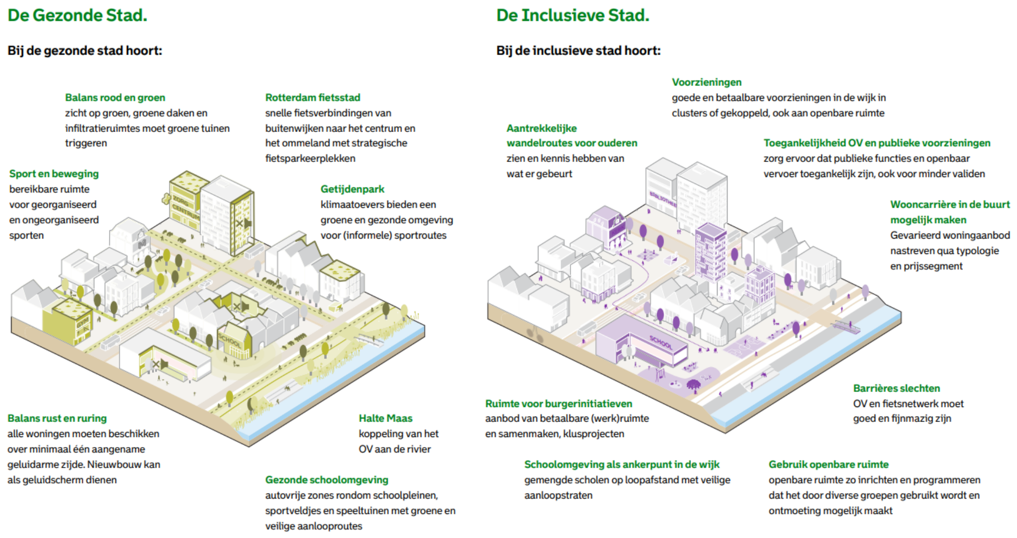


Fig. 5.34 Goals of the municipality of Rotterdam Retrieved from https://www.ruimtelijkeplannen.nl/documents/NL.IMRO.0599.OV2021Rotterdam-va01/d_NL.IMRO.0599.OV2021Rotterdam-va01.pdf

In the "Omgevingsvisie," Rotterdam proposes two key themes: the Healthy City and the Inclusive City. Additionally, Rotterdams Weerwoord has outlined the implementation agenda for 2023-2026. Among the five climate adaptation actions outlined, two focus on public space climate adaptation and engaging the people of Rotterdam in movement. In the Bospolder area, public space development is tied to ongoing development projects, while in Tussendijken, short-term goals primarily revolve around sewage replacement and renewal (Gemeente Rotterdam, nd).

In terms of financing, the municipality offers subsidies to civil organizations, state entities, and private enterprises. There's also a subsidy program aimed at greening green-blue schoolyards in Rotterdam (Gemeente Rotterdam, nd). Moreover, tailor-made subsidies are available for housing associations to facilitate the implementation of climate adaptation measures. One municipality grants subsidies to specific housing associations for this purpose. Additionally, the municipality extends subsidies to residents or companies for constructing climate adaptation measures on private property (RVO, 2013).

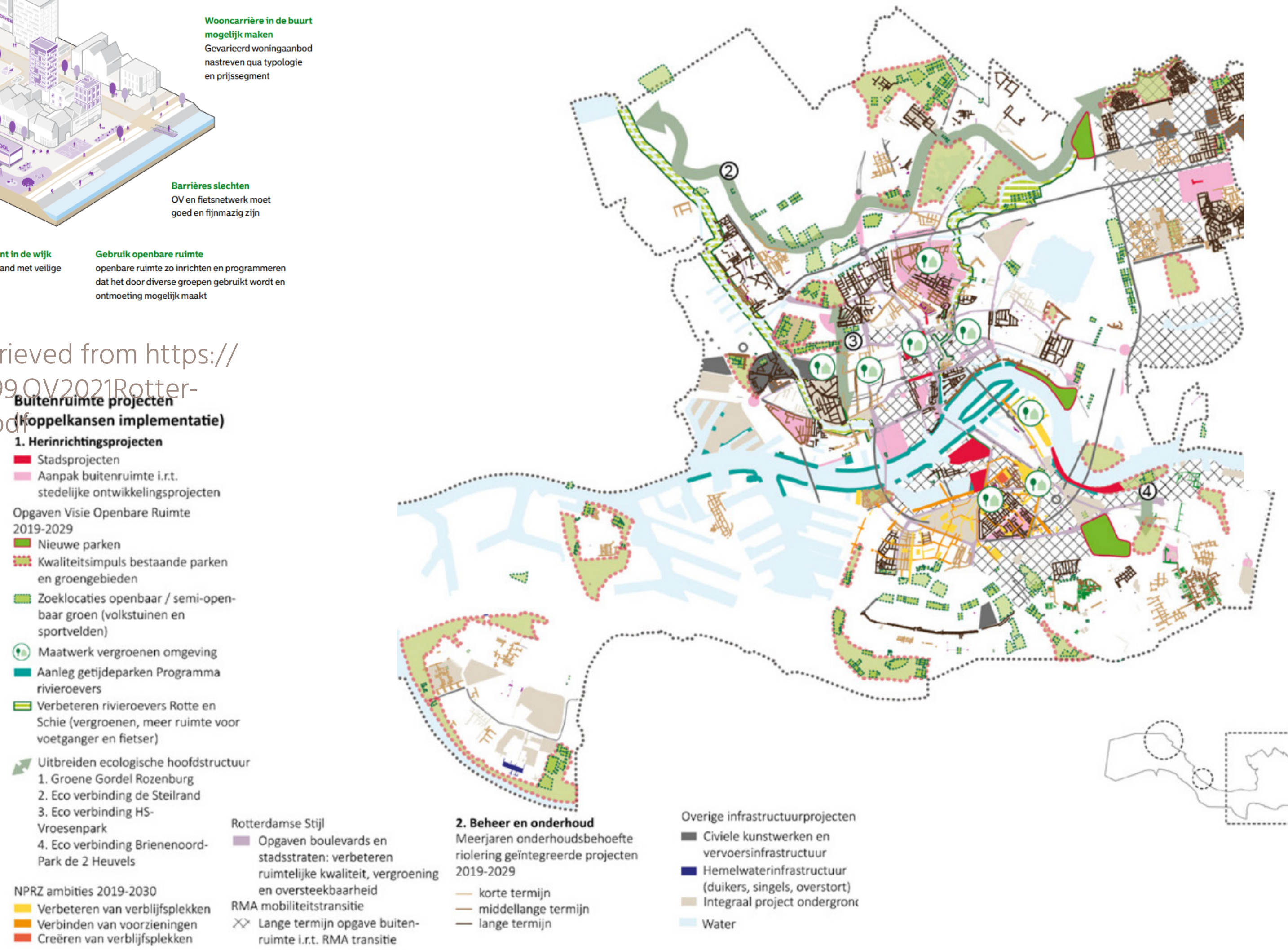


Fig. 5.35 Omgevingsvisie Rotterdam. Retrieved from Verlinde, J., et al. (2023) Rotterdams Weerwoord. Uitvoeringsagenda. Retrieved from https://rotterdamsweerwoord.nl/content/uploads/2023/06/Uitvoeringsagenda-2023-2026.pdf

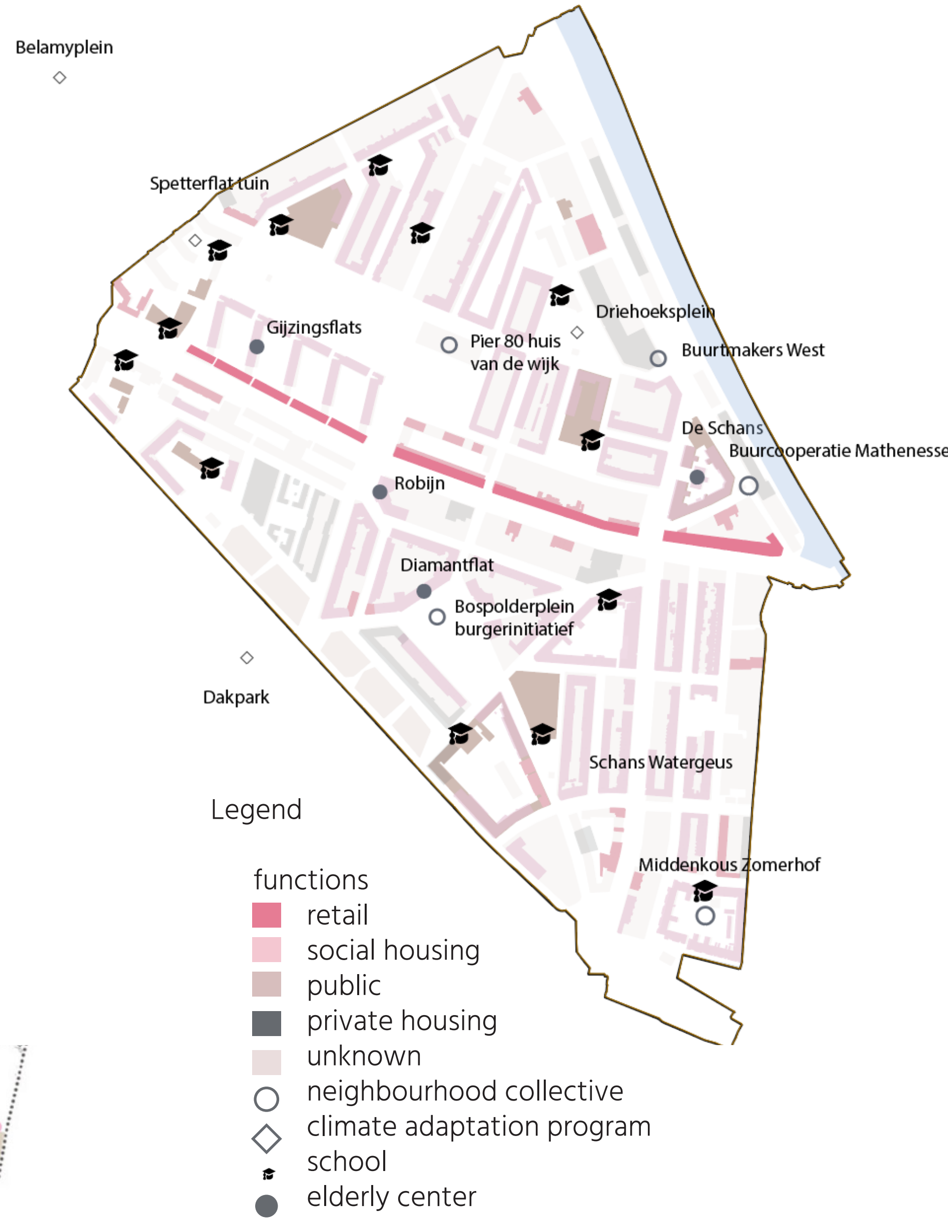


Fig. 5.36 Overview of collaborative partners for heat mitigation measures (Jong Delfshaven, nd; Veldacademie, 2020; Arcgis voorzieningspunten, nd).

5.5 SWOT

To explore design possibilities in the Bospolder Tussendijken area, it's essential to grasp the functionalities of the neighborhood and identify areas requiring improvement due to urgent issues. During the design phase, it's crucial to determine which elements should be minimized or amplified, what needs mitigation, and what aspects could be enhanced. Below, we outline some weaknesses, threats, strengths, and opportunities present in the current public spaces of these neighborhoods.
Summary of the previous analysis showcases the social liveability in public spaces and walkable environment, physical liveability in terms of thermal comfort and policies.

Opportunities

The neighborhood has mature trees that can be used to mitigate climate effects. The schoolyards can be improved, and cooler courtyards could be opened up. Smarter parking usage is recommended to free up space for social and climate purposes. Social mobility could be improved by creating better places to stay. Offering social spaces for vulnerable groups increases inclusivity. The neighborhood has ongoing initiatives to enhance quality of life, with a focus on social and environmental factors. Subsidies are available for developing green spaces, showing a commitment to sustainability.

Strengths

Rotterdam Weerwoord collaborates with local communities to provide access to public spaces, green areas, and cultural activities for all residents irrespective of their income level. The municipality promotes sustainable transportation options to reduce traffic congestion and improve air quality. They work with policymakers to establish effective policy frameworks prioritizing sustainability and social equity, including green building codes and participatory decision-making processes. This way, they aim to create a more connected and vibrant city for everyone to thrive.

Fig. 5.37 Opportunities Bospolder Tussendijken

Fig. 5.38 Strengths Bospolder Tussendijken

Threats

Barriers like Spanjaardstraat can weaken community connections, reduce accessibility, and threaten social liveability. The neighborhood's physical liveability is affected by hot streets that lack trees, creating a divide between areas and negatively impacting residents, especially single-person households as they age. Prioritizing policies to improve the quality of life, sustainability, and resilience of the neighborhood is crucial to prevent these challenges from harming residents' well-being.

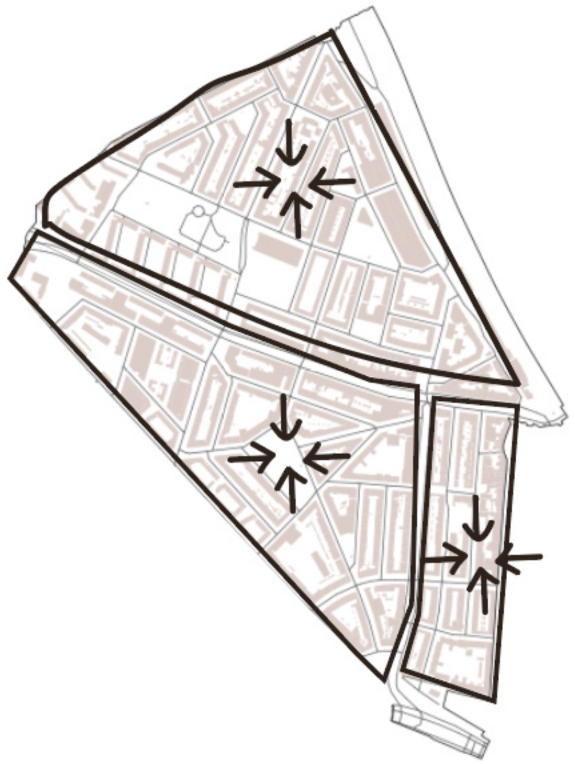


Fig. 5.39 Threats Bospolder Tussendijken

Weaknesses

The high population density of the area and the lack of public spaces can make residents feel disconnected. The mobility is poor, and pedestrians face difficulties due to the high number of cars and limited crossing options. The area also lacks greenery, and the wide streets can become uncomfortably hot during the day. However, due to the low economic status of the neighborhood, significant changes may not occur in the short term.

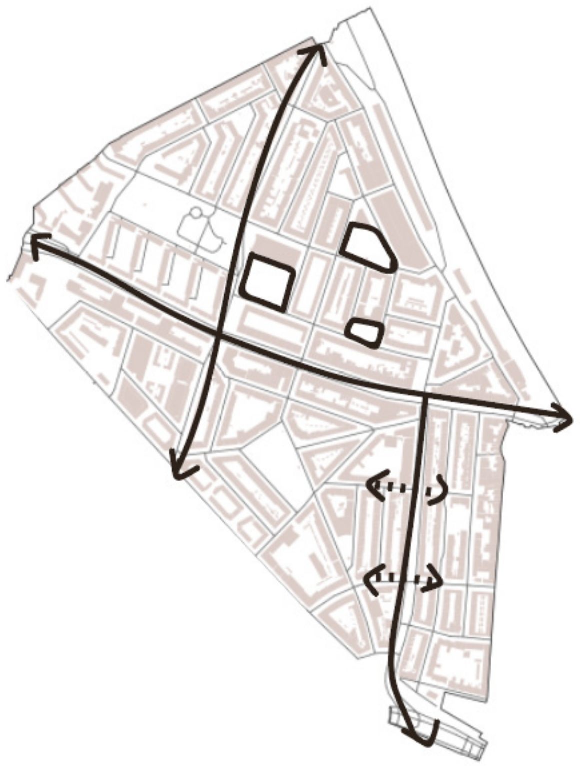


Fig. 5.40 Weaknesses Bospolder Tussendijken

In conclusion, the Bospolder Tussendijken area presents a unique set of opportunities, strengths, threats, and weaknesses that must be carefully considered in any development or improvement initiatives. Leveraging mature trees for climate mitigation, enhancing social mobility through better communal spaces, and fostering inclusivity by catering to vulnerable groups are notable opportunities. Strengths such as collaboration with local communities, promotion of sustainable transportation, and effective policy frameworks demonstrate a commitment to creating a vibrant and connected neighborhood. However, threats like barriers hindering community connections and the impact of hot streets on resident well-being highlight the importance of prioritizing policies that improve quality of life and resilience. Addressing weaknesses such as poor mobility, limited greenery, and economic constraints will require strategic planning and long-term investment. Overall, a holistic approach that addresses these aspects comprehensively is essential to creating a thriving and sustainable community in Bospolder Tussendijken.

“Chapter 6 Intervention – towards a public space health resilience network design

1. Vision statement
2. Design principles toolkit
3. General application toolkit
4. Scenario building
5. Design concept
6. Design zoom in Visserijplein
7. Design zoom in Retail street Schiedamseweg
8. Design zoom in Green Connection Schipperstraat
9. Phasing


Fig 6.0. Dakpark, Bospolder. Picture taken by Author

6.1 Vision statement

The concept of liveability urban design aims to connect city-scale climate adaptation with citizen-centric public space design. It focuses on providing access to cool, green spaces for vulnerable residents within their neighborhoods. This approach emphasizes the importance of not only reducing city-wide temperatures but also designing playgrounds, parks, and walkable streets to cater to the needs of children and the elderly so that they can thrive throughout the day. By prioritizing the creation of a network of public spaces, we can enhance the resilience of the urban environment.

The vision for Bospolder consists of three main goals. The first goal is to increase the neighborhood's ability to deal with heavy heat. The second goal is to enhance social spaces in the neighborhood. The third goal is to improve walkability and inclusivity of access. By attaching long-term goals to interventions that also yield immediate results, plans and their investments will be more easily accepted as they directly benefit the neighborhoods. These interventions have direct benefits by combating heat stress and increasing liveability for people, while the long-term goals include reducing damage during heatwaves in the future.

Mitigating heat

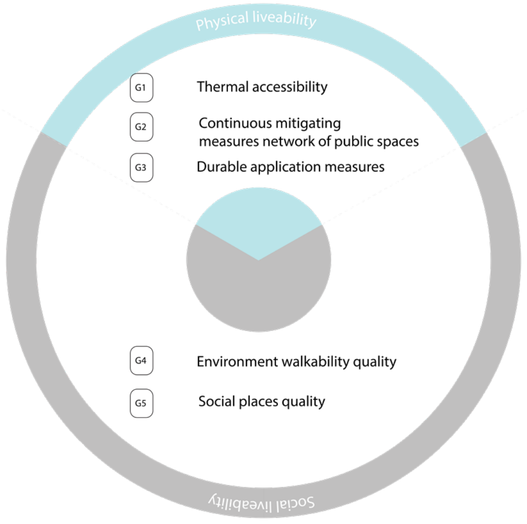
Heat can not only cause discomfort but also pose serious health risks if not managed properly. It's important to prioritize thermal comfort to ensure the well-being of individuals in various environments.

Creating social places for elderly and children

The inclusive design of the place, which was originally intended for children and the elderly, will be enhanced to benefit people of all age groups. By creating enjoyable amenities that cater to different age groups, the livability of the area will be increased for everyone.

Improving Walkability

Walkable urban environments allow everyone equal access to essential services, promoting social cohesion and inclusiveness. As more people choose to walk, the use of carbon-emitting transportation decreases, leading to a reduction in greenhouse gas emissions. This contributes to a more inclusive and environmentally conscious urban landscape.



6.2 Design principles: toolkit

In the literature, various interventions aimed at improving public spaces were categorized into patterns. For example, a toolkit represented by the card in Fig. 6.2 was developed. This toolkit differs in its goals, implementation, and tasks. Figure 6.xx illustrates the relationship between social liveability and physical liveability. For a more detailed overview of the literature and practical implementations, please refer to Appendix A.

Implementation

Abstract

Goal

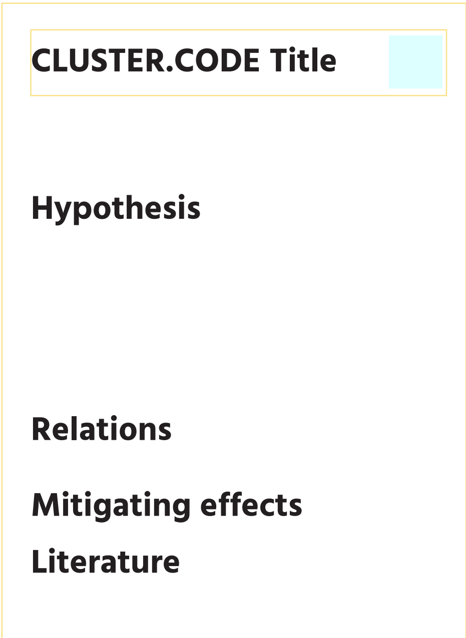


Fig. 6.2 Example of pattern language card

Mitigating heat

MH.20 Creating evaporative surfaces
MH14 Planting a tree
MH1 Tree line
MH3 Frontyard
MH.19 Designing with the wind
MH8 Let it open
MH.18 Designing with the sun
▯ green option
MH1 tree line
SP2 park with trees
MH12 pergola
▯ grey option
MH6 topping up buildings
MH2 reflective materials
MH4 arcade
MH12 pergola
MH7 permanent shading
MH5 sunscreens (ownership)
MH.18 Designing for the heat consciousness
SP1 Placing a bench
SP8 Drinking water
SP7 Informing about heat
SP6 Playing with water

Liveable environment

Walkable environment – streets
W.13 Designing for walking - streets
SP1 Placing a bench
W5 Designing for needs
W8 Clustering traffic
W6 Safe crossings
W3 Pedestrian first
W2 Continuous streets
Public spaces inviting for elderly – public spaces
SP.13 Designing for staying
SP1 Placing a bench
SP2 Park with trees
W5 Designing for needs
SP10 Human scale
SP12 Optional activities
SP3 Opening enclosed spaces
SP2 Park with trees
SP4 Ownership
SP11 Wind size squares

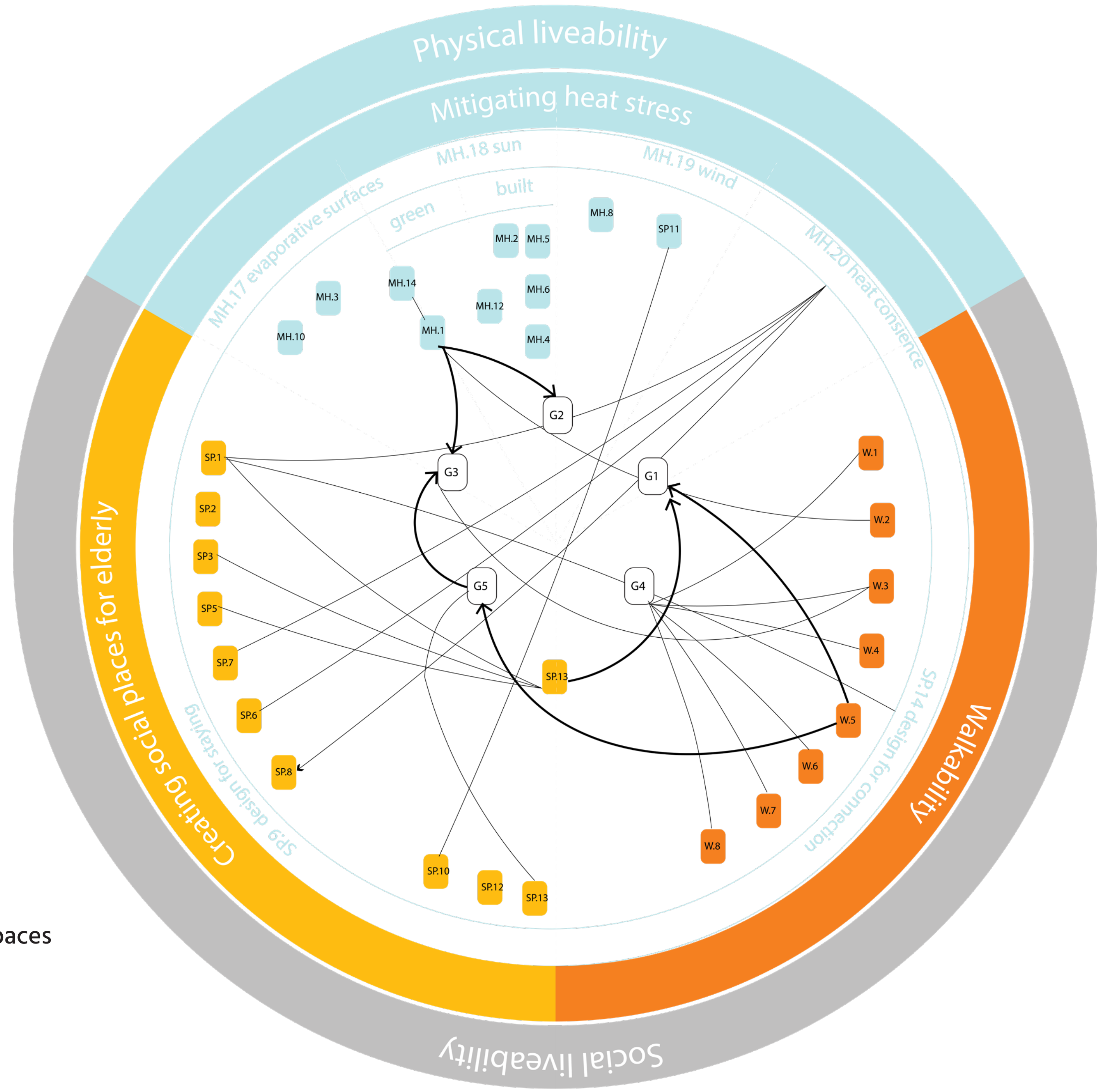
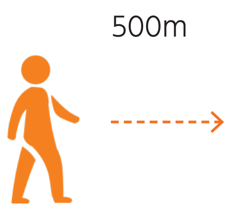


Fig. 6.1 Overview of relationship to each other and referring to the goals

W.1 Elderly in front

HYPOTHESIS: improving the whole network by taking distance of elderly into account

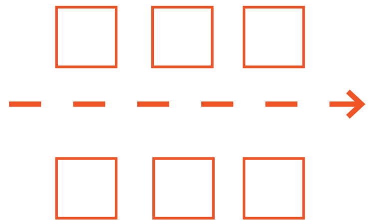


MH.12 Pergola

HYPOTHESIS: creating a natural shading improves the shading as evaporative areas

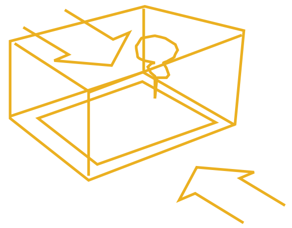
W2. Contuinuity of streets

HYPOTHESIS: continuity of look of streets improves the legibility of pedestrains



SP5. Enclosed gardens

HYPOTHESIS: lots of green and shadow formed in enclosed places can provide shelter place



MH.14 Planting a tree

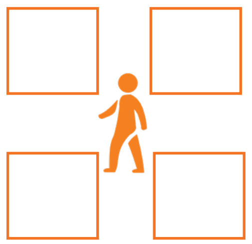
HYPOTHESIS: creating evaporative srfaces for mitigating heat

SP.6 Playful water elements

HYPOTHESIS: cooling element good for the public space

W.6 Safe crossings

HYPOTHESIS: improving the waiting time for pedestrains



MH.5 Outside sun blinds

HYPOTHESIS: people can easily adapt their climate conditions

MH.17 Height Weight ratio

HYPOTHESIS: being aware of the current H/W ratio can influence the design decision

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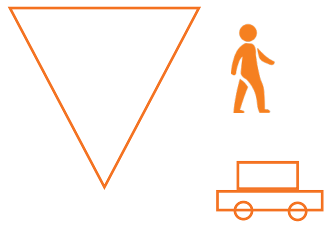
W3. Pedestrain first

HYPOTHESIS: less car dominant will lead to an pedestrain friendly environment



W4. Focus on the local

HYPOTHESIS improving the local & neigbourhood networks instead of city

MH.13 Shading route

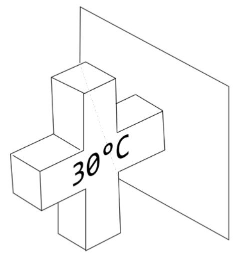
HYPOTHESIS improving the shading route for walkability

W.5 Designing for needs

HYPOTHESIS: taking into account the usability of the place can reveal the need for heat mitigation

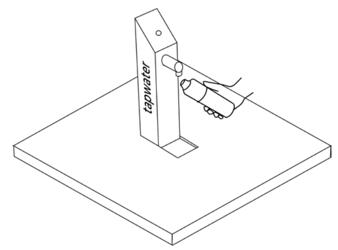
SP.7 Informing about heat

HYPOTHESIS: informing people of the heat



SP8. Water bottle mo-

HYPOTHESIS: providing the possibility to hydrate



SP.9 Accessible greenery

HYPOTHESIS: making sure that greenery is accessible to everyone

MH.18 Designing with the

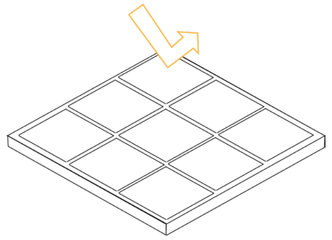
HYPOTHESIS: 12:00 causes different shadow patterns then 15:00 shadows

MH.19 Designing with evaporative surfaces

HYPOTHESIS: east west street require wind flow options for convection

MH.2 Reflective materials

HYPOTHESIS increasing the albedo of shortwave radiation

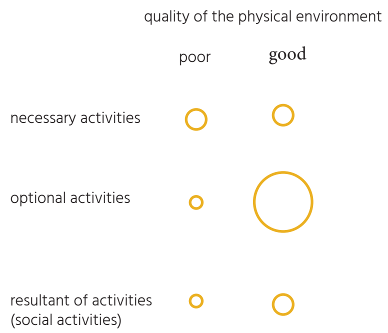


MH.8 Keeping it open

HYPOTHESIS: don't introduce blocking elements for wind

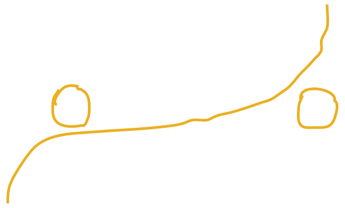
SP.12 Optional activities

HYPOTHESIS: see appendix A



SP.13 Restorative points

HYPOTHESIS increasing the albedo of shortwave radiation



SP.4 Ownership

HYPOTHESIS: whenever people feel connected to the place it will be maintained

MH.4 Arcade

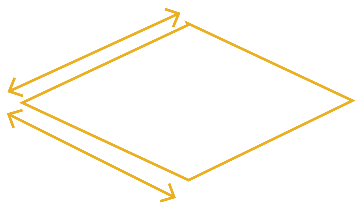
HYPOTHESIS: creating permanent shadow as permanent passive shadow

SP.10 Human scale square

HYPOTHESIS: having an appropiate size of square allows people to feel safe and seen

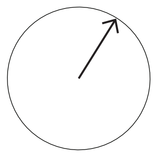
SP.11 Wind sized squares

HYPOTHESIS: with the right sizes of a square there will be no hinder during social activities



MH.9 Orientation

HYPOTHESIS: orientation influences the sun and wind of a street



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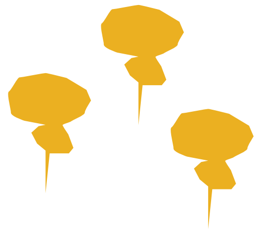
SP.2 Park with trees

HYPOTHESIS: creating more shade places to stay increases social and climate liveability

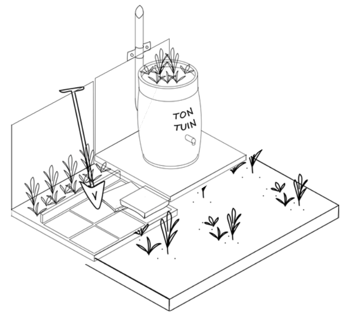


MH.1 Tree line

HYPOTHESIS: improves the evaporative areas

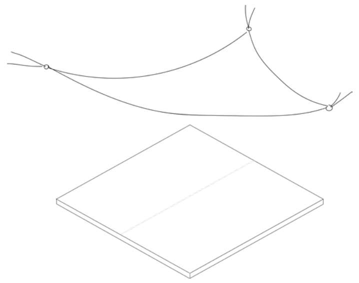
MH.3 Green Frontgardens

HYPOTHESIS



MH.5 Sun screens

HYPOTHESIS: shading element as flexible option



MH.6 Topping up buildings

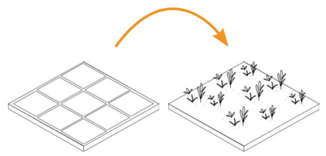
HYPOTHESIS: creating permanent shadow as permanent passive shadow generator

MH.21 Demontable structure

HYPOTHESIS: shading element as semi permanent

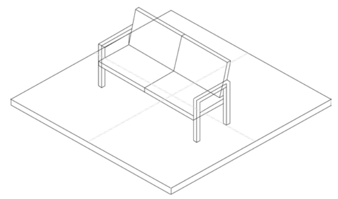
MH.10 Depaving

HYPOTHESIS: improving the evaporative surfaces will mitigate the temperature



SP.1 Bench

HYPOTHESIS: creating resting spots for elderly during a hot day



MH.11 Small pocket park

HYPOTHESIS: little spot for evaporative area as well as a little communal space

6.3 General application toolkit

Streets

mitigation implementation

drivers which streets | deter-minants street look alike | which mitigation strategy | small scale | street scale | sub goals | goal

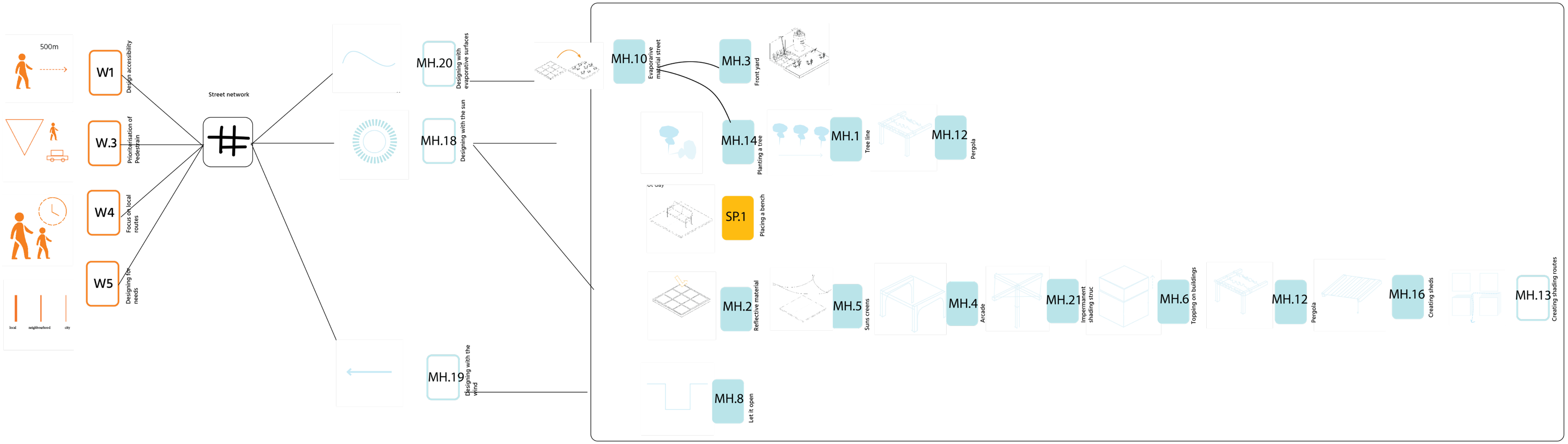
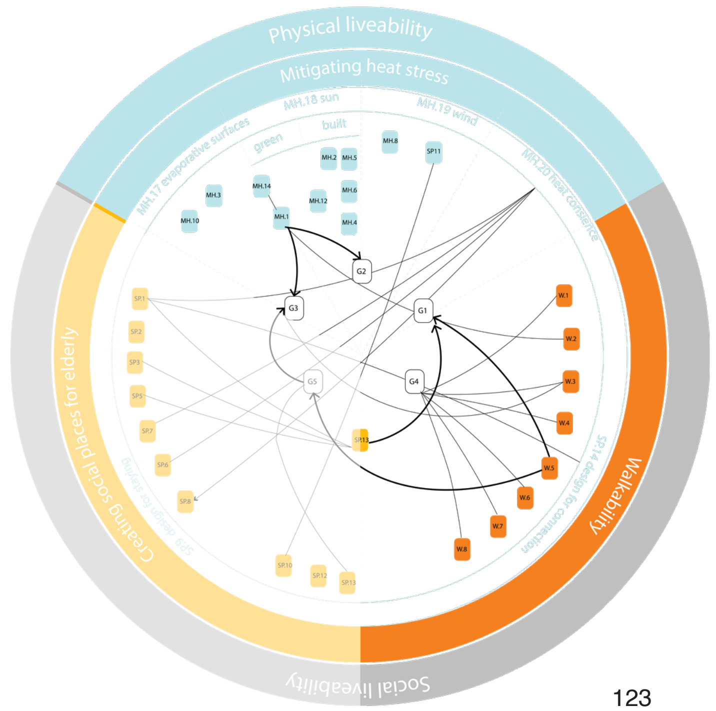


Fig. 6.2 Design decision flowchart streets. Created by Author

To improve thermal accessibility for vulnerable groups on streets, the decision design flowchart outlines three connected design principles: walkability, heat mitigation, and public spaces. It suggests prioritizing pedestrians over fast traffic and considering the orientation and proportions of streets to determine their potential for casting shadows and accommodating refurbishment. Additionally, the flowchart recommends using sun, wind, or evaporative materials for mitigation, depending on the scale of the measure, and emphasizes the importance of street continuity in implementing mitigation measures. These measures contribute to creating shading routes, accessible greenery, and ultimately improving thermal accessibility.



6.3 General application toolkit

Public spaces

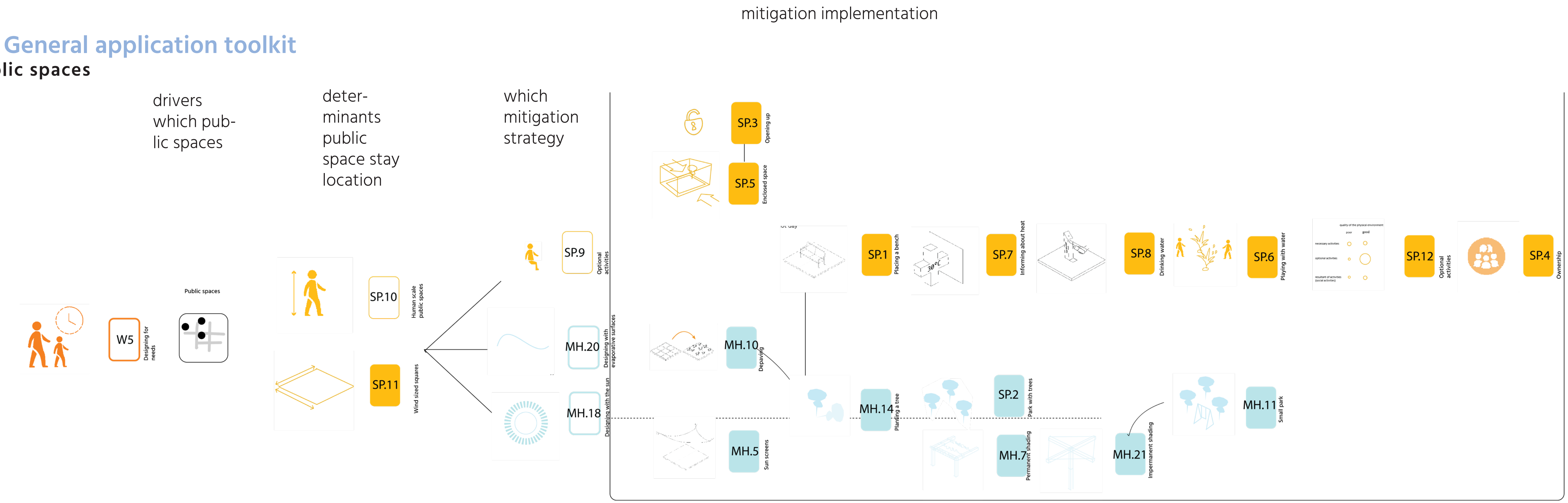


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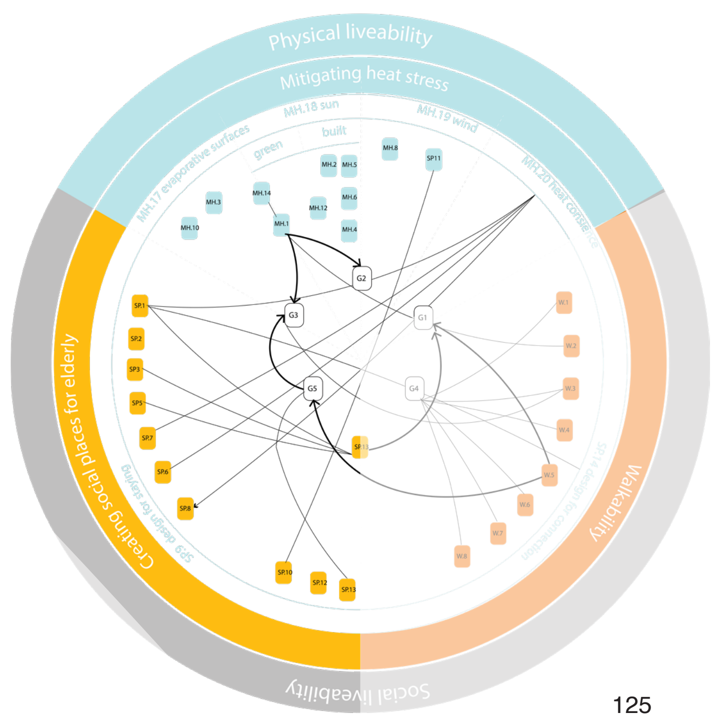
Fig. 6.3 Design decision flowchart public spaces. Created by Author

This is the decision design flowchart, which can be used as a general approach to mitigate heat stress in public spaces. A key factor for a comfortable public space is one that is human-scale and has no more than 30 meters of enclosed space. Additionally, it should be designed with consideration for wind conditions, as a square with good wind circulation is more favorable for people to stay in. The next step involves determining the mitigation strategy and implementing public space measures. Public space measures include designing for temporary needs and creating optional activities in the square to encourage social interaction. Stay qualities for heat regulation, such as access to drinking water, temperature information, shaded areas, and greenery, are also essential. Designing with evaporative materials and considering sun exposure are important aspects similar to those in the streetscape.



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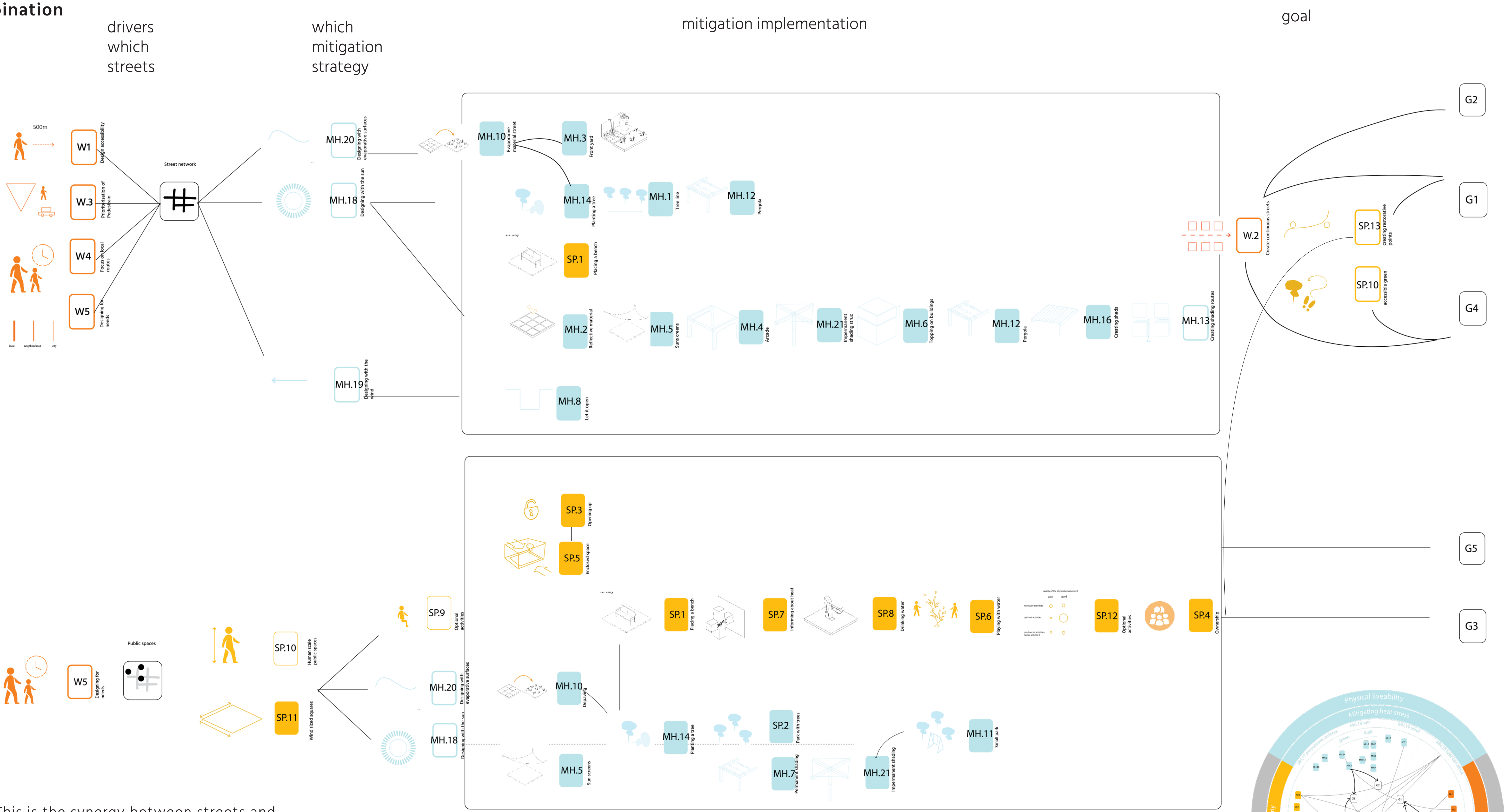
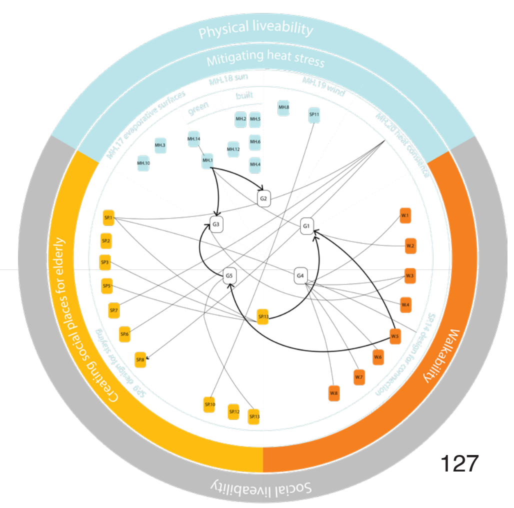
6.3 General application toolkit

Combination





This is the synergy between streets and public spaces as one public space network application of the toolkit. Depending on the scenario chosen the subgoals and final goals wil be met.

Fig. 6.4 Design decision flowchart public space network. Created by Author

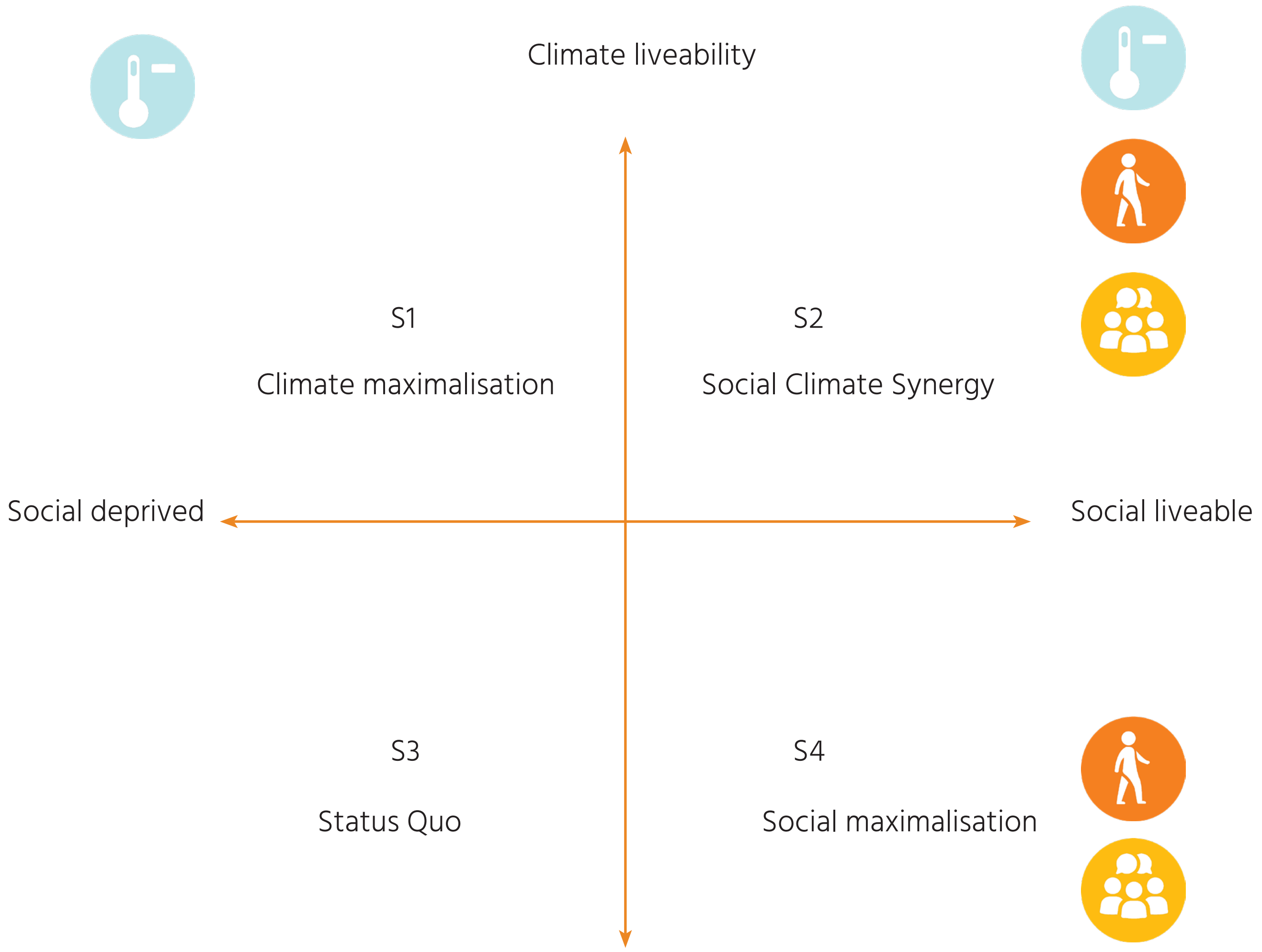
6.4 Scenario building

To tackle climate resilience. Scenario building is applied. To figure out the ideal outcome multiple pathways are laid out. Eventually, a strategy will be proposed to cope with the different scenarios.

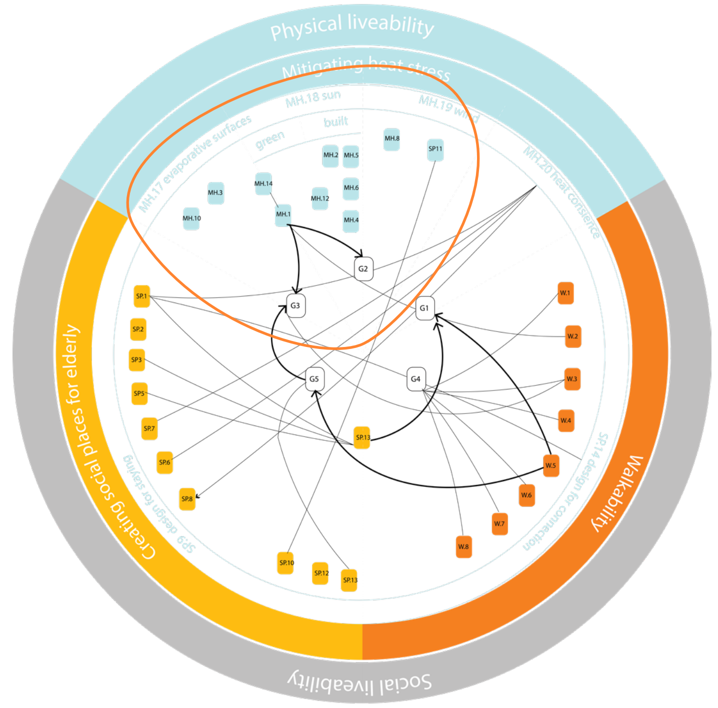
The scenarios proposed are S1. Climatic maximalisation. In this scenario, the mitigating effects are a high priority. The social aspects are present to a lesser extent. S2. Social Climatic Consensus This will be the golden ratio between social liveability and climate liveability since it enhances both aspects.

S3. Status Quo This is the state it is now. Neither good social liveability as well as climate safety. S4. Social maximisation The appropriateness of the place, as well as the social places, are in favour of this area. Climate safety is present to a lesser extent.

Fig. 6.5 Scenario building



S1. Climate maximalisation



In the climate priority neighbourhood it maximalises the climate comfort generated aspects.

The areas with a lot of heat more extensive greenery will be placed. The interconnectedness of greenery is important in order to mitigate as much heat as possible.

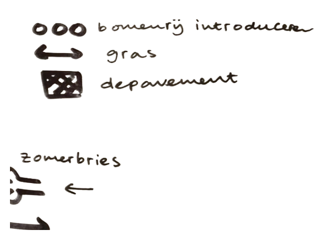
On the North south axises Schipperstraat, Grote Visserijstraat and Tram area Spanjaardstraat More extensive green structures will be introduced. Those green options have the quality to slower the wind in the winter seasons were the south wind is more dominant.

Squares will be depaved to catch as less heat as possible.

Collective gardens will be opened up.

The Spangeskade will have more greener characteristic.

Legend



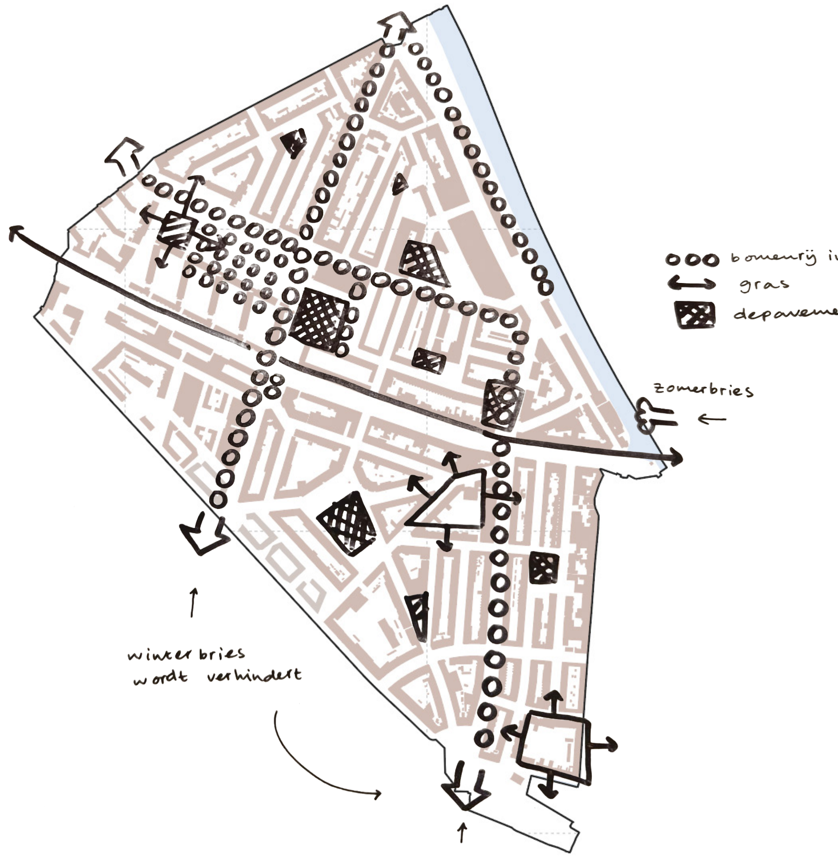
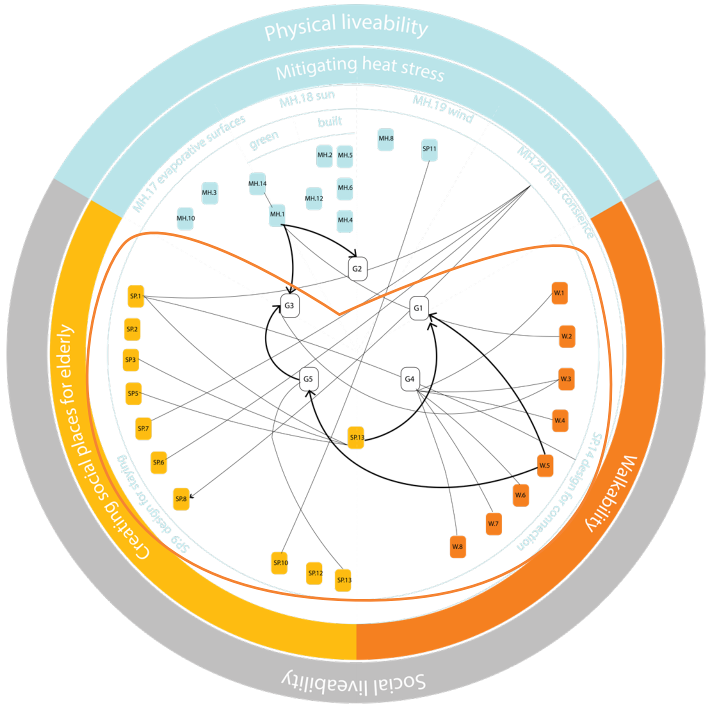
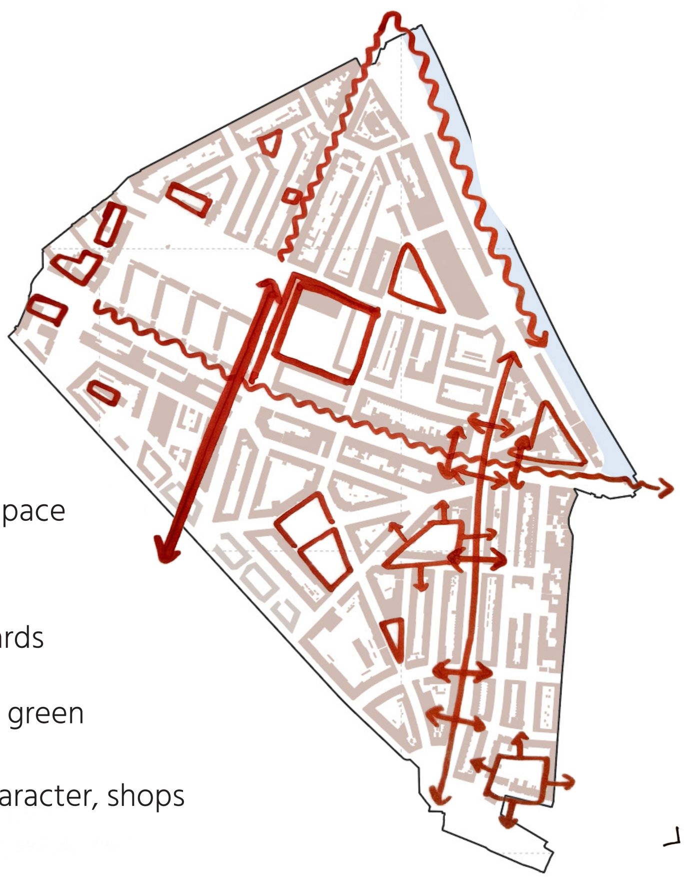


Fig. 6.6 Climate maximalisation method

S4. Social maximalisation

Enhance the adaptability and use of the existing public spaces by integrating Visserijplein with the library on top, as well as the adjacent apartment block. The apartment block currently has a poor energy label and is designated for social housing.





Legend

- opening up collective space
- solving physical barrier
- inclusive design playyards
- interconnectedness of green
- social adaptiveness character, shops

Fig. 6.7 Social maximalisation method

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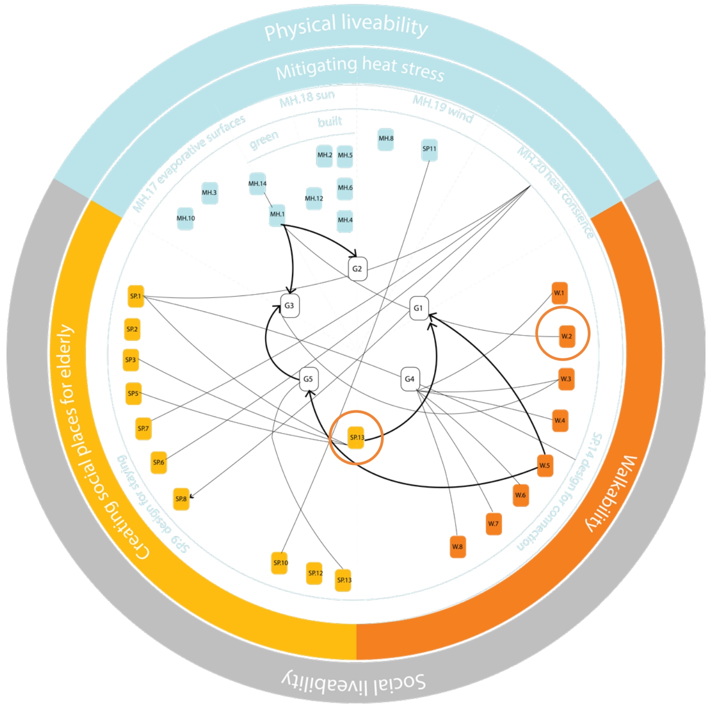
S2. Social climate synergy

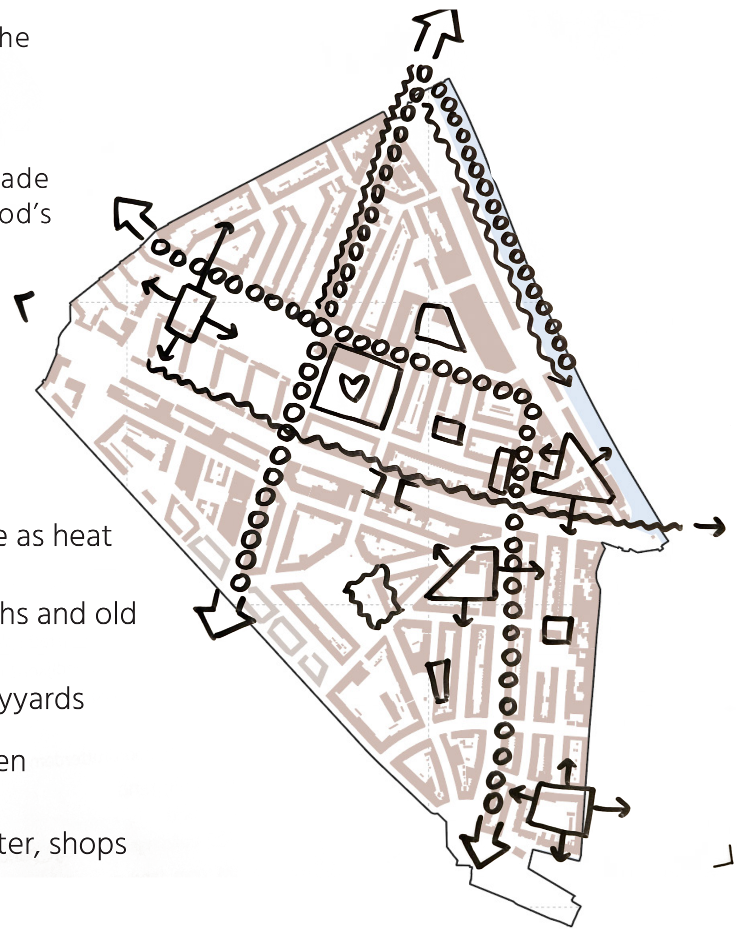
In the neighborhood, we aim to enhance climate comfort by maximizing greenery. In areas with high temperatures, we will increase the amount of greenery to help mitigate the heat. It's important that the green spaces are interconnected to provide effective heat reduction.

On certain streets like Schipperstraat, Grote Visserijstraat, and Tram area Spanjaardstraat, we will introduce more extensive green structures. These green areas will help to slow down the wind during the winter months when the south wind is dominant.

We plan to remove pavement in some areas to minimize heat absorption and create collective gardens for the community to enjoy.

Additionally, we will enhance the green features along the Spangeskade to further improve the neighborhood's overall greenery.





Legend

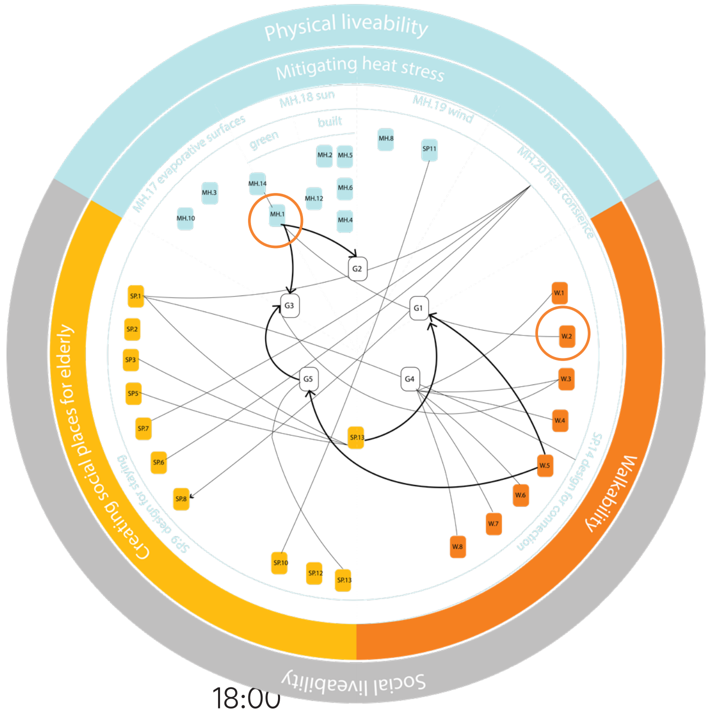
- opening up collective space as heat shelter
- nature corridor on local paths and old tree network
- inclusive elderly design playyards
- interconnectedness of green
- social adaptiveness character, shops
- visserijplein heart of the neihbourhoods

Fig. 6.8 Social climate synergy method

6.4 Toolkit applied to Bospolder Tussendijken

Streets were prioritized based on the needs of the elderly and children, with a focus on areas such as the market square, playgrounds, and parks. The yellow area highlights the prioritized streets based on these needs. Depending on the amount of shadow present the streets are depicted which need the most shade. How these maps are generated is explained in (van Esch, 2024) chapter Application and Appendix B and D.

- playground attraction betweeness
- parcs attraction betweeness
- market attraction betweeness
- overlap all the 3 cluster destinations
- no shadow, important overlap activity streets
- no shadow, second importance , important overlap activity streets
- good shadow, importance overlap activity streets
- good shadow, second importance streets



9:00 12:00 15:00 18:00

Activity pattern

Streets for intervention

Fig. 6.9 decision flowchart in practice for prioritising problematic used streets during the the peak moments of the day.

With the prioritisation of the streets in use for the elderly and children, a hierarchy is made visible. Here, the 1st grade of red visualises the overlapping paths. As could be seen over here, there is a parallel street next to the Gijsingstraat, and that is the big road Schiedamseweg with a lot of businesses such as cafes, bakeries, and restaurants. They hold ownership over the place and could potentially be more favourable than Gijsingstraat.

Next up, it is visible that there are already some old treelines which could be connected, and also one of the goals is the accessibility to the green where the green accessibility shortest routes are the most important. The other figure showcases the intervention should take place in the street profile, or the architecture needs to be adjusted.

For the public spaces destinations with high paved areas, depavement needs to take place. Other enclosed gardens like schoolyards need to act as restorative points within the network.

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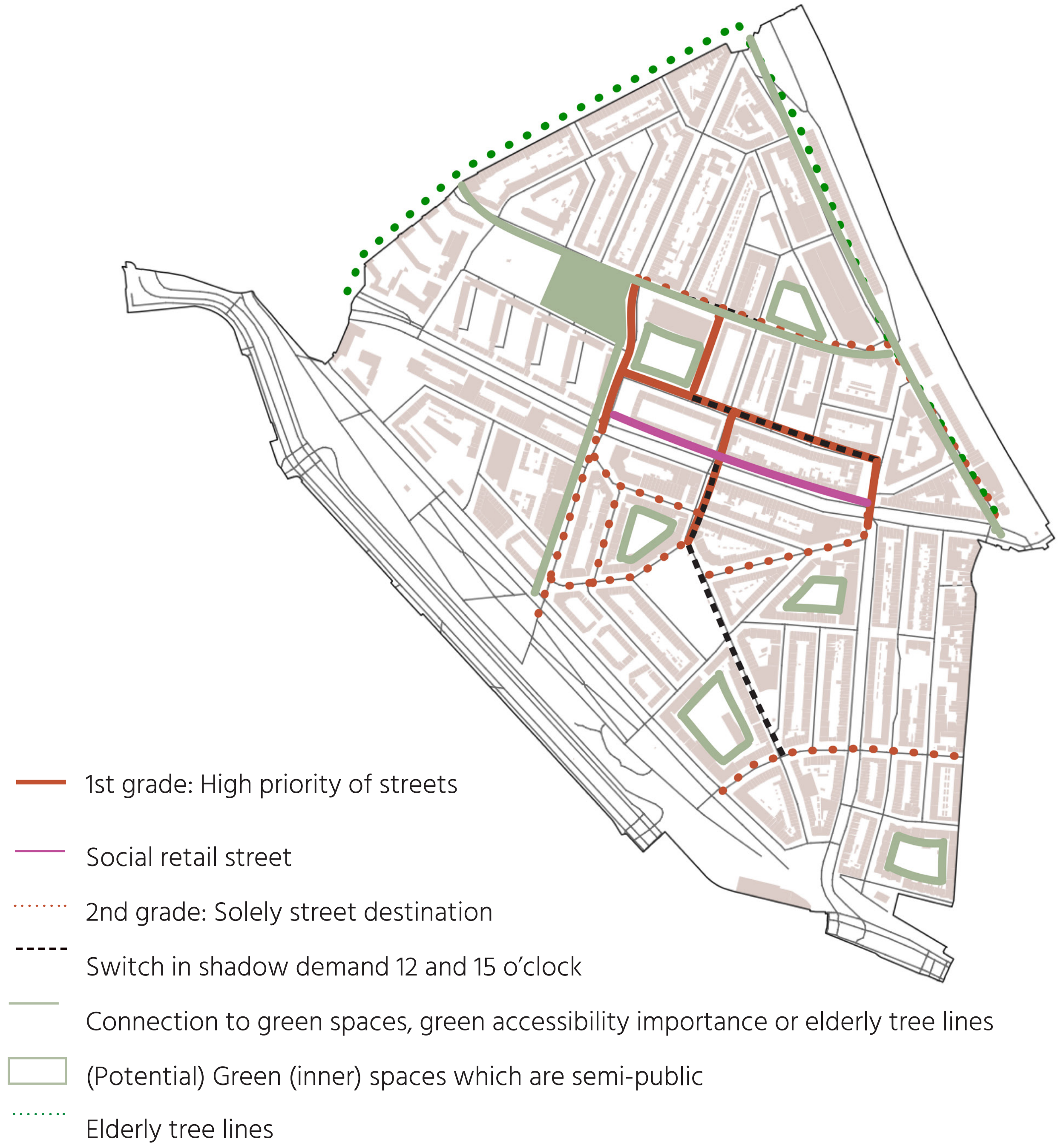


Fig. 6.10 prioritisation streets for intervention. Created by Author

6.8 Design concepts

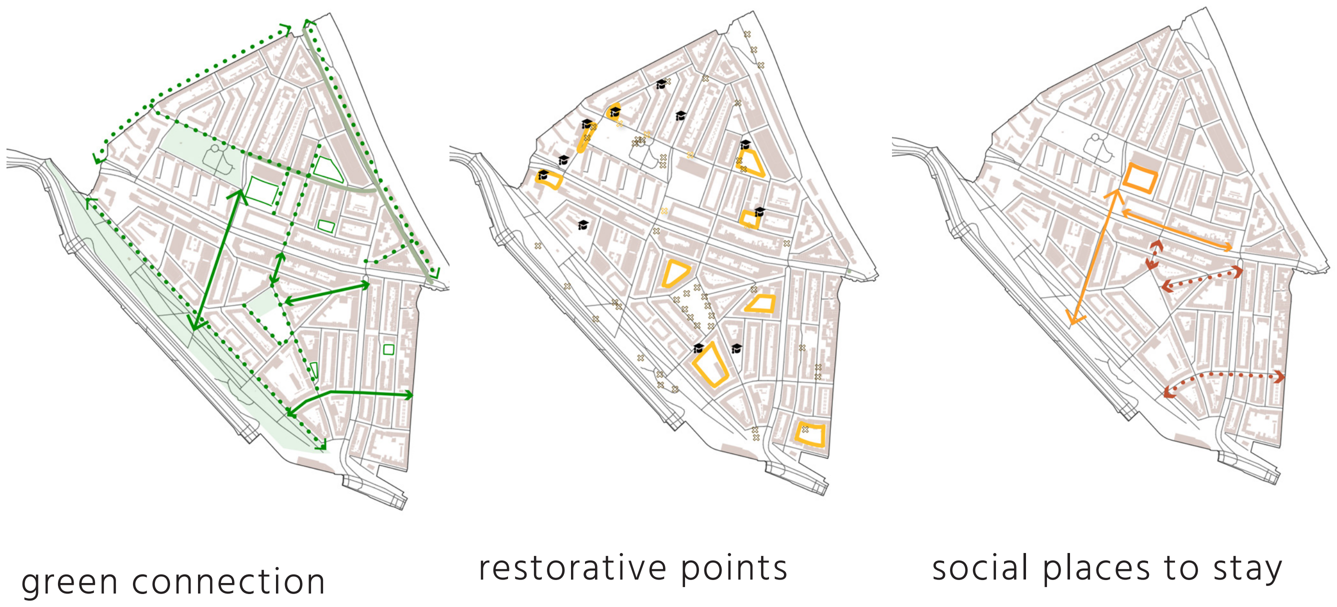


Fig. 6.11 design concepts

In Tussendijken, the strong horizontal and vertical lines in its design result in less warming of the streets, while in Bospolder, the many diagonal lines cause more streets to become warm.

One of the main issues in these neighborhoods is the lack of clear north-south-oriented streets connecting them, which creates discomfort for residents when walking to their destinations, especially at midday. To address this problem, integration strategies are being implemented, such as the development of the Schippersstraat, which will provide a green connection.

To improve network betweenness, a circuit of greenery is being created, including several trees that will serve as a good walking route between the two parks on normal days, while also providing cooling during heat peaks.

Furthermore, it has been recommended that all squares in the neighborhoods should be greened, as they are places where people tend to congregate, and therefore require a change. The minimum requirement is to plant some trees, while the maximum is to remove markets and replace them with trees.

Chapter 6 | Intervention - towards a public space health resilient network design

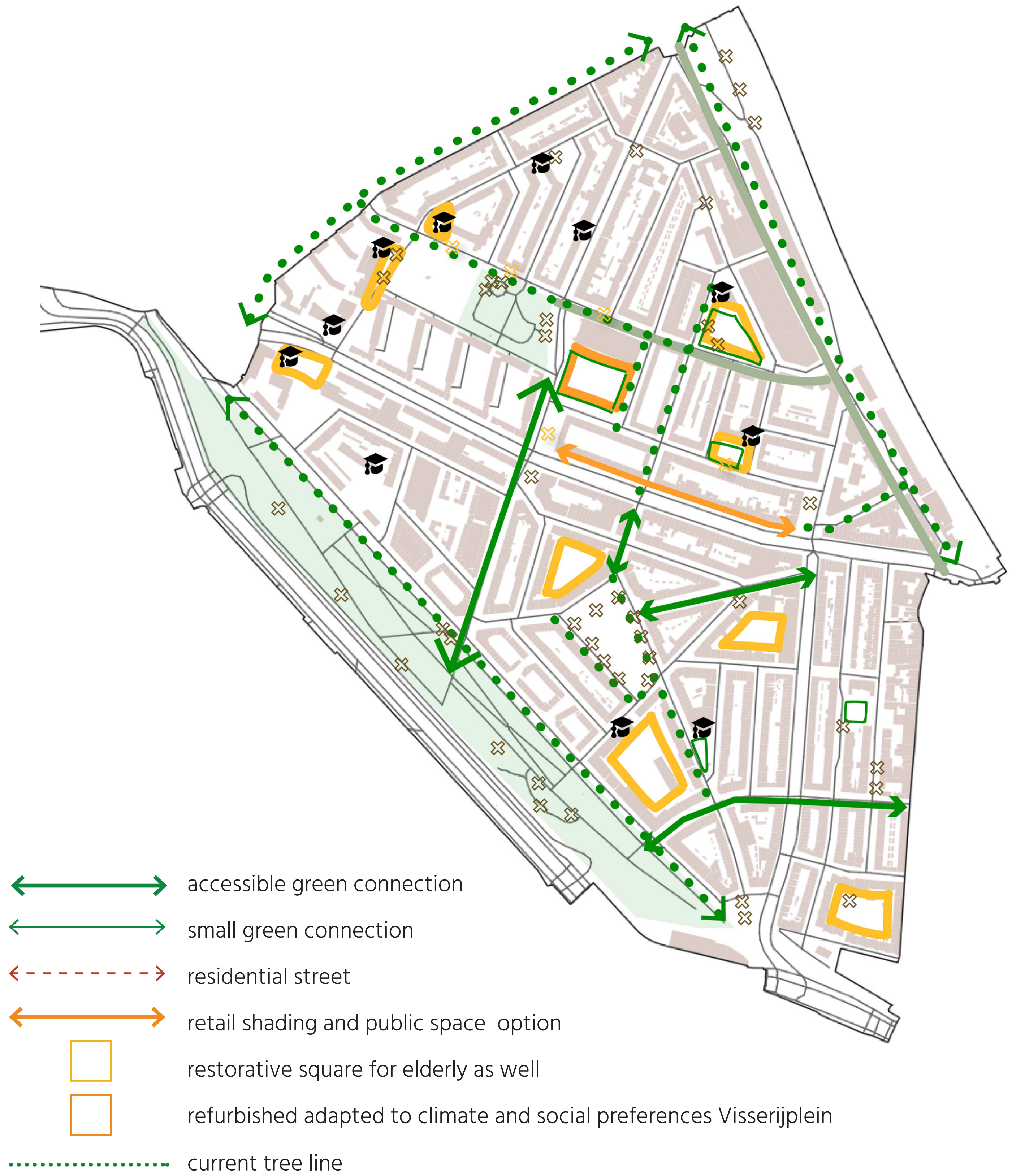
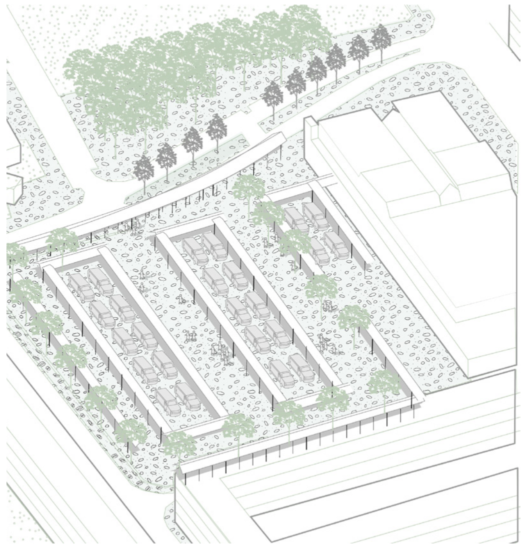
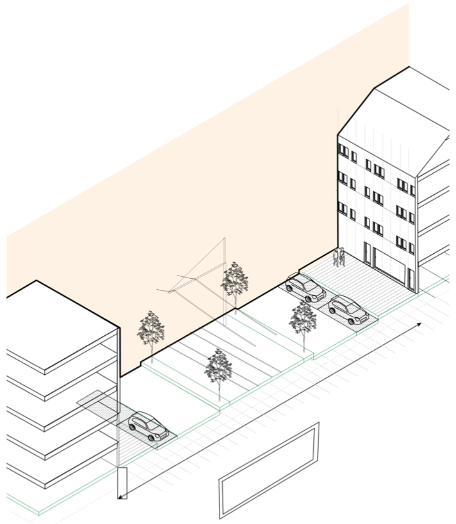


Fig. 6.12 Design concepts integrated

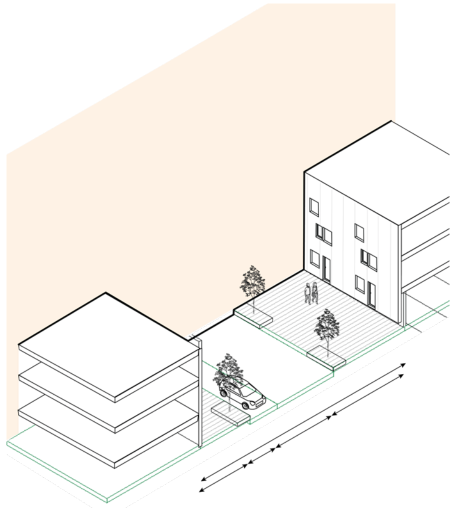
6.9 Design zoom ins



Visserijplein



Schiedamseweg



Schipperstraat

For the design zoom-ins, there will be a look into the retail street Schiedamseweg, which incorporates the climate wind corridor and the social functions. Schippersstraat is chosen to be an example street because of its strength of being the ecological corridor street from Dakpark towards Park 1943. And last but not least, there is Visserijplein, which functions as the social heart of Bospolder Tussendijken and needs mitigation measures.

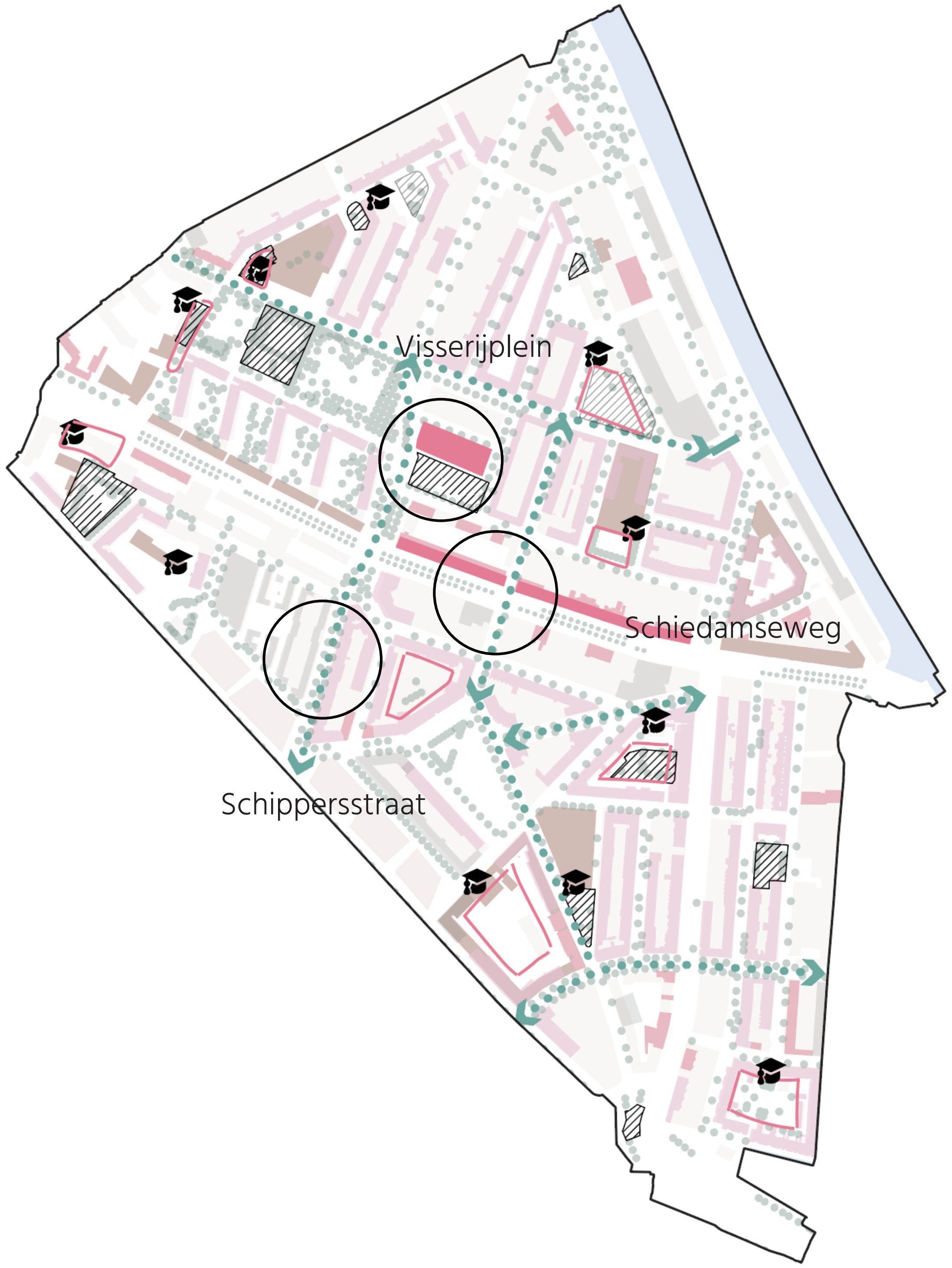


Fig. 6.13 Vison map zoom ins

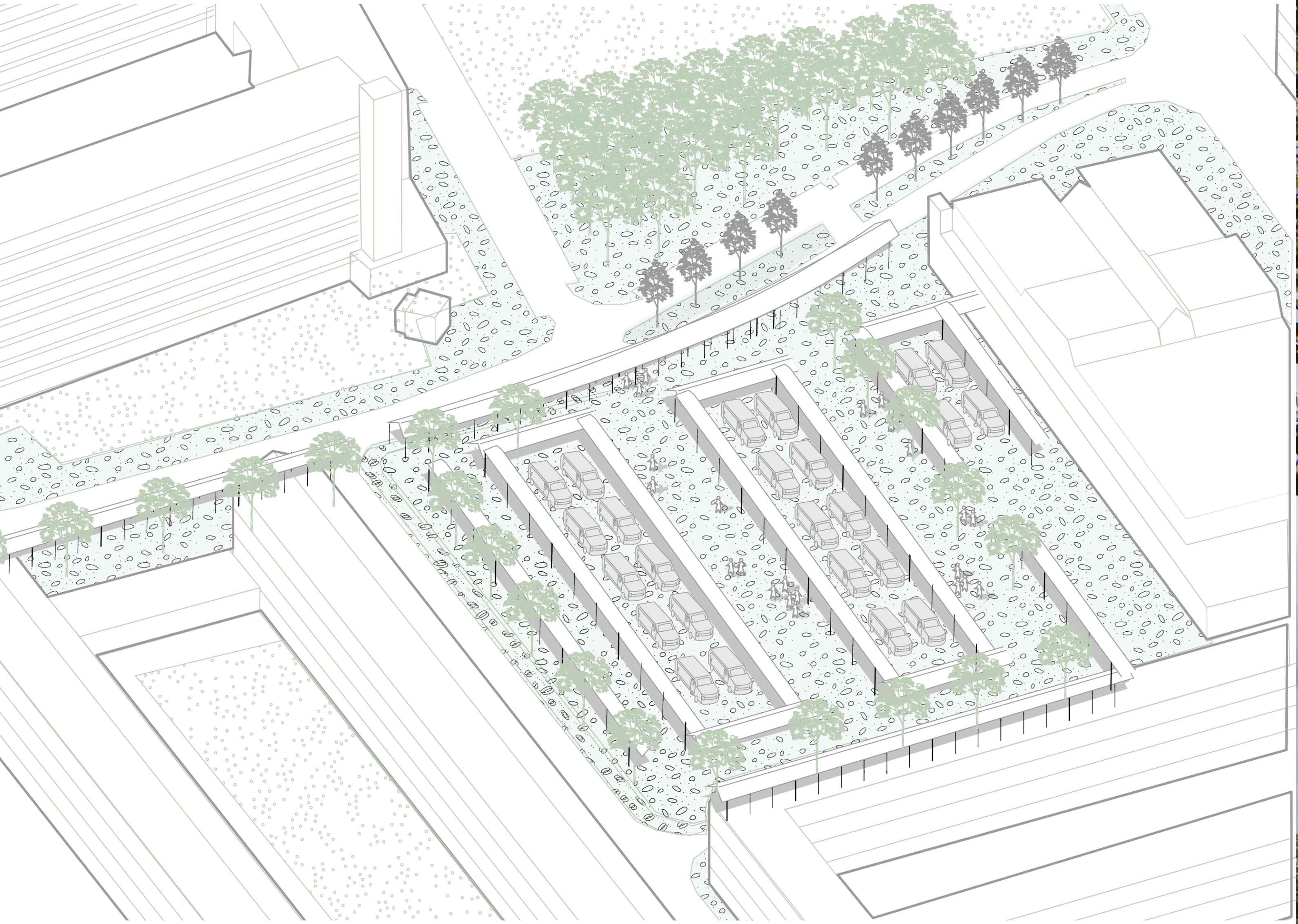
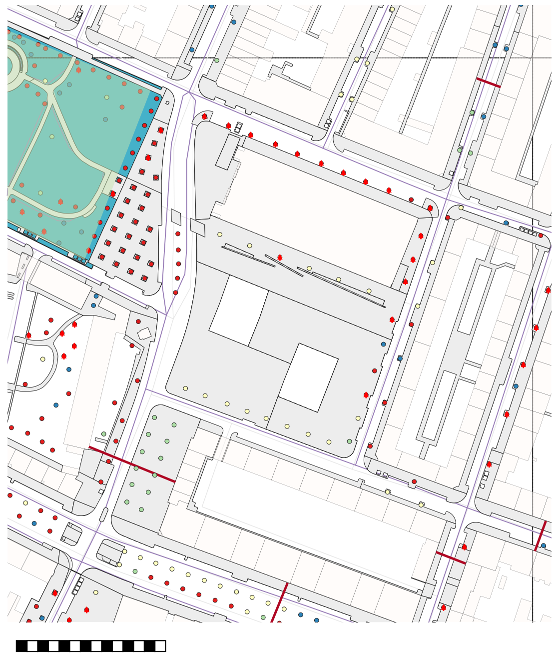


Fig. 6.14 Current situation Visserijplein

Fig. 6.15 Map of Visserijplein

6.8 Visserijplein

The Visserijplein is currently a monofunctional square that is primarily used during the market by many citizens from Bospolder Tussendijken and beyond. However, on normal days, it is simply a 90m2 square with no other purposes, entirely paved with no other green spaces. It’s essential to renew this area to make it functional not only on market days but also on regular and summer days.



Chapter 6 | Intervention - towards a public space health resilient network design

Fig 6.16. Visserijplein, Tussendijken. Picture taken by Author

fig.6.17 impression social climate synergy

Design

The proposal includes two options: one is a green solution, and the other is a more permanent shading solution. The green solution is shown in the appendix J. In both cases, the market will have to be reduced in size to make way for better quality accommodation and more mitigating effects. Both are approved as inviting places for the elderly and children. The size of the square will also be reduced to a more human scale by dividing the square into segments with more functions available. The water plaza could be integrated with a water reservoir underneath it, which would allow it to cope with other extreme weather situations and provide a pleasant place to be during the hottest moments of the year. This would be a costly decision. The indoor market is also possible for other weather situations next to the covered social space between the market and the local library with the community pier 80 Huis van de Wijk. This would probably be the most cost-effective solution, also because it preserves the social character of the market, which is very important on the Visserijplein while guaranteeing climate comfort during the hottest part of the year and throughout the year. Within each design, the addition of trees keeps the connection greenery with the network.

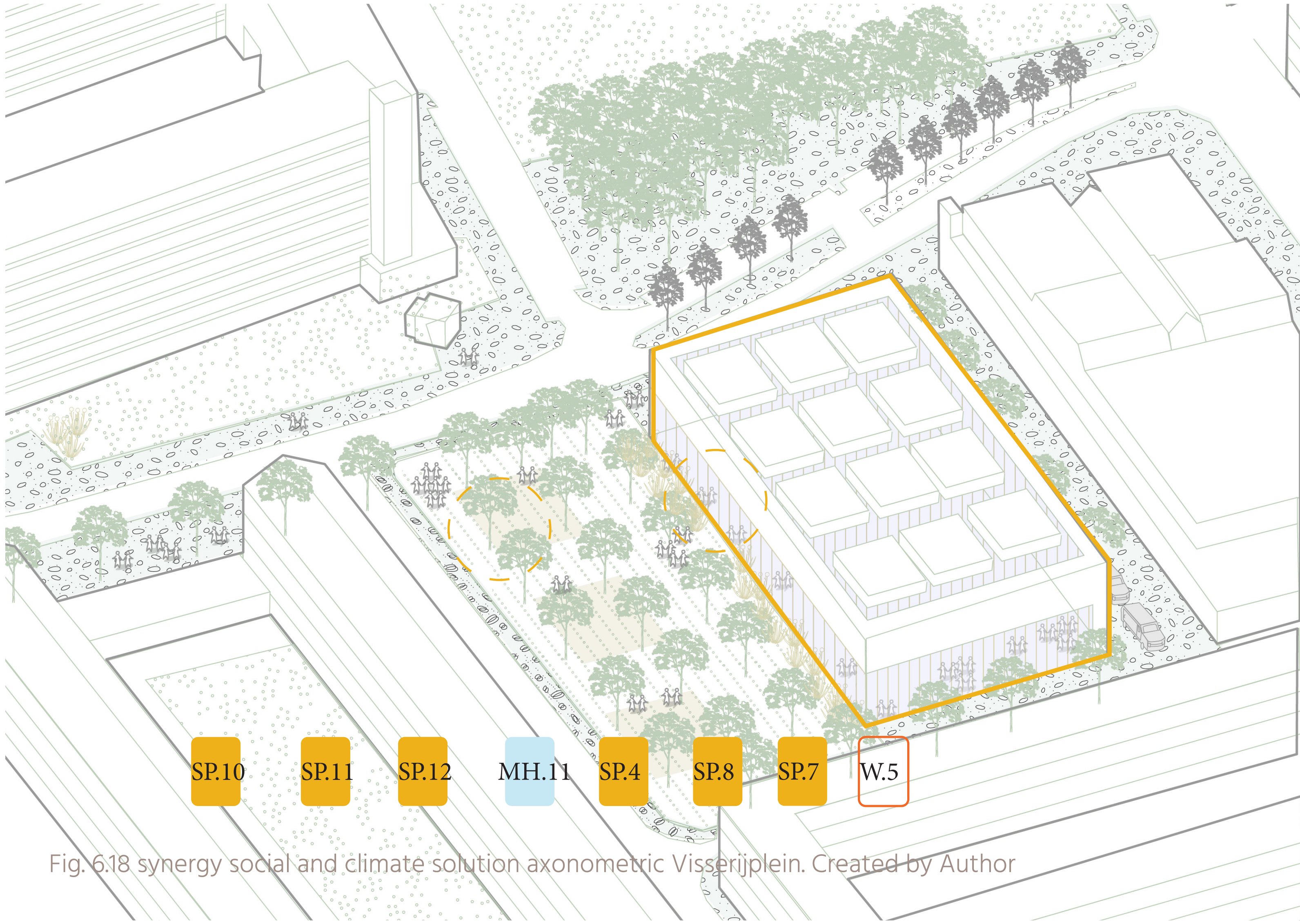


Fig. 6.18 synergy social and climate solution axonometric Visserijplein. Created by Author

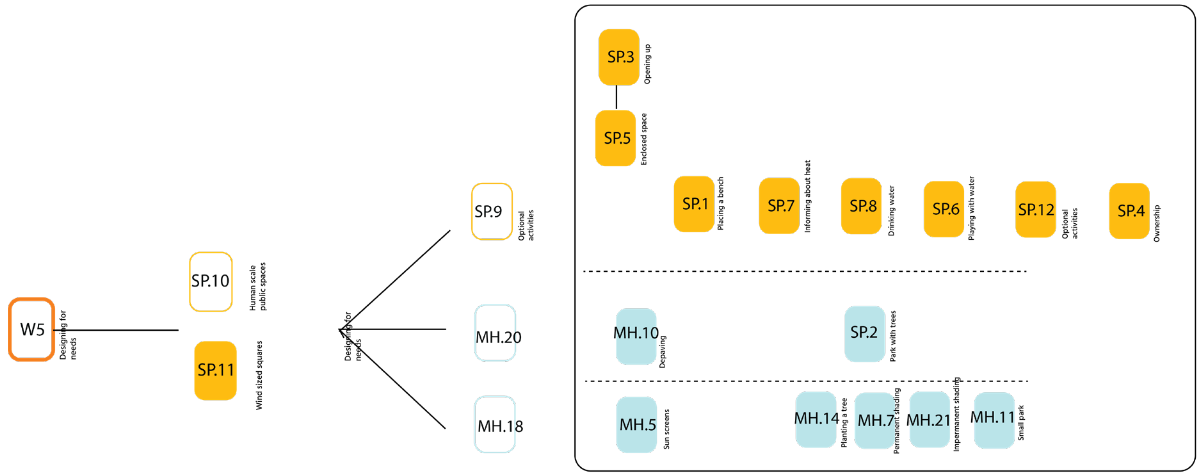


Fig. 6.19 Public space decision flowchart

6.9 Schiedamseweg

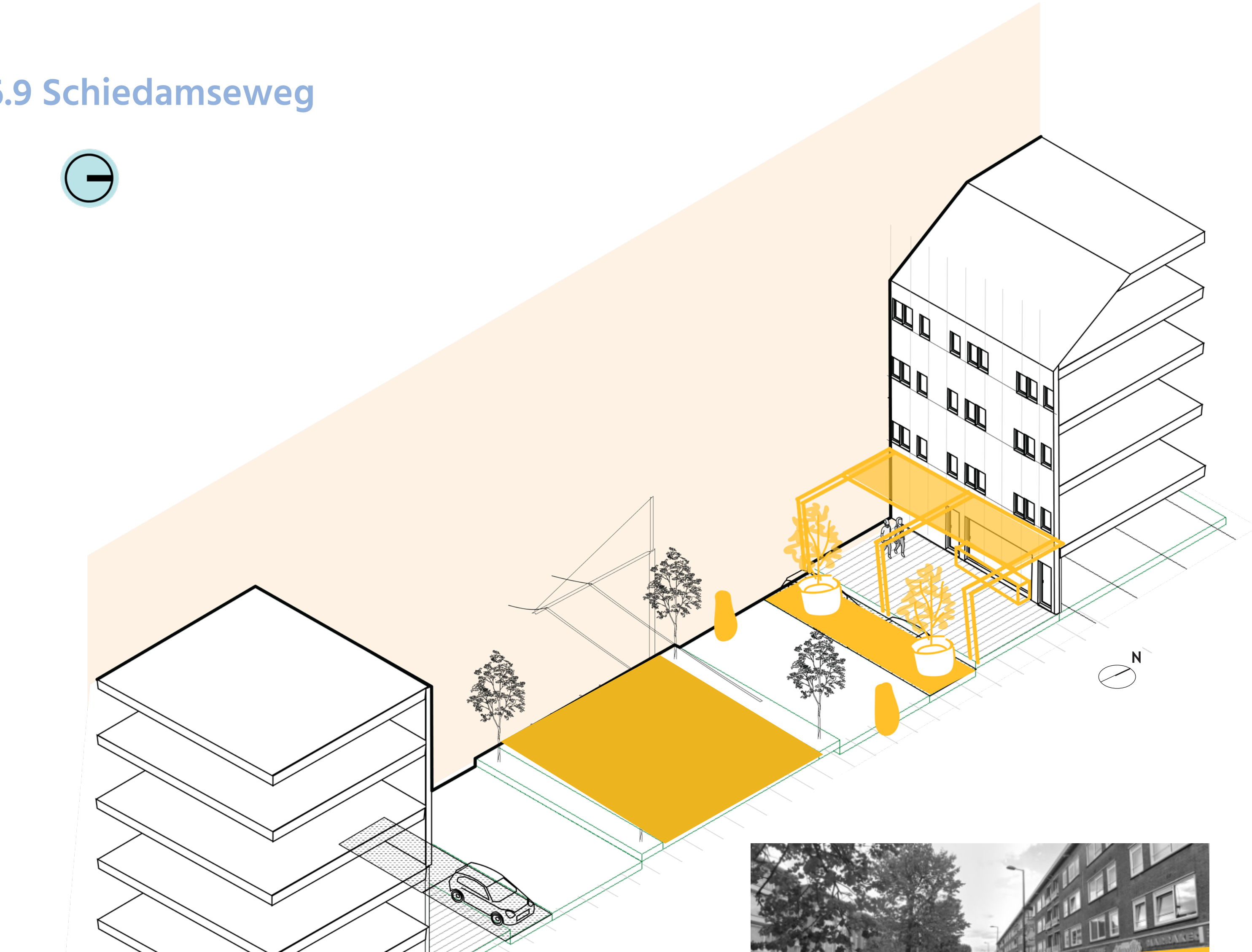


Fig. 6.20 Axonometric schiedamseweg

Fig. 6.21 Visual schiedamseweg

For Schiedamseweg, social connection remains very important. Therefore, an architectural structure is provided to create more ambiance on the retail street. This also has a multipurpose function for providing coverage during the rain. Next to that, the Schiedamseweg became a one-way direction street with the option to go through if the shops needed supplies. The tram line and metro line remain intact because they provide a greater connection to other parts of Rotterdam and support the 15-minute approach for alternatives to fast traffic (Spek, 1986).

The parking spots are replaced by evaporative material, and some trees are provided in pots to make it more socially pleasant.

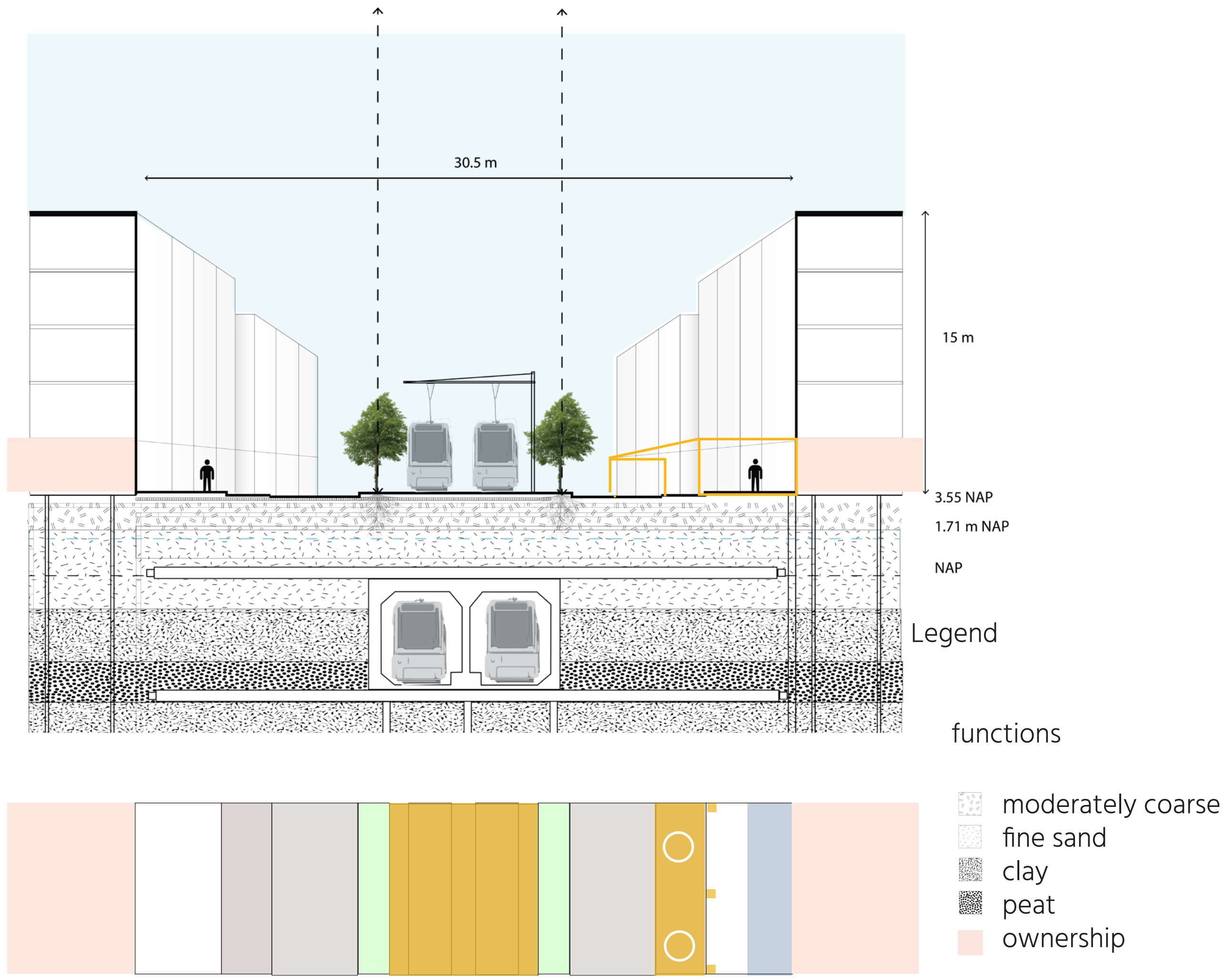


Fig. 6.22 Technical section drawing. Created by Author

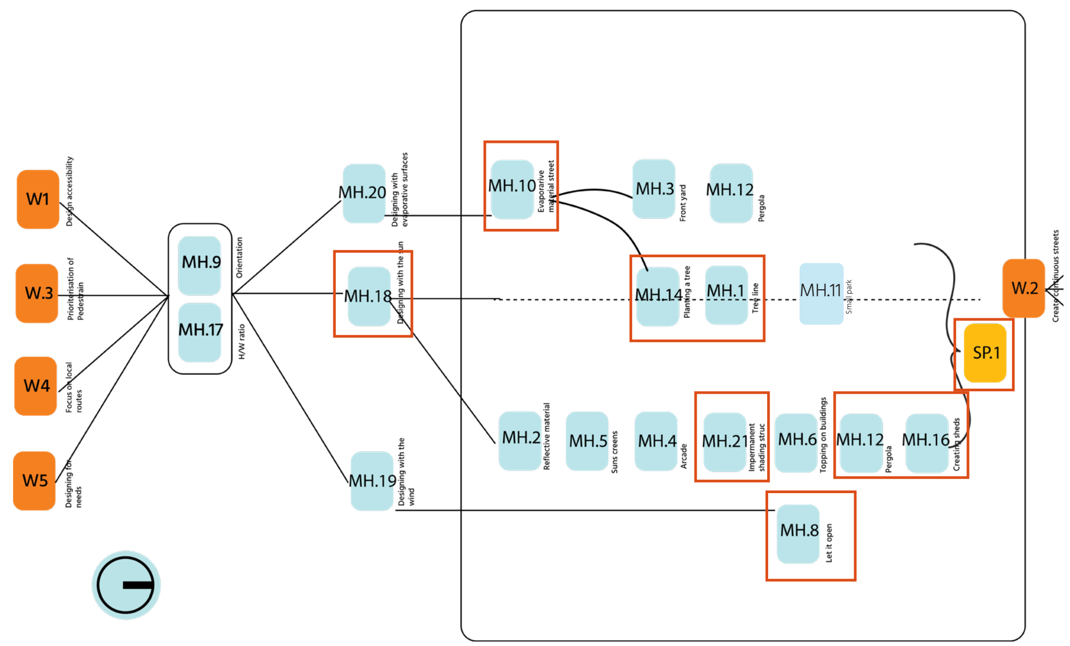
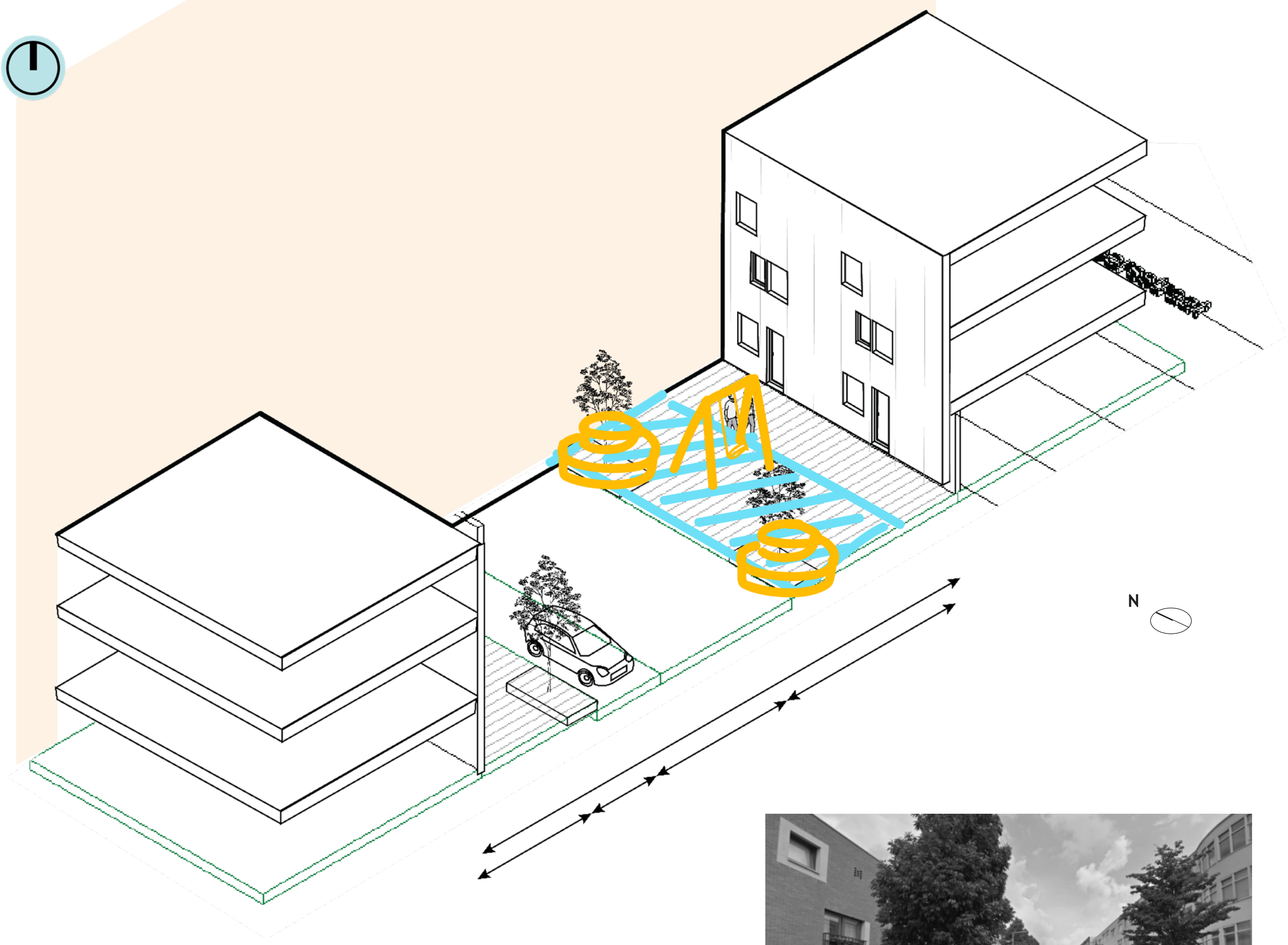


Fig. 6.23 Street decision flowchart. Created by Author

6.10 Schipperstraat



MH.10 MH.11 MH.1 SP.1 W.3 W.8

Fig. 6.24 Axonometric Schipperstraat

Fig. 6.25 Visual Schipperstraat

Schipperstraat acts as a green corridor between the two parks. Further research has shown that Schipperstraat already has the trees that are needed to mitigate the heat. These trees are only 5 years old at the moment. If there is potential to give them more space to grow, the whole neighbourhood will benefit. In that case, we need to depave the surroundings of that tree (van Loon, 2016). Also, to make it more socially pleasant, there could be a densification of green material around the trees. Also, by integrating this as a place to stay, by creating more small parks or play materials for children, this street will come to life and will function as a green corridor in the neighbourhood, connecting Dakpark with Park 1943.

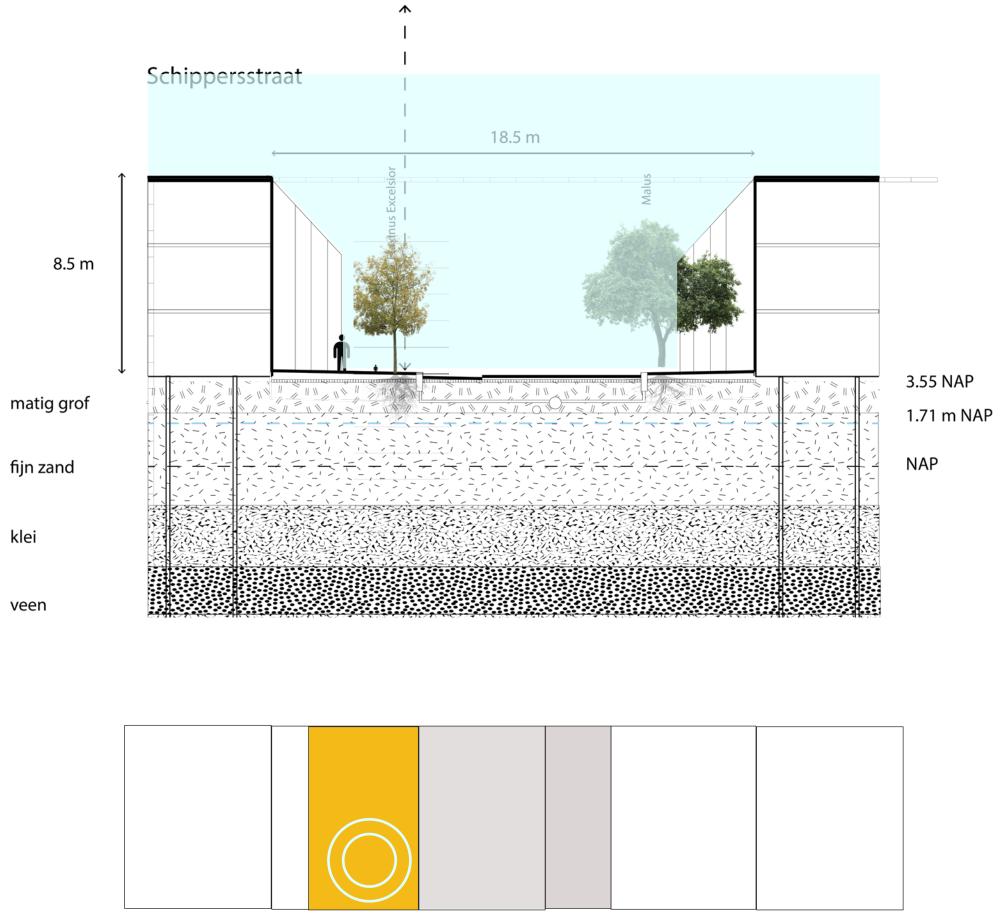


Fig. 6.26 Technical section drawing. Created by Author

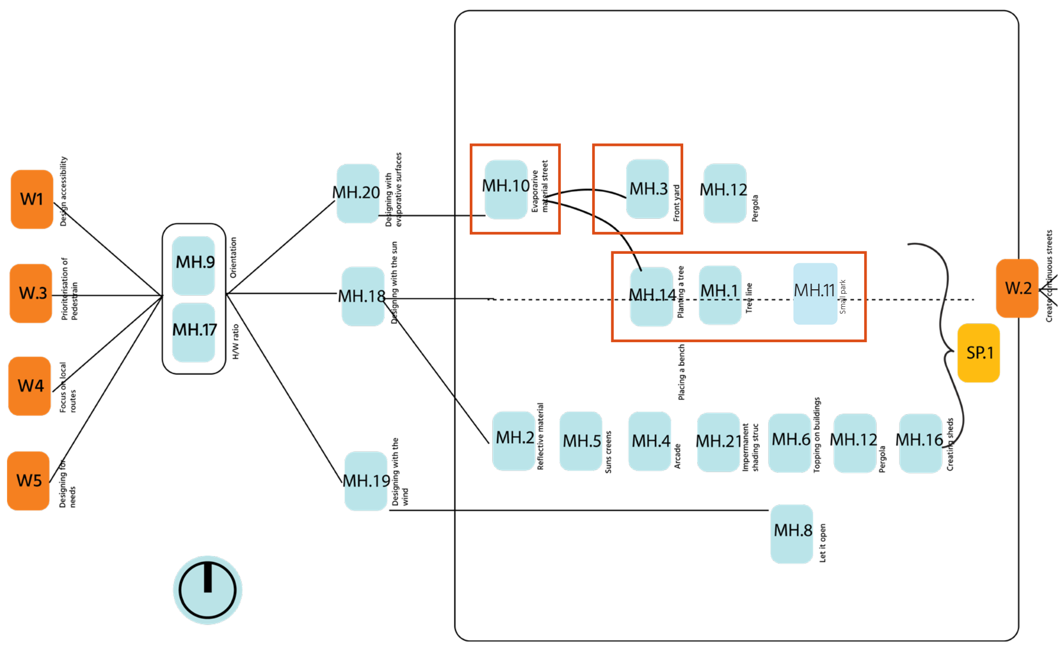


Fig. 6.27 Street decision flowchart. Created by Author

6.11 Phasing

In the plan outlined above, the strategy involves considering both the renewal of public spaces in terms of social livability and the street network approach.

In the short term, the focus will be on investing in the existing semi-public spaces and aiming to make restoration points along the network.

The priority streets will begin with the retail street Schiedamseweg, which will strengthen most of the overlapping routes. Additionally, greening the Schipperstraat will provide a pleasant walking route from one park to another, while also improving climate protection. Small shared public spaces will also be provided.

For other priority streets that are not retail streets or part of the green corridor, the car parks will be removed first. Subsequently, in collaboration with neighborhood associations and housing associations, some of these car parks will be replaced by green spaces with planters to initially give the place some function. Trees will be planted to create a more permanent solution for the neighborhood.

The largest investment will be the renovation of the Visserijplein. The square will be divided into smaller, enclosed public spaces to make it a lively place to be all year round, including in hot weather. The characteristics of a market square will be preserved, but elements for evaporation and sun shading need to be incorporated.

The greening of the Visserijplein is expected to take several years. As outlined in the phasing strategy, the planting of trees, in particular, will take time to reach full size, and the street profile will need to be adapted to accommodate this. Therefore, artificial structures will be implemented first.

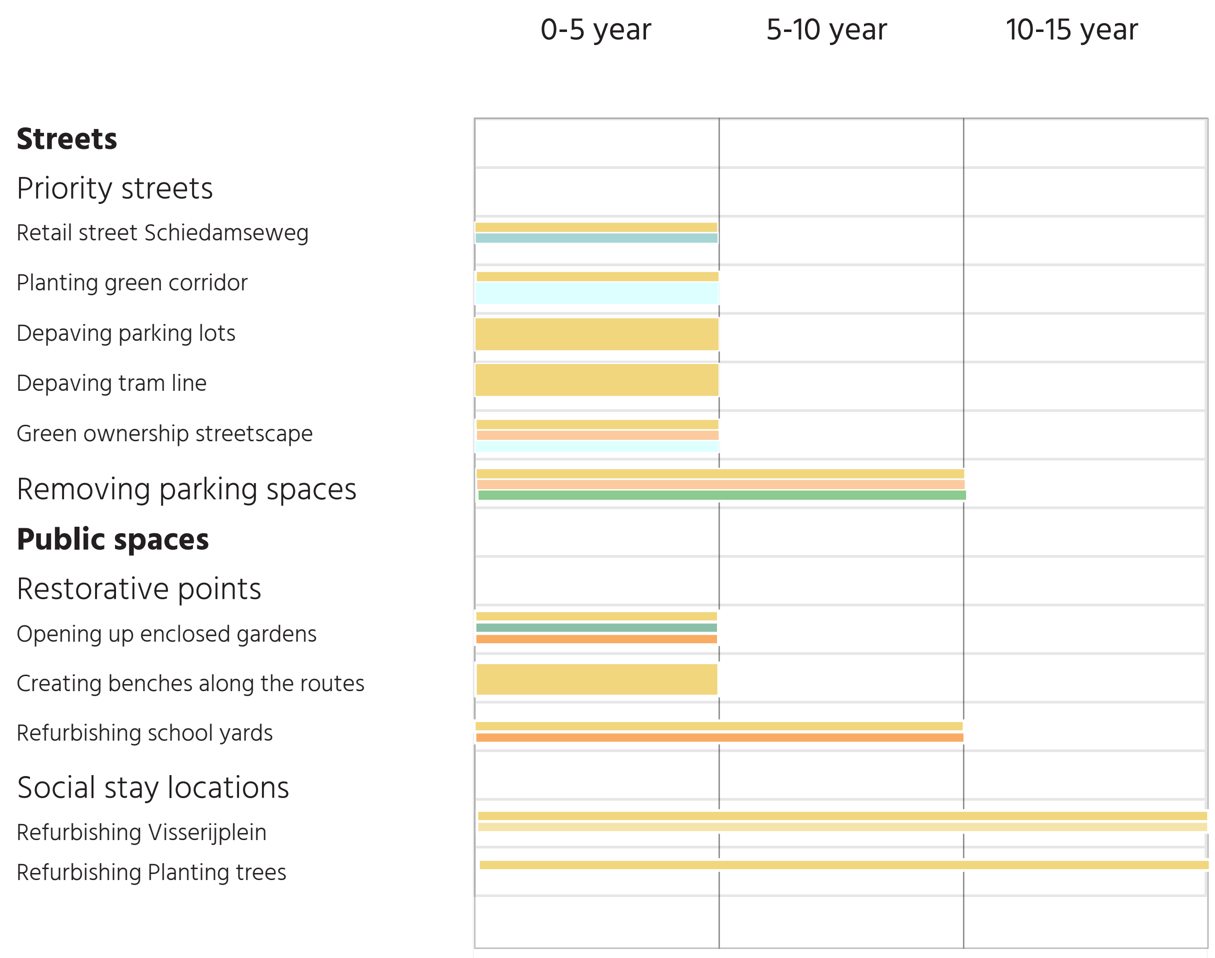
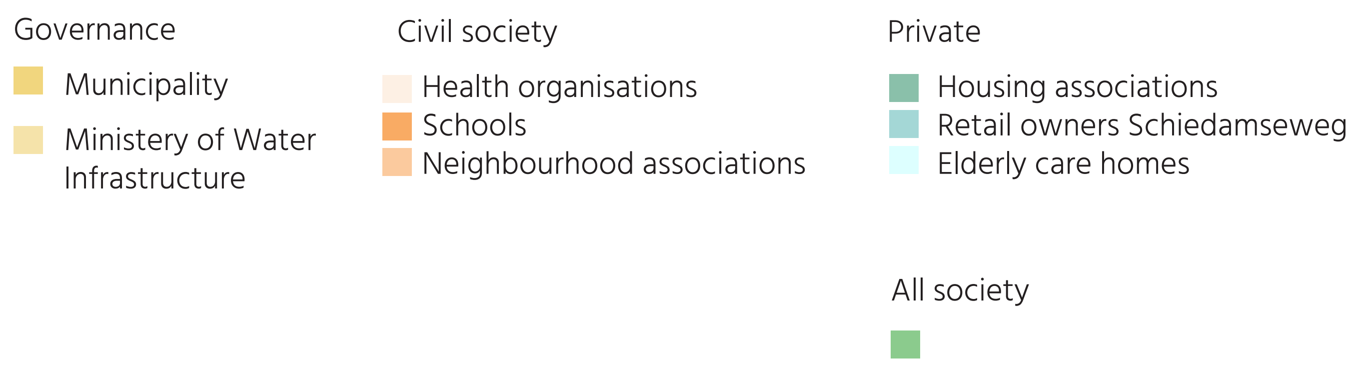


Fig. 6.28 Phasing design decisions. Created by author



“Chapter 7 Validation and assesment interventions”

1. Testing design intervention
2. Testing thermal accessibility
3. Transferability research

Fig 7.1. Bospolderplein, Bospolder. Picture taken by Author

7.1 Testing design interventions

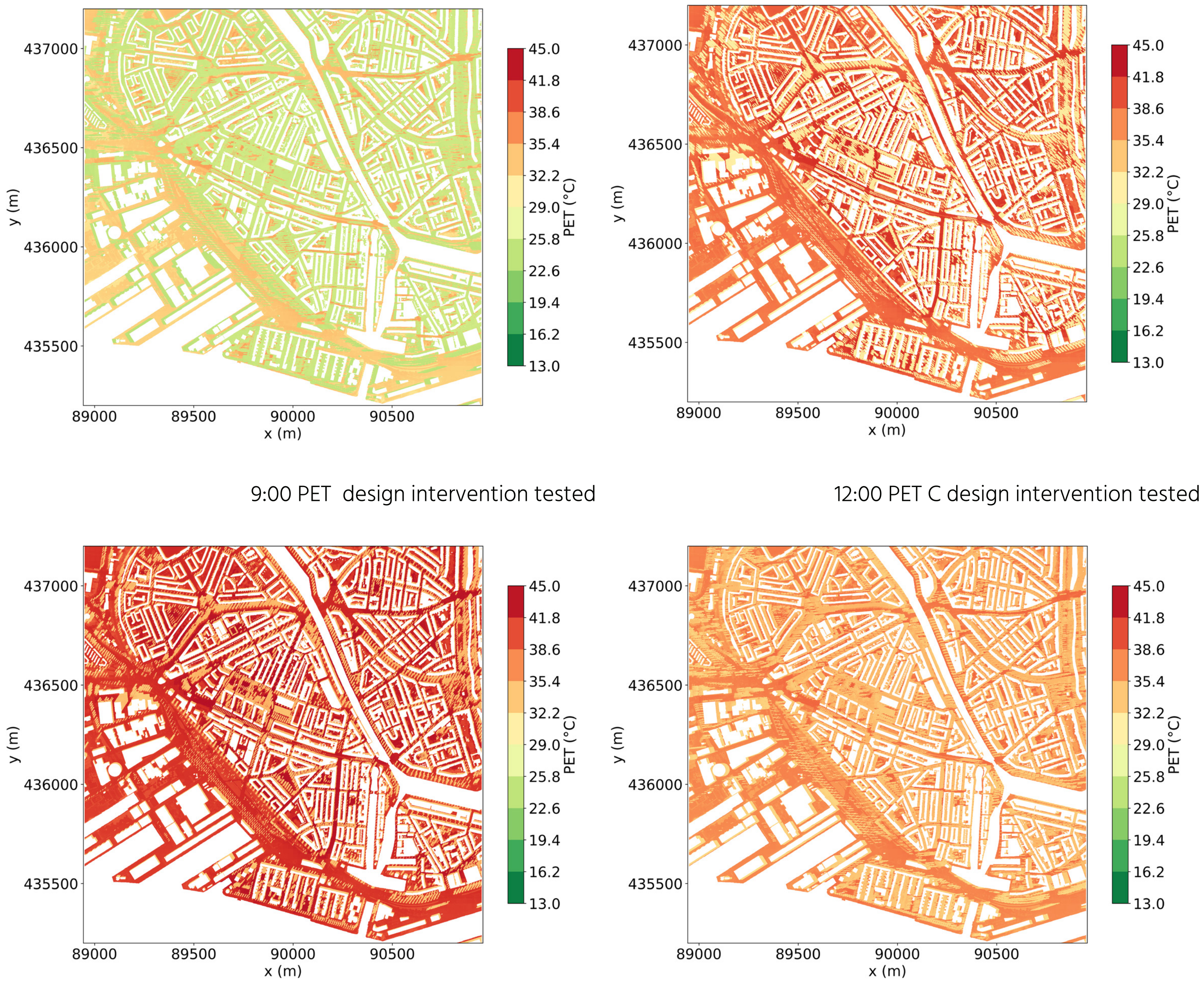
According to the suggestions on page 65, there are several objectives that have been set to achieve a more liveable Bospolder Tussendijken. These design choices will ultimately be evaluated in terms of feasibility.

The vision map in this report proposes a heat mitigation effect, which is visualized in image (xx). The creation of shadows will make it a better social place to stay in during the market and the sunscreens at the dark park and the enclosed gardens are sufficient. Additionally, the sun shading at Schiedamseweg is visible. However, just adding greenery like grass will not have major effects. Also the decision is made to shade the market square of Visserijplein in order to keep the function of being a market.

The thermal accessibility of the market did not make much of a difference, which is also due to the minimal effect of greenery and shade on the depicted streets. If there were more trees, it could make a difference. This design chose to incorporate greenery in the form of grass or with a function like planters on more residential streets. The trees on Visserijplein did make a difference.

7.2 Trees addition or update of crownsize

7.3 Intervention adding green in the streetscape



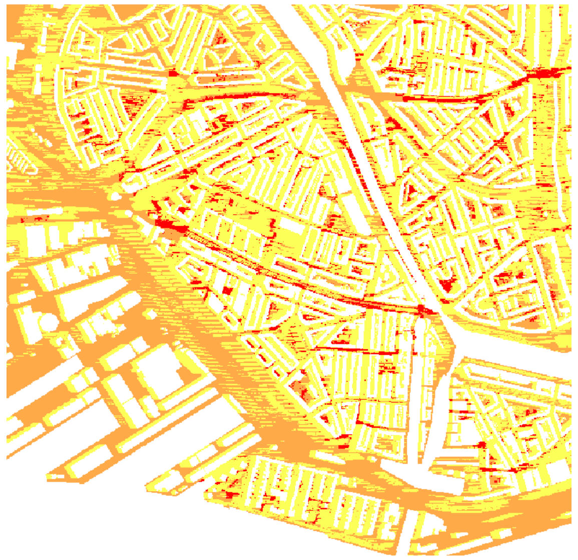
9:00 PET design intervention tested

12:00 PET C design intervention tested

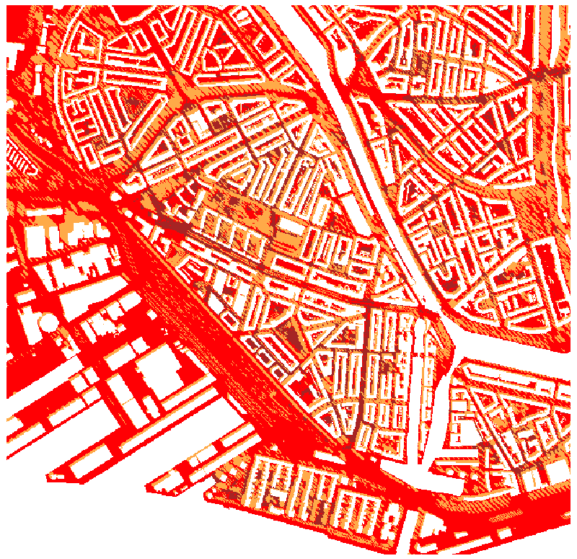
15:00 PET design intervention tested

18:00 PET C design intervention tested

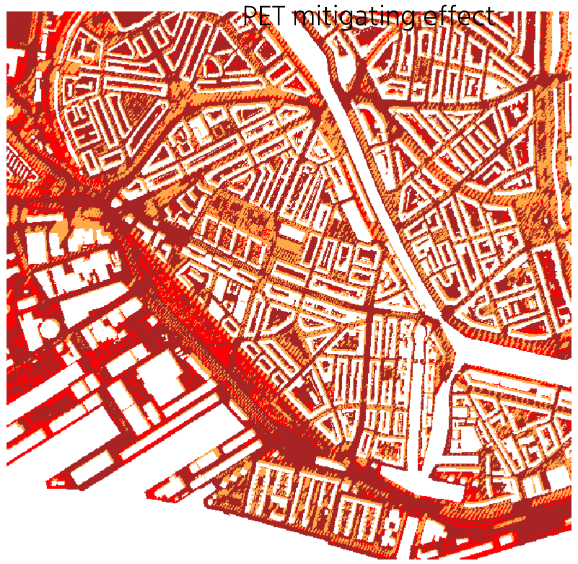
7.4 Intervention tested on the 1st of July



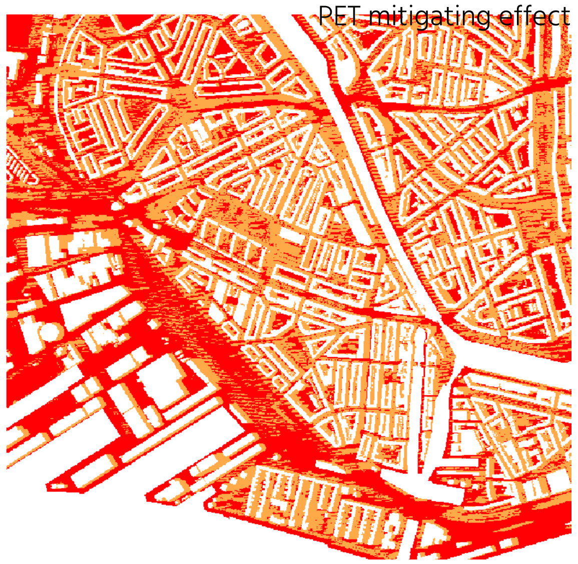
9:00 PET design intervention tested
PET mitigating effect



12:00 PET C design intervention tested
PET mitigating effect



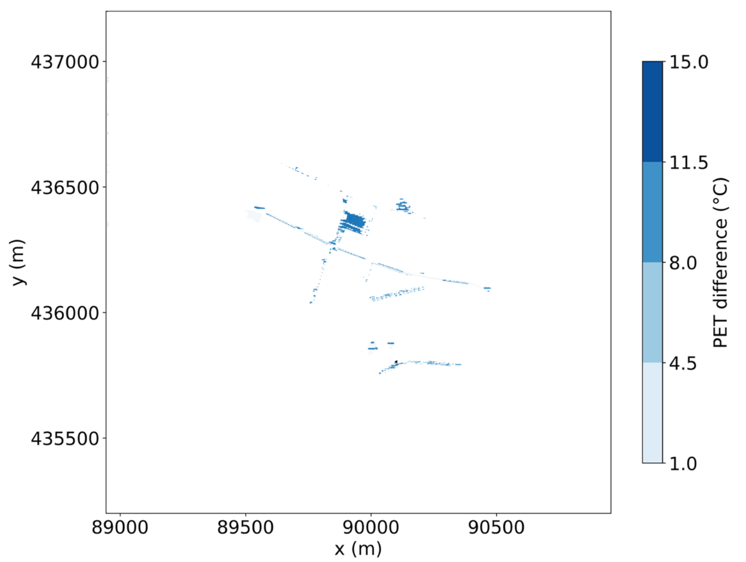
15:00 PET design intervention tested
PET mitigating effect



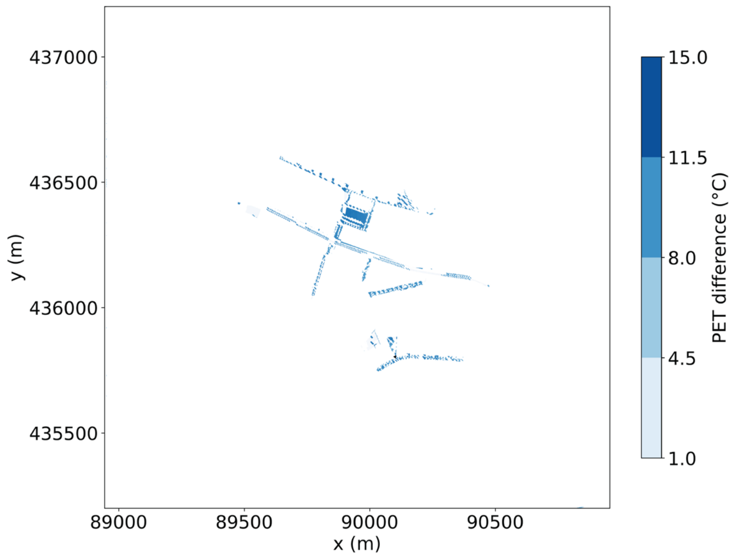
18:00 PET C design intervention tested
PET mitigating effect

Legend
PET classification

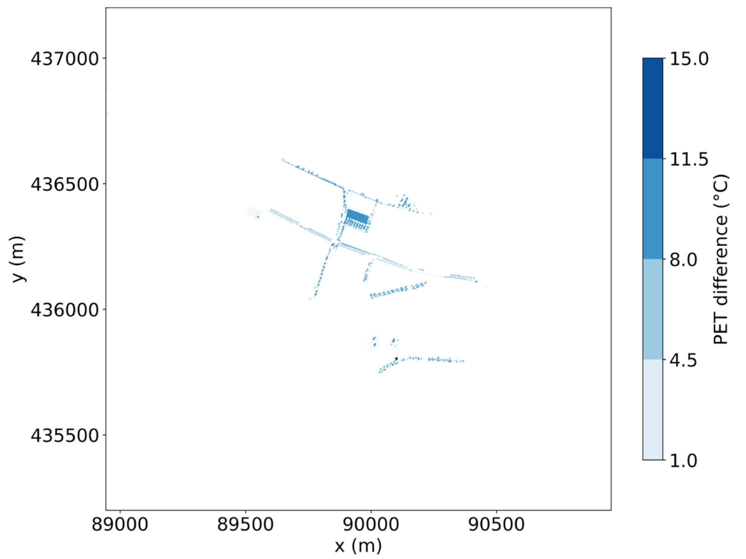
13-18	slightly cold stress
18-21	no thermal stress
23-29	slight heat stress
29-35	moderate heat stress
35-41	strong heat stress
>41	extreme heat stress



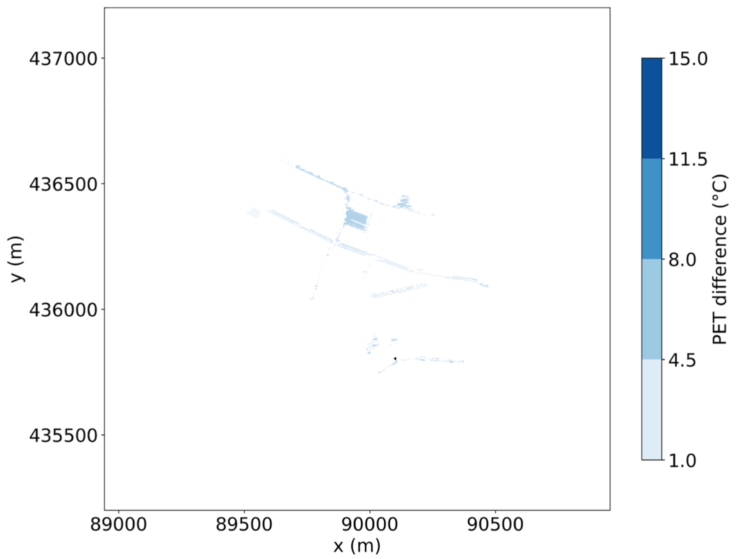
9:00 PET design intervention tested
PET mitigating effect



12:00 PET C design intervention tested
PET mitigating effect



15:00 PET design intervention tested
PET mitigating effect



18:00 PET C design intervention tested
PET mitigating effect

7.5 Intervention tested on the 1st of July

7.2 Thermal accessibility assesment

The design measures taken in the two parks were not influenced by their thermal accessibility. However, the green corridor created more greenery to maintain the connection between the two parks. There is a slight difference in the market square, as most of the streets are still too warm to traverse. Choosing the most walked routes did not immediately result in mitigating heat in the thermal accessibility.

Therefore, the shelter places at the school square that already had a covered service area of thermal accessibility in the original 1st of July simulation are still essential to the effectiveness of the design.

The continuity of the greenery is well integrated into the entire urban fabric of Bospolder Tussendijken. If greenery is placed on the roads of Schipperstraat, part of Schiedamseweg, Rosenier Faasenstraat, and 2e Schansstraat, approximately 927m2 will be greened, resulting in the removal of 650 cars in the public space. This accounts for 13% of the current situation of the amount of cars and does not fall under the 5% range of removing cars for public space livability (Utrecht, 2018).

In this design only the parking lots are sacrificed for more greenery in streets. This is a cost intensive replacement and people should be prevented to park their car on the previous parking lot spaces.
However, the cost of not mitigating the heat will be even higher. If we estimate the damage over a 50-year period, which can be a maximum of heat stress such as working, it will cost the Netherlands 3 billion euros due to climate change in the built environment. In addition, the health of citizens will be at risk, so every coin will be well spent (Source: Deltares, 2012; Appendix, E).

thermal accessibility 500m without heat mitigation (1st of juli)

thermal accessibility 500m with heat mitigation (1st of juli)

thermal accessibility 500m without heat mitigation (1st of juli)

thermal accessibility 500m with heat mitigation (1st of juli)

Fig. 7.6 assesment of the design goals

7.2 Assesment liveability conditions

Design goals	Assesment (– … +)	Methods
Physical liveabilty		
G 1. Accesibility of places for elderly during summer days	□ □ ■ □ □	cumulative thermal comfort accessibility of 500m
G 2. Continuous mitigating measures network of public spaces	□ □ □ ■ □	line segments: shadows, orientation,
G 3. Durable application of mitigation measures	□ □ □ ■ □	pattern flowchart: which mitigation elementsare there on which scale applicable
Social liveability		
G 4. Spatial mobility: investing in the environmental quality of walkable surfaces for elderly destination preferences	□ □ □ ■ □	important streets for shortest paths (towards needs of vulnerable groups within the urban evnironment)
G 5. Social mobility: destinations as social spaces which are thermal inviting for vulnerable groups	□ □ □ □ ■	layout of squares

Fig. 7.7 assesment of the design goals

The study emphasized the need to consider the unique needs and preferences of both elderly and children populations when designing public spaces. This includes providing adequate seating, lighting, and accessible amenities such as restrooms and water fountains. Furthermore, the study suggests that incorporating green infrastructure and nature-based solutions can also improve the overall quality of public spaces for both elderly and children, while enhancing the ecological sustainability of the area.

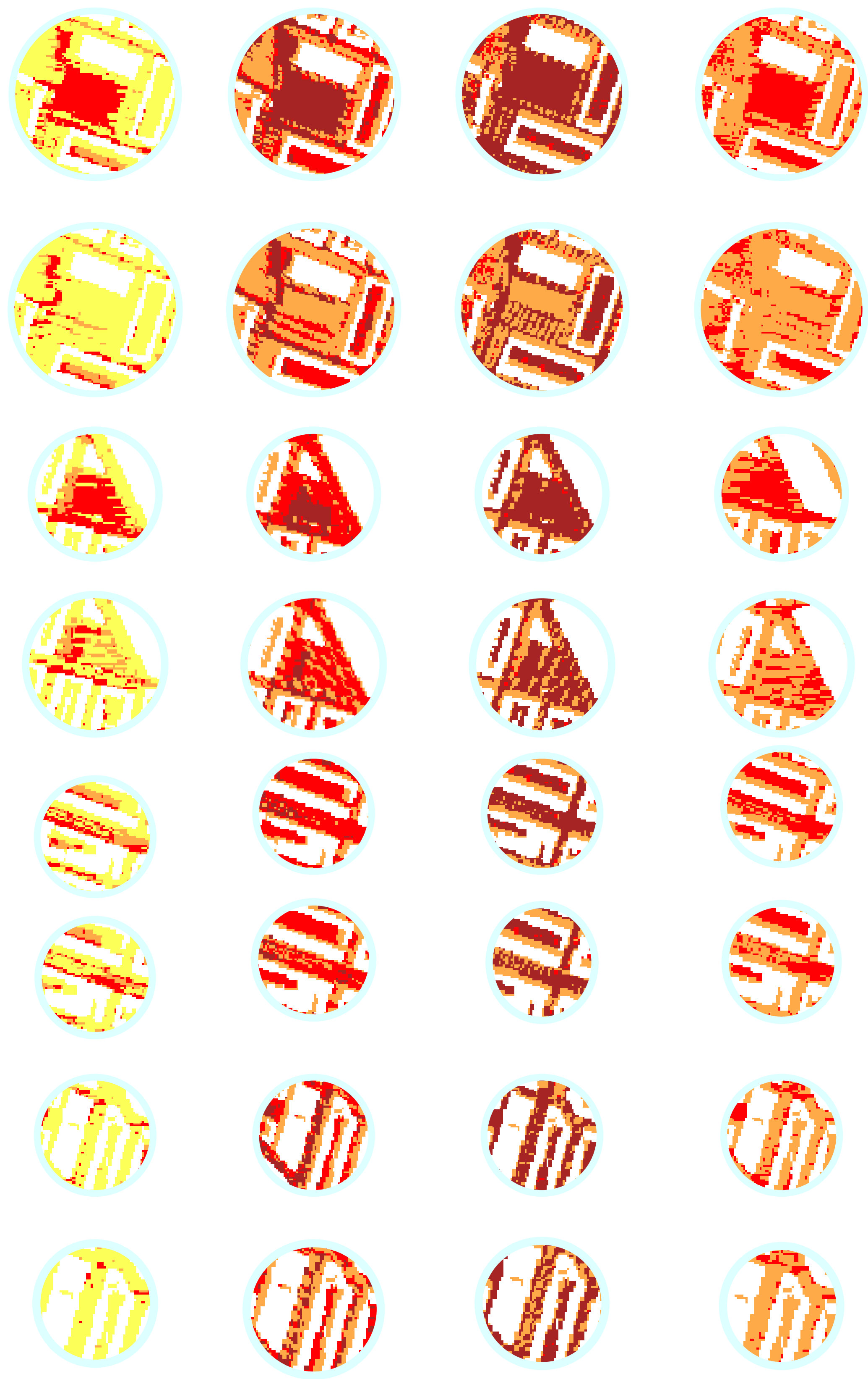


Fig. 7.8 Comparison of public spaces in heat mitigation measures

“Chapter 8 Conclusion and discussion

1. Transferability research
2. Limitations
3. Reflection
4. Conclusions Urbanism
5. Conclusion joint degree
6. Future research

”

8.1 Transferability

For the transferability of the research, we need to select other potential pre-war urban neighbourhoods with a high population density and cities with a growing elderly population at city level. This will qualify the neighbourhoods of PBL krachtwijken (2008). The qualifying streets. The applicability of the research could also be investigated for other target groups: such as commuters, travellers, etc.
It could also look more closely at the current neighbourhoods where senior citizens live and the need to renovate the public space environment. According to the current inventory, the most senior living areas are those with a garden city profile. These are less likely to qualify for heat mitigation measures due to the presence of greenery in the neighbourhood.

In this research the restorative enclosed gardens are one of the pillar of the design. If a new neighbourhood is depicted which is not a urban block, new strategies need to be discovered.

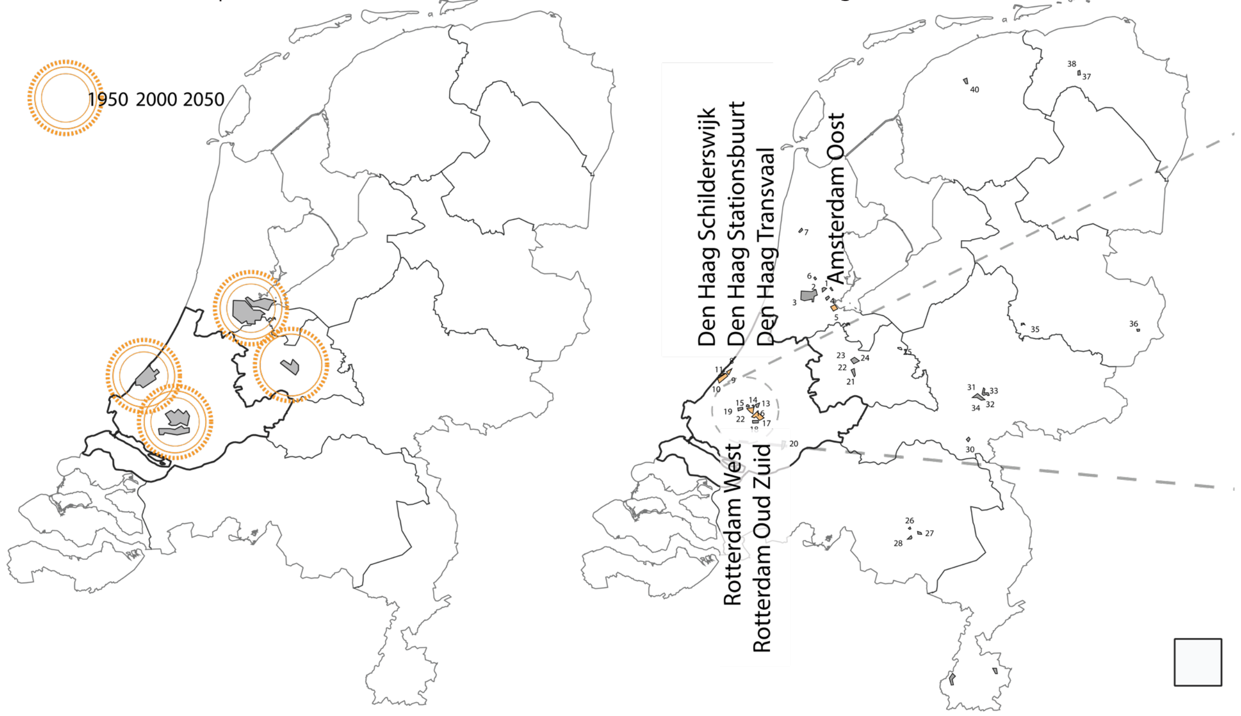


Fig. 8.1 PBL krachtwijken and population growth

8.2 Limitations

The aim of the research is to find ways to mitigate the harmful effects of heat in the public space of Bospolder Tussendijken. However, due to the urban structure of the area and limited public space, there are very few options for interventions. The available space is limited, and wind modeling principles further restrict interventions with wind in the urban form. Therefore, interventions involving shade forms are the only feasible option. Additionally, the input value of the principle is limited to 1-meter accuracy, which means that designers are restricted in their ability to test various landscape objects and are forced to consider bushes as grass.

The research focuses on heat mitigation, with a focus on the daily movements of people within the public space, which can have a negative impact on the health of vulnerable groups. However, research has shown that nightly heat exposure causes more health problems due to prolonged exposure to heat during the night. In Bospolder Tussendijken, 60 percent of households have energy label C or lower, which means that any interventions made should also involve housing and architectural changes.

One limitation of this research is that it only sheds light on the improvement of the durability of liveability to a small extent. Due to the heat, drought in the urban environment is likely to occur, which can cause problems for nature to grow properly. The research focuses on RGB and near-infrared moments on one summer day. For a more comprehensive approach, drought could be modelled by considering more moments in time.

8.3 Reflection

The graduation subject revolves around a strategy to reduce the temporality of heat stress in cities, creating a liveable environment for vulnerable groups in the specific context of Bospolder Tussendijken in Rotterdam. The first 7 questions are related to the requirements of reflection. This is about the relationship between your graduation project and your academic background, and next up the interplay between research and design. Also, the value of your way of working, using academic and social value of the research, and which ethical considerations are taken into account. Also, there is a focus on the transferability of the research. Next up, some personal input was required to reflect upon which are: what measures are taken in the urbanism design project to ensure inclusivity and equity for all members of the community and how does the project incorporate urban activities and occurrences that are intertwined with socio-political circumstances. Last but not least, some additional, non-required reflections are additional points of growth from this research.

What is the relation between your graduation project topic, the studio topic, your master track (A/U/BT, LA, MBE), and your master programme (MSc AUBS)?

This research involves a harmonious combination of Geomatics' evidence-based design to model the temporality of heat stress and the application of developing a strategy to mitigate heat stress in the public domain of the neighborhoods of Bospolder and Tussendijken in Rotterdam for Urbanism. This integrated approach is necessary to implement quantitative methods with real realization procedures in the urbanism realm.

What is the relationship between research and design?

The relationship between research and design is established by modeling the actual given environment and conducting literature research. Through literature research with different lenses on climate in terms of heat stress, social aspects, and mobility, criteria are established that must be met in the end through the proposed design principles.
Sketches embed the research in the test location. The approach for this research involved modeling the existing environment with input from experts in the field, such as Sytse Koopmans. Additionally, an approach is formulated that ensures both climate security in terms of heat stress and integration into the social context of vulnerable groups in the test area. The research explores aspects of liveability based on the inclusive aspect that designing for vulnerable groups in the neighborhood will result in better living quality.

How do you assess the value of your way of working (your approach, your used methods, used methodology)?

The two masters referred to in the text are two different methods used to design strategies for vulnerable groups. One of the methods is the heat mitigation model, which tests heat mitigation, the cumulative sum of heat to answer thermal accessibility, and building orientation/height to reveal implementation. The other method is a flowchart that helps to take action on mitigation measures, with each step dependent on the previous one and with different sub-questions.
To create a more comprehensive approach, this synthesis combines quantitative measures of modeling with qualitative measures from the literature.

What is the Academic Value of the Research?

The academic value of the research is enhanced by opening and parameterizing the code of Koopmans et al. (2020), which facilitates the generation, verification, and comparison of intermediate results. The integration of strategy development and methodology development in this research, along with the work of Marjolein van Esch (2015) and ongoing developments in the Dutch government, makes it an interesting study that addresses the daily needs of the elderly in public spaces during warm days. This study can be further expanded for other vulnerable groups such as children, and can also be extended to include other daily needs of the elderly, based on the work of Beira (2010).

What is the Social Relevance of the Research?

The societal value of the research is that it provides an open tool that can be used by a large audience to understand heat effects occurring in their neighborhood. This can facilitate a quicker dialogue and motivation for collaborative efforts with multiple stakeholders to develop mitigating measures for reducing heat stress. The societal value is in developing a strategy where redesigning the public domain can improve liveability for those living in it.

What are the ethical considerations of this research?

This design tries to serve an inclusive approach for human well-being and environmental aspects. However it solely promotes the walkability aspect of streets it is possible that people will be shortened on the use of further travel modes which are still relevant in the displacement methods of today, namely car transfer models.

What is the Transferability of the research?

The research findings can be immediately applied to neighborhoods that share similar characteristics as the pre-war urban neighborhoods with a high population density, such as the ones in PBL Krachtwijken. Also, cities with a growing elderly population can benefit from the same strategies. However, modifications need to be made to the methods used in this research to apply them to other locations or target groups.

For instance, it might be useful to consider commuters or tourists as relevant persons to study. Additionally, to apply the findings to other neighborhoods, it is essential to assess the composition of the urban fabric, including urban morphology attributes related to heat and greenery availability.

Moreover, the study suggests that it's vital to focus on the public space environment's renovation in neighborhoods where senior citizens reside. The research findings indicate that the most senior living areas are those with a garden city profile. These areas are less likely to qualify for heat mitigation measures due to the presence of greenery in the neighborhood. Therefore, the restorative enclosed gardens are one of the pillars of the design in this research.
If a new neighborhood is not an urban block, new strategies need to be discovered.

What measures are taken in the urbanism design project to ensure inclusivity and equity for all members of the community?

The project initially prioritized enhancing the urban environment through an inclusive design strategy, with inclusivity serving as the foundational principle guiding all subsequent actions and decisions. To ensure inclusivity and equity for all members of the community, extensive community engagement initiatives were undertaken to gather diverse perspectives and input, ensuring that the needs and preferences of all residents were considered. Additionally, the design process incorporated universal design principles to create spaces and amenities accessible to individuals of all ages, abilities, and backgrounds, fostering a sense of belonging and social cohesion within the community. Furthermore, targeted interventions were implemented to address socio-economic disparities, such as providing subsidies and resources to support marginalized groups and promote equal access to opportunities and resources throughout the neighborhood.

How does the project incorporate urban activities and occurrences are intertwined with socio-political circumstances?

This study advocates for a design approach that balances environmental sustainability with social considerations. To ensure practicality, the study assesses the costs and implementation timelines of the design strategy. As a result, the approach seeks a middle ground, prioritizing social solutions to promote a healthy environment, particularly for vulnerable groups, while also considering the financial feasibility of implementation in real-world scenarios. Therefore, the design is not overly extreme but rather attainable in the near future, representing a practical step toward fostering a more sustainable future for generations to come.
Heat stress visualization on a map highlights the urgent need to combat climate change. As the number of elderly individuals is expected to increase in the coming decades, there is a growing concern about the potential shortage of healthcare services that may arise as a result. This could lead to significant problems in the future if not addressed properly. The root cause of the issue lies in the manner in which we exploit our natural surroundings for our own needs. Harmful emissions, such as carbon dioxide emitted by transport by cars, are a major contributor to the fluctuations in our climate, which in turn result in a heightened risk to our health. This emphasizes the importance of reducing car emissions and use of cars. Therefore the prioritizing of sustainable transportation solutions should be promoted. The PET plugin is a vital communication tool that supports the

integration of electric vehicles, accelerates the adoption of cleaner transportation options, and creates healthier, sustainable cities.

Additional Points of Growth from this Research

Through this thesis, I have also learned to interact with various experts in the field, in-cluding academics from Wageningen, Sytse Koopmans, and Gert-Jan Steeneveld. The net-work event at HvA symposium "Hete Hangijzers" also contributed to the perspective of different municipalities and their approach to heat management in their cities. Addition-ally, discussions with researchers at the municipality of Rotterdam, such as Merel Schel-tema, and advisor Andre de Wit at Witteveen en Bos, provided an interesting interdisci-plinary mix of information alongside my interdisciplinary background in geomatics and urbanism on this issue.

Noteworthy in this report is also the alternation of research by design. Through my inter-action between evidence-based modeling of PET, there is a significant analytical aspect to this research. The design partly awaited the outcomes of the PET. Therefore, the design part entered the process later. This allowed me to discover firsthand how research by de-sign took place in the design.

8.4 Conclusion urbanism

This research attempted to answer the question

"How could a strategy be proposed that can mitigate heat stress temporality but also provide a liveable environment for vulnerable target groups in the context of Bospolder Tussendijken in Rotterdam, the Netherlands?".

The conclusion was made of the subquestions:

- What are the liveability requirements?
- What is the current state of liveability in Bospolder Tussendijken?
- How could Bospolder Tussendijken be improved on liveability?

Each of these questions will be answered seperately:

- what are the climate and social liveability requirements?
The physical liveability requirements were thermal accessible places, continous mitigating measures and durable mitigation measures depended on the practical implemenations and place specifications. For the social liveability a walkable environment should be promoted as well as inclusive design for vulnerable groups.

- What is the current state of liveability in Bospolder Tussendijken?
Bospolder Tussendijken have two parks nearby as social gathering spaces. Also the place equips of a weekly market Visserijplein. However everything is very paved and there is a lack of permeable surfaces in infrastructure. On a summer day a lot of places tend to be too hot.

- How could Bospolder Tussendijken be improved on liveability?
Based on the liveability research, it is split into improvements on social liveability and physical liveability. Physical liveability is divided in mitigating measures in the built enviornment such as evaporative surfaces, designing with the wind, designing with the sun and heat conscience. For the social liveability it is divided in creating places for vulnerable groups and promoting a walkable environment. Through the pattern language field and creating scenario's, the social and climate synergy is created.
By improving several streets with greenery, opening up social places for other groups and improving the marketsquare the goals are met.

Main conclusion of this research is multiple interpretations of liveability are required to make it a appropiate urban design plan. Several methods had their own purpose, the PET simulator model did calculate the heat mitigation, the shortest path created evidence for the most traversed walks for the destination points depicted, the r.walk tool did evaluate the thermal accessibility and the toolkit did develop the strategy and requirements of certain design interventions. According to Marjolein van Esch's research in 2015, integrating additional heat mitigation measures, next to solar radiation, and vegetation, measures or improving the wind in the PET simulator design could enhance its performance. As proposed in this research it is interesting for different stakeholders to engage in the conversation of heat mitigating measures in urban environments. Because every intervention in heatmitigation will help and we must act fast if we want to preserve the quality of life in urban neighborhoods now and in the future.

8.5 Conclusion joint degree research

The aim was to develop an reproducable spatial-temporal tool for indicating thermal comfort in urbanized areas in the Netherlands, as well as to create a strategic design for the context-specific area for Bospolder Tussendijken in Rotterdam. The research was part of a cycle of 3 steps (see figure 8.1). First the development of the PET simulator tool which made it possible to have reproducability for third-party use. Second it created the PET heat stress maps for analysis for the urban design. Third step were the urbanism requirements for design and the creation of the design. Third part was the reflection for further development of the PET tool and future work.
The PET simulator tool helped eventually to model the heat stress in the application case study of Rotterdam. Through the analysis of the input datasets, methods and results, it emerged that the methods should be publicly available with integration of computational environment. A plugin has been created in QGIS to open the Python code to a larger audience. A sensitivity analysis has been carried out for the wind modulation. Ultimately, the PET was made readable and applied to the accessibility of the area.
For designing the urbanism part formulated liveability requirements for design implementations. From the literature liveability is subdivided in physical liveability and social liveability. The physical liveability is accessibility should be guaranteed despite the increase of days above 25 degrees for vulnerable groups. Next to that the continuity of the mitigation measures are the most effective since it is scale dependent. Also to keep the mitigating effects functioning it is important that the mitigation measures are durable depended on the practical implemenations. To make it social appropiate a walkable environment should be supported and enough social spaces should be available for vulnerable groups.
Thirdly the tool evaluated the design implementations on their effectiveness which leads to additional research of the design and future work. At the moment shadow is the most contributing factor for heat mitigation. Future work to improve heat mitigation is the integration of additional heat mitigation measures, next to solar radiation, and vegetation, measures or improving the wind in the PET simulator design could enhance its performance. In addition, PET simulator should be better design and analysis integrated without too much effort for modifying the input files for the designer, in order to make it more third-party use proof.
The plugin has great prospects for future potential applications in modeling PET such as night urban heat island simulations and improving communication among stakeholders. The research aligns with field geomatics and urbanism, using GIS and spatial analysis techniques to address urban environmental challenges. The project contributes to understanding the health implications of urban micro climates and the potential effects of temperature increases, informing policymakers and urban planners about action for creating healthy and sustainable urban environments.

Chapter 8 | Conclusions

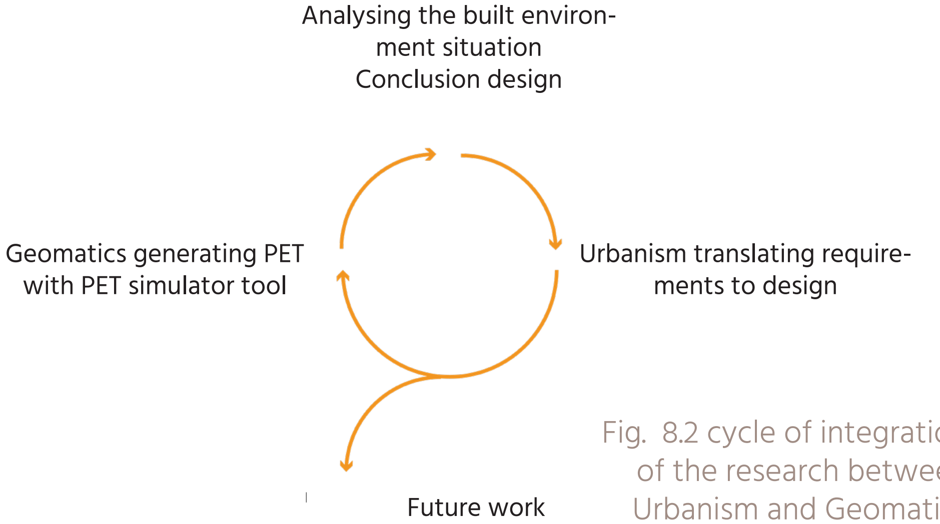


Fig. 8.2 cycle of integration of the research between Urbanism and Geomatics

8.6 Future research

This study raises new research questions.
It would be valuable to explore different urban typologies and their potential impacts. Additionally, in terms of design, it would be beneficial to experiment with building heights to address extreme wind variations. However, due to the lack of precise wind modeling, the design couldn't be thoroughly tested. The modifications in the design are currently focused on altering the RGB and Infrared layers, creating shadows through buildings and trees, and addressing the integration of reflective surfaces, which require improvement.

Given the modifications to the input layers, understanding the other thesis is necessary. Consequently, the application for designing and testing is limited to third-party use. A more user-friendly interface, potentially through sketching, could enhance the usability of design practices.

To gain a better understanding of how people choose walking routes in hot urban environments, future research could investigate to what extent individuals opt for cooler routes and the variables influencing their choices. This could provide insight into whether people base their decisions on their urban environment. In this research, the shortest path is utilized as an evidence-based method for choosing certain routes over others for redevelopment, which may involve route-tracking techniques.

‘‘Bibliography‘‘

Bibliography

Arcgis (2023) Arcgis voorzieningspunten. Retrieved from https://hub.arcgis.com/datasets/esrinl-content::punten-9/explore?filters=eyJzaG9wIjpbInN1cGVybWFya2V0Il19&location=52.083127%2C5.116641%2C14.71

AlleCijfers.nl. (2024b, February 16). AlleCijfers.nl. https://allecijfers.nl/buurt/bospolder-rotterdam/

Beira, C. G. (2010) OUD WORDEN IN OUD CHARLOIS: onderzoek naar cultuurspecifieke levensloopbestendige woonconcepten in binnenstedelijke vernieuwingsplannen. Retrieved from https://www.veldacademie.nl/pdf.html?load=/img/Document/cc/fa/ccfae287-c566-49ee-b770-0dae94e11c0e/Onderzoek%20Oud%20worden%20in%20Oud%20Charlois%20Carlos%20Galhofo%20Beira_LQ.pdf

Bernard, Thomas E., and Kenney, Larry W. Prevention and Manaaement of Hot Weather-Related Illness in Lona-Tem Care Facilities for the Elderly. (abridged); Ontario: Min. of Community and Social Services and Min. of Health; Jun. 1989.

Berghauser Pont, M., & Olsson, J. (2017). Typology based on threedensity variables central to Spacematrix using cluster analysis. Proceedings 24th ISUF 2017 - City and Territory in the Globalization Age,1–13. https://doi.org/10.4995/isuf2017.2017.5319

Bhatia, N. (1997) Mitigation of hyperthermia in outdoor environments for elderly. Retrieved by https://hdl.handle.net/10214/19991

Calvin, K. (2015, September 29). Hyperthermia: too hot for your health. National Institutes of Health (NIH). https://www.nih.gov/news-events/news-releases/hyperthermia-too-hot-your-health-1

Campbell, I. (2018) Body temperature and its regulation. Anaesthesia and Intensive Care Medicine, 19(9):507–512.

CAS (nd.) Retrieved from https://klimaatadaptatienederland.nl/overheden/life-ip-klimaatadaptatie/projecten/bewustwording-urgentiebesef/lokaal-hitteplan-gemeente-rotterdam/

CAS(nd.) Hitte bijsluiter. Retrieved from https://klimaatadaptatienederland.nl/stresstest/bijsluiter/hitte/

CAS (nd.) Klimaateffectenatlas. Retrieved from https://www.klimaateffectatlas.nl/nl/

Charalampopoulos, I., & Santos Nouri, A. (2019). Investigating the Behaviour of Human Thermal Indices under Divergent Atmospheric Conditions: A Sensitivity Analysis Approach. Atmosphere, 10(10), 580. MDPI AG. Retrieved from http://dx.doi.org/10.3390/atmos10100580

Chen, W., Albert, C., & Von Haaren, C. (2018). The elderly in green spaces: Exploring requirements and preferences concerning nature-based recreation. Sustainable Cities and Society, 38, 582–593. https://doi.org/10.1016/j.scs.2018.01.023

DAT.mobility, Kandar, Mobidot (2019) Retrieved from https://www.verkeerskunde.nl/artikel/datmobility-brengt-veranderende-mobiliteitspatronen-in-kaart

Daanen, H. (2023) Hete hangijzers: introduction lecture. City Net Zero Amsterdam. University of Applied sciences of Amsterdam, The Netherlands. Retrieved from https://www.hva.nl/city-net-zero/gedeelde-content/nieuws/nieuwsberichten/2023/07/terugblik-hitte-in-de-stad-symposium.html

Deltares. (n.d.). CRC Tool - Climate Resilient Cities | retrieved from https://www.deltares.nl/en/software-and-data/products/crc-tool-climate-resilient-cities

Dunne, A., Raby, F. (2013) Speculative Design: Design, Fiction, and Social Dreaming. Cambridge, MA: mit Press.

ENVI-met. (2024, January 3). ENVI-met high-resolution 3D modeling for Climate Adaption. https://www.envi-met.com/

Escobar, A. (2018) designs for the pluriverse. EAN 9780822371052

Fiala, D. (2012) UTCI-Fiala multi-node model of human heat transfer and temperature regulation. International journal of biometeorology, 56:429–41.

Friedmann, J. The uses of planning theory: A bibliographic essay. J. Plan. Educ. Res. 2008, 28, 247–257.

Future Earth, The Earth League, WCRP (2023). 10 New Insights in Climate Science 2023/2024. Stockholm https://doi.org/10.5281/zenodo.10034364

Girardello M. and Feyen L.(2020) JRC technical report: Global warming and human impacts of

Gehl Architects (2009) Downtown Seattle: public space and public life. Retrieved from https://issuu.com/gehlarchitects/docs/565_seattle_pspl/49

Gehl, J. (2011). Life between buildings: Using Public Space.

Gehl. (2022, August 18). Framework - Inclusive Healthy Places. Inclusive Healthy Places. https://ihp.gehlpeople.com/framework/

Gemeente Rotterdam (2022) Wijkprofiel. Retrieved from https://wijkprofiel.rotterdam.nl/nl/2022/rotterdam/delfshaven/tussendijken

Gemeente Rotterdam (2019) wijkagenda 2019-2022 Bospolder en Tussendijken Veerkrach-

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tige bewoners Inclusieve stad. Retrieved from https://www.watdoetdegemeente.rotterdam.nl/omissie2019/wijken/wijkagenda-bospolder-tuss/Wijkagenda-Bospolder-en-Tussendijken-template.pdf

Gemeente Rotterdam (n.d.). SBI INFRA trees https://diensten.rotterdam.nl/arcgis/rest/services

Gemeente Rotterdam (nd) Rotterdams weerwoord. Retrieved from https://rotterdamsweerwoord.nl/

Gemeente Rotterdam (nd) Subsidie groenblauwe schoolpleinen aanvragen. (https://www.rotterdam.nl/subsidie-groenblauwe-schoolpleinen-aanvragen

Gemeente Utrecht (nd) Procedure opheffen parkeerplaatsen gefiscaliseerd gebied

GEOFABRIK (n.d.). https://www.geofabrik.de/

GGD (nd A) Risicogroepen Richtlijn Hitte Gezondheid. Retrieved from https://www.rivm.nl/ggd-richtlijn-mmk-hitte-gezondheid

Goldsmith, Selwyn, 2000, Universal Design: a manual of practical guidance for architects,Architectural Press, Oxford

Guardian (2023) Spain braced for record April temperature of 39C as extreme heat causes misery. Retrieved from https://www.theguardian.com/world/2023/apr/27/spain-braced-for-record-april-temperature-of-39c-as-heatwave-causes-misery

Hancock, Trevor & Bezold, Clement. (2017) Futures Thinking and Healthy Cities. 10.1007/978-1-4939-6694-3_19.

Havenith, G. (1999) Heat balance when wearing protective clothing. Annals of Occupational Hygiene, 43(5):289–296, 1999. DOI: https://doi.org/10.1016/S0003-4878(99)00051-4
heat and cold extremes in the EU retrieved from: https://joint-research-centre.ec.europa.eu/system/files/2020-05/pesetaiv_task_11_heat-cold_extremes_final_report.pdf

Hiemstra, J. (2021) Stadswerk Webinar Klimaateffectief groen en de toekomstige stad. Retrieved from https://www.stadswerk.nl/documenten/handlerdownloadfiles.ashx?idnv=1991171

Hofman, J. (2022). Keep Your Hague Cool: Mitigating heat stress and the urban heat island effect through urban design. http://resolver.tudelft.nl/uuid:17f937a9-b5e5-4fde-b149-4b1d-c004ea51

Hofstad, H. (2012). Compact city development: High ideals and emerging practices. European Journal of Spatial Development, 1–23. https://www.researchgate.net/publication/288447789_Compact_city_development_High_ideals_and_emerging_practices

HVA & Kuiper compagnons (2020) De hittebestendige stad: coolkit. Toolkit voor ontwerpers van de buitenruimte. Retrieved from https://www.hva.nl/kc-techniek/gedeelde-content/contentgroep/klimaatbestendige-stad/resultaten/coolkit.html

HVA & Kuiper compagnons (2020) De hittebestendige stad: coolkit. Toolkit voor ontwerpers van de buitenruimte. Retrieved from https://www.hva.nl/kc-techniek/gedeelde-content/contentgroep/klimaatbestendige-stad/resultaten/coolkit.html

HvA (2023), 30th of June. Hete hangijzers. City Net Zero Amsterdam. University of Applied sciences of Amsterdam, The Netherlands.

Ilmer B.V. Internet, Applications, Media www.ilmer.nl. (n.d.). Handleiding Windhinder en Windgevaar | Kennisbank BWTinfo.nl. https://www.bwtinfo.nl/documenten/2023/6/handleiding-windhinder-en-windgevaar

IOWA University (nd) Windrose. Retrieved from https://mesonet.agron.iastate.edu/sites/locate.php

IPCC (2023) CLIMATE CHANGE Synthesis Report Summary for Policymakers

Jong Delfshaven (nd) Initiatieven op de kaart. Retrieved from https://www.verhalenvanbotu.nl/basiskaart/

Kadaster (2022) Kadastrale kaart. Retrieved from https://kadastralekaart.com/buurten/bospolder-BU05990321

Kluck et al. (2017) Klimaat past ook in uw straatje. Retrieved from https://klimaatadaptatienederland.nl/@162044/voorbeeldenboek-0/

Kluck, J., Klok, L., Solcerová, A., Kleerekoper, L., Wilschut, L., Jacobs, C., & Loeve, R. (2020) De hittebestendige stad, Een koele kijk op de inrichting van de buitenruimte, Hogeschool van Amsterdam.

Kluck, J., Loeve, R., & Kleerekoper, L. (2017). Het klimaat past ook in uw straatje: Klimaatbestendige inrichting voor karakteristieke straten. TVVL Magezine, 2017(3), 1-4.

KNMI (2015) Klimaatbrochure 2014. Retrieved from https://cdn.knmi.nl/knmi/pdf/bibliotheek/klimaatbrochures/Brochure_KNMI14_NL.pdf

Koopmans, S., Heusinkveld, B.G., Steeneveld, G.J. (2020) A standardized Physical Equivalent Temperature urban heat map at 1-m spatial resolution to facilitate climate stress tests in the Netherlands. DOI: 10.1016/j.buildenv.2020.106984

Koudouris, G., Dimitriadis, P., Iliopoulou, T., Mamassis, N., & Koutsoyiannis, D. (2017). Investigation on the stochastic nature of the solar radiation process. Energy Procedia, 125, 398–404. https://doi.org/10.1016/j.egypro.2017.08.076

KTH School of Architecture, Chalmers School of Architecture (SMoG) and Spacescape AB. Alexander Ståhle, Lars Marcus, Daniel Koch, Martin Fitger, Ann Legeby, Gianna Stavroulaki, Meta Berghauser Pont, Anders Karlström, Pablo Miranda Carranza, Tobias Nordström (nd) PST tool: Place synthax tool. Derived from https://www.smog.chalmers.se/pst

KvK (kennis voor klimaat) (2011) Hittestress in Rotterdam. Retrieved from https://www.publicspaceinfo.nl/media/uploads/files/KENNISVOOR_2011_0001.pdf

Lenzholzer, S. (2015) Weather in the city. How design shapes the urban climate. Page 69. Published by Nai010 publishers ISBN 9789462081987

Lindberg F, Grimmond CSB, Gabey A, Huang B, Kent CW, Sun T, Theeuwes N, Järvi L, Ward H, Capel- Timms I, Chang YY, Jonsson P, Krave N, Liu D, Meyer D, Olofson F, Tan JG, Wästberg D, Xue L, Zhang Z (2018) Urban

Multi-scale Environmental Predictor (UMEP) - An integrated tool for city-based climate services. Environmen tal Modelling and Software.99, 70-87 https://doi.org/10.1016/j.envsoft.2017.09.020

Lungman, T. (2013) Cooling cities through urban green infrastructure: a health impact assessment of European cities. DOI:https://doi.org/10.1016/S0140-6736(22)02585-5

Mallick et al. (2023). How do migration decisions and drivers differ against extreme environmental events? Environmental Hazards, 22(5), 475–497. doi: 10.1080/17477891.2023.2195152

Marcum, C.S. (2013) age differences in daily social activities. Published in final edited form as: Res Aging. 2013 September ; 35(5): 612–640. doi:10.1177/0164027512453468

Marcus, L., & Colding, J. (2011). Towards a Spatial Morphology of Urban Social-Ecological Systems. Presented at the 18th International Seminar on Urban Form. Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-53317

Marcus, L.H., Giusti, M., Barthel, S. (2016), Journal of Urban Design 21(4):1-14, Retrieved from DOI:10.1080/13574809.2016.1184565

Martini, F.H. , Bartholomew, E.F. , Poelaert, I. , Vandamme, P. (2017) Anatomie en fysiologie, een inleiding: College editie. EAN: 9789043035873

Martin, A., McGuire, S., & Sullivan, S. (2013). Global environmental justice and biodiversity conservation. The Geographical Journal, 179(2), 122–131. https://doi.org/10.1111/geoj.12018

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Maslow, A.H. (1943) A Theory of Human Motivation. Originally Published in Psychological Review, 50, 370-396. Retrieved from https://www.researchhistory.org/2012/06/16/maslows-hierarchy-of-needs/

Massey, D. For Space; Sage Publications Inc.: Thousand Oaks, CA, USA, 2005. [Google Scholar]

Matzarakis, A. & Amelung B. (2008) Seasonal Forecasts, Climatic Change and Human Health. Physiological Equivalent Temperature as Indicator for Impacts of Climate Change on Thermal Comfort of Humans. Published by Springer Netherlands, Dordrecht, Netherlands. DOI: 10.1007/978-1-4020-6877-5_10

Mayer, H. & Höppe, P. (1987). Thermal comfort of man in different urban environments, Theor. Appl. Clim. 38, 43–49
McCullough, M. (2004) Digital Ground. Cambridge, MA: mit Press.

Meyer, H., de Jong, F., Hoekstra, M. (2012) Het ontwerp van de openbare ruimte.

Michailidou, G. (2019) The influence of the visible views on cyclists' route choices. Retrieved from http://resolver.tudelft.nl/uuid:35465053-ec78-4b9e-a4c0-362cb50b7601

Millyard, A., Layden, J.D., Pyne, D. B., Edwards, A. M., Bloxham, S. R. (2020) Impairments to Thermoregulation in the Elderly During Heat Exposure Events. Gerontol Geriatr Med. 2020 Jan-Dec; 6: 2333721420932432. Published online 2020 Jun 15. doi: 10.1177/2333721420932432

Ministerie van Algemene Zaken. (2022, December 30). Programma langer thuis. Rapport | Rijksoverheid.nl. https://www.rijksoverheid.nl/documenten/rapporten/2018/06/15/programma-langer-thuis

Ministerie van Infrastructuur en Waterstaat. (2023, January 18). Het wijdverbreide autobezit in Nederland. Publicatie | Kennisinstituut Voor Mobiliteitsbeleid. https://www.kimnet.nl/publicaties/publicaties/2022/02/22/het-wijdverbreide-autobezit-in-nederland

Ministerie van Volksgezondheid (2018) Programma langer thuis. Retrieved from https://www.rijksoverheid.nl/documenten/rapporten/2018/06/15/programma-langer-thuis
MIT(n.d.) Urban microclimate. Retrieved from https://urbanmicroclimate.scripts.mit.edu/umc.php

Molster, A. (2020). Loop!: tien ontwerpprincipes voor een loopvriendelijke omgeving.

Morris, A., Patel, G. (2023) Heat stroke. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK537135/ national library of Medicine.

Naumann, G., Russo, S., Giuseppe, F., Dolores, I. R., Giovanni, F., Girardello, M., & Feyen, L.

(2020). Global warming and human impacts of heat and cold extremes in the EU. Report Number: EUR 29959 ENAffiliation: European Commission. https://doi.org/10.2760/47878

NBTC-NIPO (2018) 2018 - Continuiteits VrijeTijdOnderzoek (CVTO) basisrapport Inzicht in de uithuizige vrijetijdsbesteding van Nederlanders

Nellen en schuurman (2023) klimaatadaptie bestaande stad. maatregelen en kosten wijktypologie. Retrieved from https://pzh.notubiz.nl/document/13609370/1/230913+Klimaatadaptatie+bestaande+stad

Nuijten, D., Dwingend vergroenen: Onderzoek naar de toepassing van het richtgetal van 75 m2 groen per woning uit de Nota Ruimte en de relatie met de kwaliteit van het groen in de stad. Afstudeerscriptie Sociaal-Ruimtelijke Analyse, SAL-80436, Wageningen Universiteit, 2008

Nüst, D., Ostermann, F., Sileryte, R., Hofer, B., Granell, C., Teperek, M., Graser, A., Broman, K., Hettne, K., Clare, C., Belliard, F., and Wang Y. (December 2020) AGILE Reproducible Paper Guidelines. Retrieved from https://doi.org/10.17605/OSF.IO/CB7Z8

Pacione, M. (2003b). Urban environmental quality and human wellbeing—a social geographical perspective. Landscape and Urban Planning, 65(1–2), 19–30. https://doi.org/10.1016/s0169-2046(02)00234-7

Palmboom, F. (1995) Rotterdam, verstedelijkt landschap. Uitgeverij 010.

PBL Planbureau Voor De Leefomgeving (2012) Retrieved from https://www.pbl.nl/publicaties/woongedrag-tijdsbesteding-en-verplaatsingsgedrag-van-actieve-ouderen

PBL Planbureau voor de leefomgeving. (2016, January 24). Woongedrag, tijdsbesteding en verplaatsingsgedrag van actieve ouderen.

PBL/CBS (2022) Regionale bevolkings- en huishoudensprognose. Retrieved from https://themasites.pbl.nl/o/regionale-bevolkingsprognose/#:~:text=Begin%202021%20is%20de%20omvang,in%20de%20werkzame%20leeftijden%20verwacht.

Planbureau Voor De Leefomgeving (2022, June 24). RUDIFUN 2022: Ruimtelijke dichtheden en functiemenging in Nederland. Retrieved from https://www.pbl.nl/publicaties/rudifun-2022-ruimtelijke-dichtheden-en-functiemenging-in-nederland

PDOK. (n.d.). https://www.pdok.nl/

Peek, G.J. and M. van Hagen (2002) Creating synergy in and around stations: three strategies in and around stations, Transportation Research Record, 1793, 1–6.
Perry, C.A. (1929a) The Neighborhood Unit: A scheme of arrangement for the Family Life Community. In A Regional Plan for New York and Its Environs, Volume vii. New York: 1929.

Périard, J. D., Travers, G. J. S., Racinais, S., & Sawka, M. N. (2016). Cardiovascular adaptations supporting human exercise-heat acclimation. Autonomic Neuroscience, 196, 52–62. https://doi.org/10.1016/j.autneu.2016.02.002

Pötz, H. (2016b). Green-blue grids.

Pozoukidou, G., & Chatziyiannaki, Z. (2021). 15-Minute City: Decomposing the New Urban Planning Eutopia. Sustainability, 13(2), 928. https://doi.org/10.3390/su13020928

Province of South Holland (nd) Begroten van klimaatadaptatie – Factsheet meerkosten bij benutten van meekoppelkansen retrieved from https://www.zuid-holland.nl/publish/pages/30373/begrotingshulp_klimaatadaptatie.pdf

RIVM (2020) Ontwikkeling Standaard Stresstest Hitte. Retrieved from https://www.rivm.nl/bibliotheek/rapporten/2019-0008.pdf

RIVM (nd) nationaal hitteplan https://www.rivm.nl/hitte/nationaal-hitteplan

Robbins, A.S. 'Hypothenia and Heat Stroke: Protecting the Elderiy Patient."
Geriatrîcs. Vol. 44, No. 1 ; Pg. 73-80: Jan. 1989.

RVO (2013) Klimaatadaptatie - financiering. Retrieved from https://infographics.rvo.nl/klimaatadaptatie/financiering/#mii-rvokaf-financieringsconstructies-subsidies

Samuelsson, K., Barthel, S., Colding, J., Macassa, G., & Giusti, M. (2020). Urban nature as a source of resilience during social distancing amidst the coronavirus pandemic. Digitala Vetenskapliga Arkivet, 1–6. https://doi.org/10.31219/osf.io/3wx5a

Schulze & Grassov (2015) Parameters for public space. Retrieved from https://www.schulzeplusgrassov.com/planning-toolboxes

Sim, D. (2019). Soft City: Building Density for Everyday Life. Island Press.

Smith, M.K. Neighborhoods and regeneration: Theory, practice, issues. In The Encyclopaedia of Informal Education; INFED: London, UK, 2011; Available online: https://infed.org/mobi/neighborhoods-and-regeneration-theory-practice-issues/ (accessed on 12 September 2020).

Snel, N. (2011). Buitenspelen : kwaliteit van de speelomgeving in de eigen buurt . TNS NIPO / Jantje Beton

Soja, E. (2010) Seeking spatial justice. EAN 9781452915289

Soja, E. (2010) Seeking spatial justice. EAN 9781452915289

Spek, P. (1986). Rotterdam bouwt een metro : kwart eeuw metro. Dienst van Gemeentewerken Rotterdam

Stadswerk Webinar Klimaateffectief groen en de toekomstige stad retrieved from https://www.stadswerk.nl/documenten/handlerdownloadfiles.ashx?idnv=1991171

Stichting CAS (2018) The weather in perspective of climate change: first half of 2018. Retrieved from https://klimaatadaptatienederland.nl/actueel/actueel/nieuws/2018/weer-1helft-2018/#:~:text=Gemiddeld%20telt%20de%20Bilt%20nu,dit%20er%2033%20tot%2047

Tauw (2020) Handelingsperspectief hittestress: op zoek naar koele plekken in de stad. Retrieved from https://www.tauw.nl/nieuws/handelingsperspectief-hittestress-op-zoek-naar-koele-plekken-in-de-stad.html

Tauw (2020) Handelingsperspectief hittestress: op zoek naar koele plekken in de stad. Retrieved from https://www.tauw.nl/nieuws/handelingsperspectief-hittestress-op-zoek-naar-koele-plekken-in-de-stad.html

TNO (n.d.) Ondergrondmodellen | DINOLoket. Retrieved from https://www.dinoloket.nl/ondergrondmodellen/kaart

United Nations (2018) 68% of the world population projected to live in urban areas by 2050, says UN. Retrieved from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

UNDP Climate Promise (2023) What is climate security and why is it important? (n.d.). Retrieved from https://climatepromise.undp.org/news-and-stories/what-climate-security-and-why-it-important#:~:text=Climate%20security%20refers%20to%20the,of%20social%20tensions%20and%20instability

Unicef (2023) Parental guide for a very hot summer. Retrieved from https://www.unicef.org/serbia/en/parental-guide-very-hot-summer

Van der Hoeven, F.D. & Wandl, A.. (2015). Hotterdam: Hoe ruimte Rotterdam warmer maakt, hoe dat van invloed is op de gezondheid van inwoners, en wat er aan te doen is. TU Delft Repositories. http://resolver.tudelft.nl/uuid:75517ba0-8c41-41dc-a67e-1f8033851f98

Van der Hoeven, F.D., Wandl, A. (2015) Hotterdam: hoe ruimte Rotterdam warmer maakt, hoe dat van invloed is op de gezondheid van inwoners, en wat er aan te doen is

van Esch, Marjolein (2015) Designing for the microclimate. A framework for a design-decision support tool for the dissemination of knowledge on the urban microclimate to the urban design process. Retrieved from DOI:https://doi.org/10.7480/abe.2015.6.905

van Esch, Marieke (2024) From thermal comfort to heat mitigation necessity: An reproducable QGIS plugin for calculating the physiological equivalent temperature and testing mitigating measures in Dutch cities. Derived from (add tudelft repository link)

Van Hall, E.F., Maas, R.J.M., Limaheluw J., Betgen, C.D. 2021 Mondiaal klimaatbeleid: gezondheidswinst in Nederland bij minder klimaatverandering. RIVM 2020-0200

Van Marken Lichtenbelt, W. D., Frijns, A. A., Van Ooijen, M. J., Fiala, D., Kester, A. M., & Van Steenhoven, A. A. (2006). Validation of an individualised model of human thermoregulation for predicting responses to cold air. International Journal of Biometeorology, 51(3), 169–179. https://doi.org/10.1007/s00484-006-0060-9

van Loon, F., Tillie, N., Kleerekoper, L., Hooimeijer, F. (2016) BK3TE4 reader techniek van het stadslandschap

van Milgen, A. (2016, April). URBAN HEAT ISLANDS AND URBAN CONFIGURATION. Wageningen University. https://edepot.wur.nl/400093

Veldacademie (2020) Connect Botu. Bospolder-Tussendijken: an exploration of the opportunities that conne t the residents of Botu to labour in Merwe-Vierhavens and Spaanse Polder.

Veldacademie (2021) GEMEENSCHAPSVEERKRACHT IN ROTTERDAMSE WIJKEN TIJDENS DE CORONACRISIS Vijf inzichten uit Bospolder-Tussendijken retrieved from https://www.veldacademie.nl/nieuws/2021/09/gemeenschapsveerkracht-in-rotterdamse-wijken-tijdens-de-coronacrisis

Vereniging Deltametropool, Lola landscape architects (2018) Urban nature map. Retrieved from https://deltametropool.nl/publicaties/de-stadsnatuurkaart-van-rotterdam/

Verlinde, J., Visser, M., Knotters, J. & Pieneman, J. i.s.m. Defacto urbanism, Nelen & Schuurmans en het programmateam Rotterdams WeerWoord. (2023) Rotterdams Weerwoord. Uitvoeringsagenda. Retrieved from https://rotterdamsweerwoord.nl/content/uploads/2023/06/Uitvoeringsagenda-2023-2026.pdf

Waard, N.D. (2021). Development of a parametric PET assessment model for the early design stage and evaluation of building-related heat mitigation measures for extreme heat events in the Netherlands. TU Delft Repositories. http://resolver.tudelft.nl/uuid:6c5cdb1c-29cf-4ecc-a3a7-b11f595179bb

World Health Organisation (WHO) (2023) What is a healthy city? Derived from https://www.who.int/europe/groups/who-european-healthy-cities-network/what-is-a-health-city#:~:text=A%20healthy%20city%20is%20one,developing%20to%20their%20maximum%20potential

Appendix

Appendix A. Pattern toolkit elaborated
Appendix B. Shadow on buffered street segments
Appendix C. NDVI and trees
Appendix D. Attraction Betweeness destinations
Appendix E. costs mitigating measures
Appendix F. Tree species and their potential
Appendix G. Attraction distance 500 m
Appendix H. cost mitigating measures (nellen & Schuurman, 2020)

Appendix A. Pattern toolkit elaborated

This is the extended version of patterns showed in chapter IV. The clusters are based on the three design principles: walkability (W), Mitigating heat (MH) and Social places for elderly (SP). This is formed with a hypothesis in the context. Also it includes some conditions of implementations. The literature is shown as well as the related toolkit patterns.
The costs per implication are retrieved from Green Blue grids book from Hiltrid Potz (2016). Whenever there are specific numbers for transforming the street Factsheet climate adaptation from the province of South Holland is used (Province South Holland, 2021; HVA, 2017; Nelen en Schuurmans, 2021).

CLUSTER.CODE TITLE

Mitigating effects

Hypothesis: description

Design principle related

Context: description

Practical implication:
cost
multifunctional
implementation speed
ownership

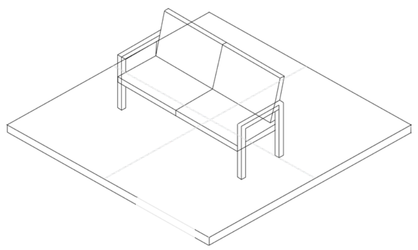
Literature: xx

Relations: CLUSTER.CODE etc.

IMAGE FROM:

SP.1 A bench in the shade

Mitigating effects



Hypothesis: creating resting spots for el-derly during a hot day

Design principle related

Context: Older people tend to overheat more easily than other groups. Therefore, it is good to have more resting places in the network where people can rest. This is also a beneficial element for the whole year.

Practical implication:

cost
multifunctional
implementation speed
ownership

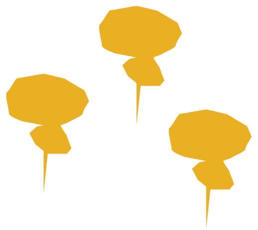
Literature: Bhati (1998), Lenzholzer (2018)

Relations

IMAGE FROM: https://english.elpais.com/science-tech/2023-06-21/a-review-of-studies-with-22-million-people-shows-that-loneliness-increases-the-risk-of-dying.html#

SP.2 Park with trees

Mitigating effects



Hypothesis: creating more shade places to stay increases social and climate live-ability

Design principle related

Context: larger spots of evaporation can help cool the city at this point. It also helps as a cool area for people to congregate as a refuge from the heat.

Practical implication:

cost
multifunctional
implementation speed
ownership

Literature: Potz (2016)

Relations: MH.18

IMAGE FROM: taken by Author, London

SP.3 Opening up public spaces

Mitigating effects

Hypothesis: opening up public spaces can enlarge the service areas of certain public spaces accessibility

Design principle related

Context: creating flexibility in the openness of public and private spaces can help to create places of refuge from the heat in the network in dense urban environments. It also helps to have an adapted behaviour in the ownership of the semi-public space, having more connection with the neighbourhood.

Practical implication:

cost
multifunctional
implementation speed
ownership

Literature: Sim (2019), Gehl (2011)

Relations:

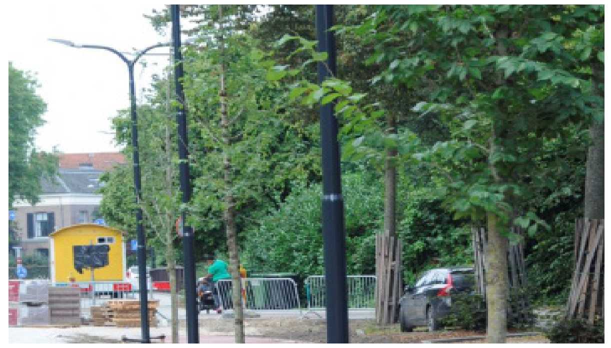
IMAGE FROM: Image taken by Author

MH.1 Tree line

Mitigating effects

Hypothesis: improves the evaporative areas

Design principle related



Context: Rather than a single tree, a continuous line of trees will dissipate heat better mitigate heat better.

Practical implication:

cost
multifunctional
implementation speed
ownership

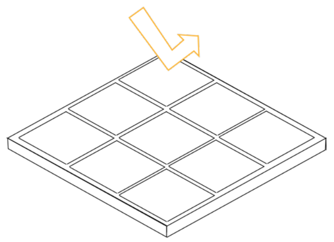
Literature: Potz (2016)

Relations: MH.18

IMAGE FROM: Image taken by Author

MH.2 Reflective material

Mitigating effects



Hypothesis: creating resting spots for elderly during a hot day

Design principle related

Context: reflective material has a higher albedo and will reflect sunrays back to the atmosphere. This could only be applied on pedestrain sidewalks.

Practical implication:
cost
multifunctional
implementation speed
ownership

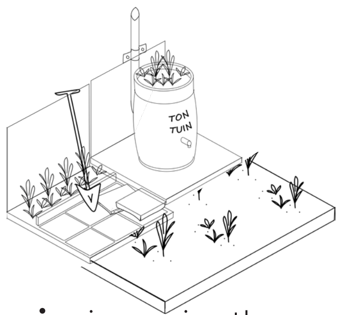
Literature: Potz (2016), Lenzholzer (2018)

Relations: MH.18

IMAGE FROM: Taken by Author Portimao, Portugal

MH.3 Frontyard: tile out, plant it!

Mitigating effects



Hypothesis: improving the evaporative surfaces and social liveability due to ownership

Design principle related

Context: **A continuous green space in front of the houses can have a more mitigating effect. At the neighbourhood level, this will mean more ownership of the place. With an arrangement of housing associations in the neighbourhood and good maintenance in combination with local neighbourhood workers, this will create a greater sense of belonging in the neighbourhood.**

Practical implication:
cost
multifunctional
implementation speed
ownership

Literature: Weerproof (2024)

Relations: MH.18

IMAGE FROM: https://weerproof.nl/tips/minder-tegels-meer-groen/

MH.4 Arcade

Mitigating effects

Hypothesis: creating permanent shadow as permanent passive shadow

Design principle related

Context: Whenever arcades are oriented correctly can offer benefits of allowing sunlight to enter during winter and providing shade in summer. They are also suitable for multiseasonal use by providing shelter from the rain. However, for this architectural implication requires long-term ownership. Nonetheless, arcades may create a sense of unsafety by creatin dark passageways.

Practical implication:
cost
multifunctional
implementation speed
ownership

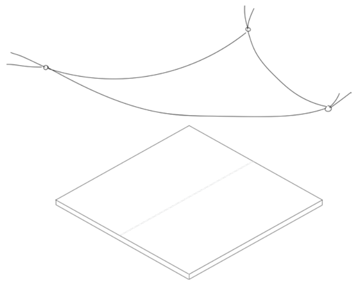
Literature: **Potz (2016)**

Relations: MH.18

IMAGE FROM:

MH.5 Sun screens

Mitigating effects



Hypothesis: shading element as flexible option

Design principle related

Context: **The shade screen's projection can result in the formation of a shadow, thereby limiting the amount of shortwave radiation reaching the area. If the projection is placed at a higher level to avoid traffic, there is a possibility that the sun's rays may come from below decreasing their functionality. It does require special attention, could be placed on a eficient manner, is more common victim of vandalism.**

Practical implication:
cost
multifunctional
implementation speed
ownership

Literature: Lenzholzer (2018)

Relations: MH.18

IMAGE FROM: Taken by Author Portimao, Portugal

MH.6 Topping up buildings

Mitigating effects

Hypothesis: creating permanent shadow as permanent passive shadow generator

Design principle related

Context: depending on the flat rooftopscape, integrated approach of energy label improvement and ownership of the dwelling. Also it should be considered that the heat will accumulate more in the night with this decision,therefore the dwellings need to

be isolate well to not cause problems in the night.

Practical implication:
cost
multifunctional
implementation speed
ownership

Literature: Potz (2016)
Relations: MH.18

IMAGE FROM: https://www.buildinc.eu/optopping/optoppen-betekenis/

MH.7 Permanent shading structure

Mitigating effects

Hypothesis: creating resting spots for el-derly during a hot day

Design principle related

Context: As a public space solution, this could provide shelter on sunny days while also providing protection from the rain.

Practical implication:
cost
multifunctional
implementation speed
ownership

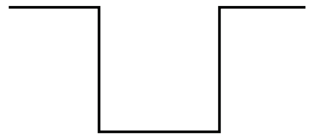
Literature: Potz (2016)

Relations: MH.18

IMAGE FROM: Photo taken by Author, Área de socialización canina Valencia

MH.8 Let the street open

Mitigating effects



Hypothesis: creating resting spots for el-derly during a hot day

Design principle related

Context: by choosing to not interfere in the streetscape with the qualities of being west east oriented and having a H/W ratio higher than 0.7 it is quite handy to use this potential to let the wind flow through this street.

Practical implication:
cost
multifunctional
implemenation speed
ownership

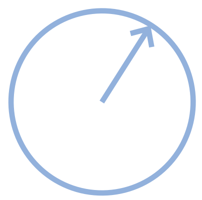
Literature: Marjolein van Esch (2015)

Relations

IMAGE FROM: Google maps Schiedamseweg

MH.9 Orientation

Mitigating effects



Hypothesis: orientation influences the sun and wind of a street

Design principle related

Context: This is a given factor for intervention in public space. The urban fabric has evolved in this way over time, and changing it will be very costly, so the best thing to do is to design with it rather than against it.

Practical implication:
cost
multifunctional
implementation speed
ownership

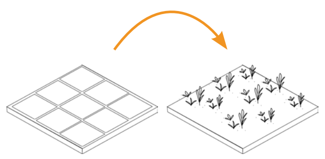
Literature: Marjolein van Esch (2015)

Relations: MH.18

IMAGE FROM: Created by Author

MH.10 Evaporative pavement

Mitigating effects



Hypothesis: improving the evaporative surfaces will mitigate the temperature

Design principle related

Context: Depaving causes a difference in the ratio between two types of heat transfer - sensible heat and latent heat. The ratio is inversely proportional to the wetness of the surface, implying that the wetter the surface, the lower the Bowen ratio. Next to a tree this has a higher potential of full grown canopies of trees. Therefore it is very important to give more room to a tree.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Potz (2016) van Loon et al. (2016)

Relations:

IMAGE FROM: https://earthbound.report/2015/06/02/10-reasons-to-depave-your-city/

MH.11 Small park

Mitigating effects

Hypothesis: little spot for evaporative area as well as a little communal space

Design principle related

Context: Greening the streets can be made more appealing by adding a social function to it. This would encourage people to change for greenery over parking spaces.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Potz (2016)

Relations: MH.18

IMAGE FROM: Google maps Frank Borselenstraat, Delfshaven, Rotterdam

SP.4 Ownership

Mitigating effects

Hypothesis: keeping responsibility towards places increases durability of mitigating effects

Design principle related

Context: ownership is of importance as the chapter policies stated, the willingness of coorporation is important to make it a succesful transformation.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership

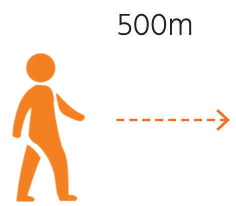
Literature: Gehl (2011)

Relations

IMAGE FROM: Created by Author

W.1 Design accessibility elderly

Mitigating effects



Hypothesis: improving the whole network by taking distance of elderly into account

Design principle related

Context: It is crucial to implement the 300-meter rule along with a 5-minute accessibility to cool places to ensure that elderly individuals can transfer themselves easily.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership -

Literature: Molster (2020), Kluck et al (2020).

Relations

IMAGE FROM: Created by Author

MH.12 Pergola

Mitigating effects

Hypothesis: creating a natural shading improves the shading as evaporative areas

Design principle related

Context: plants can offer extra cooling through evaporation as well as providing shade. They can have aesthatical and ecological value as well. Evergreen plants are preferable.

Practical implication:
cost
multifunctional
Implementation speed
ownership

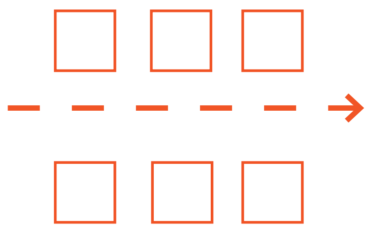
Literature: Lenzholzer (2018)

Relations: MH.18

IMAGE FROM: Photo taken by Author Dakpark, Bospolder

W.2 Continuous street pattern

Mitigating effects



Hypothesis: continuity of look of streets improves the legibility of pedestrains

Design principle related

Context: Readable street patterns with a continuous layout are more logical for walking.This is could be applied as strategic scale factor for heat mitigation measures.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership

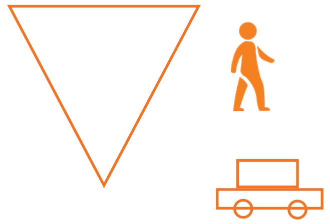
Literature: Molster (2020)

Relations

IMAGE FROM: Created by Author

W.3 Prioterisation of the pedestrain

Mitigating effects



Hypothesis: less car dominant will lead to an pedestrain friendly environment

Design principle related

Context: Giving priority to the pedestrian area instead of the fast traffic area will improve the social mobility of the neighbourhood. It will also become a safer place. This opens doors to other types of paving that are more climate-adaptive and create more residential qualities.

Practical implication:
cost variable depending on streetscape tranfsformation (sewage etc.)
multifunctional -
Implementation speed -
ownership

Literature: Molster (2020) Gehl (2011)

Relations

IMAGE FROM: Created by Author

W.4 Focus on local routes

Mitigating effects

Hypothesis: improving the local & neigbourhood networks instead of city

Design principle related

Context: focusing on the local used streets will improve the walkability of the neighbourhood. This could be detected by some sort of network betweeness (angular choice) or attraction betweeness if it is destination oriented.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership

Literature: Molster (2020)

Relations

IMAGE FROM: Created by Author

MH.13 Creating shading routes

Mitigating effects

Hypothesis: improving the shading route for walkability

Design principle related

Context: shade in the street networks have less shortwave radiation, which is more pleasant to walk through.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Tauw (2021)

Relations: MH.18

IMAGE FROM: Image taken by Author Delfshaven, perpendicular street to Heemraadsingel

MH.14 Planting a tree

Mitigating effects

Hypothesis: creating evaporative srfaces for mitigating heat

Design principle related

Context: Creating more evaporative areas will have a lower bowen ratio. The growth of the performance of the tree and the heat mitigation measures are looked into in Appendix F.

Practical implication:
cost
multifunctional
Implementation speed
ownership

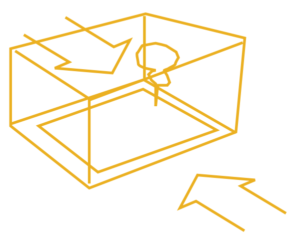
Literature: Lenzholzer (2018) Potz (2016), van Loon et al. (2016)

Relations: MH.18

IMAGE FROM: https://www.standaard.be/cnt/dmf20191203_04749440

SP.5 Enclosed space

Mitigating effects



Hypothesis: lots of green and shadow formed in enclosed places can provide shelter place

Design principle related

Context: this is a quality of urban block. The shading of trees which are dominant over there and depaved qualities can function as refugee spots for hot temperatures.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Sim (2019)

Relations: MH.18

IMAGE FROM: retrieved from https://www.seasons.nl/culinair-recepten/7-x-heerlijke-amsterdamse-binnentuinen

SP.6 Playing with water

Mitigating effects

Hypothesis: cooling element good for the public space

Design principle related

Context: cooling playgrounds can foster a social quality to a public space. Next to that it is important that the water can cool down citizens. In combination with water storage this could be a multi functional option.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Potz (2016)

Relations

IMAGE FROM: https://www.ad.nl/ede/ede-wil-draaistoelschommel-op-marktplein~af-546da3/127777806/

W.5 Designing for needs

Mitigating effects

Hypothesis: taking into account the us-ability of the place can reveal the need for heat mitigation

Design principle related

Context: adapting to the wishes of temporal spatial use can reveal the need for transformation of the area.

Practical implication:
cost
multifunctional
Implementation speed
ownership

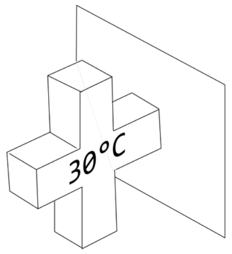
Literature: Sim (2019), Molster (2020)

Relations

IMAGE FROM:created by author

SP.7 Informing about heat

Mitigating effects



Hypothesis: informing people of the heat causing behaviour conscience

Design principle related

Context: Informing people about the heat in case people will go to the shade

Practical implication:
cost
multifunctional
Implementation speed
ownership

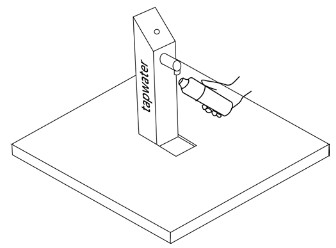
Literature: Bhati (1998)

Relations: SP.8

IMAGE FROM: retrieved from https://danews.eu/2023/03/31/record-temperatures-ca-nary-islands/

SP.8 Drinking water

Mitigating effects



Hypothesis: facilitating hydratation spots causes behaviour conscience

Design principle related

Context: providing water tap points can people determine theirselves if they are in need of hydratation. This will qualify as a good public space.

Practical implication:
cost
multifunctional
implementation speed
ownership

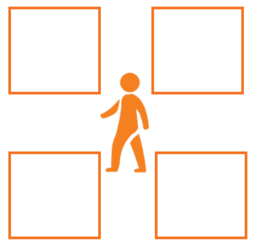
Literature: Bhati (1998)

Relations

IMAGE FROM: created by Author

W.6 Safe crossings

Mitigating effects



Hypothesis:improving the waiting time for pedestrains

Design principle related

Context: Safe pedestrian crossings will help people not to wait too long in the heat.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Molster (2020)

Relations

IMAGE FROM: created by Author

MH.16 Creating sheds

Mitigating effects

Hypothesis: people can easily adapt their climate conditions

Design principle related

Context: **creating sheds will have a positive effect of belongness of the place. However, ownership and accountability is very important to let it function as a continuous element over a pedestrain area. It is fast implemented when necessary.**

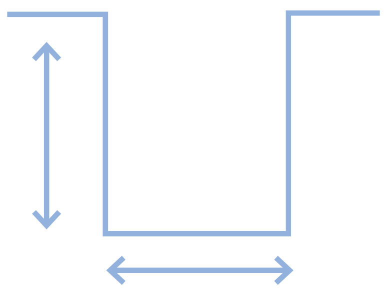
Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Lenzholzer (2018) van Tuin en Bergevoet (2024)
Relations: MH.18

IMAGE FROM: Image taken by Author, London

MH.17 H/W ratio

Mitigating effects



Hypothesis: being aware of the current H/W ratio can influence the design decision

Design principle related

Context: This is one of the factors determining if the solution for climate adaptiveness ought to be mitigated by adding extra building levels or either seek solutions in the street level.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownerhsip

Literature: Marjolein van Esch (2015)

Relations: MH.18

IMAGE FROM: Image created by Author

MH.18 Designing with the sun

Mitigating effects

Hypothesis: 12:00 causes different shadow patterns then 15:00 shadows

Design principle related

Context: Mitigating heat could be done by designing with the sun, this will influence the shortwave and longwave implementations.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership -

Literature: Matzarakis& Amelung (2018)

Relations

IMAGE FROM: created by Author

MH.19 Designing for the wind

Mitigating effects

Hypothesis: east west street require wind flow options for convection

Design principle related

Context: Designing with the wind will improve the latent heat flux. More frequently the wind will flow from east to west during hot warm days.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership **-**

Literature: Matzarakis& Amelung (2018)

Relations

IMAGE FROM: created by Author

MH.20 Designing for evaporative surfaces

Mitigating effects

Hypothesis: evaporative materials will mitigate heat

Design principle related

Context: designing with evaporative surfaces causes a lower bowen ratio which describes the heat transfer of the latent and sensible heat flux.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership -

Literature: Matzarakis& Amelung (2018)

Relations

IMAGE FROM: created by Author

W.8 Clustering traffic

Mitigating effects

Hypothesis: clustering traffic will create traffic safety to pass through as a pedes-train

Design principle related

Context: clustering traffic will create a more traffic safe environment. If it is created with the safe crossings this has the potential to be a pleasant walkable space.

Practical implication:
cost -
multifunctional -
Implementation speed -
ownership -

Literature: Molster (2020)

Relations

IMAGE FROM: created by Author

MH.21 Impermanent shading structure

Mitigating effects

Hypothesis: shading element as semi per-manent

Design principle related

Context: By introducing a flexible character for heat mitigation measures, these transient shading structures could be covered with planted greenery. Whilst greenery takes time to grow, this could be implemented quite quickly.

Practical implication:
cost
multifunctional
Implementation speed
ownership

Literature: Amores et al. (2022)

Relations: MH.18

IMAGE FROM:Amores et al. (2022) Study of bioclimatic shading strategies in Seville: Habitability in open public spacesTeresa Rocío Palomo Amores a, María del Carmen Guerrero Delgado a, Daniel Castro Medina a, Alberto Cerezo Narváez a, José Sánchez Ramos a, Servando Álvarez Domínguez a.

W7. Accessible green

Mitigating effects

Hypothesis: making sure that greenery is accessible to everyone

Design principle related

Context: By using accessible greenery as a public space measure, people will have access to cooling places.

Practical implication:
cost
multifunctional
implementation speed
ownership

Literature: HVA (2018)

Relations: MH.18

IMAGE FROM: taken by Author, London

SP.10 Human scale public spaces

Mitigating effects

Hypothesis: public spaces with 20-25 metres distances are perceived as social spaces

Design principle related

Context: It is only at a distance of 20 to 25 metres that the feelings and moods of others can be perceived relatively clearly. In his elaboration of the relationship between the scale and intensity of a place and closeness and warmth, and therefore more of a social space.

Practical implication:

cost	-
multifunctional	-
Implementation speed	-
ownership	-

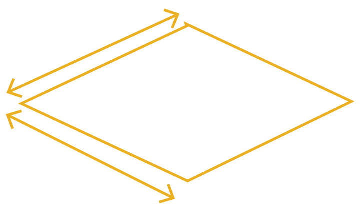
Literature: Gehl (2011)

Relations

IMAGE FROM: created by Author

SP.11 Wind optimized squares

Mitigating effects



Hypothesis: A place to stay and not to be blown away

Design principle related

Context: "with the forumala: square surface / average height of surrounding buildings x 2 =< 6 counts as a good wind optimised square. Also an opening should not exceed 25 percent of the square perimeter " by Lenzholzer (2018) (p 184)

Practical implication:

cost	-
multifunctional	-
Implementation speed	-
ownership	-

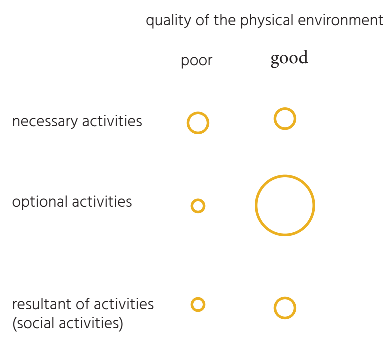
Literature: Lenzholzer (2018)

Relations

IMAGE FROM: created by Author

SP.12 Optional activities

Mitigating effects



Hypothesis: A place which offers optional activities has a residual better public space

Design principle related

Context: a place with optional activities next to the necessary activities will be used all year round and have a better public space

Practical implication:

cost	-
multifunctional	-
Implementation speed	-
ownership	-

Literature: Gehl (2011)

Relations

IMAGE FROM:Image from Gehl (2011) page 11

SP.13 Restorative points

Hypothesis: creating resorative points along the way

Design principle related

Context: By using accessible greenery as a public space measure, people will have access to cooling places.

Practical implication:

cost
multifunctional
implementation speed
ownership

Literature: HVA (2018)

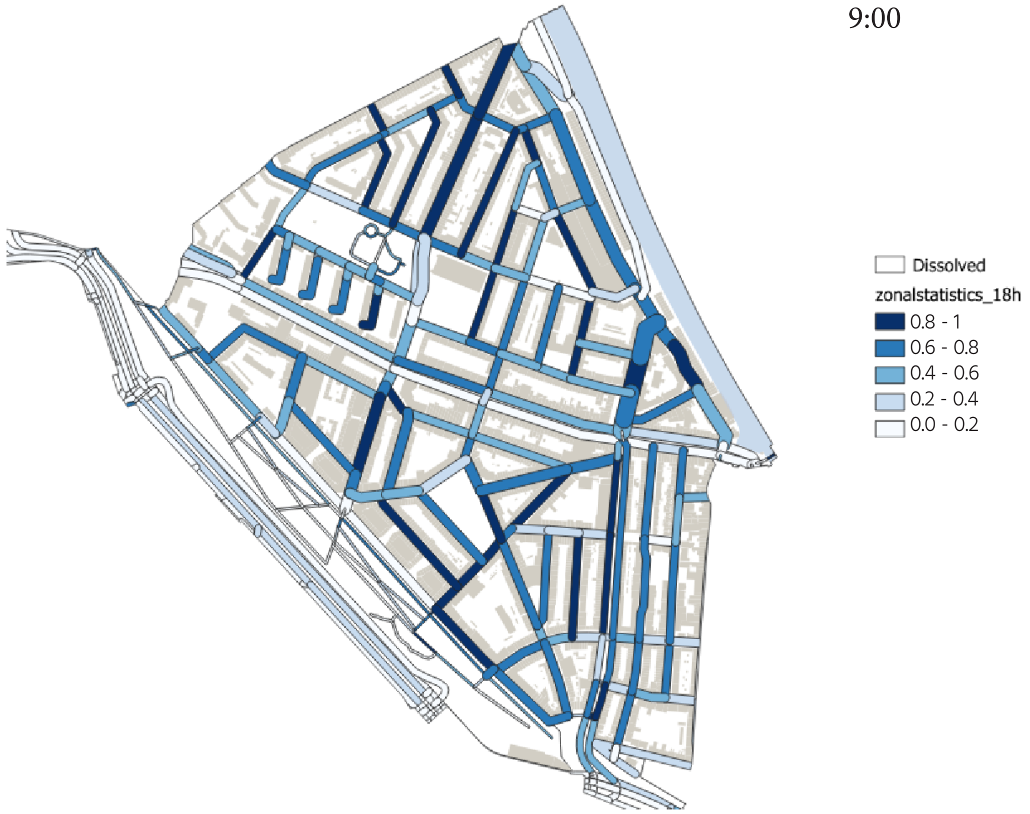
Relations: MH.18

IMAGE FROM: taken by Author, London

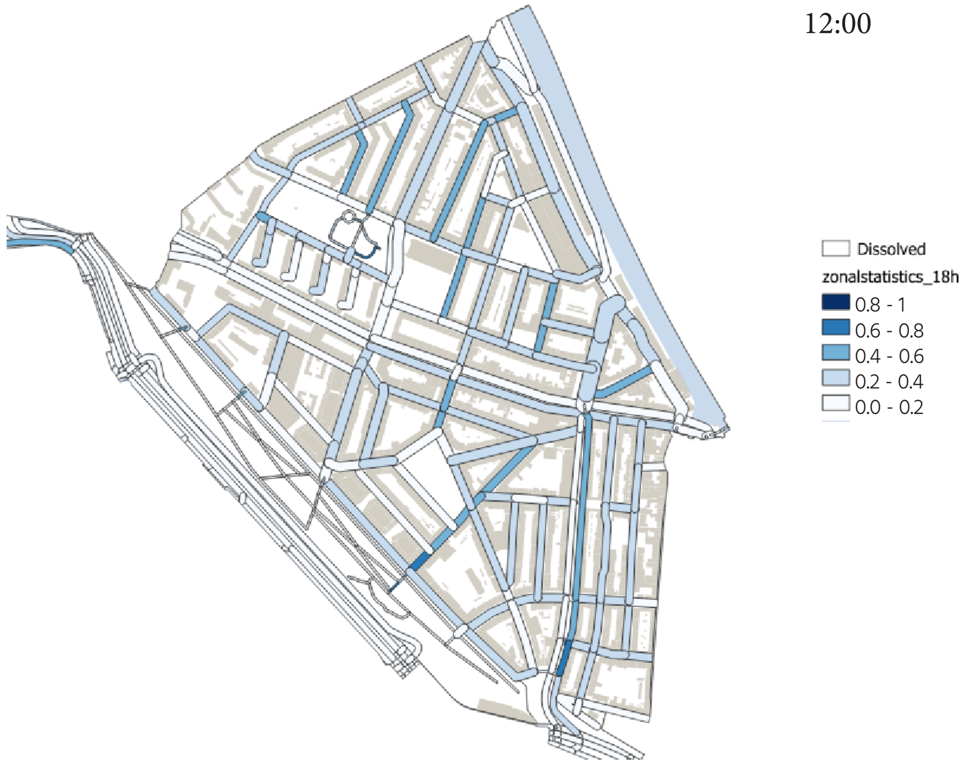
Appendix B. shadow

Shadow street segments zonal statistics segment with shadow

9:00

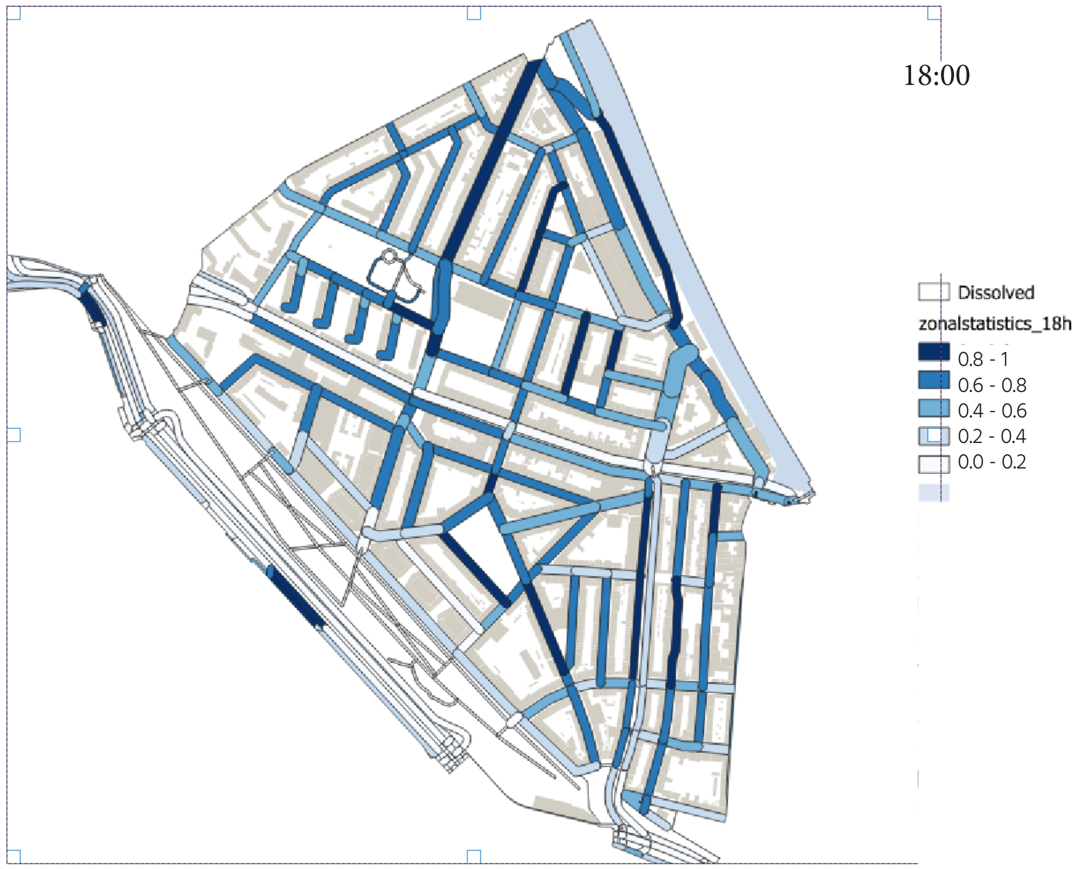


12:00

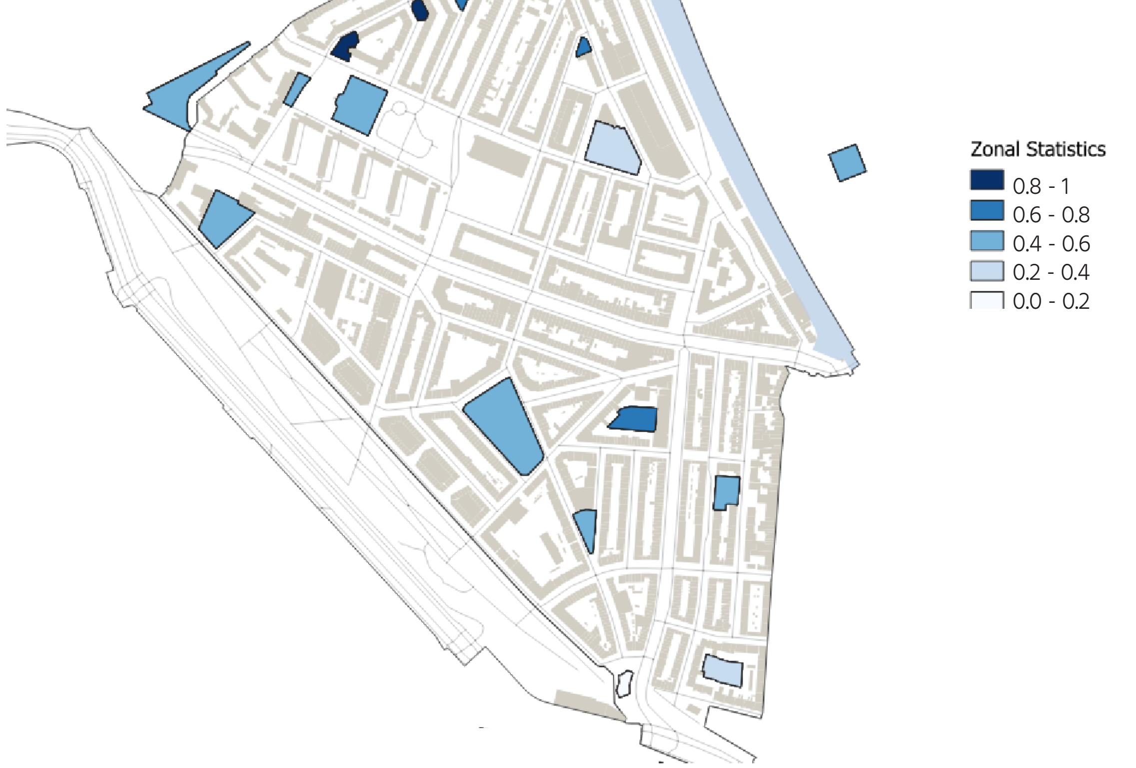


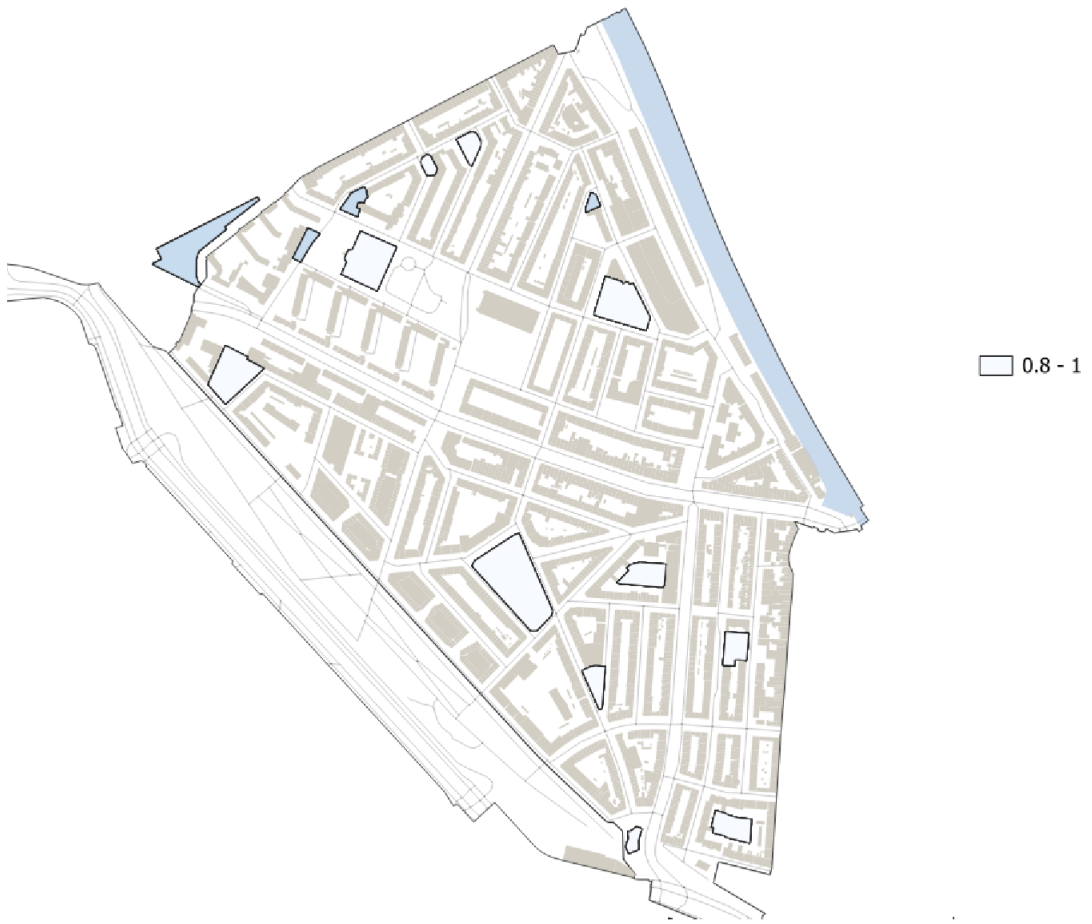
15:00

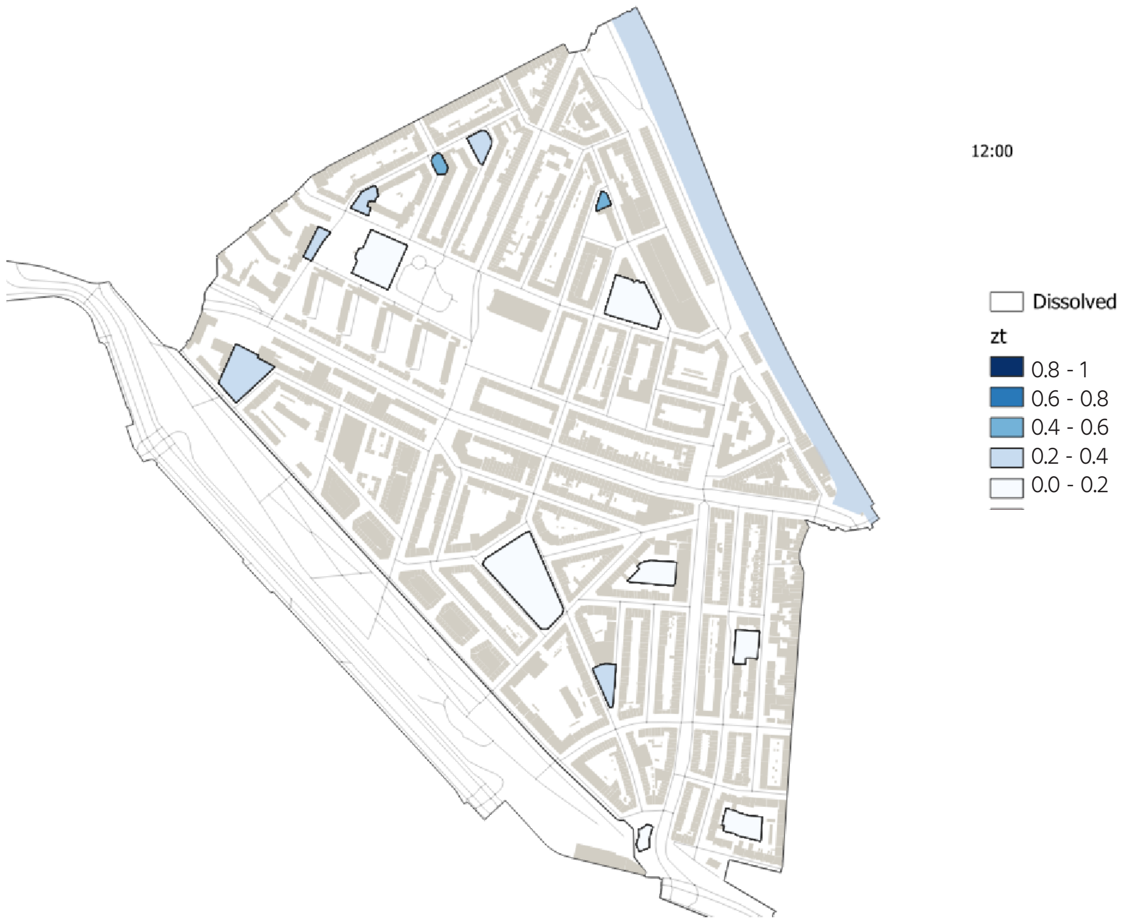
18:00

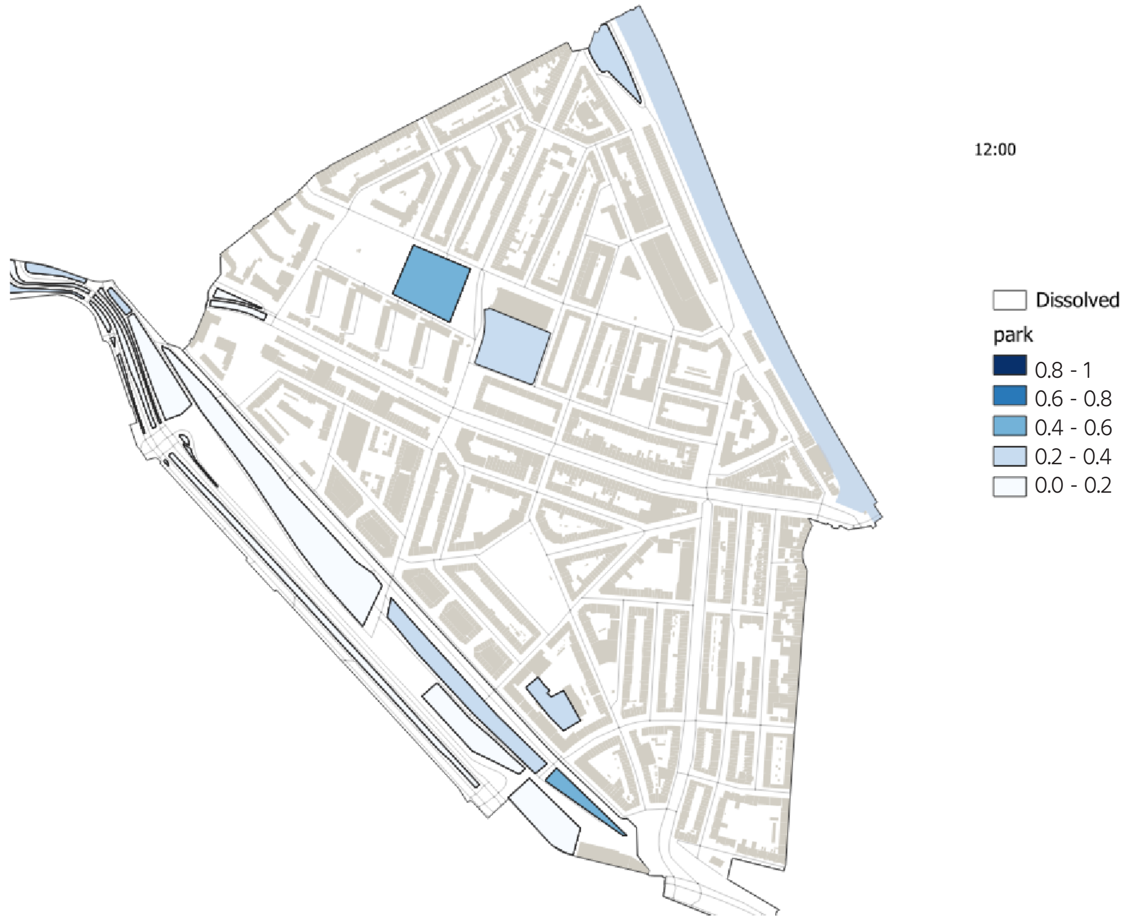


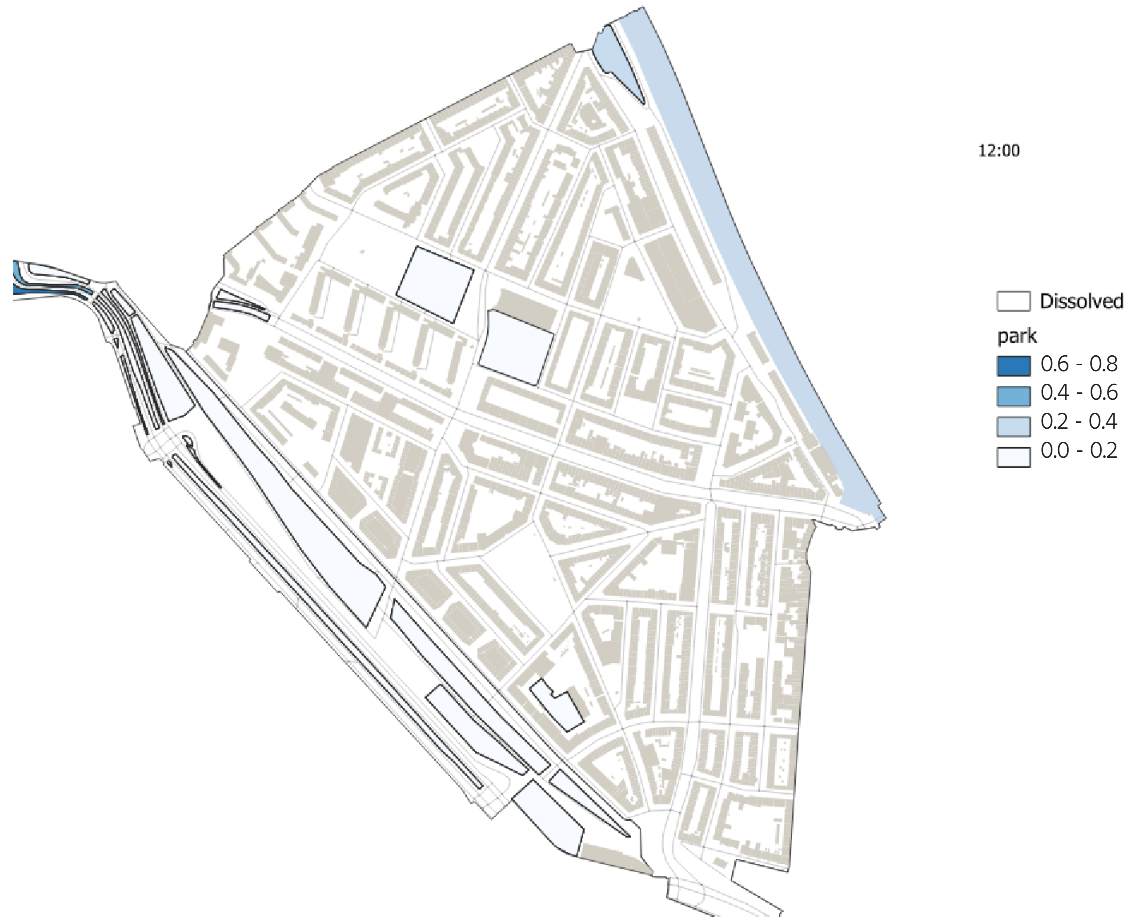
Shadow public space segments zonal statistics area with shadow



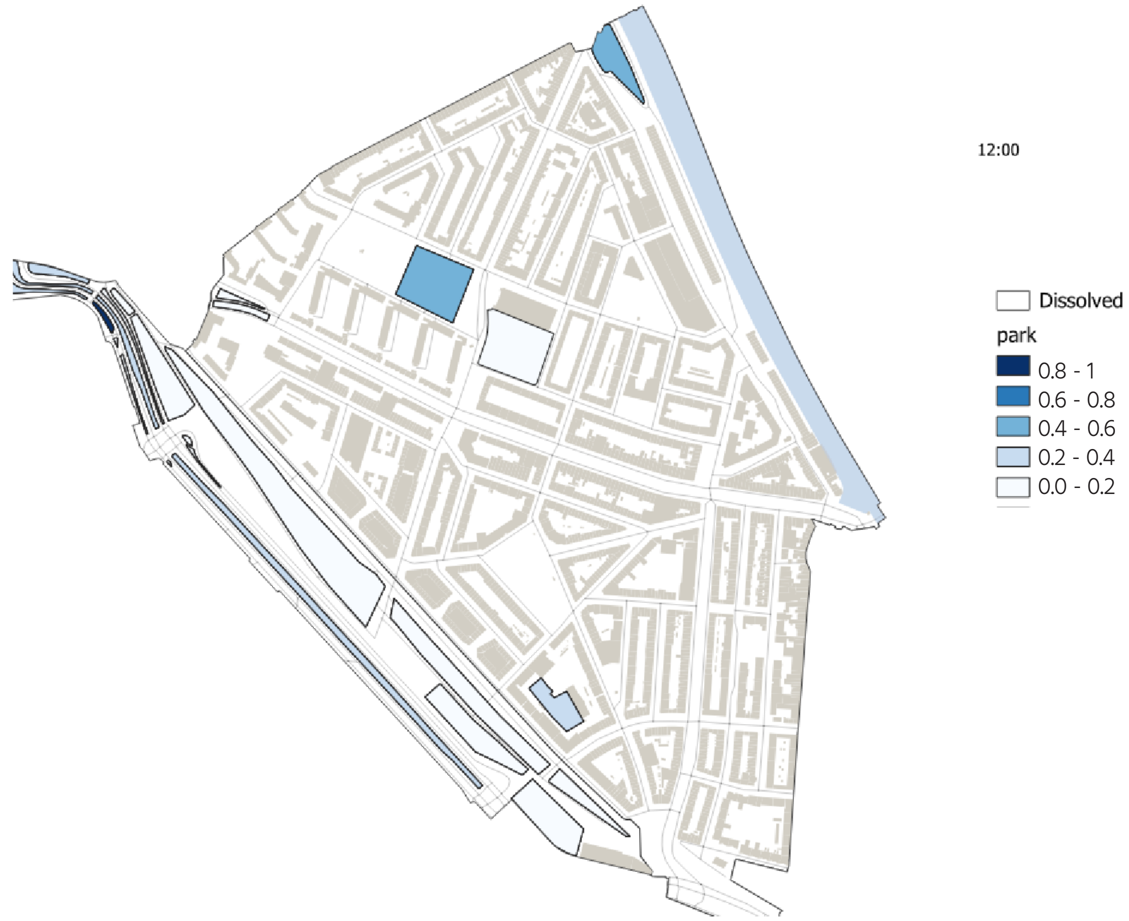





12:00
Dissolved
park
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0.0 - 0.2

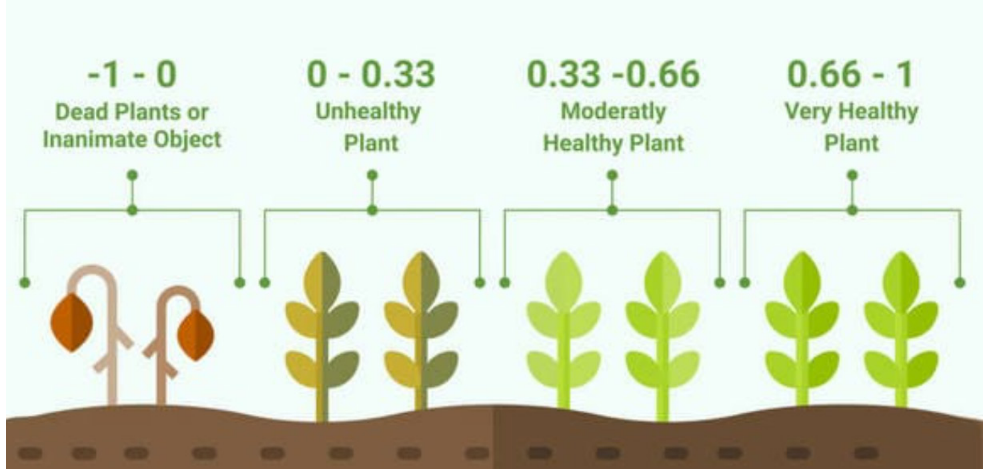

12:00
Dissolved
park
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0.0 - 0.2


12:00
Dissolved
park
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0.0 - 0.2


12:00
Dissolved
park
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0.0 - 0.2

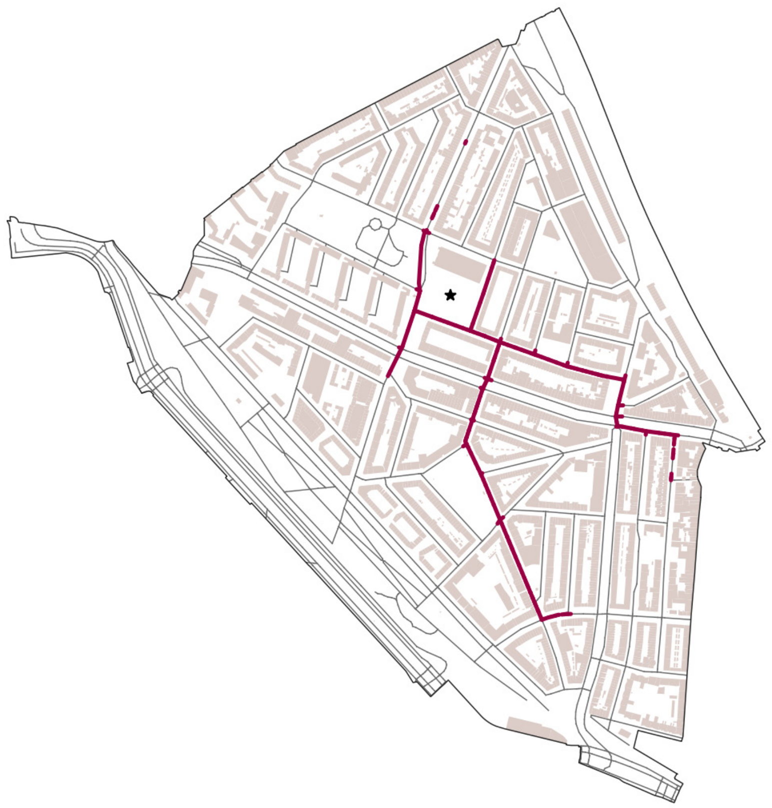
Chapter 1 | Methodology | Conceptual framework

Appendix C. NDVI and trees



Appendix D. Attraction betweeness destinations

Visserijplein markt attraction betweeness



Park 1943 attraction betweeness

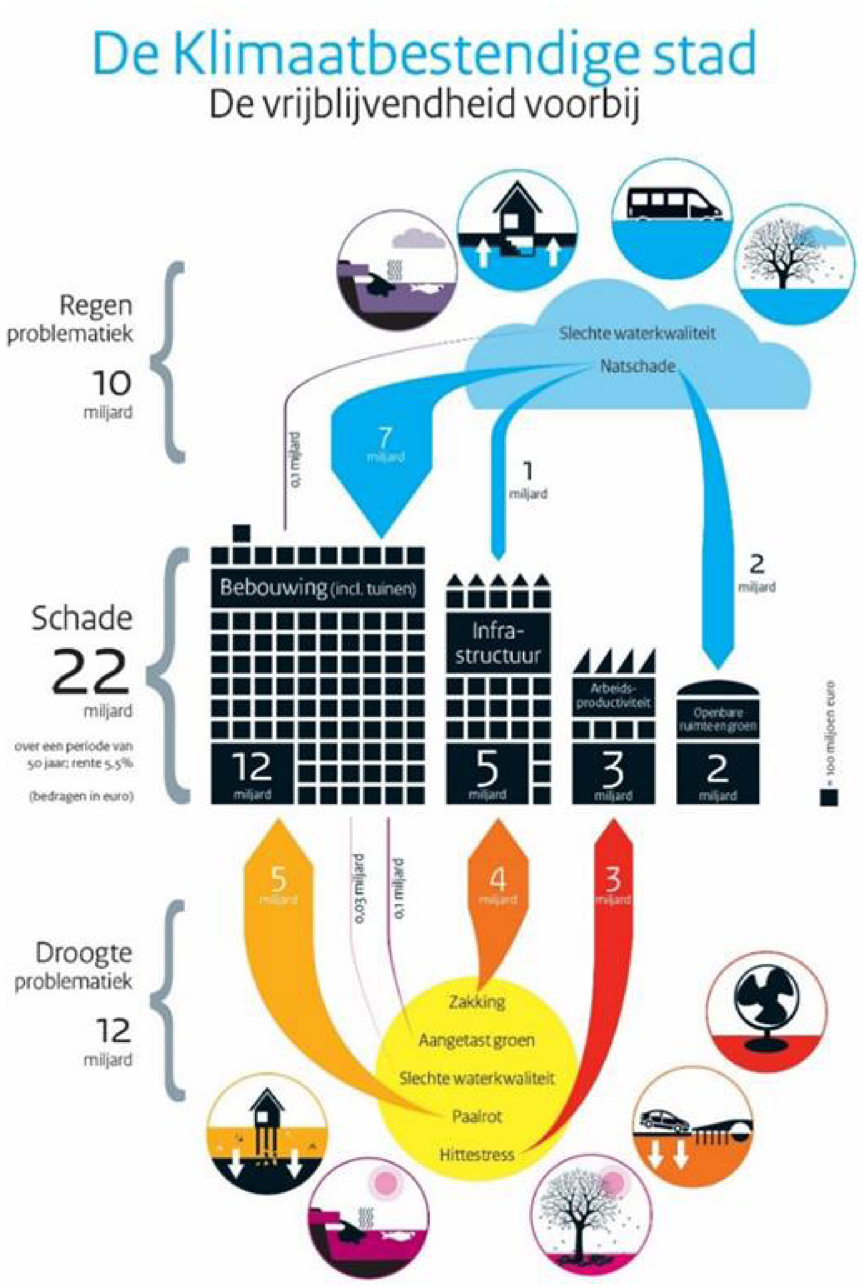
Bospolderplein attraction betweeness

Playground park 1943

Dakpark

Park 1943

Appendix E. costs mitigating measures



Appendix F. Tree species and their potential

By studying the tree species applicable to the neighbourhood and their current presence, it was possible to investigate which trees should be used. Also, with the inventory of the potential heights of the trees by consulting the 'City trees Vademe-cum' (Janson, 1994) with Hiemstra (2021), the tree species for proper heat mitigation was shown that the Prinus avium, Platanus acerifolia and Fagus sylvetica were the most favourable. Van Loon (2016) states that the growth of the tree depends on the space it is given to grow with the roots of the tree, which should be equal to the crown size of the mature tree itself.

Bomen_ExportFeatures copy
Acer
Aesculus
Amelanchier
Betula
Carya
Catalpa
Fagus
Fraxinus
Gleditsia
Juglans
Liriodendron
Picea
Pinus
Platanus
Populus
Quercus
Tilia
Ulmus
zero

Legend

functions

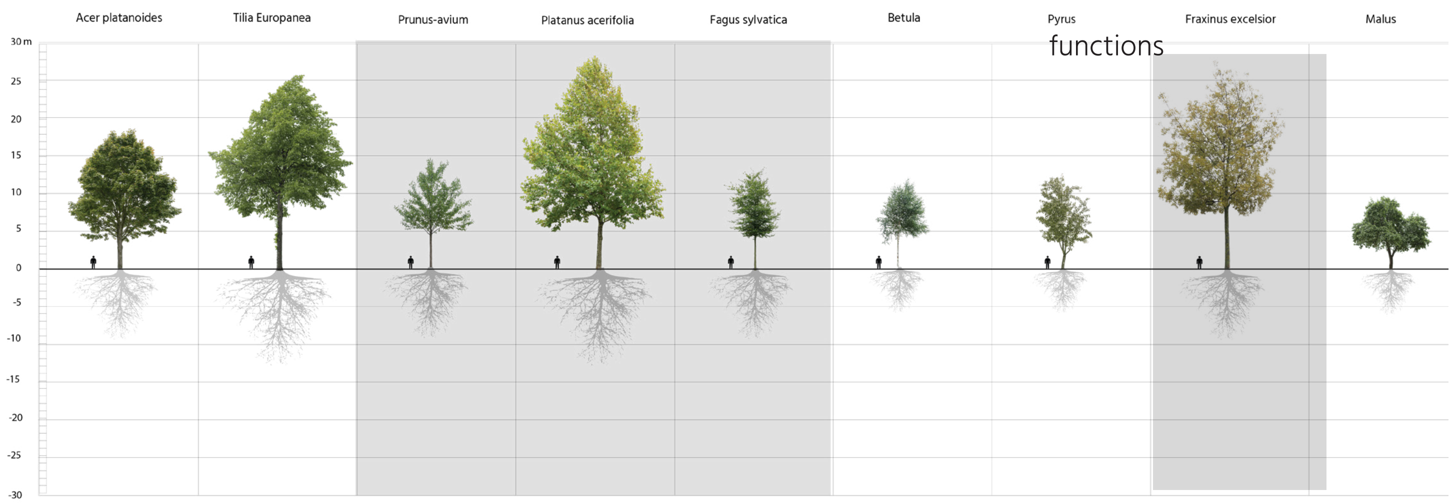
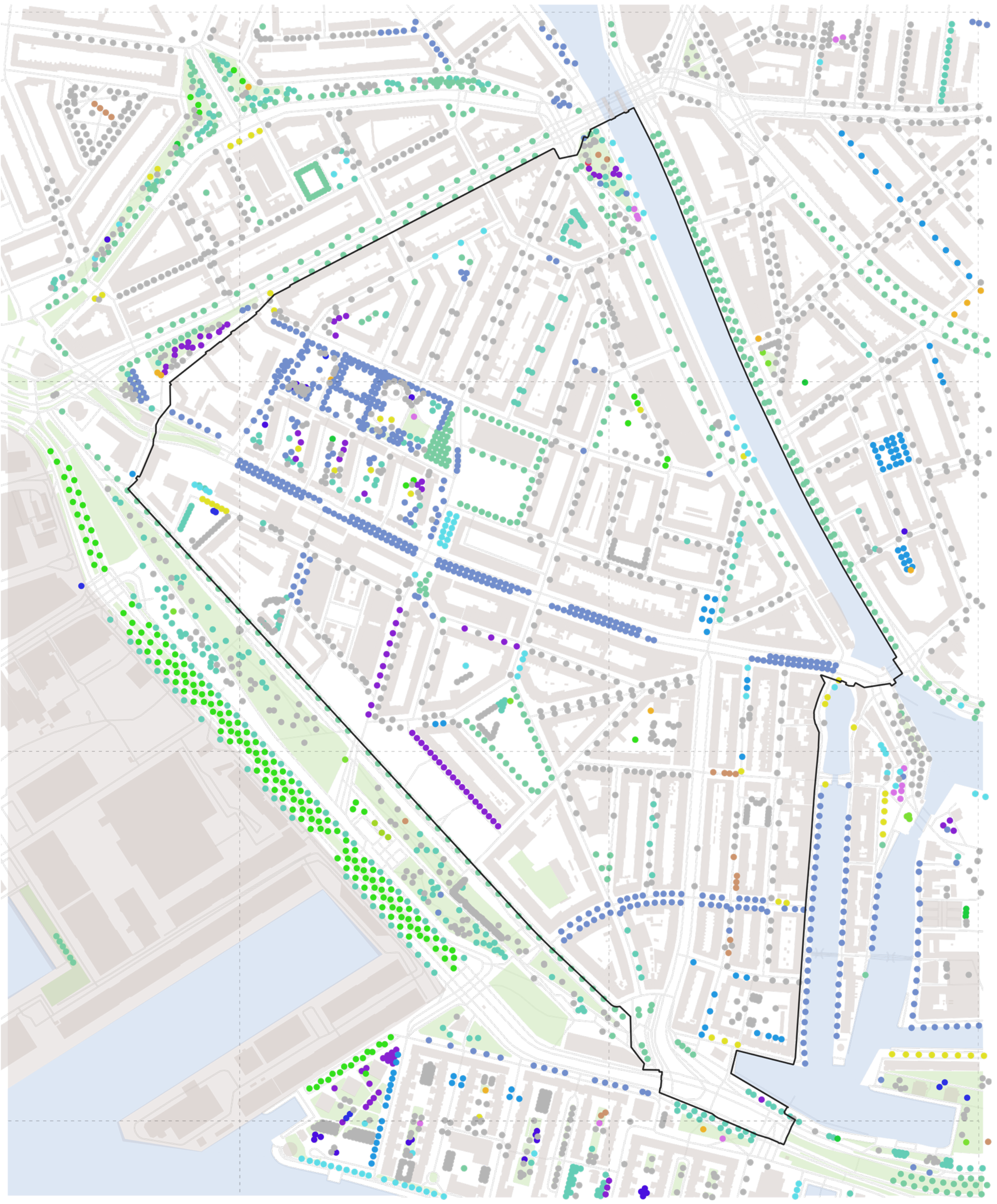


Fig. X Inventory of tree species available in the neighbourhood of Bospolder Tussendijken with the se-lection of good heat mitigating trees selected by Hiemstra (2021)

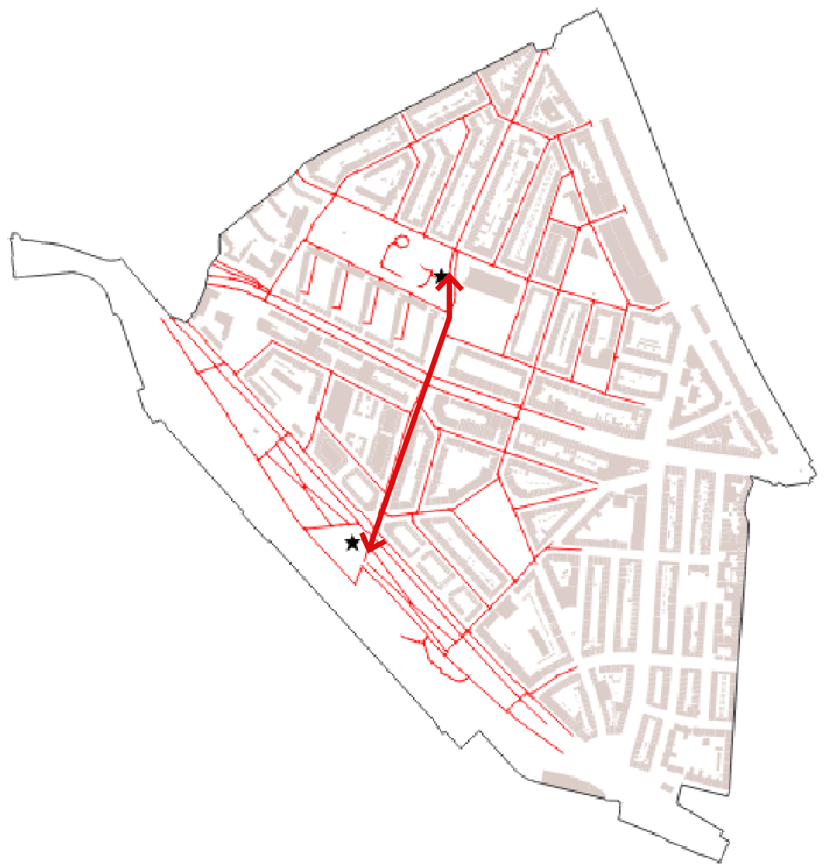


source: sbi_infra rotterdam bomen

Appendix G. Attraction distance 500 m

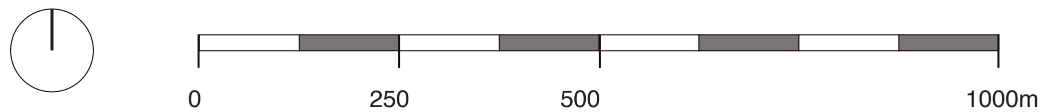
Market attraction distance 500 m

Parcs attraction distance 500m



Playgrounds attraction distance 500m

Generated by PST tool attraction betweeness feature. By highlighting the line segments there is a better overview of the reached service area instead of the raster representation.



Appendix H. costs mitigating measures

V. Opbouw van de kostenmatrix per opgave

	Historische binnenstad		Stedelijk bouwblok		Vooroorlogs bouwblok		Tuindorp		Volkswijk	
Doorlatendheid bodem	Goed	Slecht	Goed	Slecht	Goed	Slecht	Goed	Slecht	Goed	Slecht
Aanlegkosten per m² berging	€ 5.95	€ 18.48	€ 7.27	€ 17.59	€ 7.44	€ 12.72	€ 4.33	€ 15.74	€ 3.40	€ 11.92
Aanlegkosten per m² schaduw	€ -	€ -	€ -	€ -	€ 2.52	€ 2.52	€ 8.09	€ 8.09	€ 8.42	€ 8.42
Aanlegkosten per m² infiltratie	€ 2.28	€ 6.73	€ 3.13	€ 7.05	€ 2.92	€ 4.44	€ 2.94	€ 9.38	€ 2.17	€ 6.14
Aanlegkosten per m² openbare ruimte	€ 8.23	€ 25.21	€ 10.41	€ 24.65	€ 12.88	€ 19.68	€ 15.36	€ 33.21	€ 13.99	€ 26.48
Aanlegkosten per m² particulier	€ 13.42	€ 13.42	€ 11.82	€ 11.82	€ 10.75	€ 10.75	€ 10.80	€ 10.80	€ 12.04	€ 12.04
Percentage aanlegkosten aan berging	27%	48%	33%	48%	31%	42%	17%	36%	13%	31%
Percentage aanlegkosten aan schaduw	0%	0%	0%	0%	11%	8%	31%	18%	32%	22%
Percentage aanlegkosten aan infiltratie	11%	17%	14%	19%	12%	15%	11%	21%	8%	16%
Percentage aanlegkosten voor particulier	62%	35%	53%	32%	46%	35%	41%	25%	46%	31%
Beheerkosten per m² berging	€ 0.22	€ 0.05	€ 0.60	€ 0.69	€ 0.71	€ 0.79	€ 0.33	€ 0.44	€ 0.27	€ 0.38
Beheerkosten per m² schaduw	€ -	€ -	€ -	€ -	€ 0.09	€ 0.09	€ 0.28	€ 0.28	€ 0.29	€ 0.29
Beheerkosten per m² infiltratie	€ 0.08	€ 0.02	€ 0.26	€ 0.28	€ 0.28	€ 0.28	€ 0.23	€ 0.26	€ 0.17	€ 0.19
Beheerkosten per m² particulier	€ 0.08	€ 0.08	€ 0.07	€ 0.07	€ 0.07	€ 0.07	€ 0.07	€ 0.07	€ 0.08	€ 0.08
Percentage beheerkosten aan berging	57%	32%	64%	66%	62%	65%	37%	42%	33%	40%
Percentage beheerkosten aan schaduw	0%	0%	0%	0%	8%	7%	31%	27%	36%	31%
Percentage beheerkosten aan infiltratie	22%	12%	28%	27%	24%	23%	25%	25%	21%	21%
Percentage beheerkosten aan particulier	22%	56%	8%	7%	6%	5%	7%	6%	9%	8%

Appendix I. conclusion drawings inac-cessibility

accessible at warm day

warm day inaccessible for target group

summer day 9:00 inaccessible

summer day 12:00 inaccessible

summer day 12:00 inaccessible elderly

summer day 9:00 inaccessible elderly

Legend

weekly market

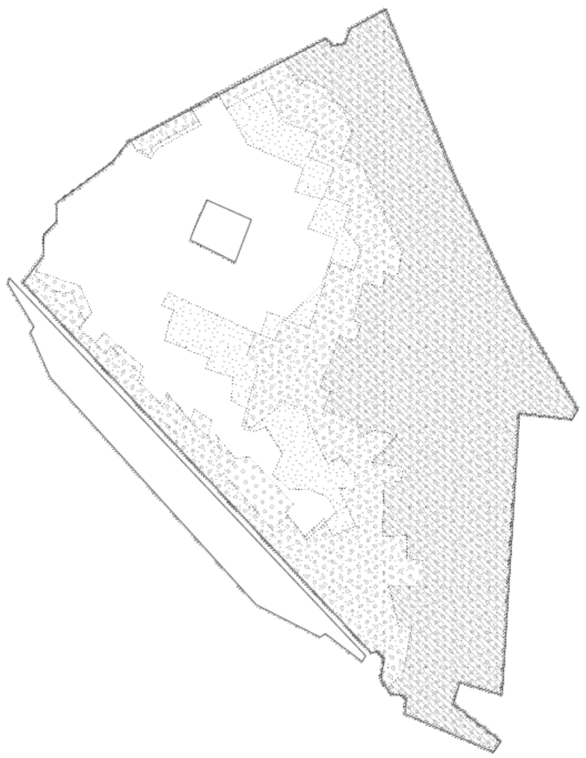
recreation

hiking for fun

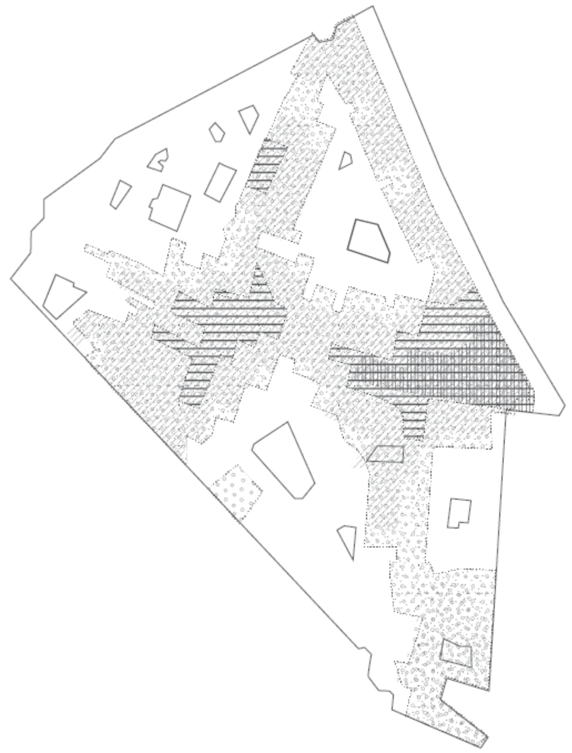
playyard

9:00 — 12:00 15:00 — 18:00

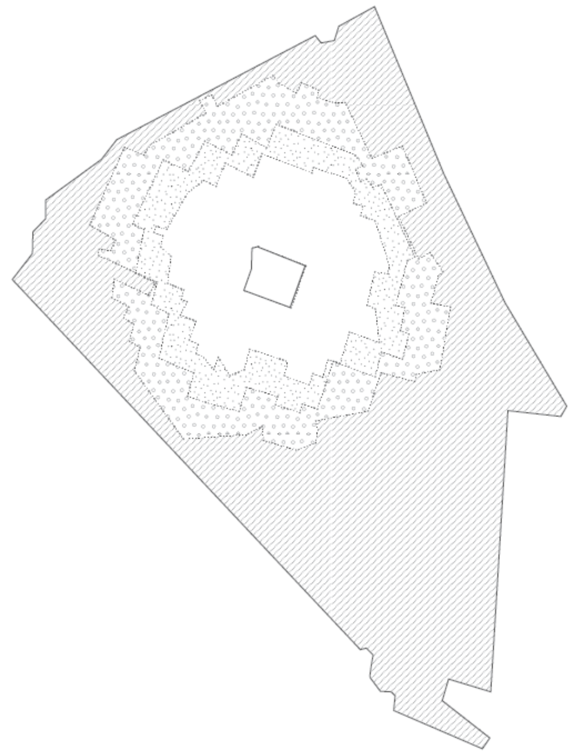
conclusion raster cumsum



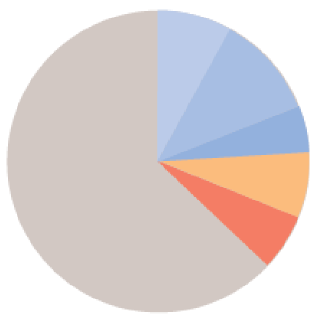
park



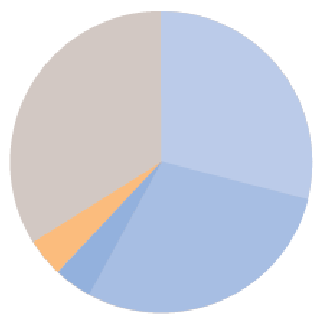
playyard



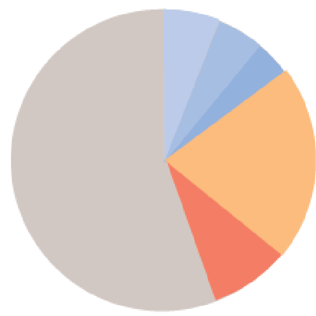
market



recreation - park



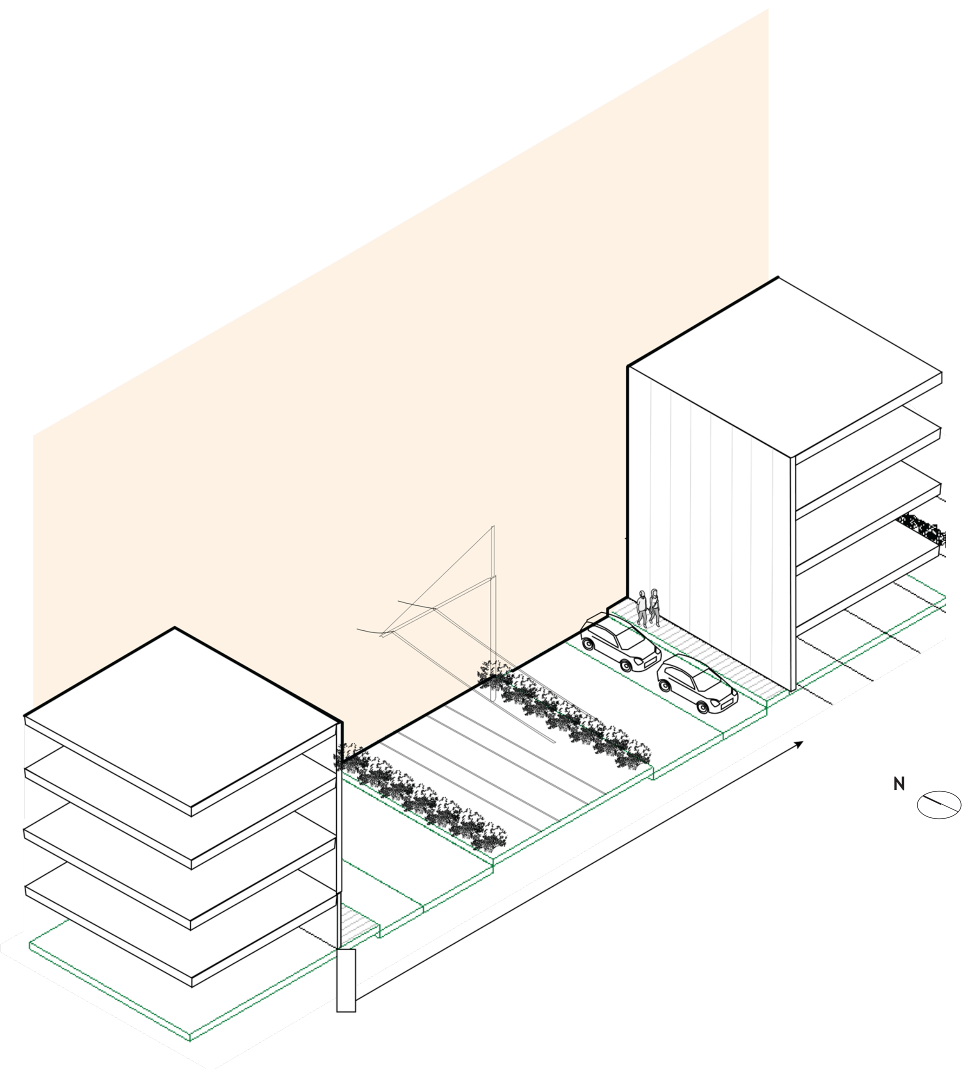
playyard

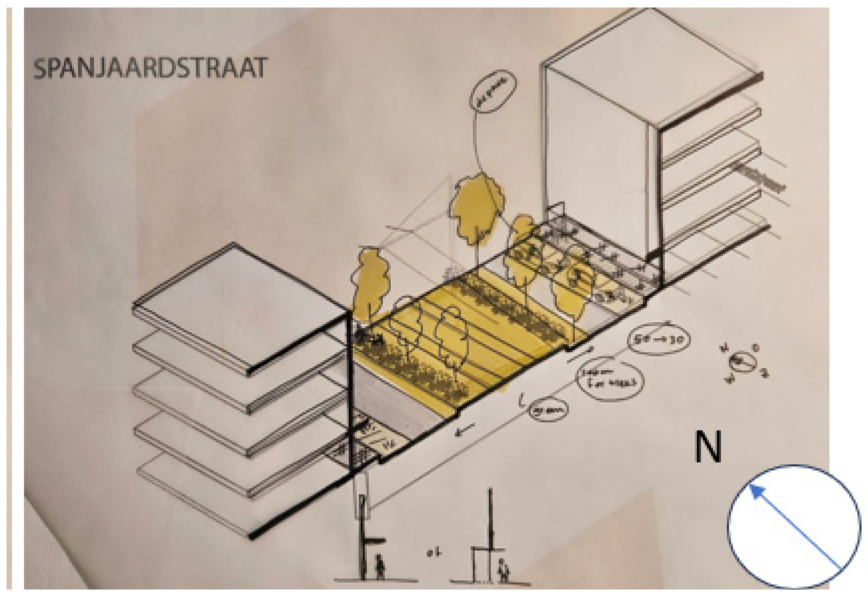


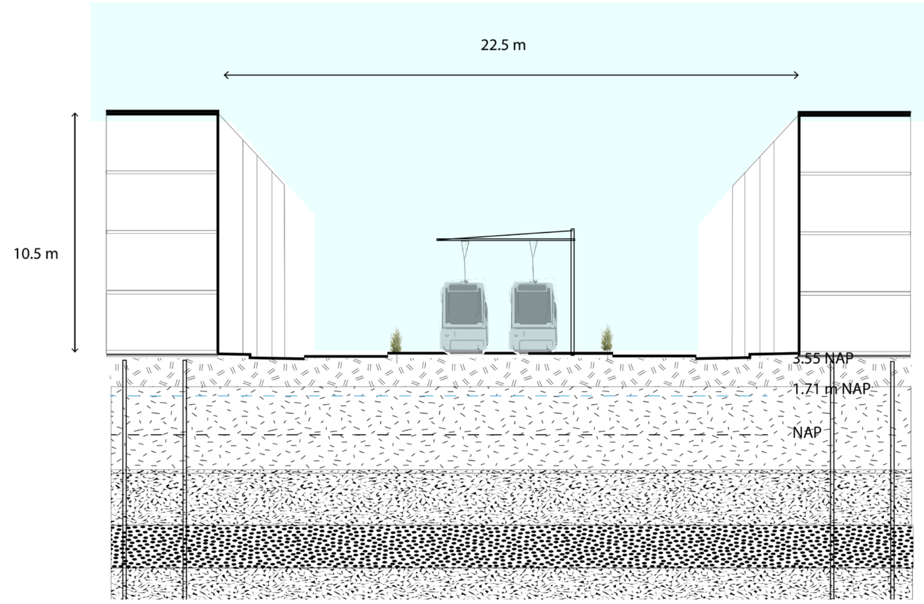
weekly market

Appendix J. provisional design for spanjaardstraat, visserijplein green solution

Spanjaardstraat crossing



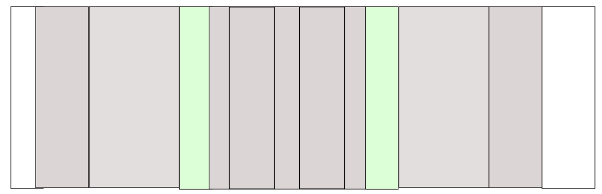


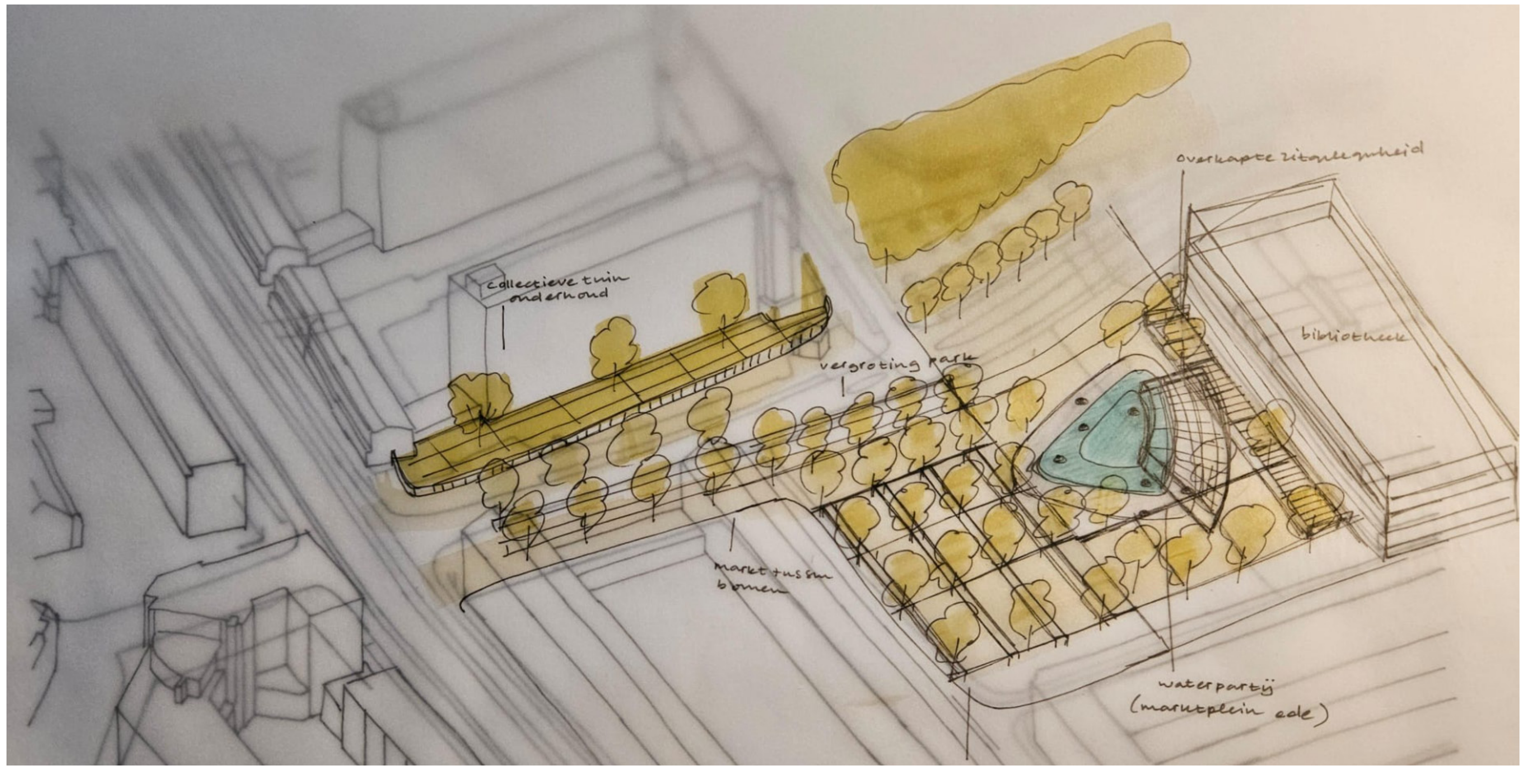


Legend

functions

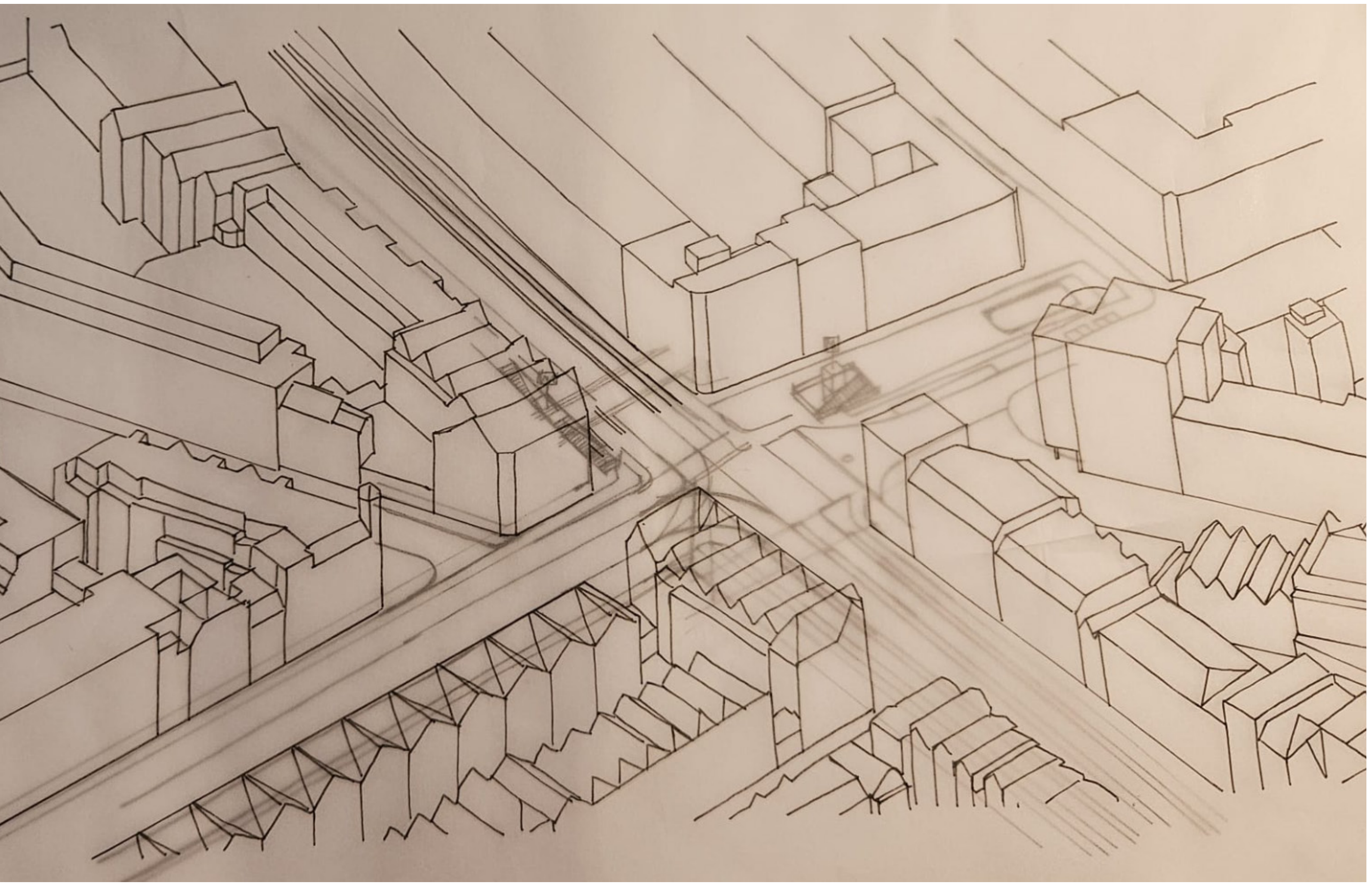
- moderately coarse sa
- fine sand
- clay
- peat

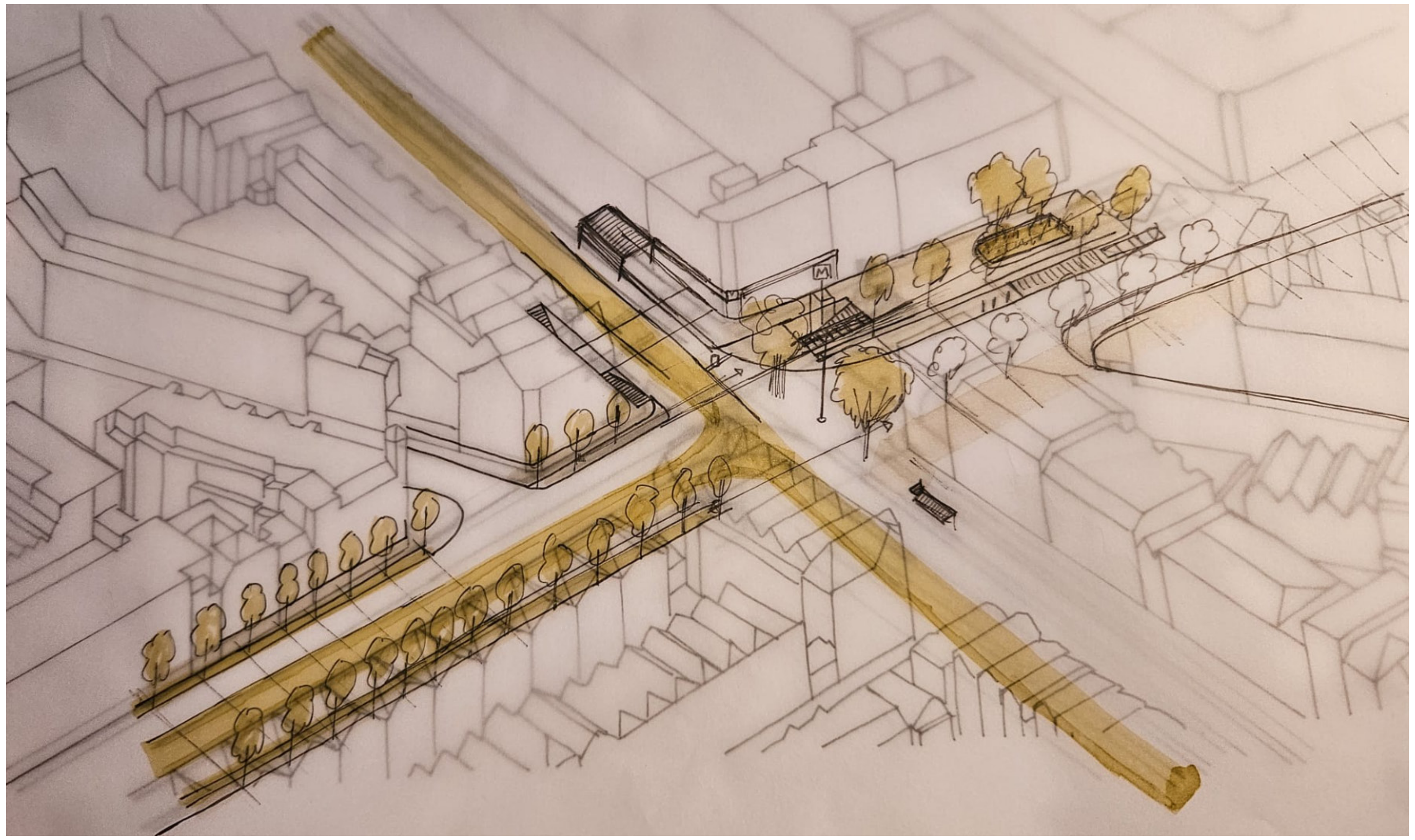


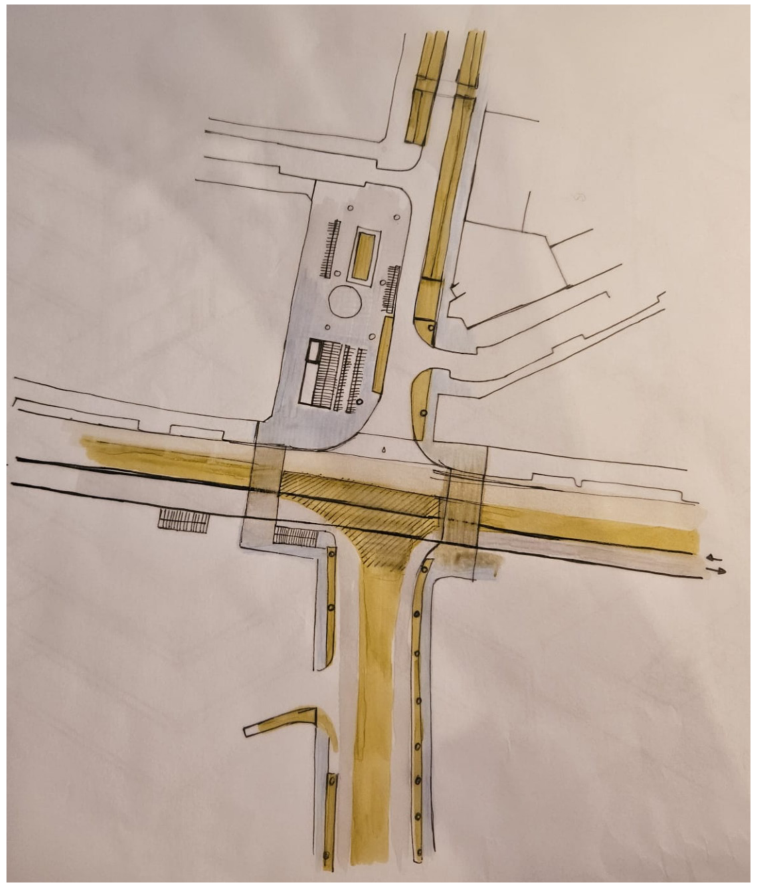


SP.10 SP.11 W.5 SP.6 SP.12 SP.7 SP.8

Fig. 6.17 maximalisation green solution axonometric Visserijplein. Created by Author

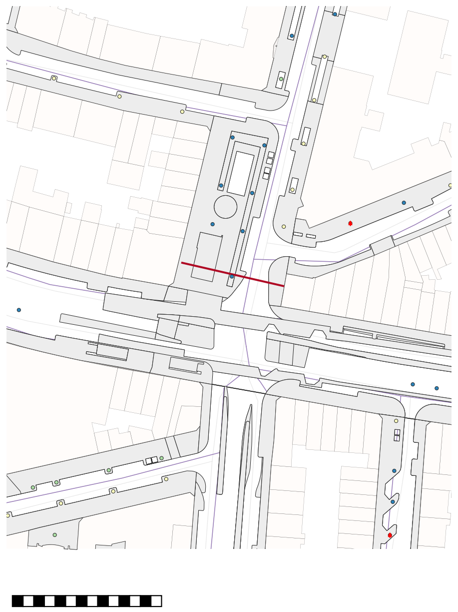






Spanjaardstraat, Schiedamseweg crossing

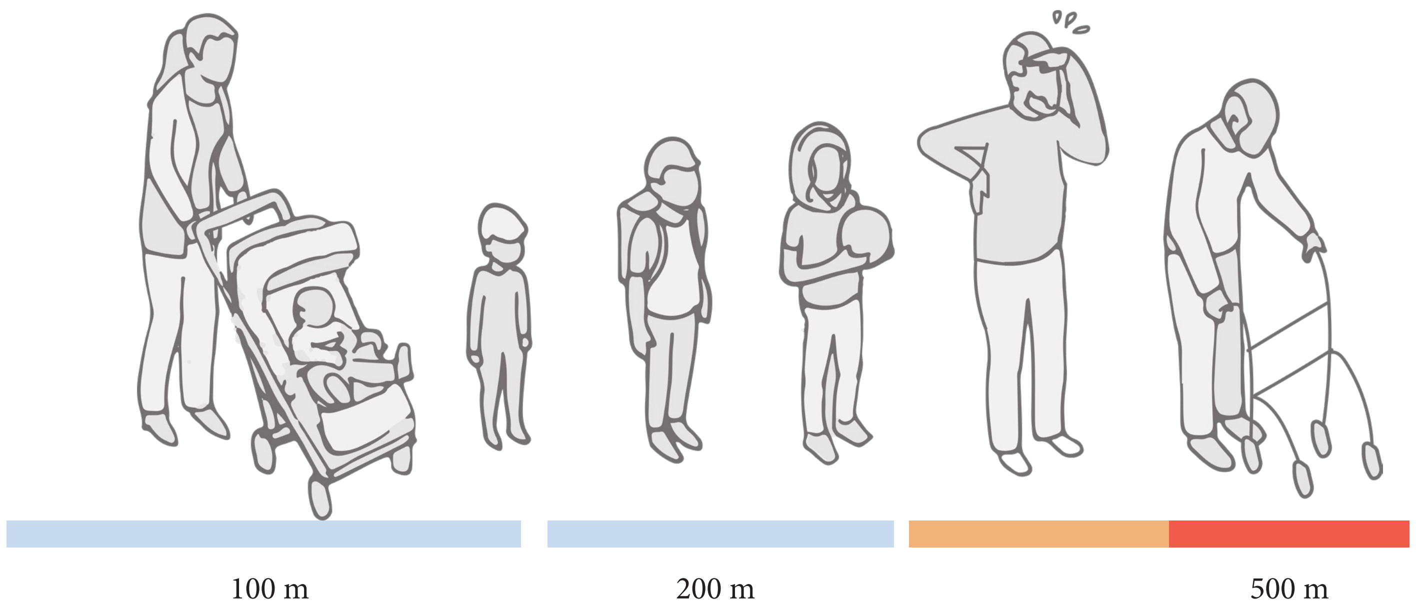
Juntion neighbourhood importance spanjaardstraat and economically viable Schiedamseweg.

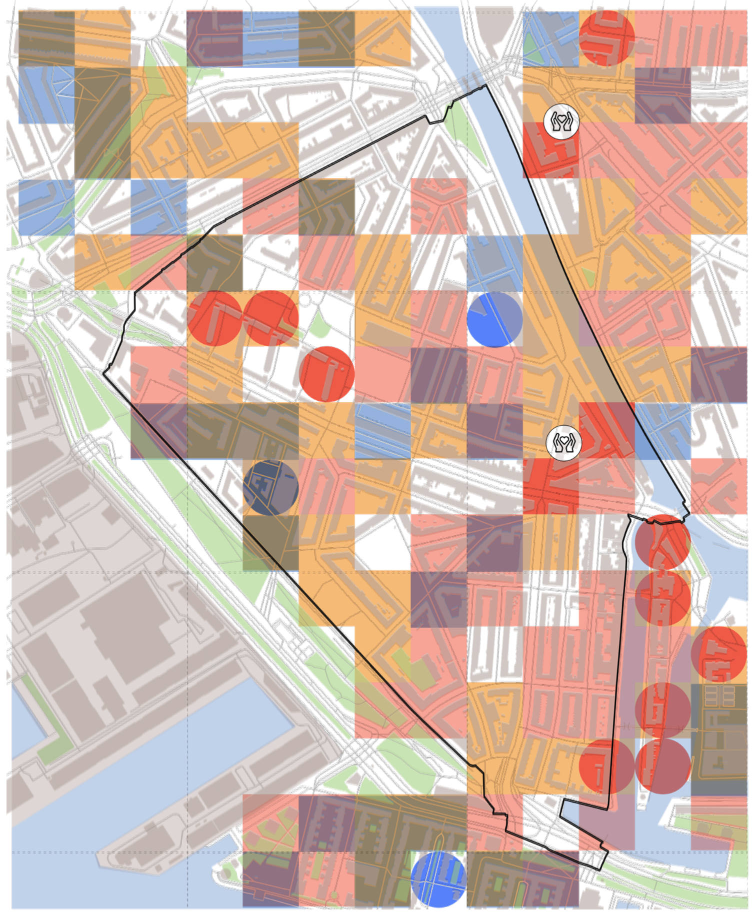


Appendix K. social liveability and consequences

Social liveability: Socio demographic locations

Bospolder and Tussendijken are vibrant residential areas that encompass a diverse population, spanning various age groups. Within the district, you can find housing options that cater to both young and elderly residents. For instance, with locations like de Schans, Gijsingflats, Robijn, and Diamant, there is a relatively significant amount of housing designed for seniors. Simultaneously, the area is home to many (single-parent) families, and nearly 20% of the population is under 15 years of age.
The common trend of elderly housing is retirement homes are not dominant anymore, this is stated by the governmental decision of "Langer thuis" program ("Staying as long as possible at home"(Ministry and public health, welfare and sport, 2018). This trend is also captured by PBL (2016).



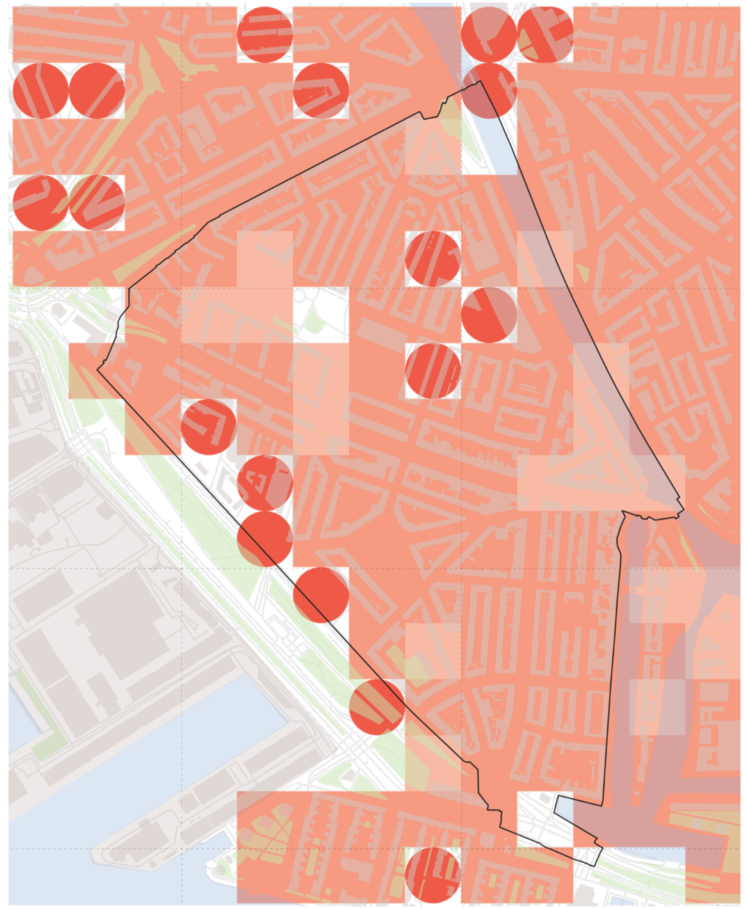


INCLUSION: Vulnerable groups

Legend

functions

- 10-20% 0-15 year
- 20-30% 0-15 year
- 20-30% 45-65 year
- 10-20% 65+ year
- 20-30% 65+ year
- 20-30% 65+ year



INCLUSION: average householdsize

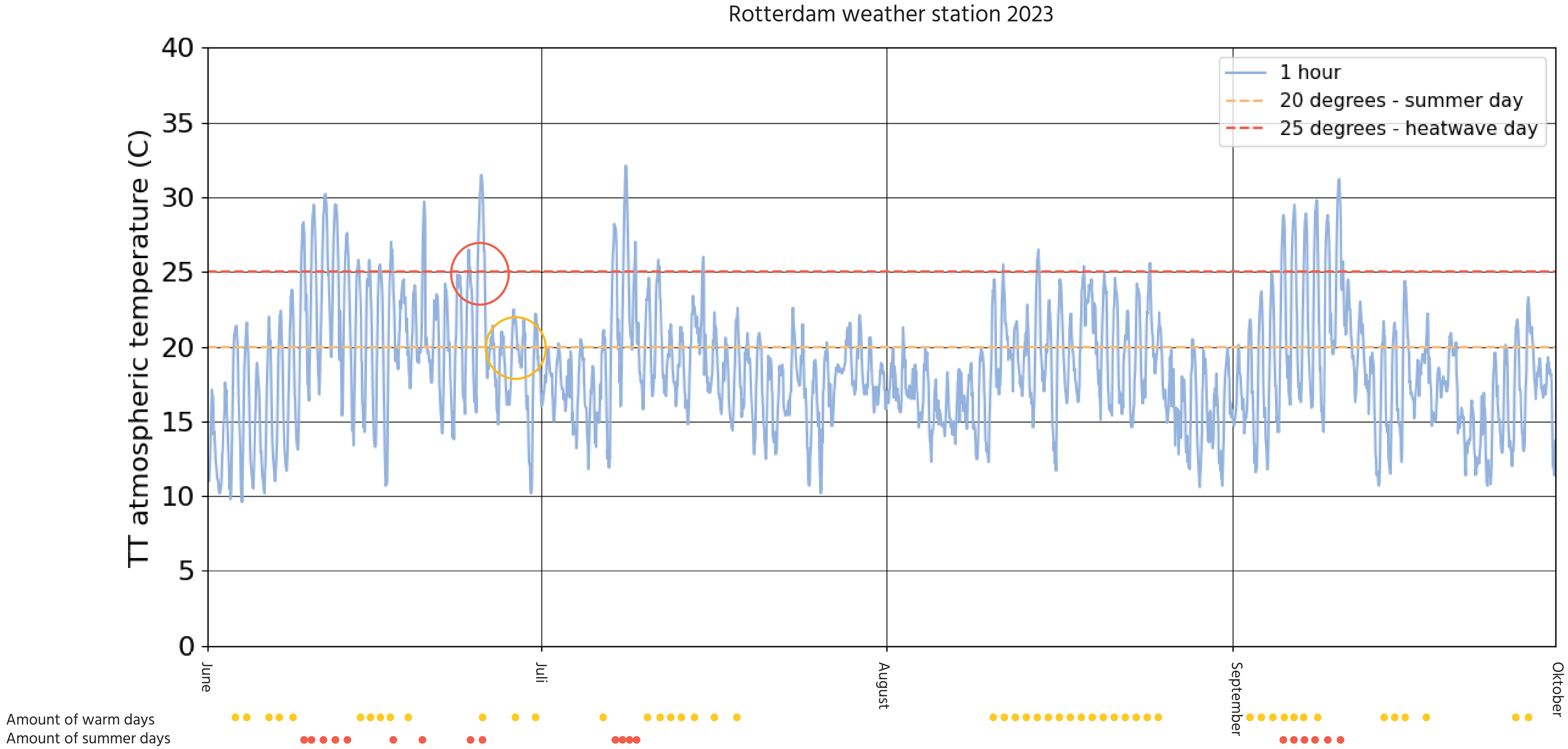
Legend

functions

- 0.0-1.5
- 1.5-2.5
- 2.5-5.0

source: cbs 2022

Appendix L. Temperature in year 2015



Appendix M. Street orientation

North South oriented streets

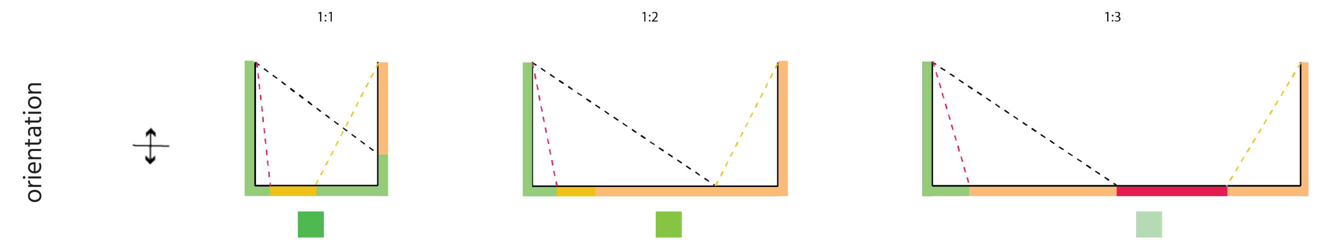
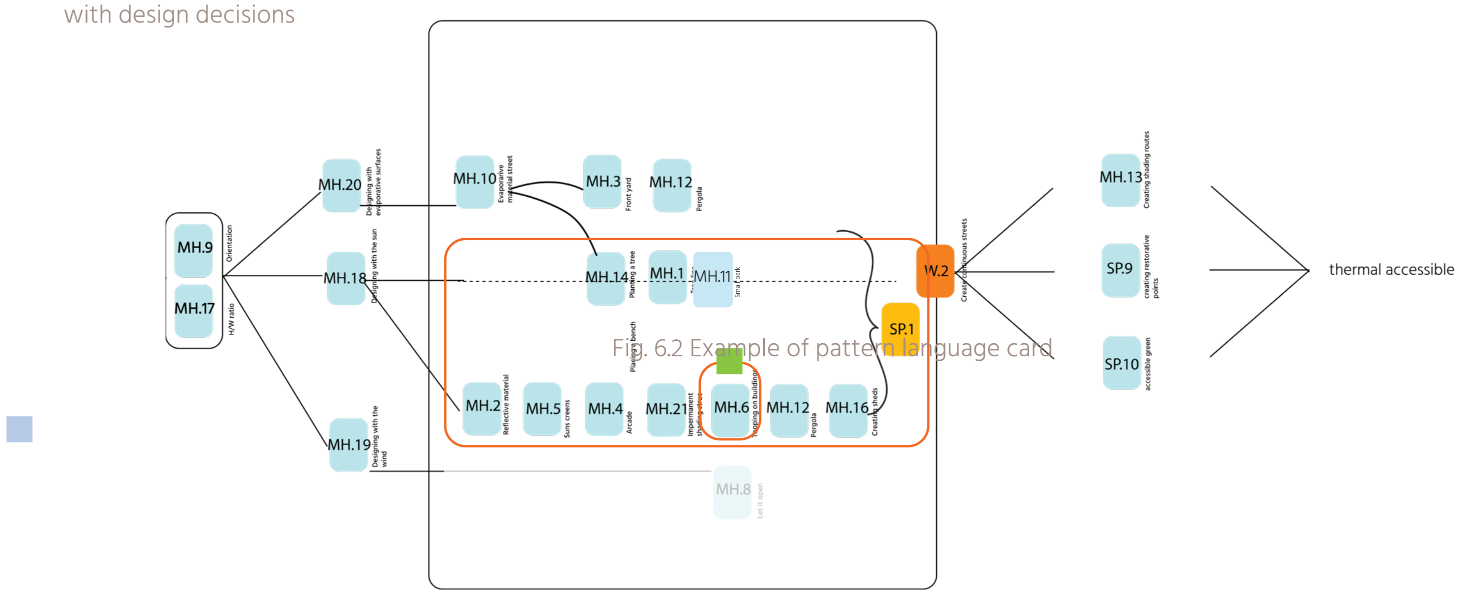


Fig. 6.9 solar exposure on street type H/W ratio and orientation from Lenzholzer (2018) (page 86) with design decisions



North East South West oriented streets

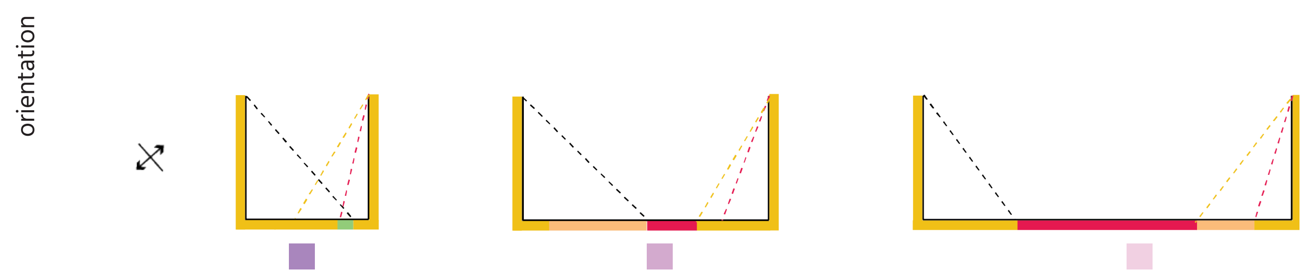
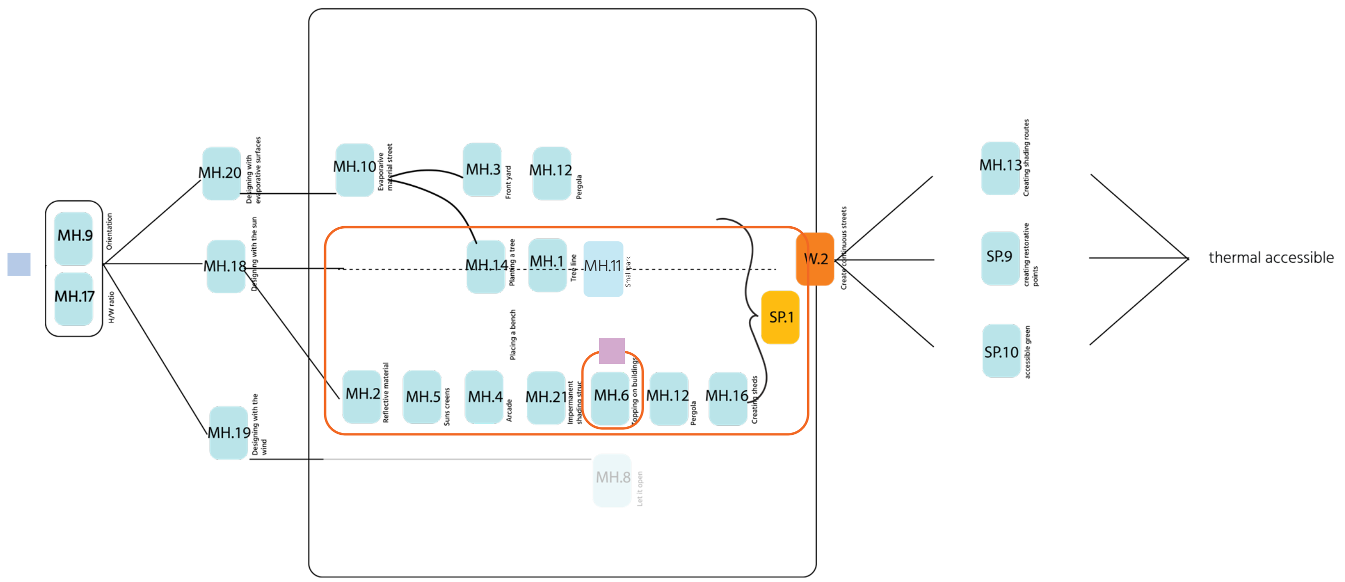


Fig. 6.10 solar exposure on street type H/W ratio and orientation from Lenzholzer (2018) (page 86) with design decisions



Chapter 6 | Intervention - towards a public space health resilient network design

East West oriented streets

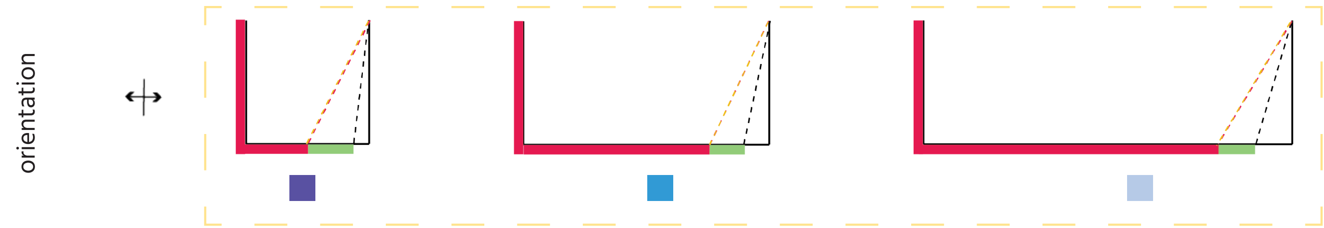
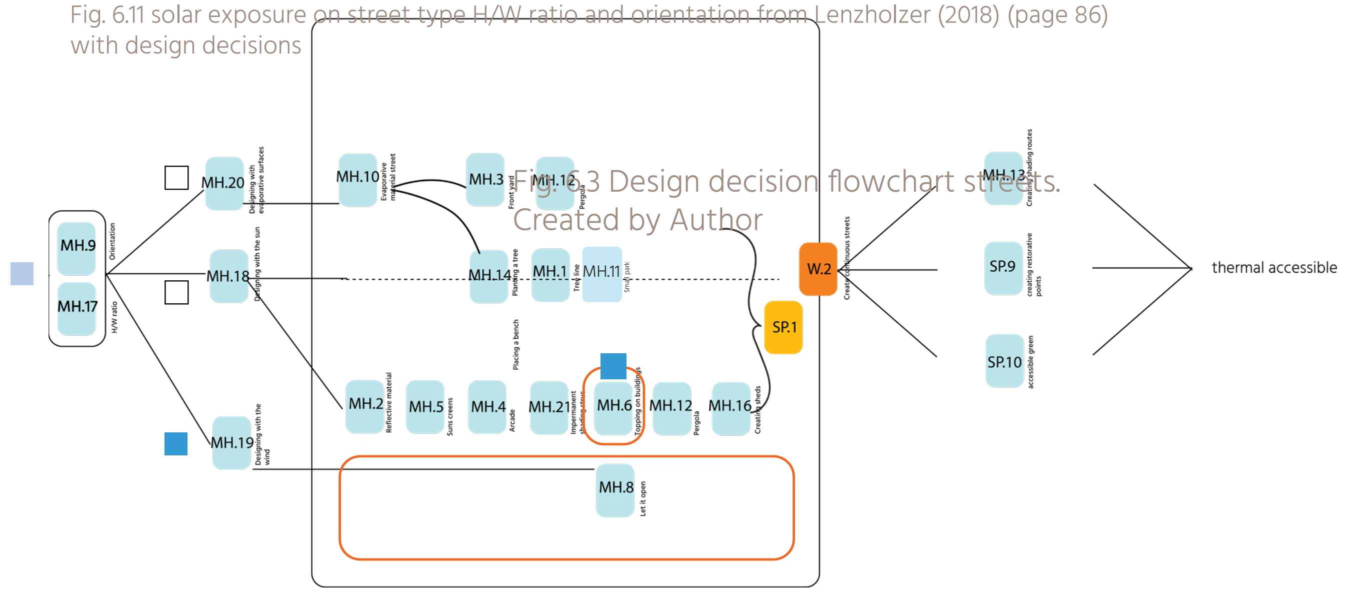


Fig. 6.11 solar exposure on street type H/W ratio and orientation from Lenzholzer (2018) (page 86) with design decisions



North East South West oriented streets

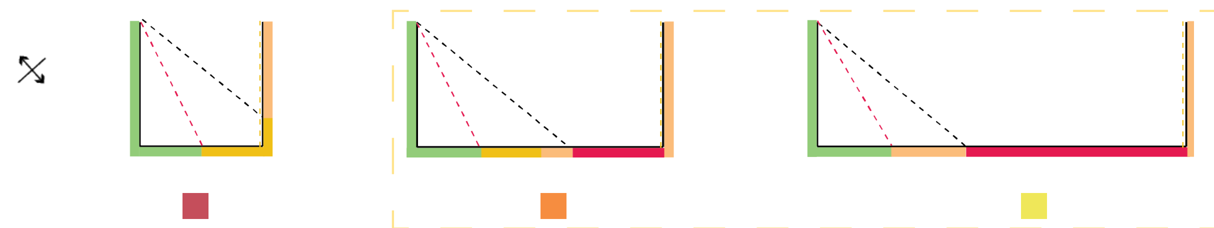
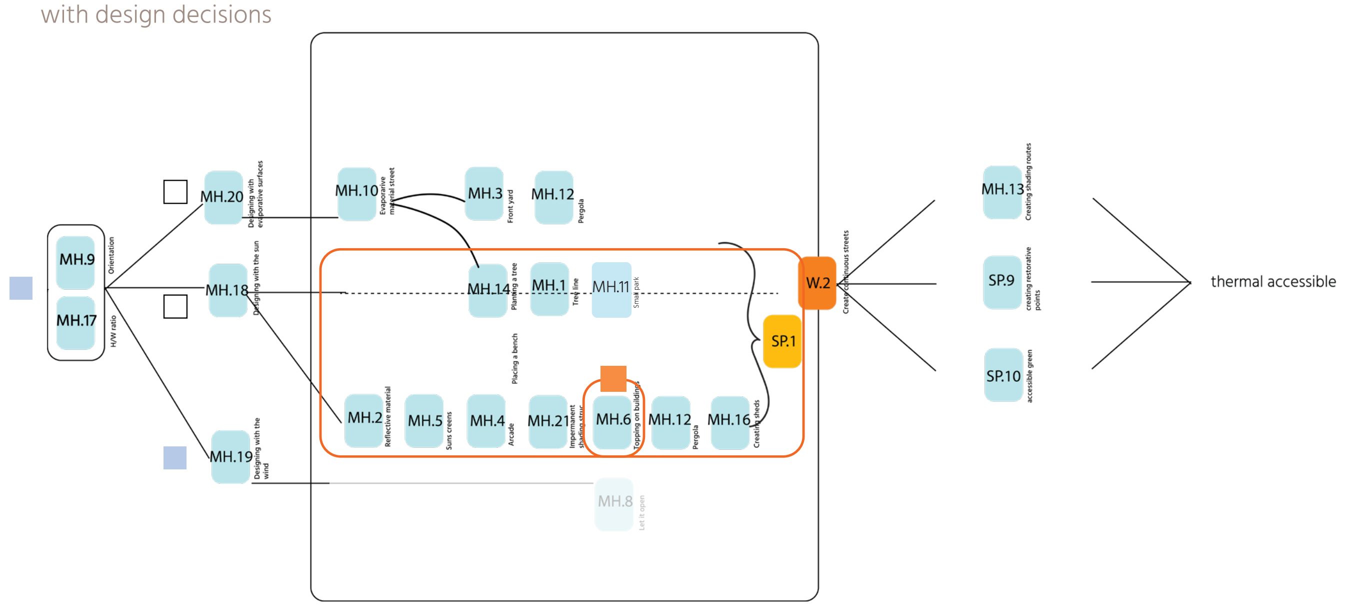


Fig. 6.12 solar exposure on street type H/W ratio and orientation from Lenzholzer (2018) (page 86) with design decisions



Appendix N. Rosenier Faasenstraat

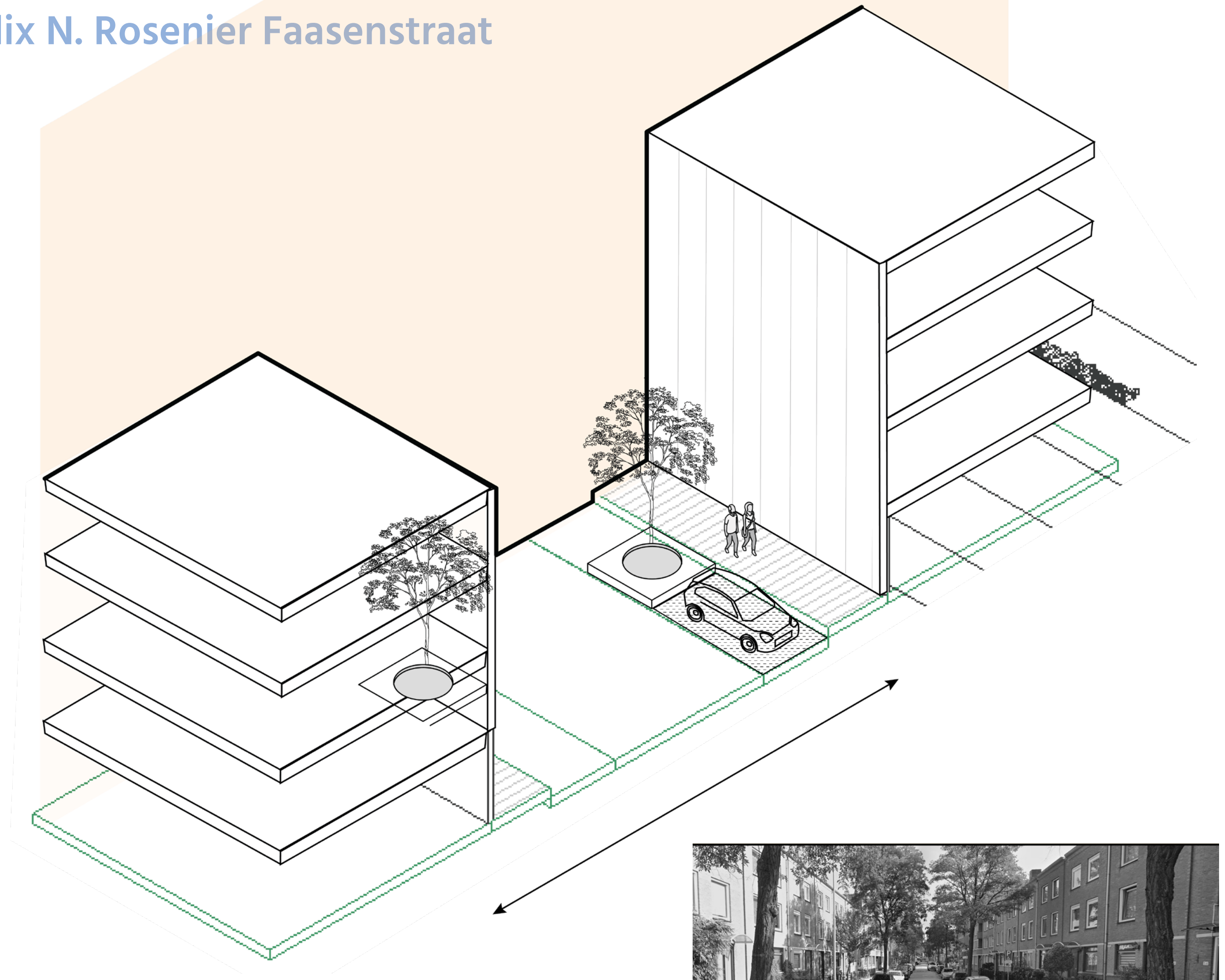


Fig. 6.31 Axonometric Rosenier Faasenstraat

Fig. 6.32 Visual Rosenier Faasenstraat

In this area, the community is considering a project to transform the local street, Bospolderplein, by involving residents and removing some of the parking spaces. The plan is to start by removing pavement from some of the parking spots to make room for trees to grow. Additionally, planters may be placed in some areas to give neighbors control over the public space and provide a functional purpose. Most of the housing in the area is owned by social housing corporations, which means that residents could collectively maintain the planters. Eventually, the goal is to replace all the parking spots with green spaces in the long term. Furthermore, the plan includes depaving all the front gardens in the area.

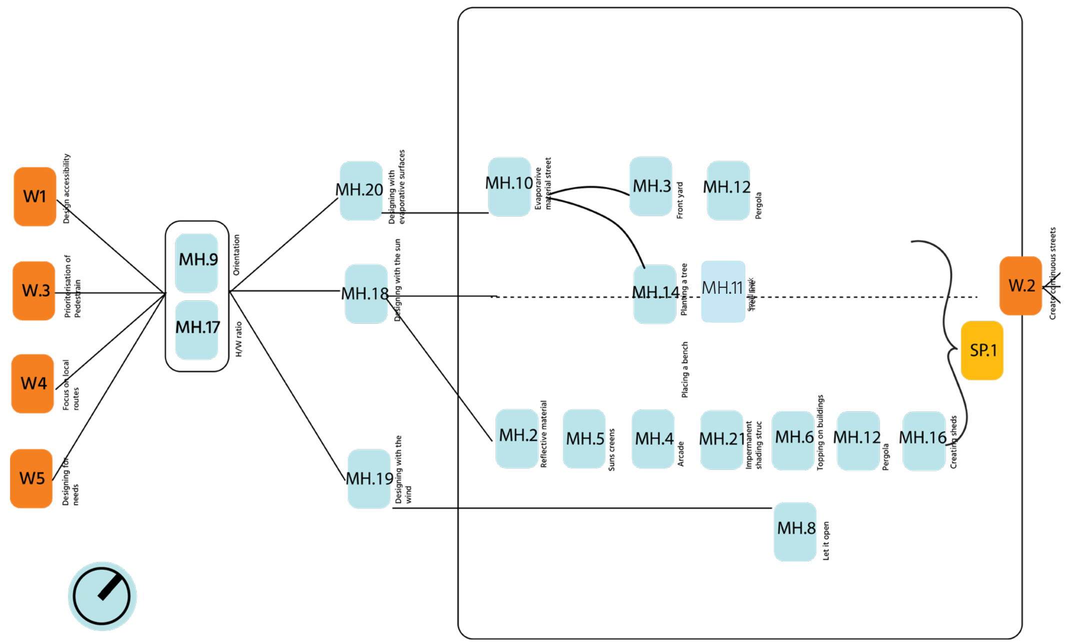


Fig. 6.33 Street decision flowchart. Created by Author