Designing Heat Refuges

for the Dutch Elderly

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Abstract

Netherlands is a coastal country with a typical maritime climate such as mild summers and cold winters but the intensity, duration and frequency of heat waves has been observed increasing since 21st century. The elderly, as one of the vulnerable groups of continuous hot weathers, are the first to be affected by the heat waves with regard to increasing mortality and morbidity while the aging population combined with uneven distribution of the urban heat risks is exacerbating the situation and placing challenge to the public. Public health interventions have been applied in the past few years which have been proved to be effective but the overall effect for the future scenario is questionable. Strategies from urban planning have been focusing on the mitigation of urban heat island and adaption to extreme weather conditions but the effect should be expected in a long term. Since the urban heat island and the uneven distribution of heat risks have strong interaction with physical environments in the urbanized areas, the thesis is seeking for the solutions to intervene within existing urban settings to reduce heat stress for the Dutch elderly through urban design approach to fill in the gap between public health and urban planning interventions.

The thesis, by analyzing and researching in The Hague as the test field, introduced an approach to uncovered the causation of the uneven distribution of urban heat risks among the public and evaluate the heat risks level among the elderly from large scale to small scale. The further research on the courtyard block dwellings in the study areas reveals the potential heat risks from the perspective of building configuration and several interventions have been applied within the blocks to reduce the heat stress for the residents.

The design outcomes consist of strategies and temporal spatial interventions, 'Cooling sheds', and urban microclimate design following the instruction of strategies has been applied in the study areas to the test effectiveness of the strategies. The combination of the application of strategies through urban microclimate design process and the placing of cooling sheds on neighborhood streets could work as a network on various scales to reduce the heat stress for not only the citizens and healthy elderly but also the elderly with restriction of movements in different times in The Hague. The ideas behind the research and strategies could also be applied broadly in the urban renewal process from the microclimate perspectives in the Netherlands to reduce the heat stress among the public.

Key words: Heat waves, the elderly, heat refuges, microclimate, urban design.

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Figure - More deaths during recent heat wave (CBS, 2019a).

Source: https://www.cbs.nl/en-gb/news/2019/32/more-deaths-during-recent-heat-wave.

1 INTRODUCTION

A brief introduction of the situation with regard to heat waves, ageing population and relative issues in the Netherlands to offer a comprehensive impression of the background of the heat-related issues in the thesis. The sub-question 1 (***background***) will be also uncovered through each step in the chapter.

- Global Warming & Heat Waves
- Glossary of Terms
- Background
- Theory & Empirical Knowledge

1.1 Global Warming & Heat Waves

Global warming is placing challenge and pressure to the whole public with regard to extreme weather conditions like heat waves. For example, with the higher temperatures recorded, around comparable times of heat waves by governments are recorded in the Netherlands since 21st century compared with those in 20th century (accurate statistics as 16 times in the 20th century and 12 times by 2019) (KNMI, 2019) and more extreme heat waves could become commonplace by the 2040s (Christidis, Jones, & Stott, 2015). One of the most severe heat waves which occurred across Europe in August 2003 had caused at least 30,000 death, most of whom are the young and the elderly, and enormous economic losses as well. With the continuous emission of greenhouse gases, the rising global mean temperatures will be common and the chance to face heat waves in cities is increasing. More attention from different sectors should be focusing on the prevention of the impact from unpredictable extreme weathers.

As an urbanist, one of our ambitions is to offer citizens livable spaces in urbanized areas to enjoy their lives. However, urban heat risks have already posed a challenge to the society all over the world while vulnerable groups like the elderly and the people with underlying diseases are suffering more from the excessive heat. Moreover, the extreme hot weathers are also changing the behavior of citizens (Figure 1.1). Therefore, urban planning and design should response to extreme hot summers positively and more attention should be focusing on the mitigation of the impact from heat waves on the health of the vulnerable group. To achieve the ambition of livability and deal with the challenge from climate change, the climate-adaptive urban planning and design could be introduced in coming years to make cities resilient to the extreme weathers.

Figure 1.1. People cool off next to the fountains at the Louvre Museum in Paris, on July 24, 2019. Temperatures in Paris are forecast to reach 41 degrees on Thursday. (AP Photo/Rafael Yaghobzadeh)

Source: https://mainichi.jp/english/articles/20190726/p2g/00m/0in/052000c

1.2 Glossary of Terms

Heat stress

Right now, there is no acknowledged definition of heat stress. The website 'HEATSTRESS' defines heat stress as a situation where too much heat is absorbed by a person, a plant or an animal and causes stress, illness or even death (HEATSTRESS, 2019). However, it is well accepted that some people are more at risk of heat stress, including babies and young children, the elderly, and people with some illness or on certain medications.

In the research papers and reports, different criteria are applied to evaluate that if people are experiencing heat stress. Matzarakis and Mayer have applied the thermal indexes predicted mean vote (PMV) and physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings (Matzarakis & Mayer, 1996; Matzarakis, Mayer, & Iziomon, 1999) and it could be interpreted that people are facing heat stress when PET is over 23 °C (Table 1.1). Molenaar et al. also estimated that the number of hours of experienced heat stress defined as the hours with physiologically equivalent temperatures above 23 °C in their research in the Netherlands (Molenaar, Heusinkveld, & Steeneveld, 2016). In the research on quantifying urban planning strategies on heat stress in The Hague, heat stress is expressed as the number of days with the minimum temperature no less than 20 degree (Koopmans, Ronda, Steeneveld, Holtslag, & Tank, 2018).

PMV	PET (°C)	Thermal perception	Grade of physiological stress
		Very cold	Extreme cold stress
-3.5	4		
		Cold	Strong cold stress
-2.5	8		
		Cool	Moderate cold stress
-1.5	13		
		Slightly cool	Slight cold stress
-0.5	18		
		Comfortable	No thermal stress
0.5	23		
		Slightly warm	Slight heat stress
1.5	29		
		Warm	Moderate heat stress
2.5	35		
		Hot	Strong heat stress
3.5	41		
		Very hot	Extreme heat stress

Table 1.1. Ranges of the thermal indexes predicted mean vote (PMV) and physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo (Matzarakis & Mayer, 1996; Matzarakis, Mayer, & Iziomon, 1999).

Source: Reproduced by author.

Physiological equivalent temperature (PET)

PET is the abbreviation of physiological equivalent temperature to evaluate the thermal perception by human beings in the outdoor microclimate and there are four factors which codetermine the physiological equivalent temperature which are air temperature, wind velocity, mean radiant temperature and relative humidity. When it comes to the empirical value of the comfortable range of PET, Matzarakis and Mayer have argued that the value of PET between 18 and 23 °C could be interpreted as comfortable range (Matzarakis & Mayer, 1996). However, the comfortable range of PET is also influenced by the local climate with regard to thermal adaption as well as personal factors such as clothing and health situation. For example, the study of the users' thermal comfort in a public space in Taiwan 'derived the thermal comfort range for open spaces in a hot and humid region as being between 21.3 - 28.5 °C PET' (Deb & Alur, 2010). Therefore, the thermal comfort range for the elderly in the public space in the Netherlands still need more research due to the comprised health situation of the elderly.

Heat wave, Tropical day & Tropical night

There are different criteria to define what is a heat wave due to different geographical situation and thermal adaption of local residents but all of the definitions are trying to describe uncommon continuous hot weathers with the temperature exceeding a threshold. Heat waves are most common in summer when high pressure develops across the area. High pressure systems are slow moving and can persist over an area for a prolonged period of time (Koopmans et al., 2018). Recent study on the relationship between heat waves and climate change by Met Office showed that climate change is making heat waves more frequently as the concentration of greenhouse gases increases (Press Office, 2018).

KNMI, which is known as Netherlands Royal Meteorological Institute, defined a heat wave as a sequence of at least 5 summer days in De Bilt (maximum temperature 25.0 °C or higher), of which at least three are tropical days (maximum temperature 30.0 °C or higher). (KNMI, 2019a). The impact of heat waves is strongly represented by exposure to continuous heat, which poses serious challenge to the public especially during the later periods of heat waves. According to meteorology, a tropical day is a day on which the maximum temperature is 30.0 °C degrees or higher and the majority of the Netherlands usually has two to five tropical days on average per year (KNMI, 2019b). When it comes to tropical nights, which are known as the minimum temperature no less than 20 °C during nights, they are likely to occur in urban areas particularly during relatively long warm episodes or heat waves, which will negatively impact sleep quality and furthermore influence the well-being of people (Koopmans et al., 2018).

Climate change & Global warming

Climate change is defined by Intergovernmental Panel on Climate Change, which is known as IPCC, as any change in climate over time, due to either natural variability or the result of human activity (IPCC, 2001). NASA also gives the definition to 'climate change' that a long-term change in the Earth's climate, or of a region on Earth (NASA, 2008). Climate change is used to describe the change of climate in a long term while global warming is employed for the rising of the surface temperature globally. NASA defines global warming as the increase in Earth's average surface temperature due to rising levels of greenhouse gases (NASA, 2008). IPCC argues that 'Global warming is defined [...] as an increase in combined surface air and sea surface temperatures averaged over the globe and over a 30-year period' in the report (IPCC, 2018). It is widely believed that the continuing CO2 emission is one of the causes of climate change as well as global warming and extreme weathers are becoming commonplace through this process.

Urban heat island (UHI)

Urban heat island is defined as the presence of significantly higher temperatures in urban areas compared to temperatures in surrounding rural area (Pariona, 2019). The UHI intensity is defined as the difference between the highest air temperature recorded in the urban canopy and the lowest one recorded in the surrounding rural areas (Alcoforado & Andrade, 2008). Urban heat island effect is strong during nighttime and threatens the health of the public, especially the people living in the city center.

Urban microclimate

Urban microclimate is a place where has a local set of atmosphere conditions that differ from the rest of areas surrounding the place. Usually, 'microclimate' refers to regions that range in sizes which can range from being a few square feet as a garden or being as large as many square kilometers with unique climatic conditions (Wanjohi, 2017). The term of urban microclimate in the thesis is mainly refer to the microclimate on a small scale such as street scale and neighborhood scale.

Intrinsic factor & extrinsic factor

Intrinsic and extrinsic factors are used to describe the factors which influence the level of urban heat risk. Intrinsic factors 'refer broadly to the physical condition of individuals in the literatures' and age is at the forefront among the susceptible explanatory variables of unequal risk distribution (Fernandez Milan & Creutzig, 2015). Moreover, 'People with lower mobility and confinement to bed, people suffering from cardiovascular diseases and those with pre-existing psychiatric and pulmonary illnesses and renal problems show higher susceptibility' (Fernandez Milan & Creutzig, 2015, p224). When it comes to extrinsic factors, they 'point to stratified levels of risk across socio-economic and spatial urban settings.' The research on extrinsic factors in terms of social, economic, environmental and political characteristics could help to explain the uneven distribution of risk among the population (Fernandez Milan & Creutzig, 2015). The main consideration of intrinsic factors and extrinsic factors in the thesis are the age and health situation of the citizens and physical environmental characteristics respectively.

Commutative justice & Distributive justice

Commutative justice and distributive justice are the terms to evaluate the equity of welfare or benefits and they relate to how fairly policies or interventions are distributed among the various targeted groups by considering how much of needed benefits the individuals in each recipient group received in the thesis. Fernandez Milan and Creutzig explained these two terms in the paper as 'Commutative justice is the equal provision of a good or service to each group or individual. Distributive justice considers that a fair amount should be provided according to the level of need' (Fernandez Milan & Creutzig, 2015, p223).

When it comes to the public response to reduce urban heat risks, Fernandez Milan and Creutzig argued that, in general, public health interventions address citizens with higher intrinsic risks from the perspectives of distributive justice with regard to prioritizing the assistance of individuals at high risks while urban planning performs well for commutative justice at various scales since it helps to decrease the overall urban heat island effect. For example, the urban planning strategies including the increase of albedo and optimizing the urban canopy layer are cost-efficient at the household level for the occupants with middle and low income from the commutative justice perspective (Fernandez Milan & Creutzig, 2015).

1.3 Background

1.3.1 Climate Change & Heat Wave

Netherlands is a coastal country with a typical maritime climate such as mild summers and cold winters. Since 21st century, there are already several heat waves recorded and the duration and frequency of heat waves could be observed increasingly (KNMI, 2019a) (Figure 1.2).

The Royal Netherlands Meteorological Institute (KNMI) has developed four scenarios to describe how the climate may change, namely the G_L, G_H, W_L and W_H scenarios (Figure 1.3). There is an equal chance of the occurrence of four scenarios and 'Both the mean temperature and mean precipitation will increase in the future in all four scenarios except for summer precipitation.' (Attema et al., 2014). It is predictable that summers in the Netherlands will become hotter and drier and citizens are more likely to experience heat waves in coming years.

1.3.2 Heat-related Health Issues

During the heat wave of 2019, 400 more deaths were recorded by Statistics Netherlands (CBS) due to the heat wave in the week 30, 300 of which are the people aged 80 years and over. Relatively speaking, mortality among the elderly per week was lower during the heat wave in 2019 compared with the heat wave in 2006 which is known as the most serious heat wave in the Netherlands. However, the mortality per week around the weeks during heat waves in 2019 still witnessed an increasing compared with the same period in the past few years. When it comes to the age composition, all of the age groups saw a relative decline in mortality in the past few years compared with that in 2006 and for the people with age groups of 0 to 64 years and 65 to 79 years, mortality seems to stay stable, no matter there were heat waves or not. However, the elderly aged 80 years and over were more likely suffered from the intense heat wave in 2019 with higher temperature recorded (CBS, 2019 a) (Figure 1.4).

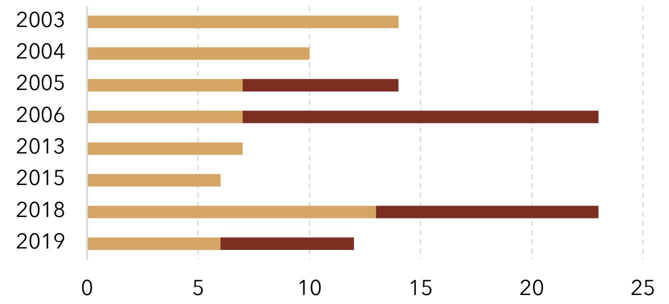


Figure 1.2. Recorded heat waves (days) in the Netherlands since 21st century (KNMI, 2019a).

Source: Reproduced by author.

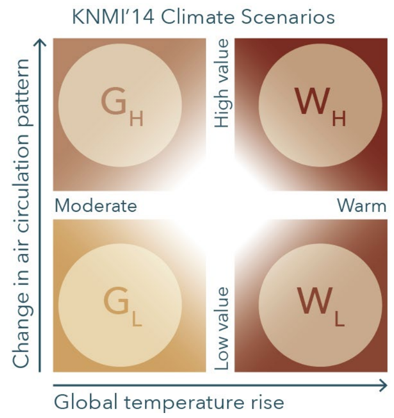


Figure 1.3. Four scenarios are used to predict the climate change in the Netherlands. They differ in global temperature rise and change in air circulation. Horizontal axis represent the different temperature increases with 'G' from 'Gematigd' or 'moderate' and 'W' from 'Warm' while vertical axis denotes the two scenarios for precipitation, which are a strong response labeled with subscript 'H' with wetter winters and drier summers as well as a relatively weak response labeled with subscript 'L' with smaller changes in precipitation (Attema et al., 2014).

Source: Reproduced by author.

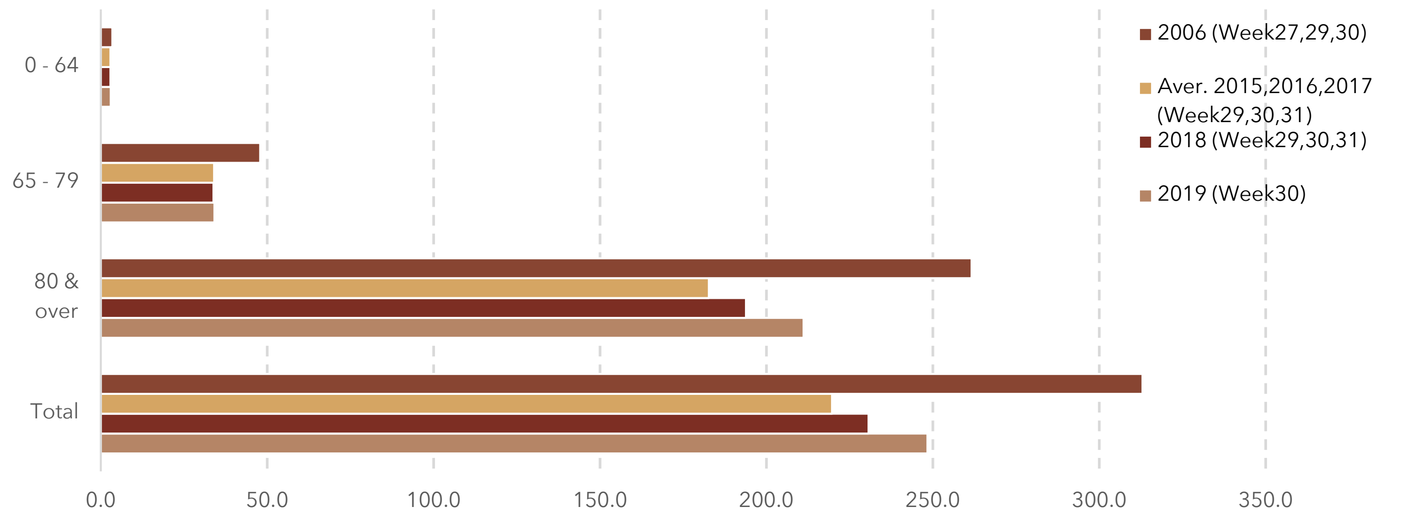


Figure 1.4. The death in different age groups during same period with heat wave in 2006, 2018 & 2019 (death per 100 thousand inhabitants per week) (CBS, 2019a).

Source: Reproduced by author.

The numbers of mortality during heat waves in the Netherlands are one of the most accessible data but the impact of heat waves on the public results in not only excessive death but also mortality and heat-related symptoms. The health issues such as respiratory diseases and cardiovascular diseases as well as the impact of persistent hot weathers on the daily life of the public including sleep disturbance and tiredness are always mentioned in the literatures with regard to heat-related health issues as well. (Huynen, Martens, Schram, Weijenberg, & Kunst, 2001; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; van Loenhout et al., 2016). (More details could be uncovered in the chapter '1.4 Theory & Empirical Knowledge' and 'Appendix I').

1.3.3 Ageing Population

Netherlands is also a developed country and the number of the elderly, who are widely defined as the people who are 65 years old and over, has increased over one million since 21st century (2,152,442 in total in 2000 and 3,314,004 in 2019). According to Statistics Netherlands (CBS), half of Dutch adults have been over 50 in 2019 and around half of over-50s are the elderly (CBS, 2019 b). There is already a swift growth of the number of the elderly since 2010 and the trend is likely to go on until 2040. By 2050, it is predicted by CBS that there will be 4.75 million inhabitants aged 65 years and over, 40 percent of which will be over-80s (CBS, 2017) (Figure 1.5). However, although the number of the elderly is growing rapidly in the Netherlands, the number of them living in care and nursing homes is decreasing while the share of old people living alone and living with a partner is rising. Moreover, six out of seven over-80s live independently and only some of them could get support (CBS, 2011). The ageing population has already become a challenge to the economics with regard to pension and health care while the growing amount of the elderly will pose more pressure on the society. The heat risks among the elderly posed by the heat waves in coming years will be more likely to aggravate the burden on the public.

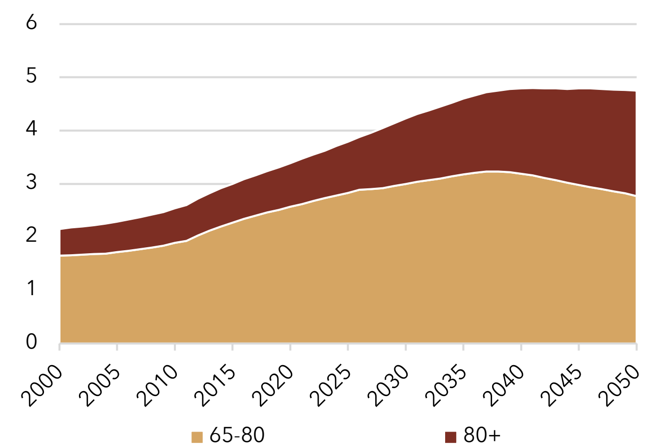


Figure 1.5. Current and predicted amount of the elderly (in million) in the Netherlands, by CBS (Forecast as of 2018) (CBS, 2019b).

Source: Reproduced by author.

1.3.4 Uneven Distribution of Urban Heat Risks among the Elderly

The Hague is the capital of the province of South Holland which is located on the western coast of the Netherlands. The Hague has been a member of the age-friendly city network since 2015 and some actions and several activities including improving vitality, reducing loneliness and enhancing older people's participation have taken place in the municipality of The Hague (WHO, 2019) . According to prediction by Netherlands Environmental Assessment Agency (PBL), about half of the population will live in the Randstad and there will be a significant increase of the number of the elderly in large municipalities such as The Hague and Rotterdam (PBL, 2014) (Figure 1.6). Moreover, the study on heat islands by TNO claimed that The Hague was facing the worst heat island effect during daytime (TNO, 2012) (Figure 1.7). Although another study concluded that the heat island effect in The Hague was not more serious than that in the rest of the Metropolitan region, the UHI is indeed significant in The Hague (Hoeven & Wandl, 2018). To sum up, the urban heat island is indeed severe in The Hague while the population and the number of the elderly are predicted to grow in coming years, which makes The Hague an ideal municipality as a test field for the graduation thesis.

When it comes to the existing urban fabrics in The Hague, uneven distribution of heat risk could be uncovered by mapping the heat levels. There are already some research about the heat island effect or heat risk in The Hague. The overlay of urban heat maps with maps of the concentration of the elderly could help to identify the area where the elderly are vulnerable to hot weathers. The report 'Haagse Hiite', which means 'The Hague's Heat' in English made a social heat map from surface energy balance perspective and the result is divided into six clusters (Figure 1.8). For example, clusters with color black refer to the highest value of heat island effect while the ones with color red show the high concentration of the elderly with lower heat island effect. Moreover, some clues from the report, such as city center and the areas built around the 1930s encouraging the urban heat island most, also illustrate the uneven distribution of urban heat risks among the public (Hoeven & Wandl, 2018).

1.3.5 Conclusion

With the global mean temperature rising, urban heat risk in the Netherlands will increase due to extreme weathers with regard to the number of heat wave days and the vulnerability will also be increased by individual susceptibility in term of ageing population (Fernandez Milan & Creutzig, 2015). Heat wave has become one of the factors to add up to the challenge of ageing population while more elderly prefer to live individually or with a partner, which exacerbates the threat of heat waves. The increasing temperatures and uneven distribution of urban heat risks have already been a threat to the life quality of citizens especially for the elderly and more attention should be drawn on the vulnerable groups who are facing severe urban heat risk.

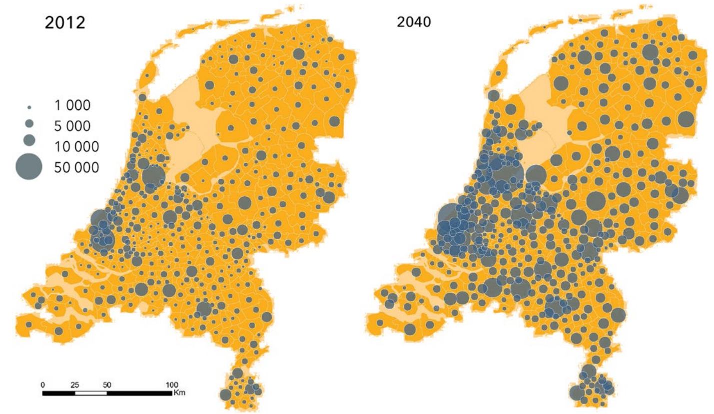


Figure 1.6. The prediction of the concentration of the elderly in the Netherlands (PBL, 2014).

Source: DE NEDERLANDSEBEVOLKING IN BEELD ('The Dutch population in image' in English).

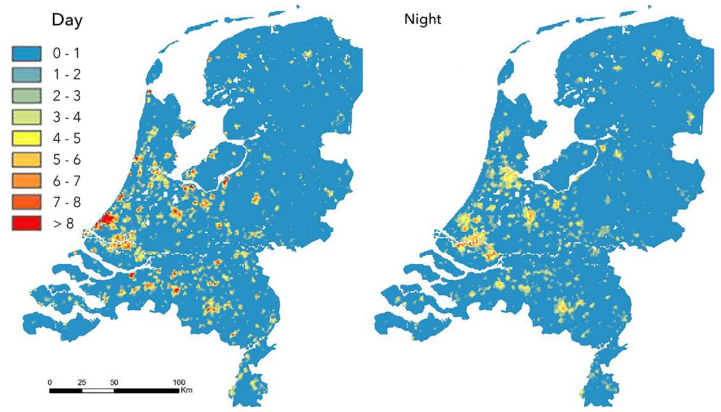
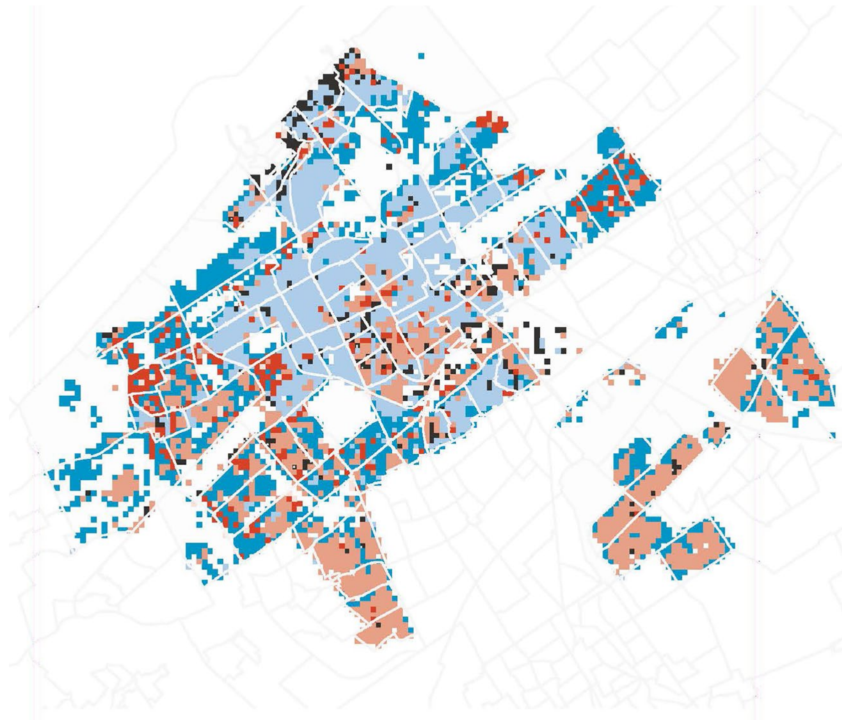


Figure 1.7. Average temperature difference with respect to ambient temperature in The Hague during the day and at night, 16 & 17 July 2003 (TNO, 2012).

Source: De stedelijke hitte-eilanden van Nederland in kaart gebracht met satellietbeelden. ('The urban heat islands of the Netherlands mapped with satellite images' in English).



Legenda	sterfte + 50-60% / sterk hitte-eiland	sterfte + 40-60% / concentratie 75 +	sterfte + 40-50% / weinig 75 +	concentratie 75 + / historisch	lichte sterfte + / vooroorlogs	lichte sterfte + / zwak hitte-eiland
75-plussers/ha	4	30	2	97	5	3
Ouderdom gebouw	gem. 1962	gem. 1968	gem. 1994	gem. 1881	gem. 1923	gem. 1965
QH + QS (W/m2)	325	223	238	218	248	190
Overleden 75+ ers juli 06	61	81	32	29	67	17
Overleden 75+ ers juli '06 / juli '07	25 (+61%)	34 (+58%)	12 (+53%)	8 (+38%)	11 (+17%)	3 (+16%)
Overleden 75+ ers juli '06 / juli '01-'15	20 (+48%)	23 (+39%)	9 (+41%)	8 (+39%)	1 (+2%)	-2 (-9%)

Figure 1.8. Social Heat Map - The spatial pattern of vulnerability of the elderly in particular to heat in The Hague. (Hoeven & Wandl, 2018).

Source: Haagse Hiite.

In order to have a comprehensive understanding of the impact of continuous hot weathers on the health and daily life of the elderly in the Netherlands to support further research and design, the review of literatures and reports about the contents in the Netherlands and surrounding countries with the key words such as heat, heat wave, mortality, morbidity and the elderly, has been conducted. The contents in the chapter 'Theory & Empirical Knowledge' could be divided into three aspects, which are heat-related mortality, morbidity and symptoms respectively.

Background

With the continuing emission of greenhouse gas, it is now widely accepted that climate change is occurring. As one of the consequences of global warming, heat waves are increasing in frequency, intensity and duration across the world (IPCC, 2007) and more extreme heat waves could become commonplace by the 2040s (Christidis, Jones, & Stott, 2015). The increasing mean temperatures and continuous hot weathers are increasing the chance of exposure to high ambient temperatures which will lead to an increase both in mortality and morbidity. One of the most severe heat waves in 2003 across the Europe was estimated to cause around 40,000 deaths in Europe, most of which are the elderly, and it also highlighted the widespread unpreparedness of the society to cope with such large events (García-Herrera, Díaz, Trigo, Luterbacher, & Fischer, 2010).

When it comes to the situation in the Netherlands, the maritime climate with mild summers and cold winters is typical. However, during the heat waves in 2003 and 2006, the hot weather in the summer of 2003 led to between 1,000 and 1,400 more deaths while one thousand more deaths were recorded in July 2006 in the Netherlands (CBS, 2003; CBS, 2006). It could be interpreted that the buildings and urban settings in the Netherlands are considered to prepare and design for cold weathers such as large windows to gain more sunlight and common indoor heating system while residential buildings are always not equipped with active cooling systems like air conditioners (van Hooff, Blocken, Hensen, & Timmermans, 2014), which makes the residents more vulnerable to the continuous hot weathers with less consciousness and preparation. Meanwhile, the Netherlands is also one of the countries that are facing the challenges of population ageing and various studies have uncovered that the elderly are most vulnerable to heat waves and high temperatures (Baccini et al., 2008; Li, Gu, Bi, Yang, & Liu, 2015; Sartor, Demuth, Snacken, & Walckiers, 1997; van Loenhout et al., 2018). Aging population and heat waves have already interacted with each other resulting in serious issues among the society and more attention from different sections should be focusing on the solutions to mitigate the risks with interdisciplinary thinking.

Heat-related mortality

The relationships between meteorological data and regional or national mortality have been analyzed in most studies to learn about the impact of heat waves or hot weathers on the public. Huynen et al. have conducted the study to investigate the impact of ambient temperatures on mortality in the Netherlands during 1970-1997 and a V-like relationship between mortality and temperatures with an optimum temperature value of 16.5 °C for total mortality and mortality among the elderly was found for Dutch population (Huynen, Martens, Schram, Weijenberg, & Kunst, 2001). It was also argued that 'Mortality increased significantly during all of the heat waves studied, and the elderly were most affected by extreme heat' since the health status of the elderly is more compromised with a reduced thermo-regulatory system and less sensitive thermal perception (Huynen et al., 2001).

When it comes to the causation of mortality during the heat waves, cardiovascular diseases and respiratory disease are most mentioned with most contribution to the deaths and all of the studies found that mortality increased during hot weathers for all cause-of-death groups examined (Baccini et al., 2008; Garssen et al., 2005; Gasparrini, Armstrong, Kovats, & Wilkinson, 2012; Huynen, Martens, Schram, Weijenberg, & Kunst, 2001). There are also some studies showing the impact of hot weathers interacting with air pollution which prevailed during heat waves on the mortality since ozone is readily formed under warm and sunny conditions while PM_{10} concentrations also tend to rise during hot weathers (Filleul et al., 2006; P. Fischer, Ameling, & Marra, 2008; P. H. Fischer, Brunekreef, & Lebret, 2004; P. H. Fischer, Marra, Ameling, Janssen, & Cassee, 2011; Sartor et al., 1997; Sartor, Snacken, Demuth, & Walckiers, 1995; Willers et al., 2016). The upward trends were discovered in respiratory-related causes of death for PM_{10} during the period from 1992 to 2006 in the Netherlands and the direct effect of cardiovascular diseases are in part the result of increased stress on the circulatory system while the increasing number of cardiovascular deaths were found with more concentration of O_3 (P. H. Fischer et al., 2011; Kunst, Looman, & Mackenbach, 1993). Moreover, the elderly are also vulnerable to the interactions between high temperatures and air pollution and spatial differences in temperatures and air pollution could also result in different risks between not only cities but also neighborhoods (Willers et al., 2016).

In addition to the persistent hot weathers and accompanying air pollution, the intensity and duration of heat waves play an important role in increasing mortality and the sharp change in temperature at the beginning or end of the heat waves can also contribute to high risks of death (Guo et al., 2011; Huynen et al., 2001). When compared the mortality after heat waves with the same period during normal years, forward displacement of deaths, which is also known as harvest effect of heat, was also discover but it is hard to define the relationship between them, especially in the content of the Netherlands (Baccini et al., 2008; Garssen et al., 2005; Huynen et al., 2001).

Heat-related morbidity

Due to the limitation of data and privacy, there are a few literatures studying the effect of heat on morbidity focusing on the relationships between temperatures and hospital admissions (Kovats, Hajat, & Wilkinson, 2004; Mastrangelo et al., 2007; Michelozzi et al., 2009; van Loenhout et al., 2018). The recent studies based on the emergency room admissions and GP (general practitioners) consultations in the Netherlands illustrated a positive relationship between increasing admissions and hot weathers and the elderly are proved as one of the risk groups, especially for the 85+ aged group who had the highest relative risk for potential heat-related diseases and respiratory diseases (van Loenhout et al., 2018; Hondema, 2019).

The intensity of hot weathers also results in high morbidity and it was argued by Loenhout et al. that 'the impact of a single day with extreme heat is comparable to the impact of several days with moderate heat' (Joris Adriaan Frank van Loenhout et al., 2018), which emphasized that the impact of heat waves on the morbidity among the society could not be overlooked.

Heat-related symptoms and self-response measures

The impacts of individual perceiving heat on the daily life of the person have been studied by experiments and questionnaires on a group of people in different municipalities in the Netherlands (Table 1.2). There are only three research papers focusing on the heat-related symptoms, two of which also study how the investigated residents responded to heat waves and hot weathers (Daalen, Radboud, & Nijmegen, 2010; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; J. A.F. van Loenhout et al., 2016). The conclusion from these papers are inconclusive, but some points in common could be found from the results.

In the investigation of heat-related symptoms, most people reported the perception of extra heat during heat waves and sleep disturbance is most reported followed by tiredness and feeling exhausted (Daalen et al., 2010; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; J. A.F. van Loenhout et al., 2016). When it comes to reducing individual heat stress during hot weathers, most people were aware of extra perceived heat and could take some proper measures to reduce heat stress. However, during the investigation in Arnhem and Groningen the scholars also found that 'one in four participants in this period reported not to usually undertake any measures' (J. A.F. van Loenhout et al., 2016), which emphasizes the importance of the role of public health institutions in reducing heat risks among the public.

Conclusion

To conclude for the discovery from the literature review, mortality and morbidity increase significantly during consisting hot weathers in the Netherlands and surrounding countries and the elderly are proved to be vulnerable to hot weathers. Besides the impact of intensity and duration of heat waves on mortality and morbidity, the interaction between increasing temperatures and accompanying air pollution should not be overlooked.

When it comes to the individual level of perceiving heat, most people have reported perception of heat and could take some proper measures. However, a quarter of the investigated elderly took less action during the heat wave in Arnhem and Groningen (J. A.F. van Loenhout et al., 2016). (J. A.F. van Loenhout et al., 2016). The elderly are more vulnerable to heat stress due to less sensitive thermal perception (Huynen et al., 2001) and social segregation, especially for the ones who live alone and more attention should be paid to protect them from heat stress.

	Region & Cities	Number & Population	Heat-related Symptoms	Self-response to Reduce Heat Stress
Loenhout et al.	Arnhem, Groningen	113 (the elderly)	Thirst (42.7%); Sleep disturbance (40.6%); Excessive sweating (39.6%);	Drinking more water (69.8%); Reducing physical activity (62.5%); More natural ventilation (50.0%); Going outside (24.0%); Mechanical ventilation (16.7%); Leaving the city (13.5%);
Huynen	Province of Limburg	588 (adults)	Sleep disturbance (35.0%); Tiredness (around 33%); Swollen legs, feet or hands (14.3%); Feeling exhausted (13.4%); Respiratory problems (9.7%); Heart complaints (3.4%);	Drinking more water (94.0%); Wearing appropriate clothing (93.0%); Opening windows at night (91.0%); Avoiding strenuous activity (65.0%); Staying inside (60.0%); Taking a cool shower (58.0%);
Daalen et al.	Tilburg	316 (the elderly)	Sleep disturbance (61.7%); Fatigue (61.1%); Stuffiness (28.5%); Headache, dizziness, skin complaints, muscle cramps and problems with concentration (Around 20 to 25%);	----

Table 1.2. Heat-related symptoms and self-response to reduce heat stress (Daalen, Radboud, & Nijmegen, 2010; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; J. A.F. van Loenhout et al., 2016).

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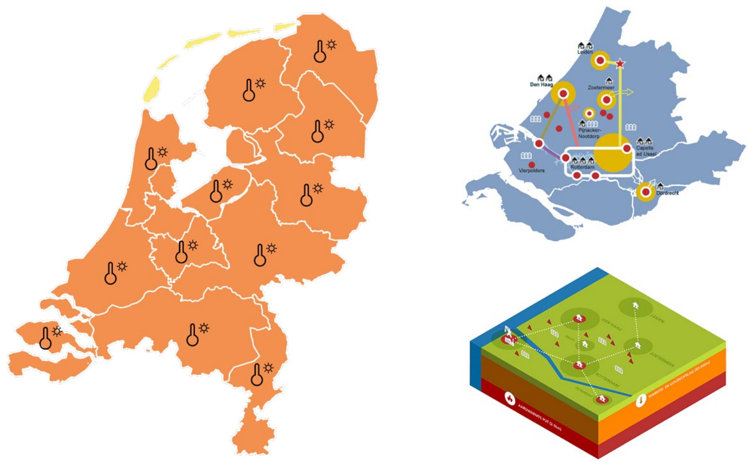

Figure. Code orange is issued when temperatures in the Netherlands reach above 30oC for three days in a row and temperatures don't cool down past 18C during the night. (Mina Solanki, 2018) & Heat roundabout in province Zuid Holland (Provincie Zuid-Holland, 2019).

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2 SCOPE

The chapter 'Scope' defines what is the issue of the thesis and illustrate how the research framework is built up and how the methods will be applied for further research and design. The sub-question 2 (***causation***) will be uncovered partially by the knowledge from literatures in the chapter.

- Public Response
- Problem Statement
- Research Aim
- Research Questions
- Conceptual Framework
- Research Framework
- Conclusion

2.1 Public Response

With the awareness of the impact of urban heat risks in the Netherlands, the practices and applications of the public responses to the urban heat risk are mainly from two perspectives which are public health and urban planning.

Public health institution, known as RIVM in the Netherlands implemented the National Heat Plan (Hagens & Bruggen, 2015) – a warning for everyone to be aware of the risks posed by persistent heat and also calling on everyone to pay extra attention to each other, especially for groups of vulnerable people, such as the elderly, babies, the people with chronic illness (Figure 2.1). Interventions from public health sectors were taken from distributive justice perspective and it has been proved that with the enhancing public awareness of the heat waves the heat-related death during heat waves saw a decline in the past few years compared with the mortality during the heat wave in 2006.

Meanwhile urban heat has a strong interaction with existing urban fabrics, resulting in urban heat island effect and uneven distribution of heat risks, showing that urban planning interventions become increasingly relevant (Fernandez Milan & Creutzig, 2015). The current responses from urban planning perspective to reduce heat risks among the public are mainly taken from two aspects in the Netherlands. On one hand, urban planning strategies like improving of energy structure and increasing albedo could contribute to the mitigation of urban heat island and global warming. On the other hand, the urban planning and design should be adaptive to the extreme weathers in order to make cities livable and sustainable (Figure 2.2 & 2.3).

2.2 Problem Statement

The intervention from public health institution has been proved to be efficient against heat wave in reducing individual susceptibility in past few years but it is difficult to up-scale public health interventions to city level because of uneven distribution of heat risk caused by extrinsic factors such as social and environmental factors as well as larger socio-economic inequalities (Fernandez Milan & Creutzig, 2015). Moreover, when it comes to the over-80s, an increasing trend of mortality could be observed in past few years (Figure 1.4), showing that overall performance of public health interventions for the future scenarios is questionable.

Urban planning interventions which are applied from commutative justice perspective increase in effectiveness with scale. However, the effectiveness at individual level to cope with susceptibility is rather low compared to public health interventions, which lower the equity outcomes of urban planning with regard to distributive justice (Fernandez Milan & Creutzig, 2015). Meanwhile, time is required to make decision of as well as apply the urban planning interventions to mitigate urban heat island and global warming as well as solve the uneven distribution of heat risks so that not enough interventions have been deployed so far and the effect could hardly be seen in a short period. To conclude, there is an obvious gap between time-efficient public health interventions focusing on individual level and urban planning interventions of which effect should be expected long afterwards. The spatial interventions which take distributive justice could be a possible solution to reduce the impact of the emergent urban heat risk for the elderly with the consideration of time efficiency (Figure 2.4).

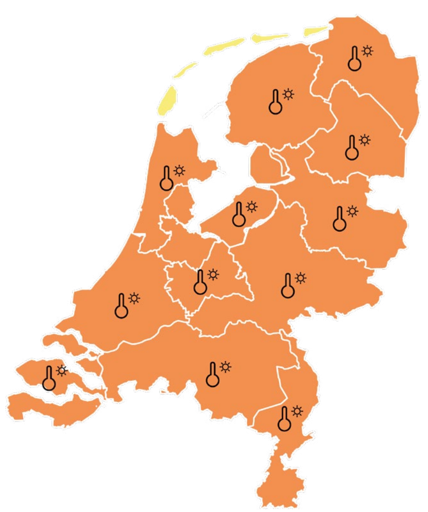

Figure 2.1. Code orange is issued when temperatures in the Netherlands reach above 30ºC for three days in a row and temperatures don't cool down past 18ºC during the night. (Mina Solanki, 2018).

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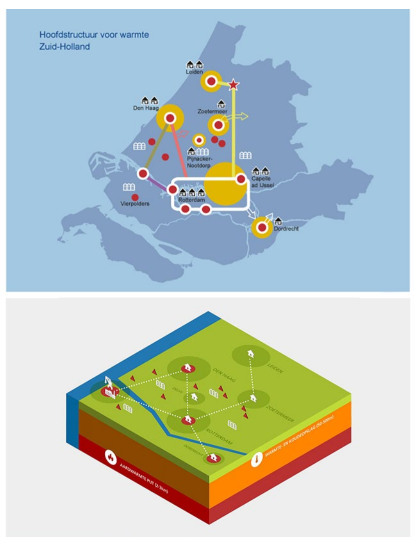

Figure 2.2. Heat roundabout in province Zuid Holland (Provincie Zuid-Holland, 2019).

Source: https://www.zuid-holland.nl/onderwerpen/energie/productie-duurzame/warmte-warmterotonde/.

Figure 2.3. Rainproof strategies in neighborhood (Amsterdam Rainproof, 2019).

Source: https://www.rainproof.nl/.

2.3 Research Aim

The impact of urban heat wave with regard to intensity, duration and frequency on the elderly has been proved to be enormous especially for the over-80s so spatial interventions need to be applied into practice to cool down the inside temperatures as well as the ambient temperatures in the public space especially for the areas where most of the elderly gather as soon as possible. Urban microclimate design could be the one of the best solutions on neighborhoods level but even planting some new trees also need years for trees to grow in order to have the proposed effect. Therefore, time-efficient spatial interventions to cool down the ambient temperature are necessary for the elderly or other vulnerable groups especially when heat wave is coming. The proposed urban microclimate design could improve microclimate both indoor and outdoor for the public and spatial interventions will meet the demands from the elderly for usage of the public space so the overall interventions could be taken from the joint of commutative and distributive justice perspectives.

The research and design in the thesis will attempt to figure out how to improve thermal performance by innovations on daily-used public space with more consideration of the elderly to contribute to the transition from efficient public health instructions of which overall performance is questionable in the future (Fernandez Milan & Creutzig, 2015) to proposed urban microclimate design which is taken from commutative justice perspective (Figure 2.4). Moreover, the knowledge from the research and design could contribute to the discussion of urban renewal process from the joint of distributive and commutative justice perspectives for climate-adaptive cities with high efficiency of time.

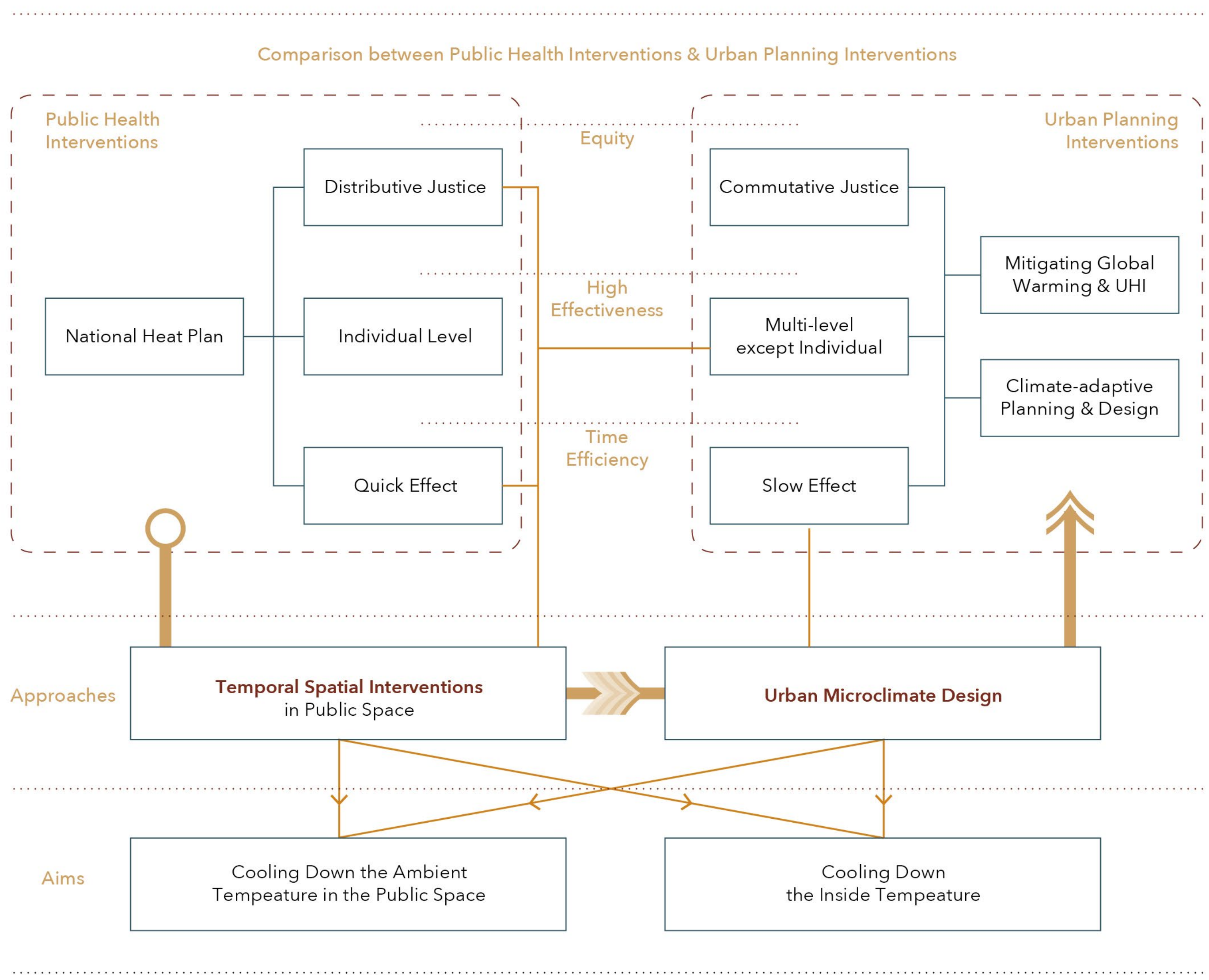

Figure 2.4. Comparison between public health interventions and urban planning interventions as well as research aims and approaches.

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2.4 Research Questions

The research question of the thesis is:

*How could **urban design** reduce **heat stress** for **the elderly** in the Netherlands?*

Through the thesis, the urban design from the perspective of urban microclimate will be conducted to reduce urban heat risks among the public and more consideration will be focused on the demands from the elderly to protect this vulnerable group from continuous hot weathers. The Hague, which is one of the age-friendly cities has been selected as the test field of the thesis since the urban heat island is severe and more elderly are predicted to live in The Hague. Following the main research question, there are also some sub-research questions which help to explain the research question and illustrate the content of the research and design in The Hague:

1. How did heat waves influence the life of the public and the elderly respectively?

Through the literature review, how heat waves influenced the daily life of the citizens, especially the life of the elderly, could be explored and how individuals response to the hot weathers during heat waves could also be learned from the literatures. Afterwards, corresponding research and design could be introduced to have more effective and efficient study or strategies on specific people or areas.

2. What are the reasons that cause the uneven distribution of the heat risks among the public or the elderly in The Hague?

Through this research question, the aim is to have a better understanding of the factors that cause uneven distribution of heat risks among the public such as physical characteristics of urban settings and intrinsic factors among the public. The results could help public health sectors and urban planning sectors to pay more attention to the groups of citizens with higher hierarchy of facing heat risks. Moreover, some knowledge could also contribute to the field of architecture and urbanism to design and construct resilient cities.

3. To what extent could the strategies and urban design improve the outdoor thermal performance to protect the elderly from heat stress in outdoor spaces and contribute to better indoor thermal comfort?

The initial ideas of the thesis are to introduce some strategies which will further instruct urban design to reduce the heat risks among the public as well as the elderly and temporal spatial interventions will be considered to response to the heat waves or hot weathers as soon as possible to reduce the heat stress for the public as soon as possible. Through urban design with the consideration of microclimate, to what extend could the physiological equivalent temperature be reduced during hot summers for outside spaces to contribute to the livability of the public or the elderly? If there will be a heat wave in the coming year, to what extent could temporal spatial interventions cope with the challenge from urban heat risk for senior citizens?

4. How could urban design be taken from the joint of commutative and distributive justice perspectives to reduce heat stress among the public?

The public health interventions focus on the demands from the vulnerable groups such as the elderly, babies and people with chronic illness and offer more assistance to them while urban planning strategies aim to mitigate urban heat island and global warming and share the benefits among the public. Urban design which follows the instructions from urban planning is always applied from commutative justice perspective on neighborhood scale or street scale but it also has the potential to apply widely through distributive justice such as the street furniture for the elderly. How could urban design achieve the ambition to fill in the gap between public health interventions and urban planning interventions to make the joint of commutative and distributive justice perspectives to reduce heat stress among the public?

5. Is it possible to have the similar effect when the strategies and urban design are applied to some places else in the Netherlands?

The urban microclimate design always depends on the situation of the site which limits its potentials to be easily applied anywhere else. However, some common physical characteristics of urban settings could be discovered in the Netherlands and the strategies as well as temporal spatial interventions could be probably applied in various places with a proper design and combination. They might have an efficient effect on reducing the ambient temperature for the elderly or even for the public. The possibility of the application of the strategies will be tested and if so, it could contribute to the discussion of the urban renewal process for climate-adaptive cities with the consideration of high time efficiency.

2.5 Conceptual Framework

The conceptual framework (Figure 2.5) illustrates the concepts related to heat stress and the health of the elderly as well as the relationships between them. Firstly, the causes of heat stress on the public will be explained from the perspective of existing urban fabrics, urban heat island and global warming. Then how the mortality and morbidity of the elderly are influences by heat stress will be stated. Finally, the current response from public sectors will be interpreted in order to address the position of the ideas from the thesis.

2.5.1 Urbanization & Heat Stress

Heat stress is challenging the health of the public and three main factors which address heat stress on the elderly are defined as existing urban fabrics, urban heat island and global warming respectively. Each factor not only has direct or indirect impacts on thermal comfort but also cause heat stress together with other factors.

Existing Urban Fabrics

Existing urban fabrics which refers to physical environments in urbanized area play a key role in shaping the heat stress for the society. On one hand, the composition and arrangement of urban settings result in not only the uneven access to cooling spaces like parks and large water body but also uneven distribution of urban thermal effect with regard to urban heat island effect and various local microclimate (Fernandez Milan & Creutzig, 2015). On the other hand, bad insulation of old buildings and the direction of building facades also contribute to heat stress inside the buildings during hot summers.

Urban heat island

There is a strong interaction between urban fabrics and urban heat island. The specificities of urban climate and the resulting urban heat island are strongly determined by both morphological characteristics and material properties of urban landscape (Lemonsu, Viguié, Daniel, & Masson, 2015). Urban heat island always results in hotter temperature in urbanized areas which increase the chance to experience heat stress. In addition, the urban heat island occurs most strongly during nighttime and is likely to extend the time for citizens to suffer heat stress as a result of higher temperature and less wind (Koopmans et al., 2018).

Global Warming

Global warming shows lower relevance with heat stress and existing urban fabrics. Alcoforado and Andrade argue that there is no direct impact but indirect impact from existing urban fabrics. Cities are not only the most important source of greenhouse gases which is known as one of the main reasons of global warming but also a major source of air borne particulate material which is known as aerosols. Aerosols has a distinct climatic effect and generally tend to slow the trend of the increasing temperature (Alcoforado & Andrade, 2008). When it comes to the relationship between heat stress and global warming, some people argue that 'the potentially deadly consequences of heat stress linked to global warming [...] should not be overlooked' and in terms of metric, timing and duration the challenge of heat stress from global warming is acknowledged (Matthews, Wilby, & Murphy, 2017). However, there is no direct relationship between global warming and heat stress with the consideration of the ability of adaption of the population but increasing temperatures and less precipitation are more likely to increase the chance to face heat stress in urbanized areas.

2.5.2 Heat Stress & The Elderly

Heat stress is to describe the body facing too much heat which causes stress, illness or death. Heat stress on the individual level and heat wave on city or regional level are always discussed with mortality and morbidity. There is a large body of research to document the significant increase in mortality and morbidity during heat waves all over the world, which also reveal how heat stress influence the health of individuals (Błażejczyk, Błażejczyk, Baranowski, & Kuchcik, 2018). The health problems related to heat stress which are the combined effects of air temperature, solar radiation, air humidity, wind speed and other factors like clothing place stress on the thermo-regulatory system resulting in heat-related death and illness (Błażejczyk et al., 2018; Huynen, Martens, Schram, Weijenberg, & Kunst, 2001).There are also studies about the factors which increased the risk of dying and the results show that being confined to bed, not leaving home daily and being unable to care for oneself were associated with the highest risk of death during heat waves (Bouchama et al., 2007). To conclude, the heat stress has not only direct impact on the rate of mortality but also influence the health situations of the public which will further result in high risk of death.

Heat-related mortality

Heat stress link directly to mortality in terms of shortening life span with disease exacerbations. Cardiovascular diseases and respiratory disease are most mentioned in terms of increased stress on the circulatory and respiratory systems by hot weathers when people try to uncover the relationships between heat waves and mortality and it is found that mortality increased during hot weathers for all cause-of-death groups examined. Huynen, Martens and Schram also found that the number of heat-related death is compensated for by a temporal fall in numbers in subsequent weeks after heat waves, which reveals the lag effect of the heat waves (Huynen et al., 2001). Some research has also shown that preexisting psychiatric illness ranked the first risk of death, followed by cardiovascular and pulmonary (Bouchama et al., 2007). When it comes to Dutch content, the increasing in the number of cardiovascular, respiratory and cancer mortality was observed in the Netherlands during the recorded heat waves and the significant excess total mortality was particular due to respiratory. Moreover, the heat-related mortality increases mainly occur among the elderly who were expected to be more sensitive because of compromised health situation (Huynen et al., 2001).

Heat-related morbidity

Heat stress is not only associated with excess mortality

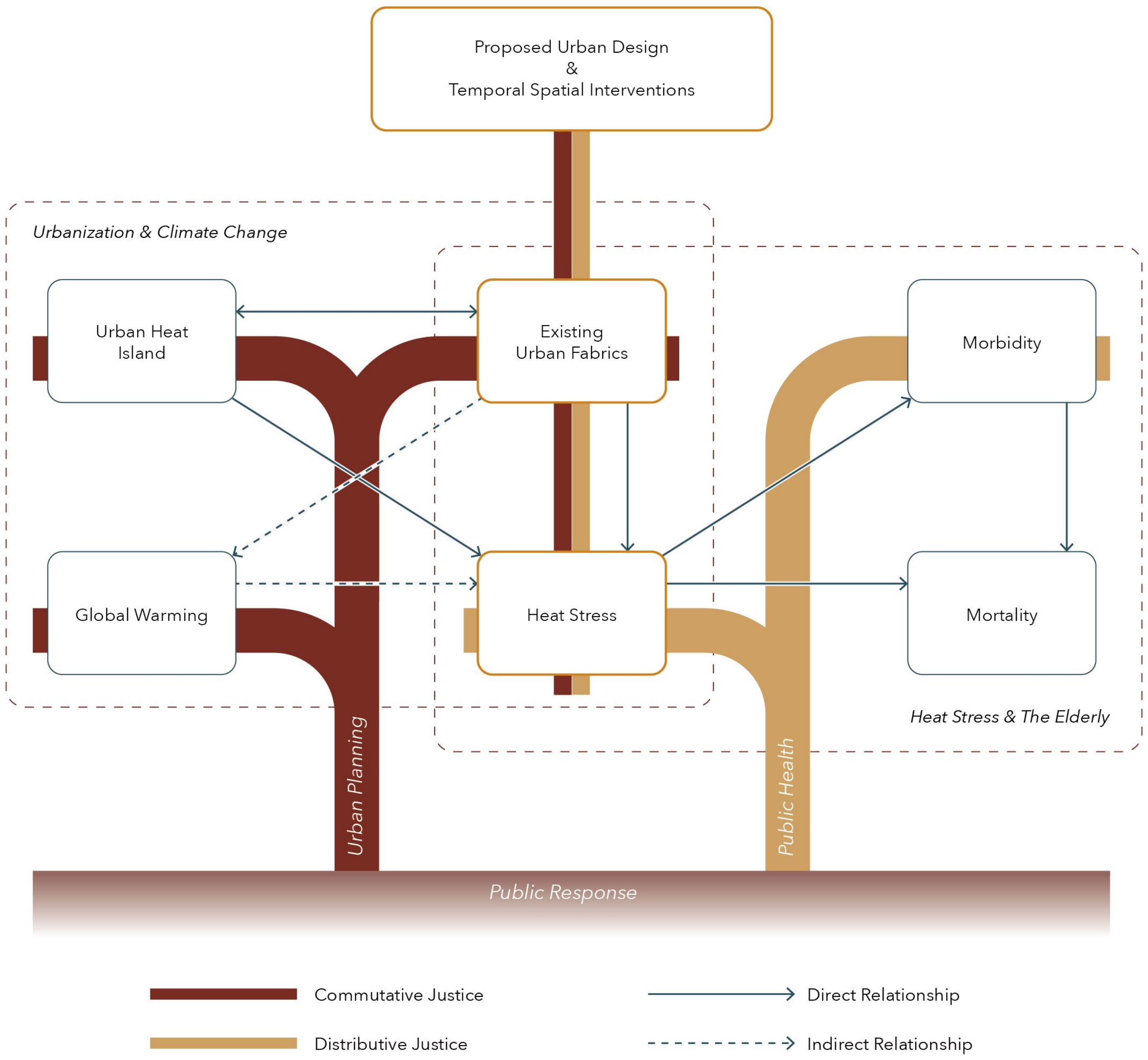

Figure 2.5. Conceptual Framework.

Source: Produced by author.

but also increase in morbidity and sometimes illness could further result in heat-related death due to continuous exposure to excessive heat. There are a set of studies on the relationship between morbidity and heat waves. However, 'there is a consistent result indicating that the demand for medical care increased for people with renal diseases and heat-related illness. For cardiovascular disease (CVD), respiratory disease (RD) and mental illnesses, the results remain inconsistent.' (Li, Gu, Bi, Yang, & Liu, 2015). Some studies also speculated that the larger effect of heat on air pollution might be accounted for the indirect impact of heat waves on human health (Bakhsh, Rauf, & Zulfiqar, 2018; Li et al., 2015).

2.5.3 Public Responses

With the awareness of the impact of urban heat risks globally, the research and applications of the responses to the urban heat risks are mainly taken from two aspects which are public health and urban planning. Health literature explores how and why particular populations are more at risk than others, which is known as intrinsic factors, while climate change, risk reduction and urban planning research addresses extrinsic factors (Fernandez Milan & Creutzig, 2015).

Public Health

When it comes to the interventions in practice, public health interventions are applied from the distributive justice perspective. Besides informing the public about the coming heat waves and suggesting prevention against probable heat stress, heat plans from public health institutions also paid much more attention to the vulnerable group to ensure the health of the public. For example, it was suggested that the housing for care homes and hospital should aim at meeting the specific requirements for the thermal environment by European Commission (European Commission, 2003). Another example is that in France the government has recommended that elderly-care institutions have at least one cooled room (World Health Organization, 2007). The interventions from public health institutions have been proved to be highly efficient against hazard and susceptibility on individual level but because of the uneven distribution of urban heat risk within existing urban fabrics and larger socioeconomic inequalities, it is difficult to up-scale these actions to city level (Fernandez Milan & Creutzig, 2015).

Urban Planning

Urban planning strategies and interventions usually address the urban heat risk from commutative justice perspective because the effects are in principle equally distributed among the whole population with the help to mitigate urban heat island (Fernandez Milan & Creutzig, 2015). Furthermore, most strategies increase in effectiveness with scale but sometimes the effect could be seen in a long period especially for the measures on mitigation of global warming and urban heat island. For instance, land-use changes and mitigation of climate change through energy efficiency are highly effective in reducing the urban heat island but potentially costly both in budget and time, and require political will to be implemented (World Health Organization, 2007). Other strategies like albedo modification and increase in vegetation cover are quite effective in reducing the heat risk in household level and neighborhood level respectively but not enough actions has been done with regard to these interventions (Fernandez Milan & Creutzig, 2015).

To conclude, public health and risk reduction interventions address person-specific risks like heat stress and illness effectively and could be easily applied in practice. Meanwhile, urban planning strategies could tackle the urban heat risk in the long term by interventions on either existing urban fabrics or mitigation of global warming and urban heat island, which is efficiently both in scale and scope. However, due to factors like political will and cost-efficiency, urban planning are not fully deployed and the effect should be expected in the long term (Fernandez Milan & Creutzig, 2015).

2.5.4 Position of Thesis

The approach of the thesis to reduce heat stress for the elderly is to design and intervene within existing urban fabrics where the elderly are gathered while facing high heat risks. The urban microclimate design for the citizens and spatial interventions to protect the elderly from extra heat in the public space especially when there is a heat wave are taken from commutative and distributive justice respectively so the whole project will also try to discuss the possibility of the joint of distributive and commutative justice perspective.

2.6 Research Framework

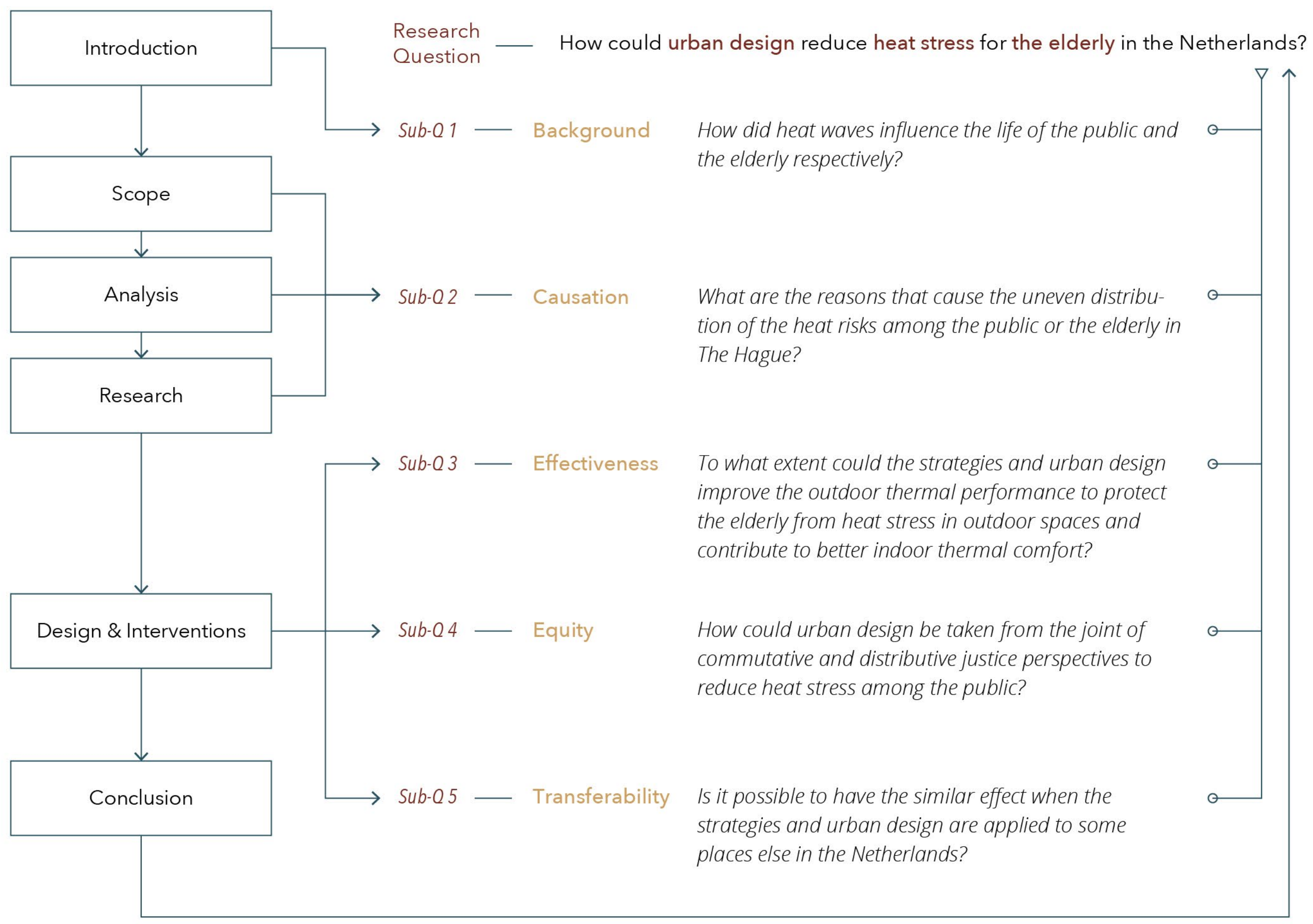

Figure 2.6. Conceptual research framework and the relationship with research questions

Source: Produced by author.

Following the research framework (Figure 2.7), how the research and design have been conducted is illustrated and conceptual research framework (Figure 2.6) delivers a brief impression of the storyline of the thesis. The relationship between research questions and each parts of the thesis has also been uncovered in the conceptual research framework. The research question is followed by five sub-questions which focus on the background and causations of the heat risks among the public as well as the effectiveness, equity and transferability of the design and interventions respectively while different parts of the thesis try to offer the answers to the research question and sub-questions (Figure 2.6).

When it comes to research framework (Figure 2.7), more details including contents, methods and outcomes about each part and the relationships between each part has been demonstrated as following:

#1 Analysis on The Hague

The first step is to make the decision on the site(s), which should be representative. There are two main parts in the analysis of The Hague, which are 'Heat risks & place' and 'The elderly & place'. By mapping physical characteristics of The Hague, there will be a preliminary understanding about the distribution of heat risks in The Hague while in the section of 'The elderly & place', not only the concentration of the elderly but also the development and prediction of the elderly as well as the evaluation of each neighborhood by the elderly will be mapped and analyzed. The overlaying of the maps could help to define the relationship between spatial distribution of heat risks and concentration of the elderly to make a reasonable decision on the site(s) for design.

Outcome - Physical heat map; Social heat map of the elderly; decision of study areas.

#2 Analysis on study areas

Analysis from spatial and microclimate perspectives on study areas will help to have a better understanding of existing urban settings and spatial causation of urban heat risks in study areas. Some conclusions with regard to building typology and open spaces will be discussed in order to focus on the key points in following research and design parts.

Outcome - Diagrams and maps of spatial analysis and analysis from microclimate perspective; the key points for further research and design.

#3 Research for design

The 'research for design' is aiming to feed the design process with the objectives to increase the quality and credibility of the design outcomes. The research on the typology of courtyard block dwellings with various configurations helps to learn about the influence of the orientations and the shapes of the blocks, which will further instruct the evaluation and design. The data collection of wind direction and wind speed during heat waves and normal summers could illustrate the impact of heat waves on wind pattern. Last but not least, the effect of different vegetations on outdoor environments will be discussed with literature reviews and simulations to make a reasonable choice with the vegetations such as the way of planting. The overall research outcome could instruct the further research by design as well as decision making of strategies and design outcomes.

Outcome – Evaluation of different building configurations; knowledge of prevailing wind during heat waves; the effect of various vegetation on microclimate; instructions on general strategy making.

#4 Research by design

In 'research for design' phase, various ideas of spatial interventions will be applied on the specific blocks with relatively high risks from the perspectives of building configurations to explore the possibility to improve the outdoor thermal performance in order to generate solutions. The design will be tested by simulation with ENVI_MET and the conclusions from the 'research by design' will contribute to the decision making of the strategies as well as urban microclimate design.

Outcome – Effective spatial interventions within the blocks of courtyard dwellings to instruct the decision of strategy making.

#5&6 Design & Intervention & Conclusion

The last main component of the thesis is design and intervention from the perspectives of microclimate as well as conclusion. The making of strategies is based on the empirical knowledge from literature review and case study as well as the outcomes from the process of 'research for design' and 'research by design'. Afterwards, the (re)developments within study areas through urban design process will demonstrate how the strategies could be applied in practice and how effective the strategies are. The designing of cooling shed offers another choice to protect the elderly from heat stress from the perspective of temporal spatial interventions and the combination of cooling sheds and urban microclimate design could help to discuss the possibility of the joint of commutative and distributive justice. In the conclusion phase, the main research question will be answered and the transferability of the outcomes from the thesis will be discussed.

Outcome – Strategies to reduce urban heat risks; urban design from microclimate perspectives on selected neighborhood associated with evaluation of the design outcome; design outcome of cooling sheds; the discussion of the answer to the research question.

2.7 Conclusion

The chapter of 'Scope' illustrates how the problem field is defined and how the research will be conducted. The issues between urban heat risks and the health of the elderly are interpreted and the gap of deployment with consideration of time efficiency between public health interventions and urban planning is defined. Then, research topics and relative methods as well as the relationships between each topic and sub-questions are demonstrated in the research frameworks. Moreover, how the research outcome could be linked to strategies and urban design is also demonstrated in the framework and proposed outcomes are discussed in the last of each step to deliver the impression of the final design outcomes.

Following the research framework, the research could be conducted and the first step is to make a decision on study areas on neighborhood scale. Then spatial analysis and analysis from microclimate perspectives could be addressed on the study areas, which could further instruct the strategy making and design process.

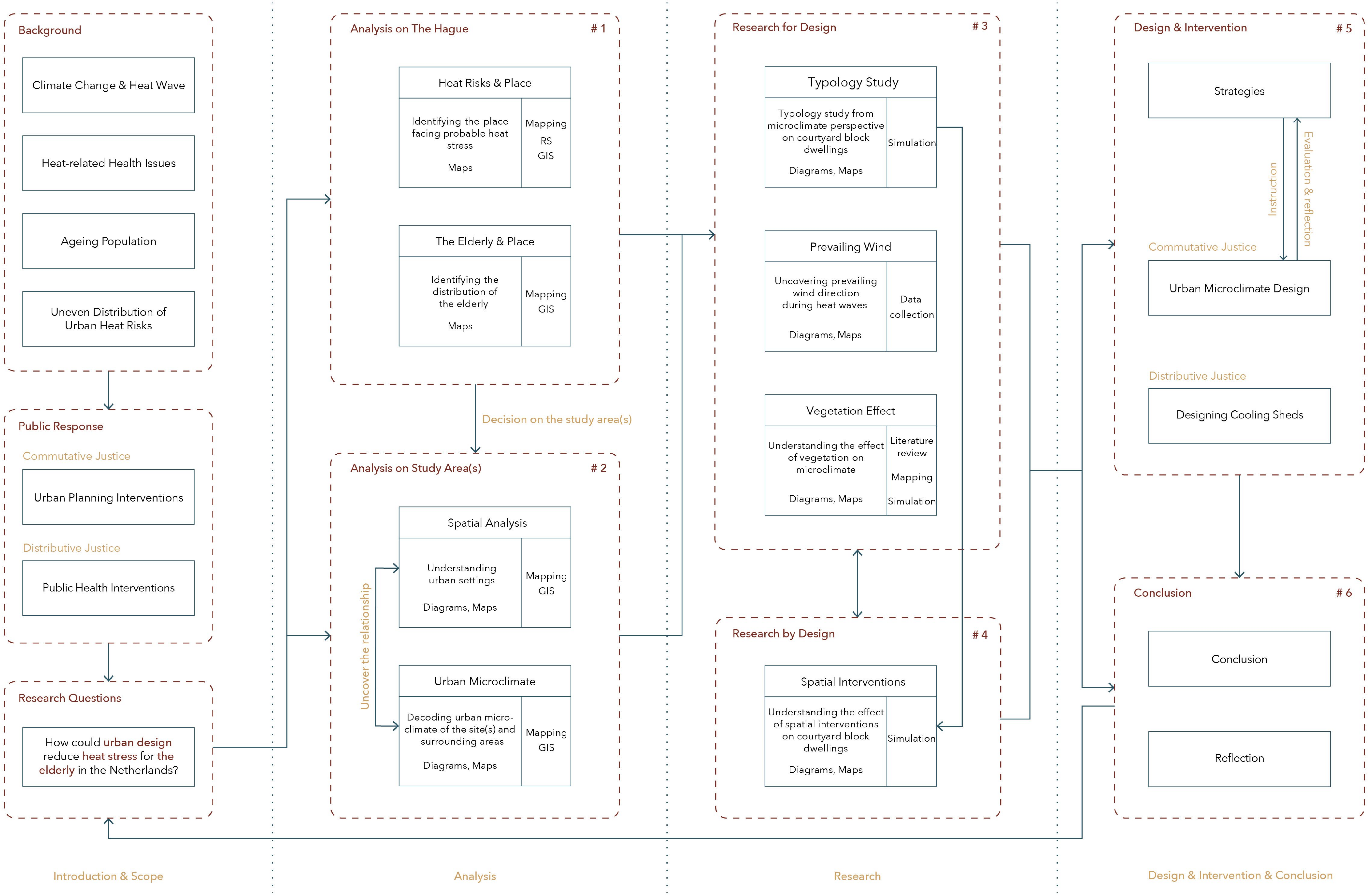

Figure 2.7. Research framework.

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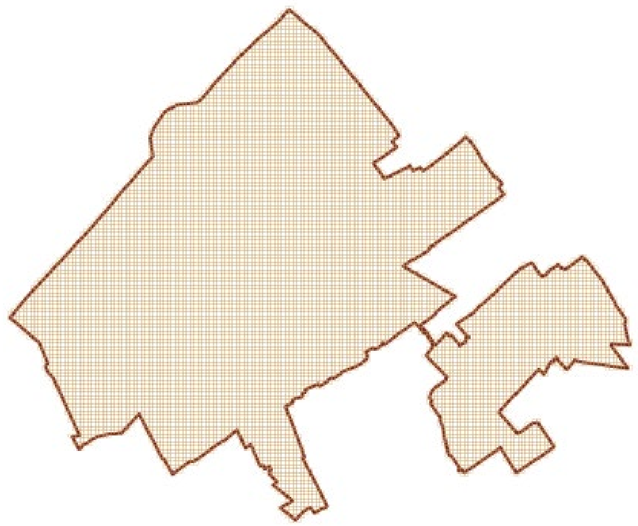


Figure. Decoding heat risks in The Hague.

Source: Produced by author.

3 ANALYSIS

The chapter 'Analysis' introduces the process of the analysis in The Hague to make the decision of the study areas. Afterwards, analysis from spatial and microclimate perspectives has been conducted on the study areas. The sub-question 2 (***causation***) will be uncovered partially by the mappings in The Hague in the chapter.

- *Introduction*
- *Decoding heat risks in The Hague*
- *Analysis on the study areas*

3.1 Introduction

Following the analysis framework, analysis on The Hague from the perspectives of climate and the elderly will be conducted first to make a decision on study areas on neighborhood scale (Figure 3.1). Analysis based on the physical characteristics of The Hague and the concept of surface energy balance can identify the places where people are more likely to experience heat stress in The Hague and a comparison between Rotterdam could help to draw some conclusions about urban settings that probably cause the urban heat island effect. Overlaying the maps of 'surface energy balance' and 'concentration of the elderly', initial impressions of the elderly who are facing severe heat risk could be concluded from 'Integrated map'. The map of 'indoor temperature' combining with maps of other factors, such as the scores of neighborhoods in The Hague from the perspective of age-friendly city, could help to make a final decision on study areas.

Afterwards, more analysis on chosen study areas from spatial and microclimate perspectives will be conducted in order to have a comprehensive understanding of heat stress of the elderly. The outcome of the analysis will also help to instruct the research and design.

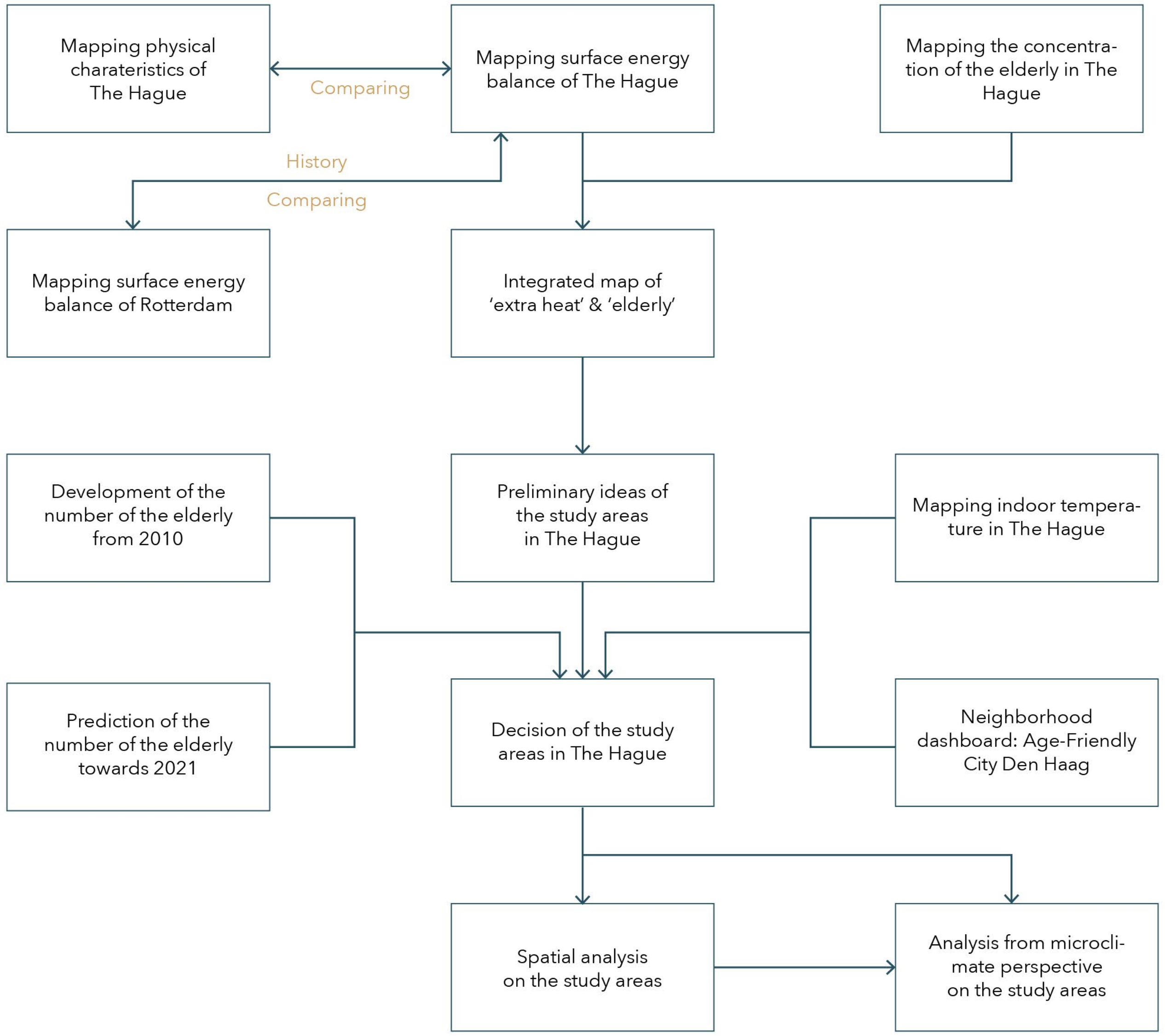


Figure 3.1. Analysis framework.

Source: Produced by author.

3.2 Decoding heat risks in The Hague

3.2.1 Decoding Physical Characteristics in The Hague

Urban Heat island has strong relationship with existing urban fabrics and the combined impacts of them could have negative effects on public health through heat stress. Remote sensing has been applied in urban areas to learn about the urban heat island and more physical characteristics of existing urban settings such as albedo and Leaf Area Index (LAI) could also be achieved from remote sensing. Uneven distribution of heat risks could be uncovered by decoding characteristics of physical environments in The Hague in order to have a better understanding of the causation of heat risks from the perspectives of existing urban settings. The following atlas contains the research of several elements that contribute to various urban microclimate in The Hague and the map of 'Surface Energy Balance' (Figure 3.11) reveals the place with relatively high level of heat risks.

Data

NASA, Landsat 8, 27th May 2017, 26th July 2018 & 2nd August 2018; OpenStreetMap; Tijdreis meer dan 200 jaar topografie ('Time travel over 200 years of topography' in English) (Source: https://www.topotijdreis.nl/).

Method

a. Mapping statistics data on grids of 100 by 100 meters

To facilitate data with different scale and uncover the relationship between each element, the approach of computation to divide the Hague into grids has been introduced. The grid has been set as 100 by 100 meters and the size of it is one hectare which is a common unit in city study. The grids have the same geographical coordinates of grids from CBS in order to analyze the relationship between demographic data and conduct the analysis on municipality scale in later analysis. The data has been collected on each grid through the approach called 'Join attributes by location' and then visualized in an open source Geographic Information System (GIS): QGIS (Figure 3.2).

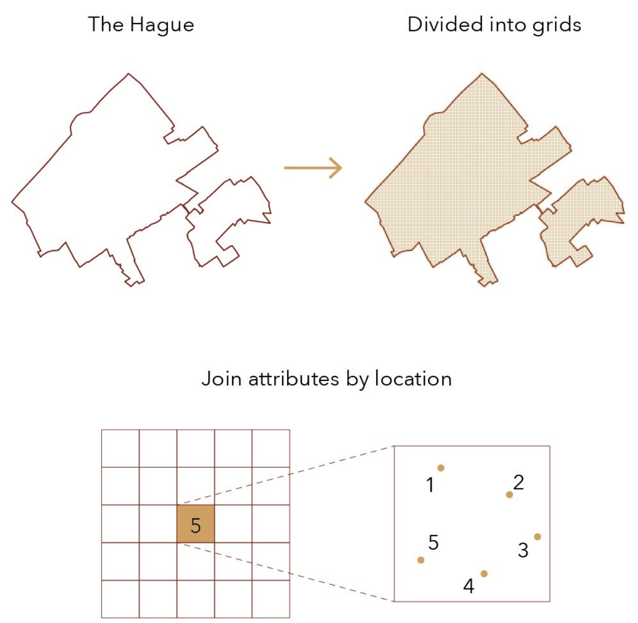


Figure 3.2. The approach of 'Join attributes by location'.

Source: Produced by author.

b. Surface energy balance

The heat people experience in urbanized areas could be explained the concept of 'surface energy balance' which is based on the principle that energy is not lost. Surface energy balance 'means that the net energy that the surface of a city receives from the sun is equal to the energy that passes through the heat processes that take place in the city' (Hoeven & Wandl, 2015).

The surface energy balance is expressed as the following formula:

$Q^* = Q_E + Q_H + Q_S$

Q^* - Net solar radiation received by the earth's surface;

Q_E - Energy consumed through evaporation (by water and greenery);

Q_H - Sensible heat (conversion of heat from surface to air);

Q_S - Energy absorbed by the ground, buildings and surface water.

The energy* that causes urban heat island and poor outdoor thermal performance could be explained by the following formula:

$Energy^* = Q^* - Q_E$.

The higher numbers from the formula are, the more probable people could suffer from heat in indoor and outdoor spaces (Hoeven & Wandl, 2015).

Result

The historical development of The Hague has been demonstrated and the following atlas contains the data that delivers the impression of the physical characteristics of The Hague to introduce the factors that probably cause the uneven distribution of heat risks among the public. The remote sensing data on these mappings was recorded on the 26th of July 2018, which is the day with the highest air temperature measured at De Bilt weather station and the worst situation could illustrate how serious the situation is in The Hague. The comparison between the history of urban development of The Hague and the distribution of heat illustrates that the areas constructed around 1930s are the places with higher potential to face heat risks in The Hague.

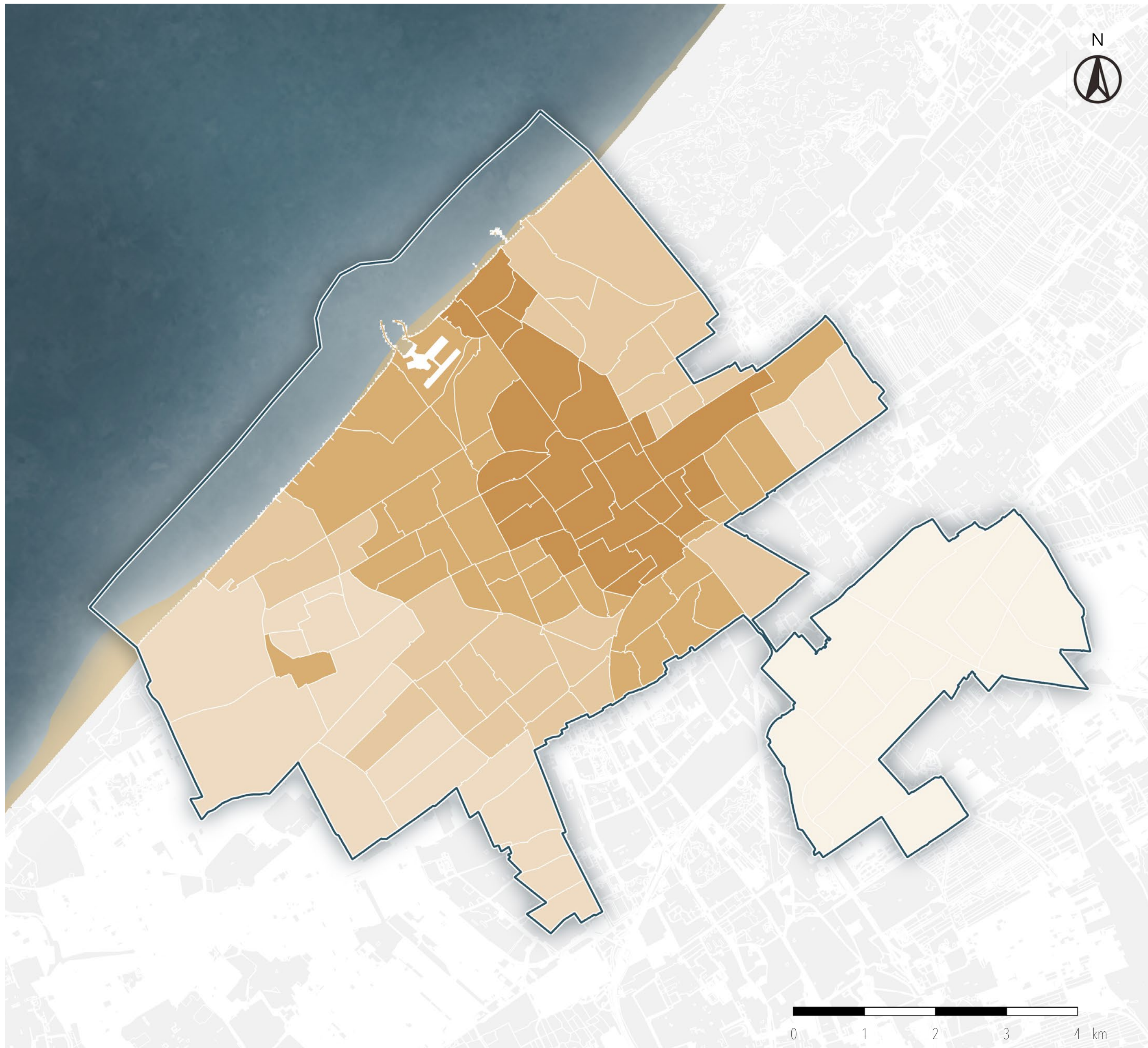


Figure 3.3. Historical development map of The Hague.

Source: Produced by author.

Legend

1910	1935	1960	1985	2010	2020

History of The Hague

When looking into the history of recent 100 years of The Hague, the development of urbanized areas could be concluded as the above image (Figure 3.3). After world war II, The Hague witnessed a massive urban expansion to the south-west and in the 21st century the construction of Leidschenveen-Ypenburg has been applied on the south-east of the city. However, the urbanized areas which has already existed around 1930s mainly consisting of the districts Centrum and half of the Scheveningen are found to the places with relatively higher potentials to face heat stress in the following mappings.

Figure 3.4. Surface temperature measured on 26th July 2018.

Source: Produced by author.

Legend (ºC)

21.0	30.0	34.0	38.0	42.0	46.0	50.0

Surface Temperature

The above image (Figure 3.4) describes the difference among the temperature of surface including streets, roofs and ground in The Hague. Higher surface temperature is more likely to result in higher air temperature above the surface or high indoor temperature under the roofs or behind the facade. The city center, industrial areas as well as the areas which were constructed around 1930s are the places with higher surface temperature while the areas with recognizable vegetation on the satellite image have lower surface temperature.

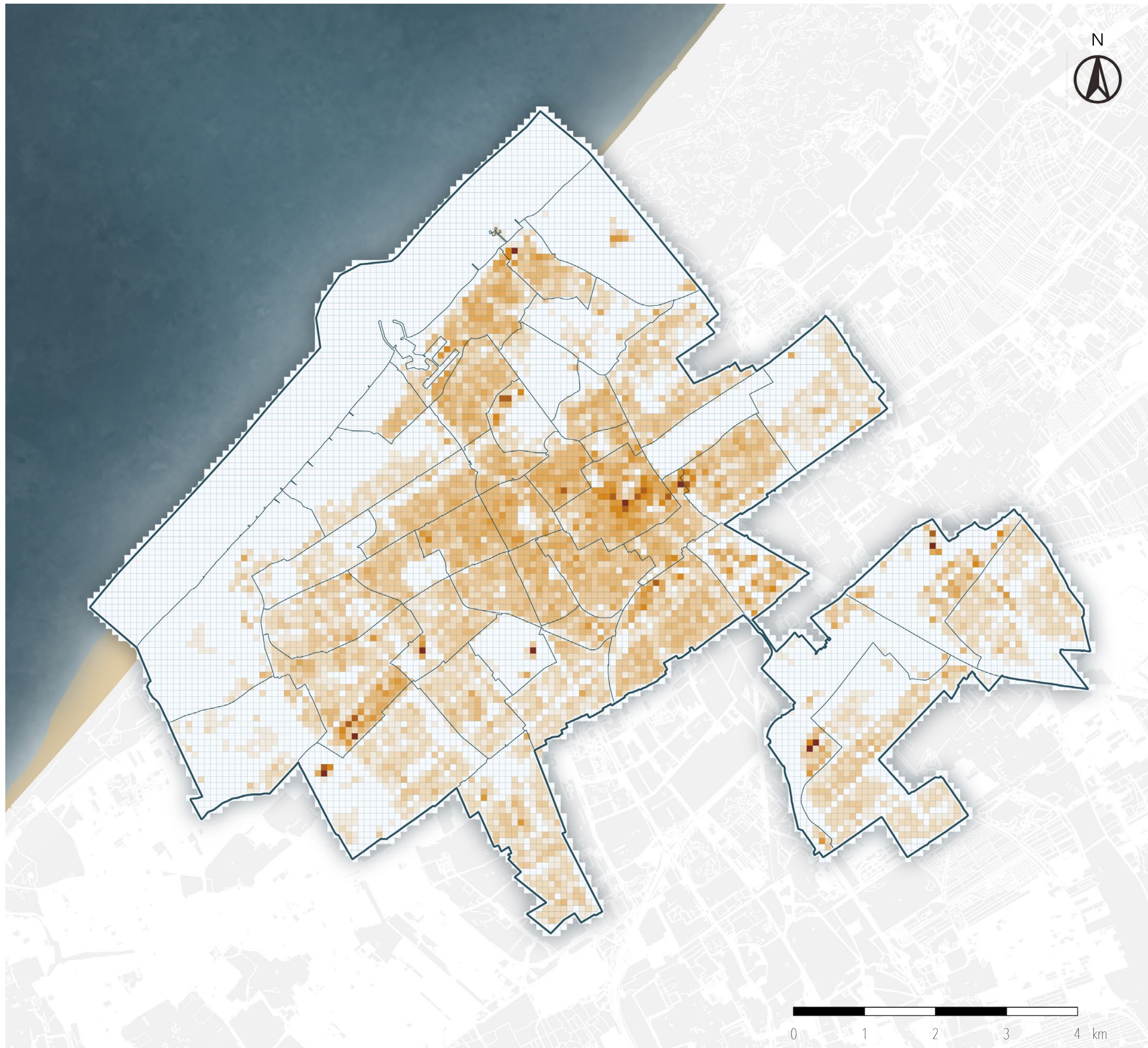


Figure 3.5. Ground Space Index in The Hague.

Source: Produced by author.

Legend

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

Ground Space Index (GSI)

Ground Space Index is defined as the value that equals the footprint of buildings divided by plan area, which is one of the variables to describe built density (Berghauser Pont & Haupt, 2005). GSI demonstrates the relationship between built-up spaces and non-built spaces (Figure 3.6). The value of GSI varied from 0 to 1 and the higher value of GSI illustrates that more spaces are occupied by buildings and less spaces are available for water or vegetation from the perspectives of urban climate. From the above image, the higher value of GSI could be discovered in the city center and the areas which were constructed around 1930s in The Hague (Figure 3.5).

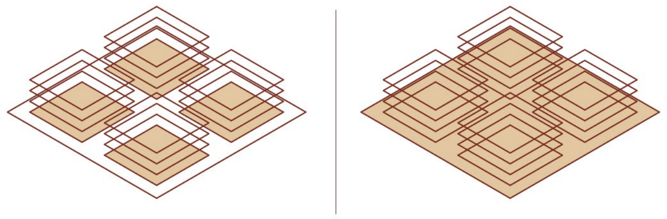


Figure 3.6. Ground Space Index (GSI) (Berghauser Pont & Haupt, 2005).

Source: Reproduced by author.

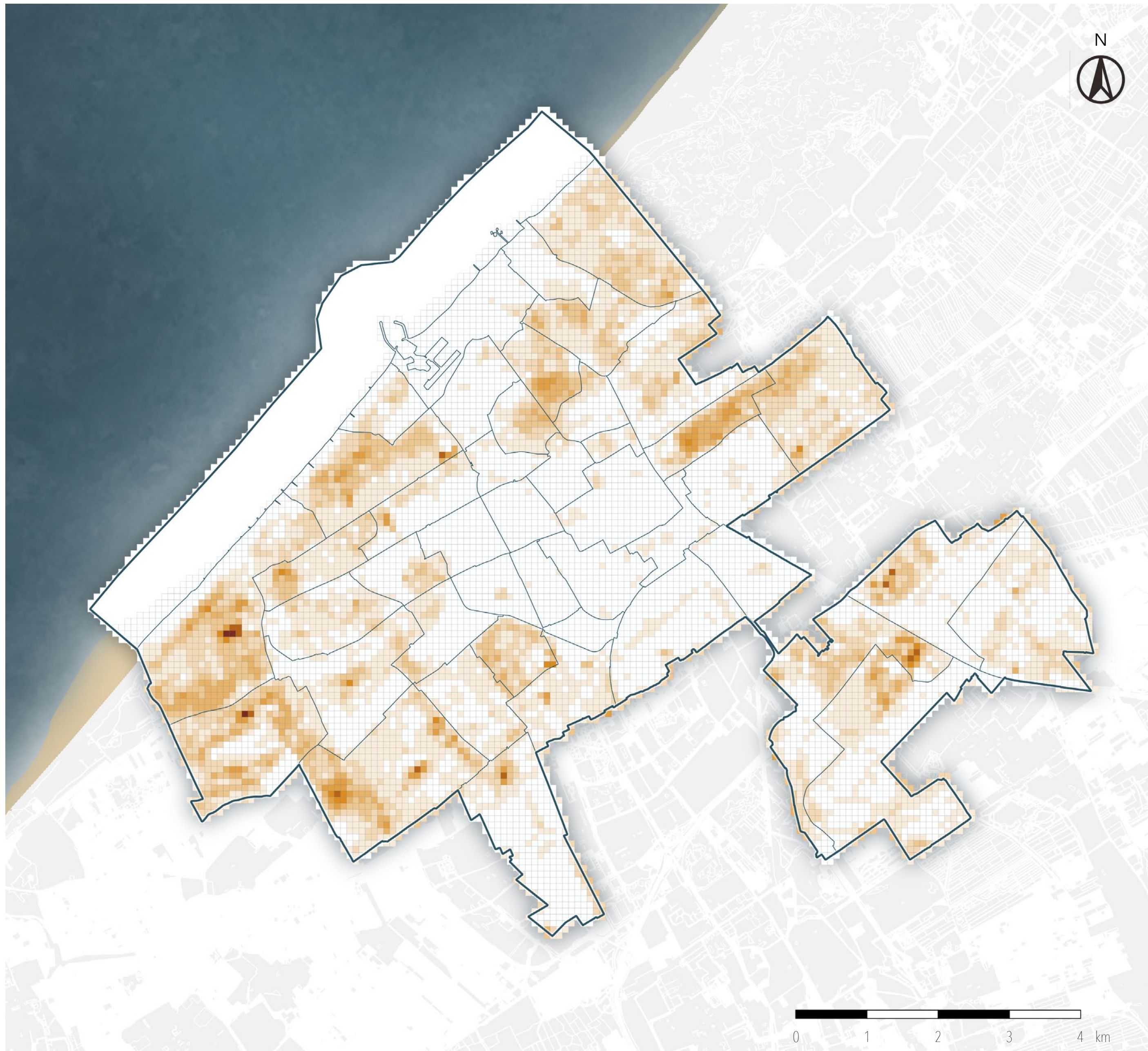


Figure 3.7. Leaf Area Index in The Hague.

Source: Produced by author.

Legend

0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50

Leaf Area Index (LAI)

Leaf area index is a measure of canopy foliage content included in the research of vegetation and it is broadly known as the amount of leaf area (m^2) in a canopy per unit ground area (m^2) (Iio, Hikosaka, Anten, Nakagawa, & Ito, 2014). LAI could be used as a descriptor of vegetation condition in urbanized area for the research of urban climate. The higher value of LAI normally describes the larger amount or higher quality of vegetation per unit. From the image above, the grids with higher LAI value could be found in city parks as well as the areas near the boundary of The Hague and the relationship between picture and background could be discover among the grids of LAI and GSI (Figure 3.5 & 3.7).

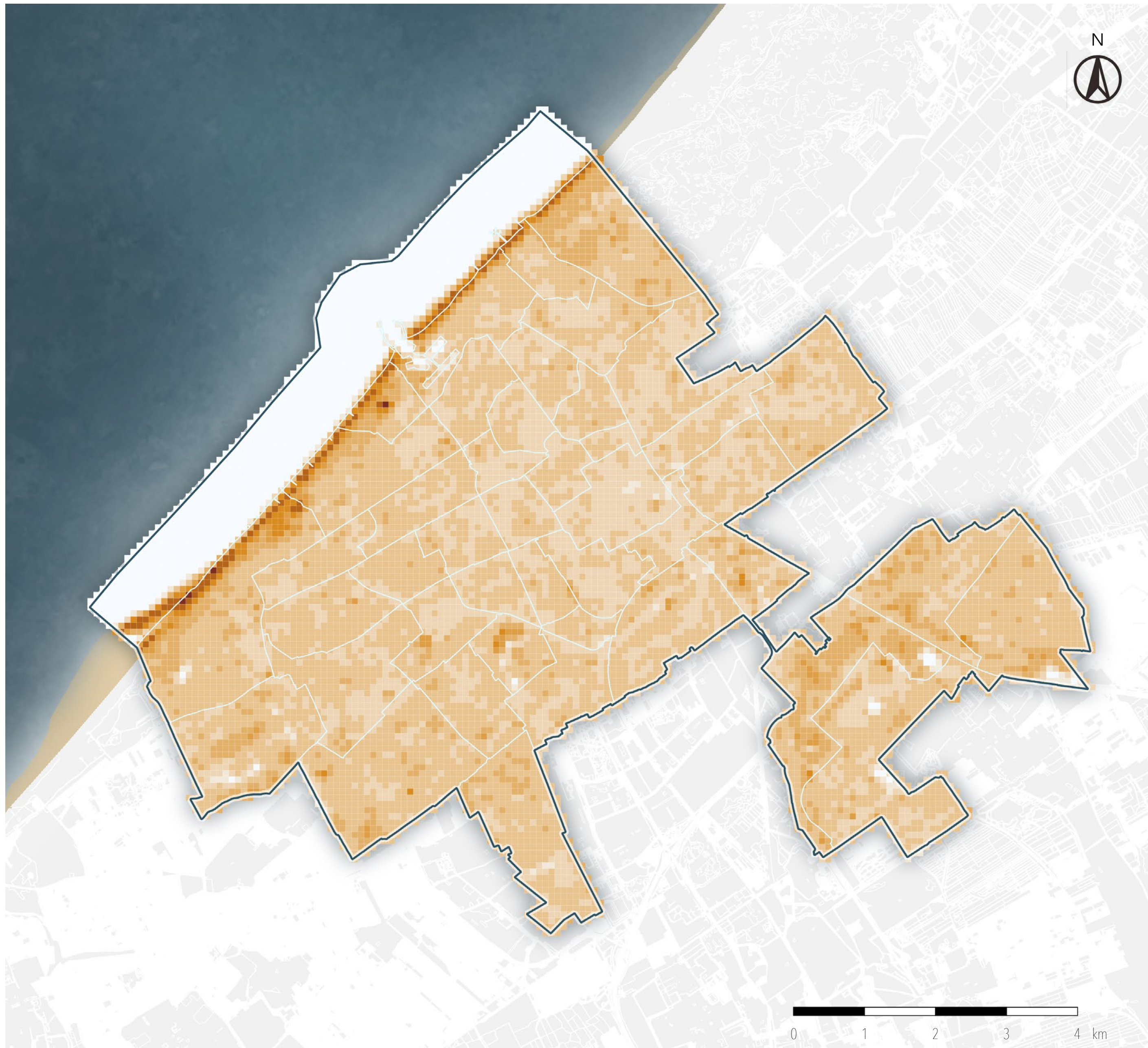


Figure 3.8. Albedo in The Hague.

Source: Produced by author.

Legend (%) 0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0

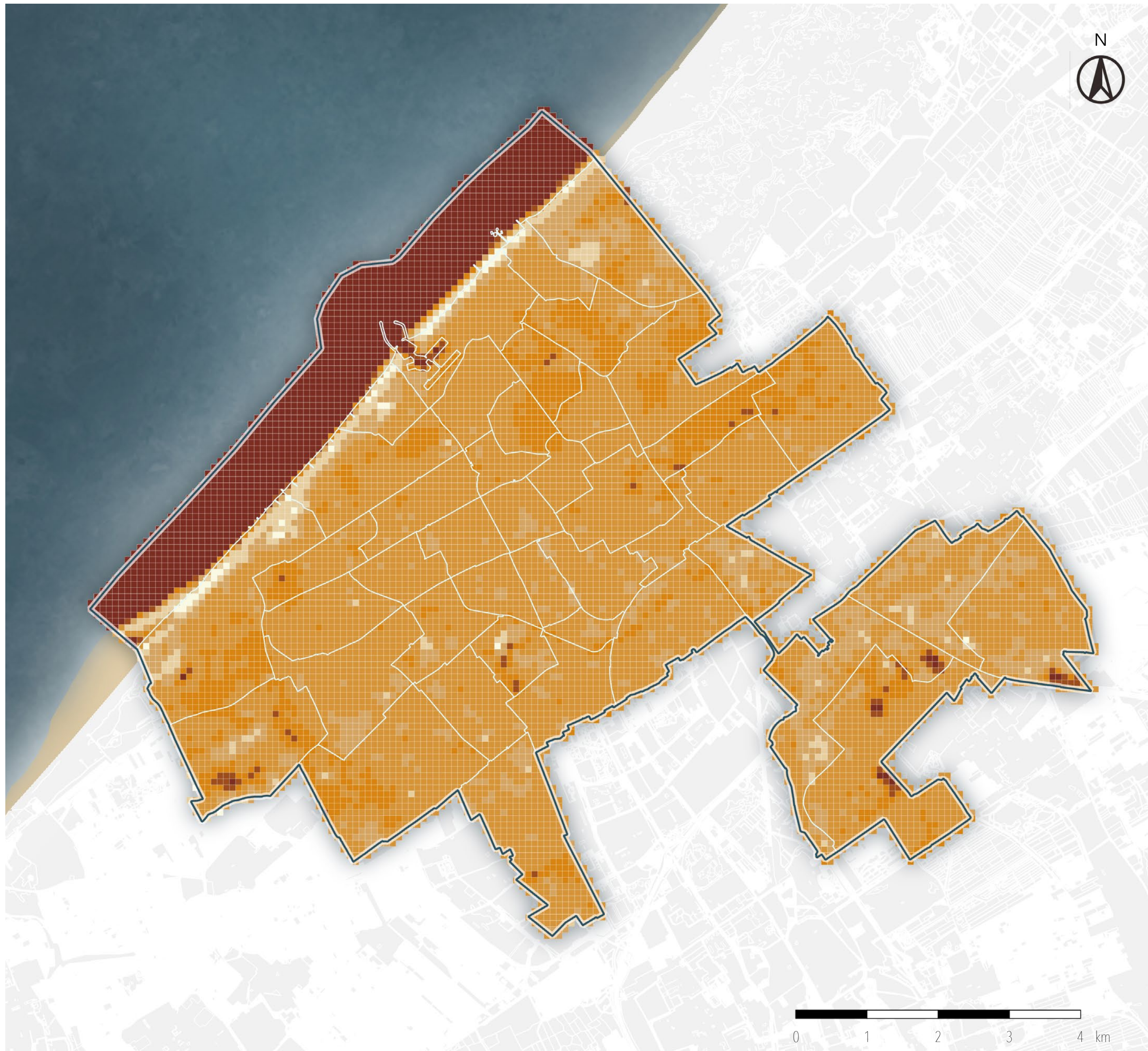


Figure 3.9. Net solar radiation measured on 26th July 2018.

Source: Produced by author.

Legend (W/m²) 75 125 175 225 275 325 375 425 475

Albedo

Albedo is an indicator that reveal the degree to which building facades, roofs, streets and so on reflect solar radiation and a higher value of albedo means that the area could be heated up less quickly in general (Hoeven & Wandl, 2015). From the above image, the highest value of albedo is found on the dune alone the North Sea and the lowest value is found around water body. For the areas with buildings and pavements, relatively lower albedo value could be discovered in the city center and the areas which were constructed around 1930s in The Hague, where hard pavements, dark-colored roofs and less vegetation is recognizable (Figure 3.8).

Net Solar Radiation

Net solar radiation is the energy that the earth's surface receives from the sun. There is not much difference among the global radiation in The Hague since the albedo of the earth's surface mainly determined net solar radiation. Albedo expresses the degree to which the earth's surface reflects radiation and the reflected radiation dose not contribute to the heating up of the city unless the radiation is then reflected back by clouds or air pollutants (Hoeven & Wandl, 2015). The higher value of net solar radiation could be discovered in the areas where extensive water body and vegetations are located. The dune along the North Sea absorbs the least net solar radiation while the rest in gains similar radiation (Figure 3.9).

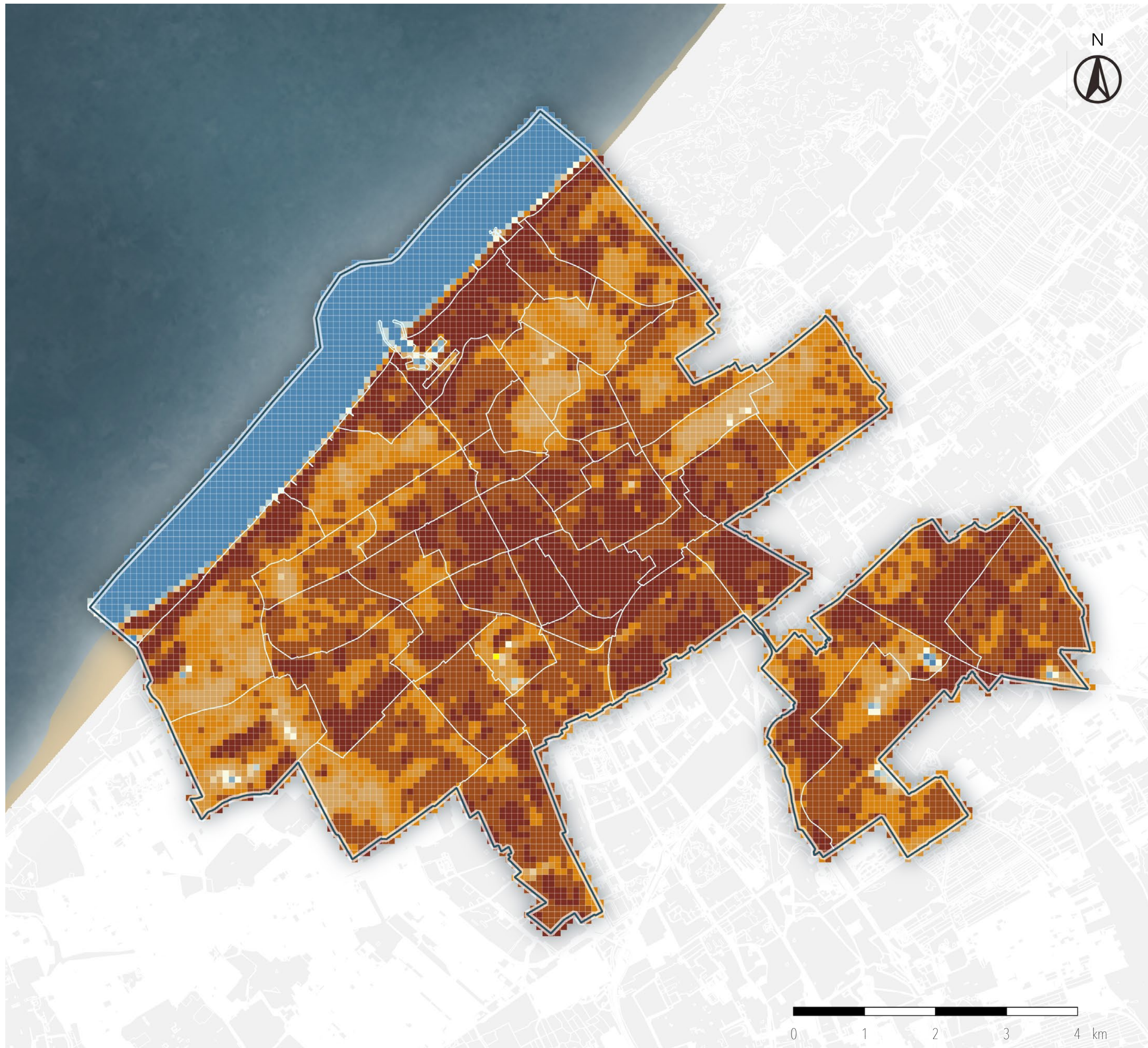
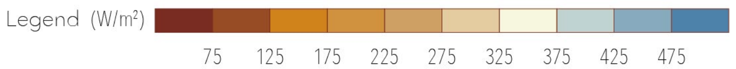


Figure 3.10. Latent heat measured on 26th July 2018.

Source: Produced by author.



Latent Heat

Latent heat is the energy consumed through the evaporation of water and vegetation is an important 'consumer' of latent heat. Surface water also contributes to latent heat when the heat received by water is converted into evaporation (Hoeven & Wandl, 2015). From the image above, the North Sea and large water body consume most latent heat and extensive vegetations have the medium value of latent heat even though they gain more net solar radiation. However, the rest of urbanized areas consume less latent heat especially for the city center and the areas which were constructed around 1930s in The Hague (Figure 3.10).

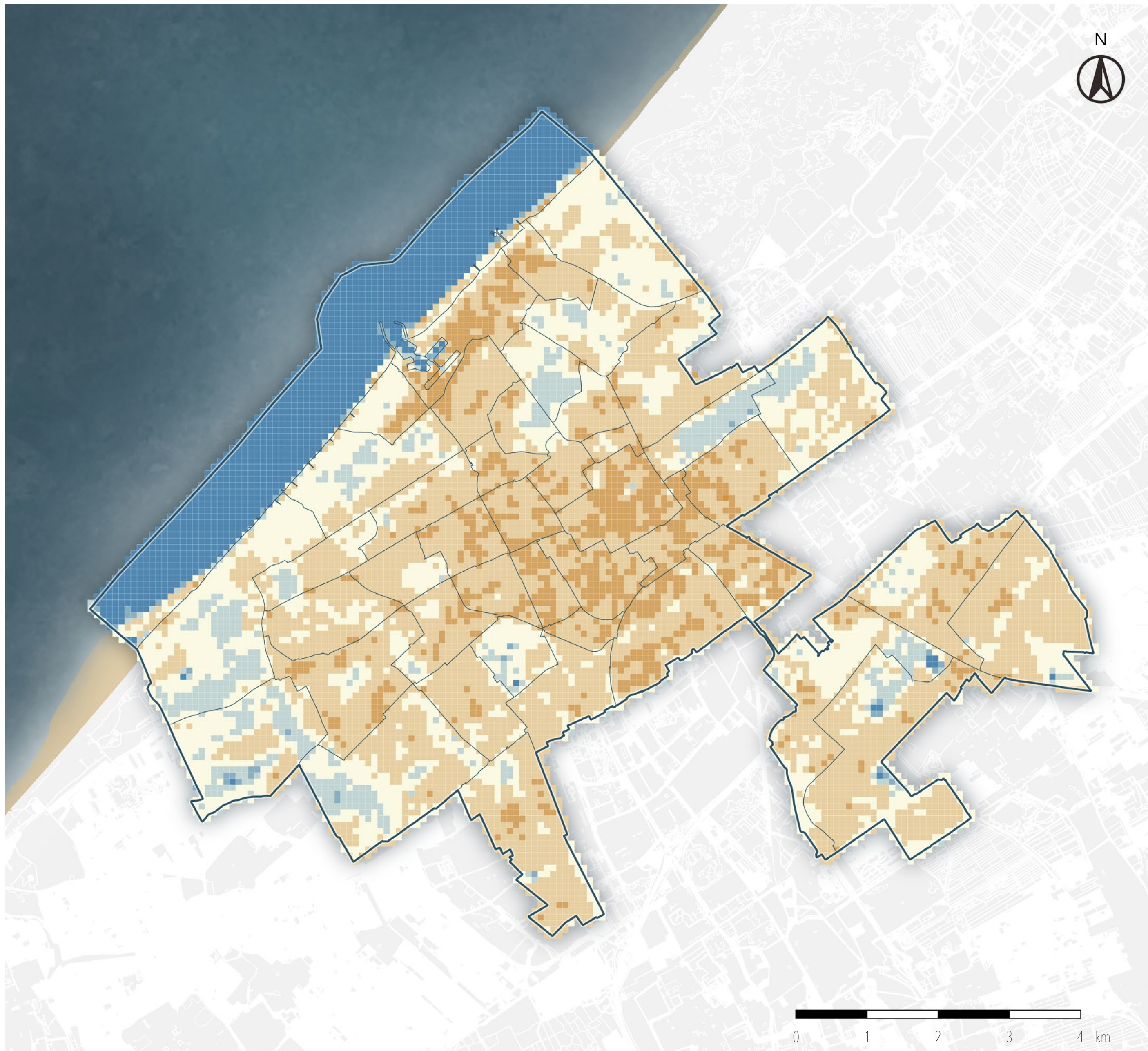


Figure 3.11. Surface energy balance measured on 26th July 2018.

Source: Produced by author.

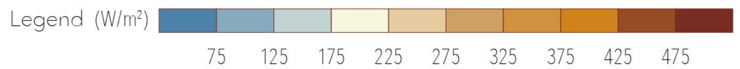


Figure 3.12. Satellite images that describe dark-colored roofs, impervious pavement, less vegetation and linear blocks (From left to right).

Source: Google Map.

Surface Energy Balance

From the above image, the city center and the areas which were constructed around 1930s in The Hague are the places characterized by the urban settings that promote the urban heat island (Figure 3.11). The same methods of analysis have also been conducted on Rotterdam (Appendix II) and some common characteristics among the urban settings have been uncovered. The dark-colored roofs, impervious pavement and less vegetation in the neighborhoods strongly contribute to the urban heat island and there are many linear blocks with row houses along the street as well as small courtyards surrounded by buildings (Figure 3.12).

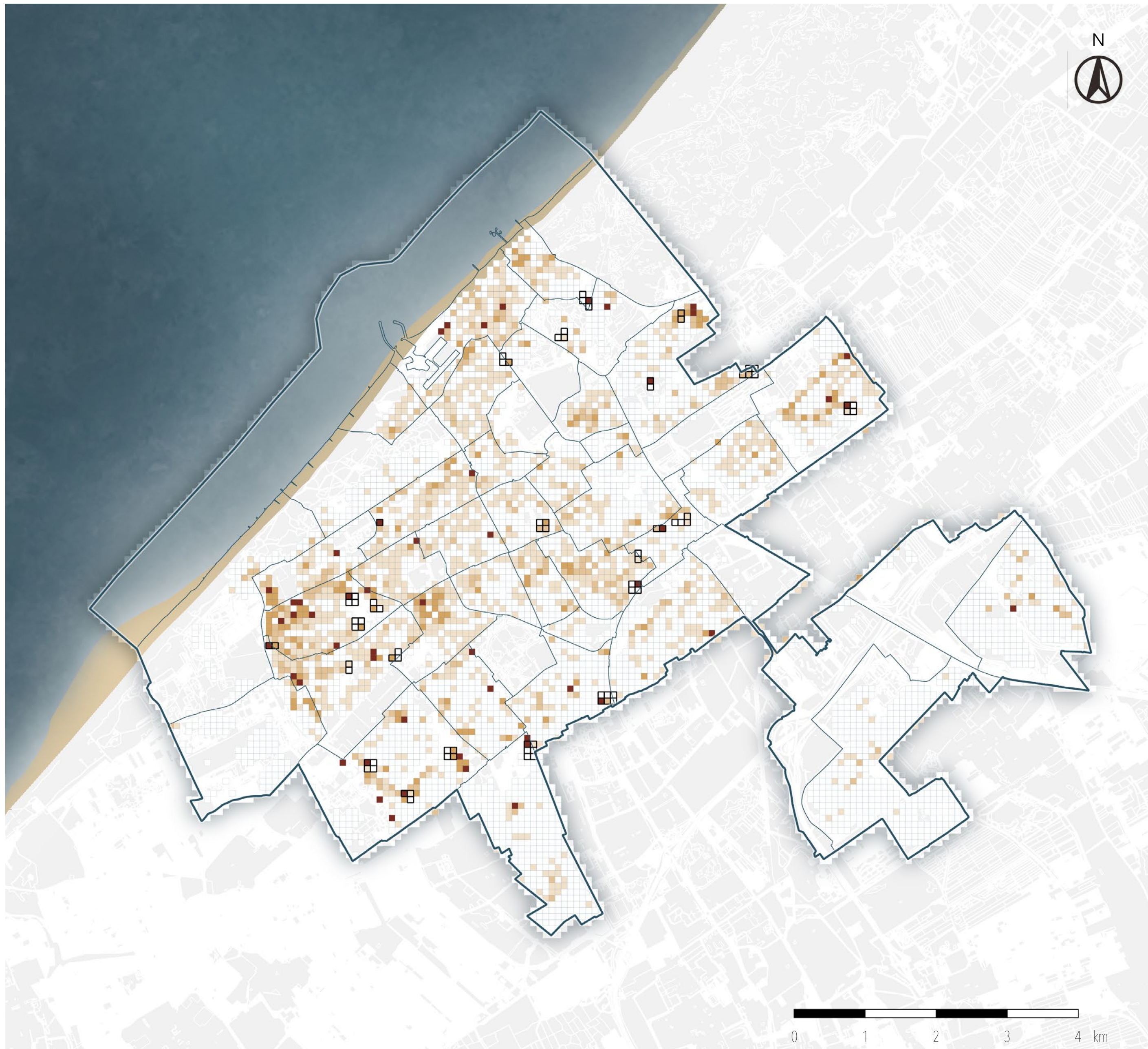


Figure 3.13. Concentration of the elderly in The Hague.

Source: Produced by author.

3.2.2 Concentration of the Elderly in The Hague

Data

Map of 100 by 100 meters with statistics, CBS 2018; OpenStreetMap.

Method

Statistical data has been included on each square by CBS with the themes such as demography, housing, energy, income, social security and so on. The locations of retirement homes and nursing homes have been identified from OpenStreetMap and illustrated by an open source Geographic Information System (GIS): QGIS.

Result

The elderly are living in the most of areas in The Hague except for the district Leidschenveen-Ypenburg and the west part of district Loosduinen. The largest concentration of the elderly can be found in the east part of district Loosduinen which could be explained by the concentration of retirement homes. The districts Centrum and Scheveningen also attracted many senior citizens to live in (Figure 3.13).

3.2.3 Integrated Map of 'Heat' & the Elderly

The integration of the maps 'Surface Energy Balance' and 'Concentration of the elderly in The Hague' aims to locate the areas where more elderly are likely to face heat stress during heat waves and hot summer for further research and design.

Method

The same approach for the map of surface energy balance on 26th July 2018 has been applied for the date 27th May 2017 and 2nd August 2018 (Figure 3.11, 3.14 & 3.15). Three maps share the similar pattern that the city center and the areas which were constructed around 1930s in The Hague are promoting the urban heat island when it comes to the spatial difference of the value of surface energy balance. However, the map of the date 27th May 2017 illustrates larger difference of the value among grids compared with the maps of the dates during heat eaves in 2018, which is probably caused by concentration of air pollution during heat waves that reduce the amount of solar radiation reaching the earth's surface. In order to locate the study areas more accurately, the map of surface energy balance on 27th May 2017, which reveals more spatial difference of surface energy balance, has been selected for the integrated map (Figure 3.14).

Statistical data about the absolute number of the elderly as well as the percentage of the elderly among citizens per grid and the value of surface energy balance on 27th May 2017 have been included on each grid by software QGIS. The percentile, which is known as 'a measure used in statistics indicating the value below which a given percentage of observations in a group of observations falls', of forementioned three aspects have been listed in the table respectively (Table 3.1). Some groups of criteria based on the percentile of three aspects have been tested to locate the grids with high values of surface energy balance, absolute number of the elderly and percentage of the elderly. The grids with higher value of the percentage of the elderly but lower value of absolute number of the elderly have been excluded. Finally, the criteria shown in table (Table 3.2) illustrate the clearest difference between each class.

Result

The neighborhoods, Scheveningen, Schildersbuurt and Transvaalkwartier, are places where people are likely to experience extra heat with high concentration of the elderly and more research and analysis will be conducted on them (Figure 3.16).

Percentile	Surface energy balance (W/m^2)	Number of the elderly (ppl)	Percentage of the elderly among citizens (%)
95th	373.3	55	67
90th	318.2	35	47
85th	293.4	30	35
80th	278.8	25	29
75th	267.6	25	25
70th	258.8	20	22
65th	250.6	20	19
60th	242.9	20	17
55th	235.0	15	15
50th	227.1	15	14

Table 3.1. Value of surface energy balance, number of the elderly and percentage of the elderly among citizens at each percentile among all the grids in The Hague.

Source: Produced by author.

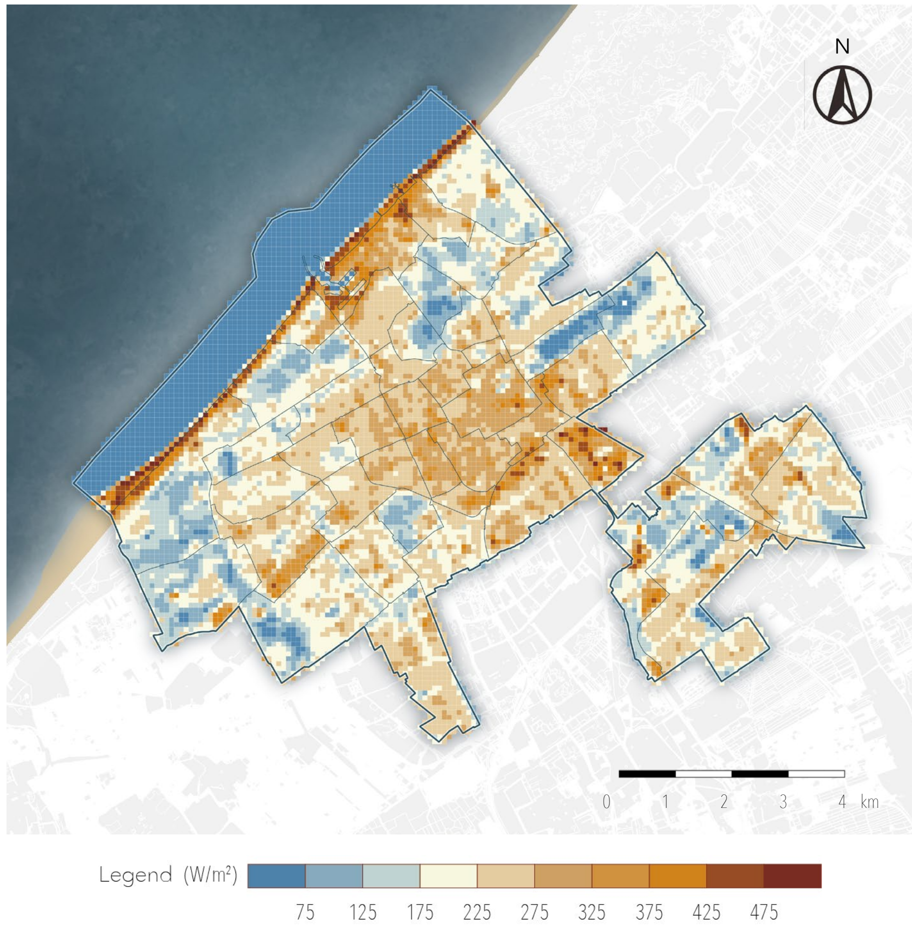


Figure 3.14. Surface energy balance measured on 27th May 2017 (Selected for the integrated map of 'heat' and the elderly in The Hague).

Source: Produced by author.

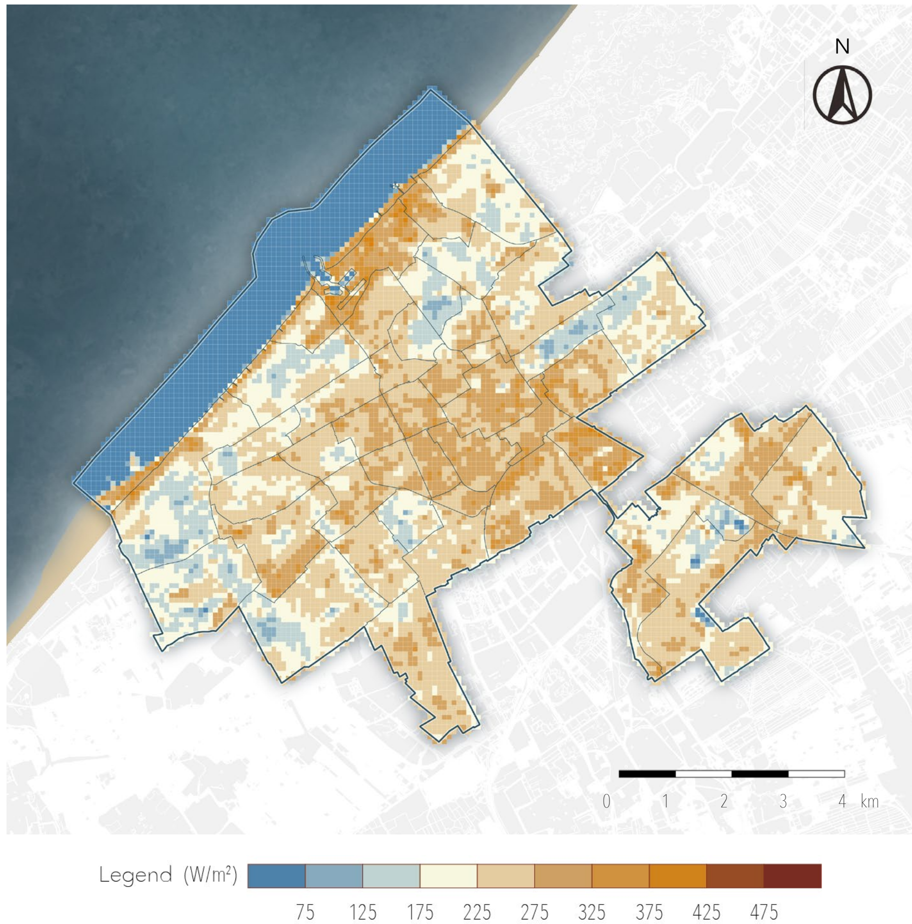


Figure 3.15. Surface energy balance measured on 2nd August 2018.

Source: Produced by author.

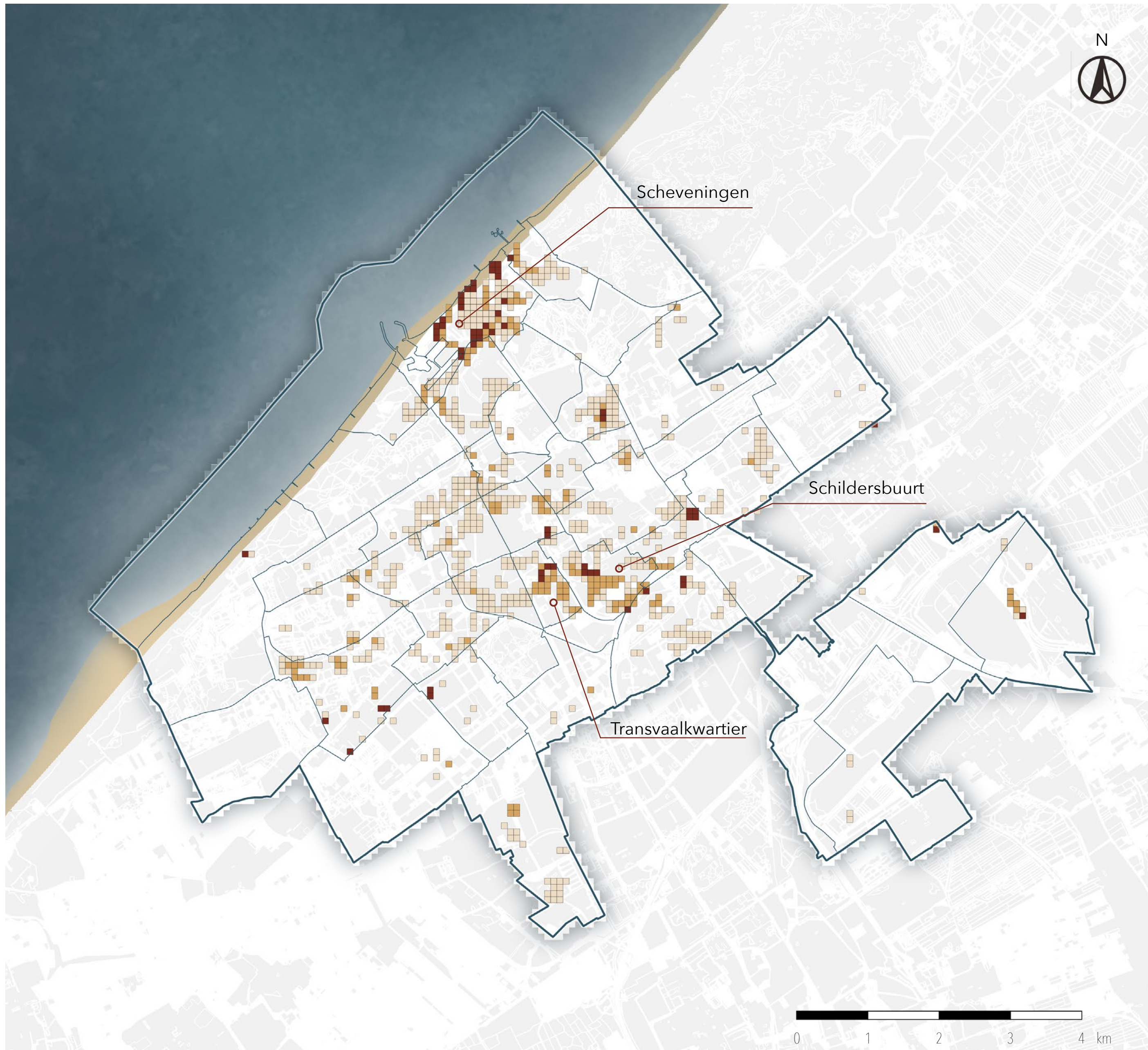


Figure 3.16. Integrated map of 'heat' and the elderly in The Hague.

Legend: Class 3, Class 2, Class 1

Source: Produced by author.

Class	Surface energy balance (percentile)	Number of the elderly (percentile) / Percentage of Elderly (percentile)
3	≥ 300 W/m^2 (14th)	No. ≥ 40 (9th) or Percentage ≥ 60% (9th) & No. ≥20
2	≥ 275 W/m^2 (22nd)	No. ≥ 30 (19th) or Percentage ≥ 40% (18th) & No. ≥20
1	≥ 250 W/m^2 (36th)	No. ≥ 20 (42nd)

Table 3.2. Criteria for each class (each square has a priority to be included in the highest class).

Source: Produced by author.

3.2.4 Indoor Temperature

Data

The data was provided by Quby which is a high-technical company who provide service to individuals to achieve a efficient and comfortable home. Due to privacy policies, the data was measures as the average Celsius degrees of indoor temperatures per neighborhood with at least five sensors connected to the mega-Internet. The data was collected hourly during the two heat waves in 2018 which from July 15th to July 27th and from July 29th to August 07th respectively.

Method

The data which is in txt. format has been converted into csv. format by software Excel and imported as well as visualized in the software QGIS afterwards.

Result

The date July 26th 2018 was selected since it was the hottest day during the heat waves in 2018 and the influence of hot weather on the indoor temperature during the night could also be analyzed while for the date August 07th, which is the hottest day during the second heat wave, the data has also been analyzed (Appendix III).

Through the whole day on July 26th, the highest average indoor temperature was recorded on 5:00PM which is 29.54 degree (Figure 3.17). When it comes to spatial distribution of indoor temperature, the neighborhoods along the coastline are relatively cooler than those far away from the North Sea, which could be explained by the cooling effects of the North Sea and better insulation of buildings. During the afternoon, the indoor temperature increases sharply and the people staying the buildings in the city center or in the south of The Hague probably suffer more from hot indoor temperature. Moreover, the impact of heat accumulated inside the building could be discovered by comparing the indoor temperature on 5:00AM on 26th and 27th respectively, which further reveals the severity of the continuous hot weathers (Figure 3.18).

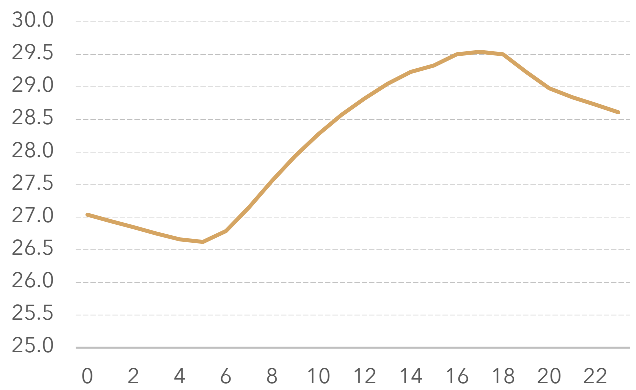
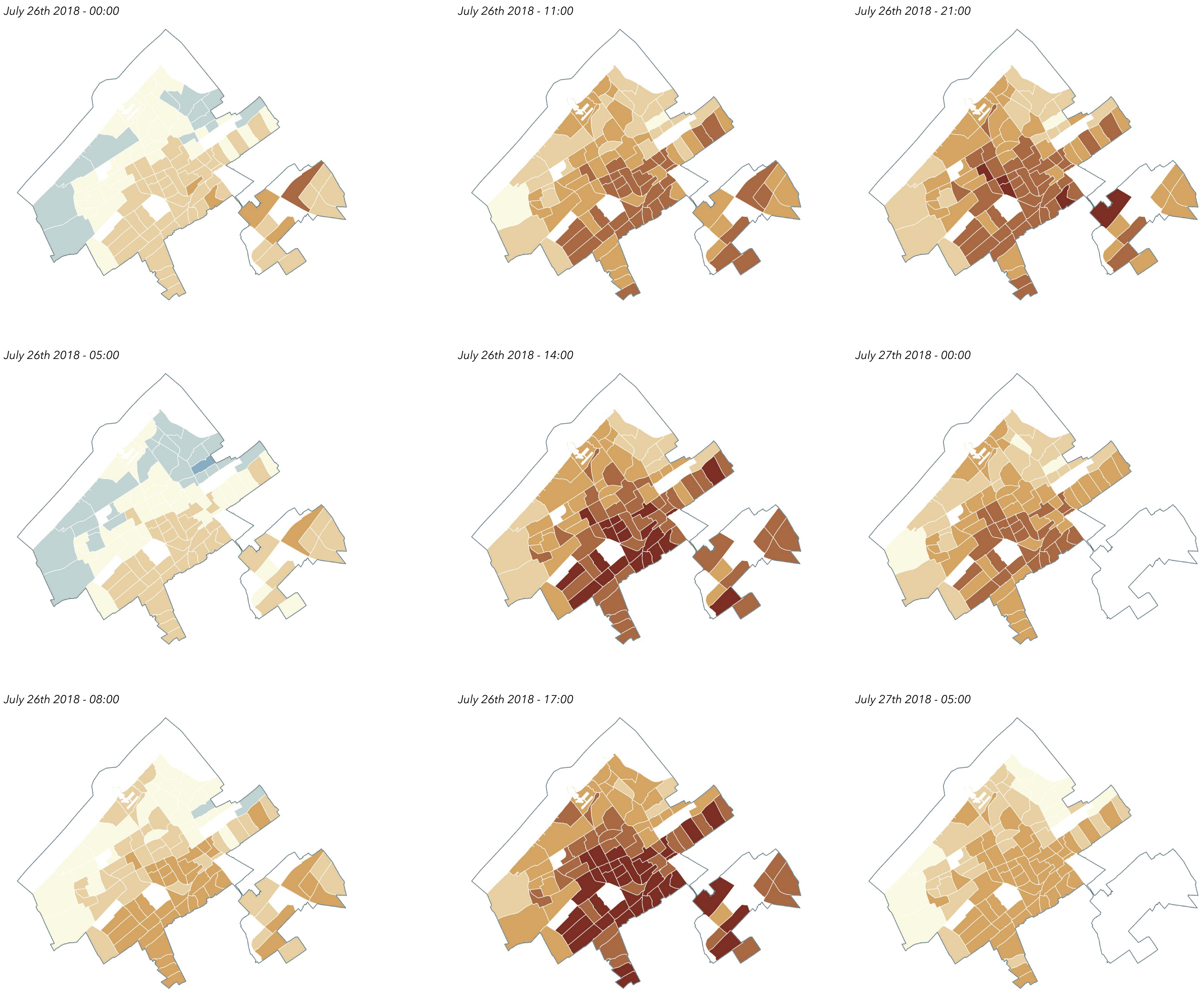


Figure 3.17. Average indoor temperatures among all of the neighborhoods on July 26th 2018 in The Hague.

Source: Produced by author.



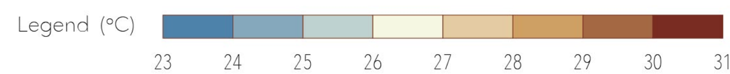


Figure 3.18. Average indoor temperature per neighborhood in The Hague.

Source: Produced by author.

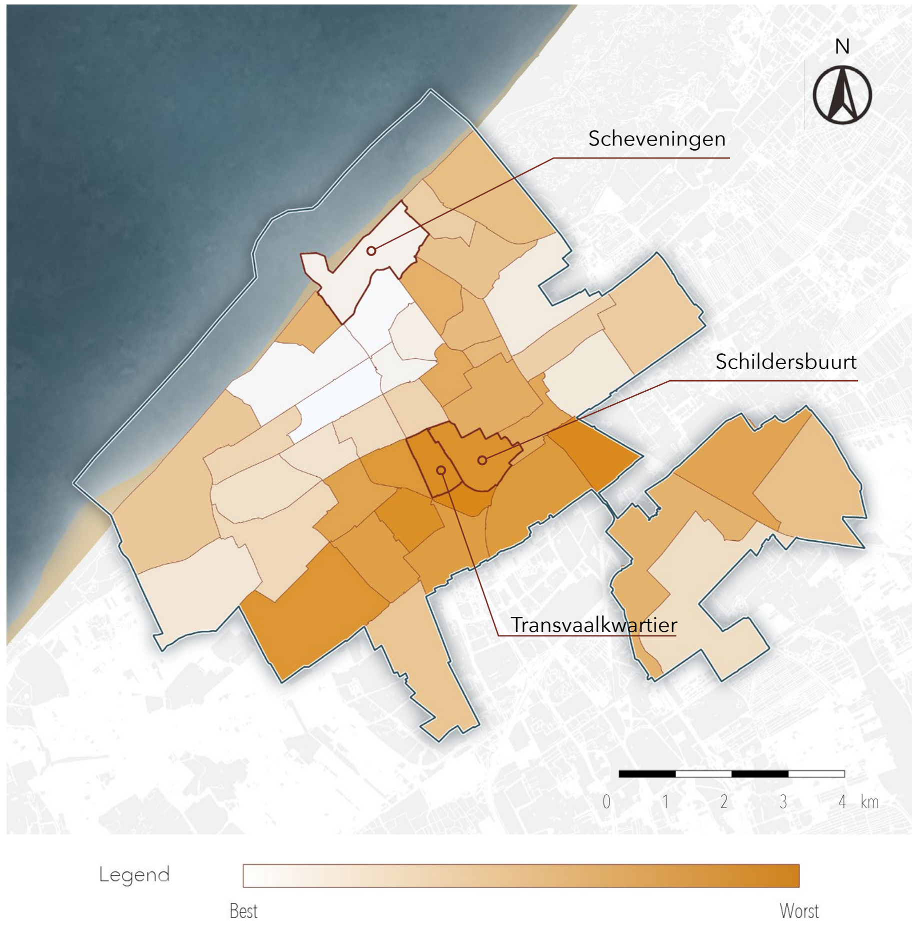


Figure 3.19. Ranking of neighborhoods in The Hague with regard to total score (Bottenheft, Doleweerd, & Engbers, 2015).

Source: Reproduced by author.

3.2.5 Neighborhood Dashboard: Age-Friendly City Den Haag (The Hague)

Data

Wijkdashboard: Age-Friendly City Den Haag (Neighborhood dashboard: Age-Friendly City Den Haag), TNO 2015.

Method

According to the guide called 'Global Age-friendly Cities: A Guide' by World Health Organization (WHO, 2007), eight themes (Table 3.3) (referring to Appendix IV) were selected to score each neighborhood by senior citizens and professionals in the report in The Hague. Afterwards, the eight themes were given equal weights in the total score to evaluate the facilities and services from the perspective of age-friendly city (Bottenheft, Doleweerd, & Engbers, 2015).

Result

There are 44 neighborhoods in The Hague and Scheveningen performs best among the select neighborhoods. The neighborhoods Schildersbuurt and Transvaalkwartier performs worse in all of the themes and total score except the theme 'community and health services' (Figure 3.19 & 3.20). The forefront position of these two neighborhoods in the theme 'community and health services' can be explained by the fact that the average distance to the various health care facilities is shorter than that for the neighborhoods in The Hague (Bottenheft, Doleweerd, & Engbers, 2015).

	Scheveningen	Schildersbuurt	Transvaalkwartier
Outdoor Spaces & Buildings	3	38	40
Transportation	13	36	42
Housing	7	42	44
Social Participation	1	24	33
Respect & Social Inclusion	16	34	38
Civic Participation & Employment	22	39	39
Communication & Information	16	36	36
Community & Health Services	19	1	2
Total Score	5	40	42

Table 3.3. Ranking of selected neighborhoods in The Hague with regard to each theme, (Bottenheft, Doleweerd, & Engbers, 2015).

Source: Reproduced by author.

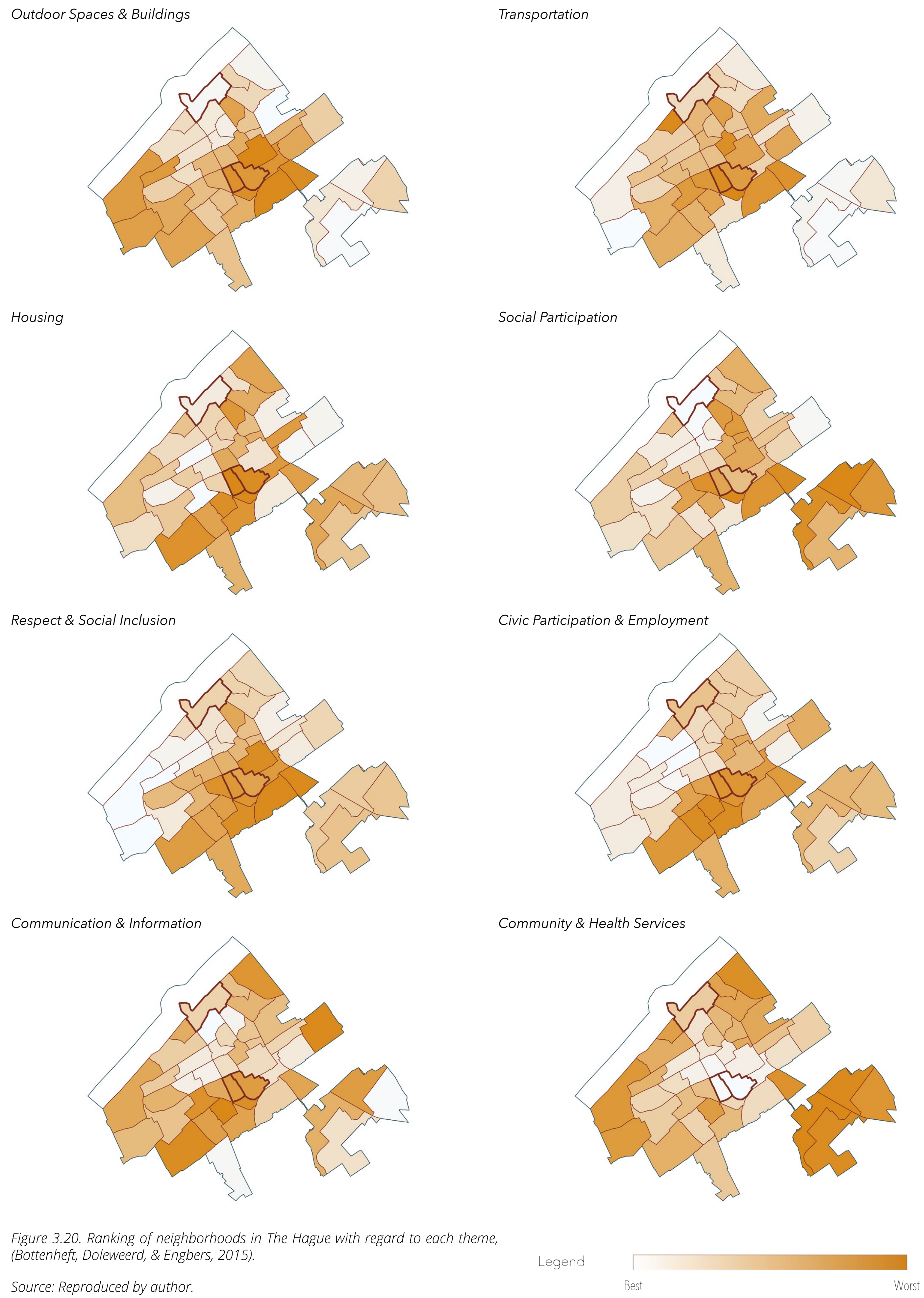


Figure 3.20. Ranking of neighborhoods in The Hague with regard to each theme, (Bottenheft, Doleweerd, & Engbers, 2015).

Source: Reproduced by author.

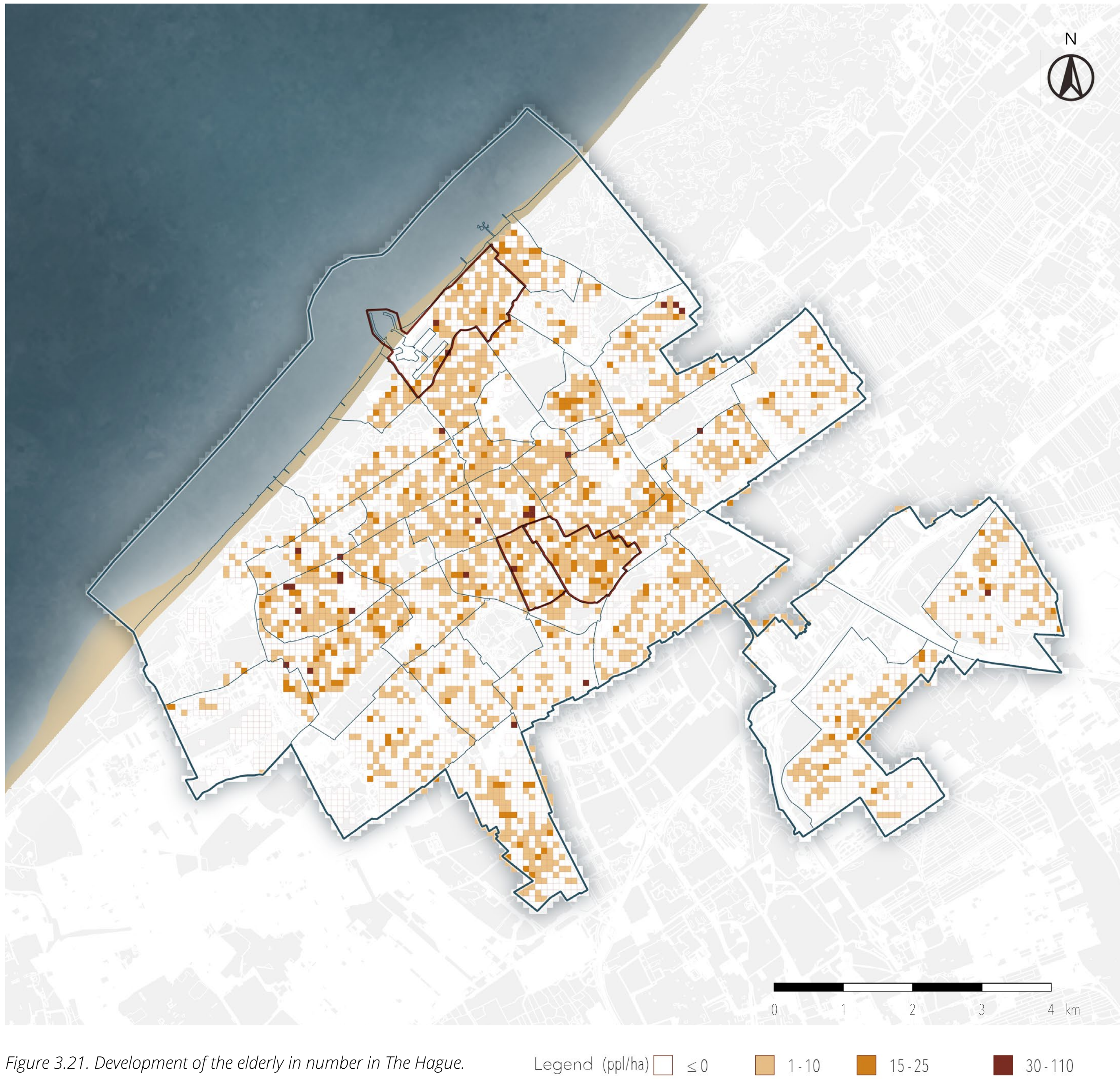


Figure 3.21. Development of the elderly in number in The Hague.

Source: Produced by author.

3.2.6 Development & Prediction of the Elderly in The Hague

Data

Map of 100 by 100 meters with statistics, CBS 2018 & 2010; Forecasts of the development of the elderly in The Hague towards 2021(Den Haag in Cijfers, 2015).

Method

The number of the elderly has been included on each square by CBS for 2010 and 2018 respectively. The difference between them illustrates the development of the number of the elderly. The forecasts have been translated into percentage and number per neighborhood and all the data has been analyzed and illustrated by software QGIS.

Result

The increasing number of the elderly reflects the trend of the places which attracted senior citizens. Due to the aging population and the popularity among the elderly living at their homes, almost half of The Hague witnessed the growth of the number of the elderly. The city center as well as the west and north part were most welcome among the elderly, which could be probably explained by the factor that senior citizens could get well access to services and facilities in or around the city center (Figure 3.21). When it comes to the prediction of the elderly, neighborhoods Transvaalkwartier and Schildersbuurt are forecasted to witness the largest growth in percentage and number among all the neighborhoods respectively (Figure 3.22 & 3.23).

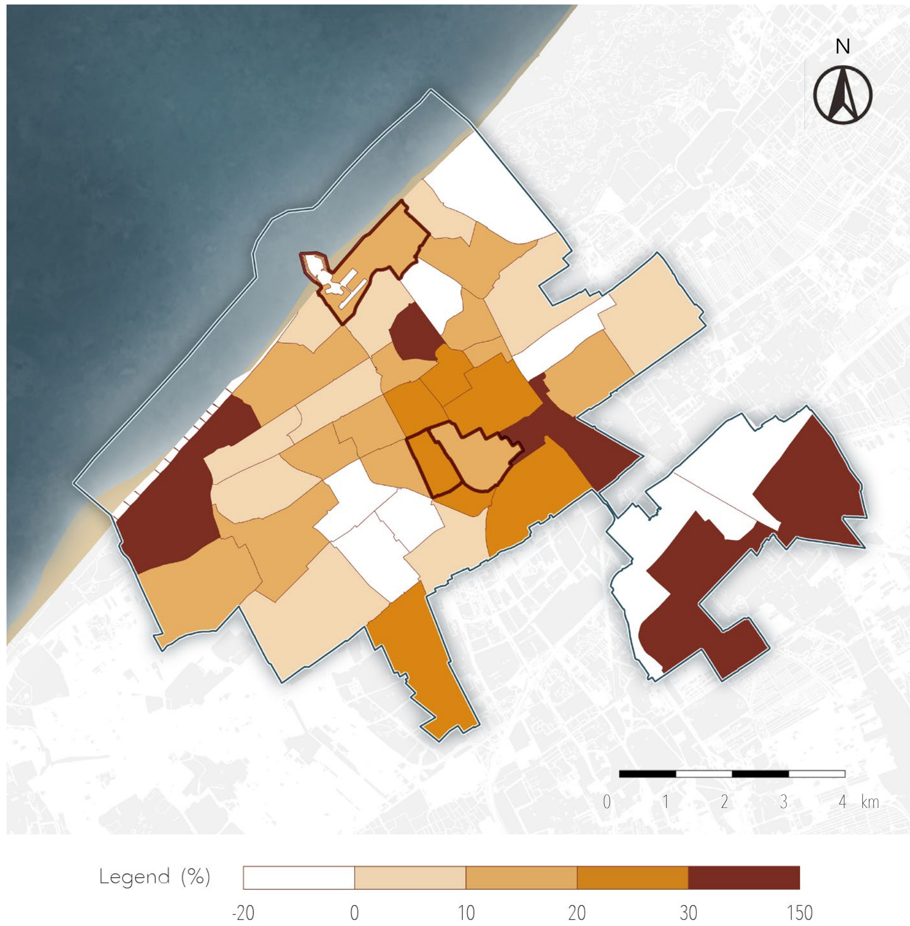


Figure 3.22. Prediction of the elderly in percentage in The Hague.

Source: Produced by author.

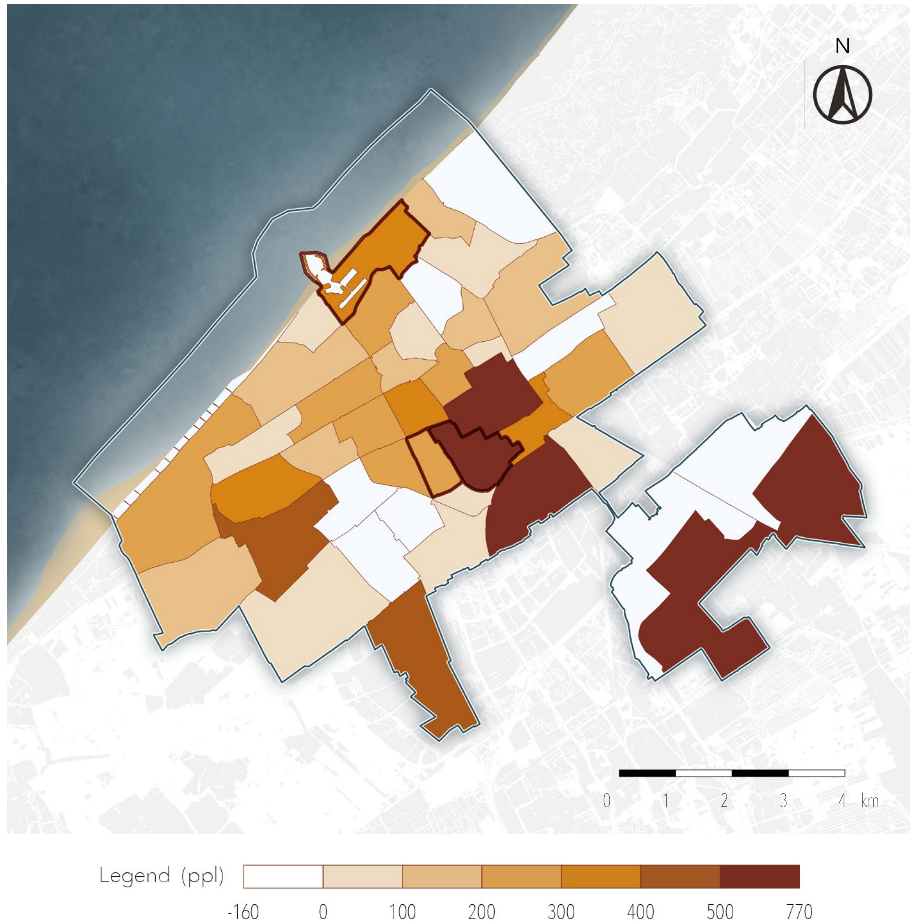


Figure 3.23. Prediction of the elderly in number in The Hague.

Source: Produced by author.

Figure 3.24. Selected neighborhoods in The Hague for further research.

Source: Produced by author.

3.2.7 Conclusion for Analysis on The Hague

To conclude for the analysis on The Hague, three neighborhoods which are Scheveningen, Schildersbuurt and Transvaalkwartier are selected after mapping the 'surface energy balance' and the concentration of the elderly. Afterwards, other indicators like indoor temperature and neighborhood dashboard have been analyzed and illustrated. All of three selected neighborhoods have witnessed the growth of the number of senior citizens in the past few years and neighborhoods Transvaalkwartier and Schildersbuurt are forecasted to witness the largest growth in percentage and number among all the neighborhoods respectively by 2021 in The Hague. When it comes to age-friendly city, the neighborhoods Schildersbuurt and Transvaalkwartier perform relatively worse compared with the neighborhood Scheveningen. Therefore, the neighborhoods Schildersbuurt and Transvaalkwartier are selected as the study areas for further research and desgin (Figure 3.24).

3.3 Analysis on the Study Areas

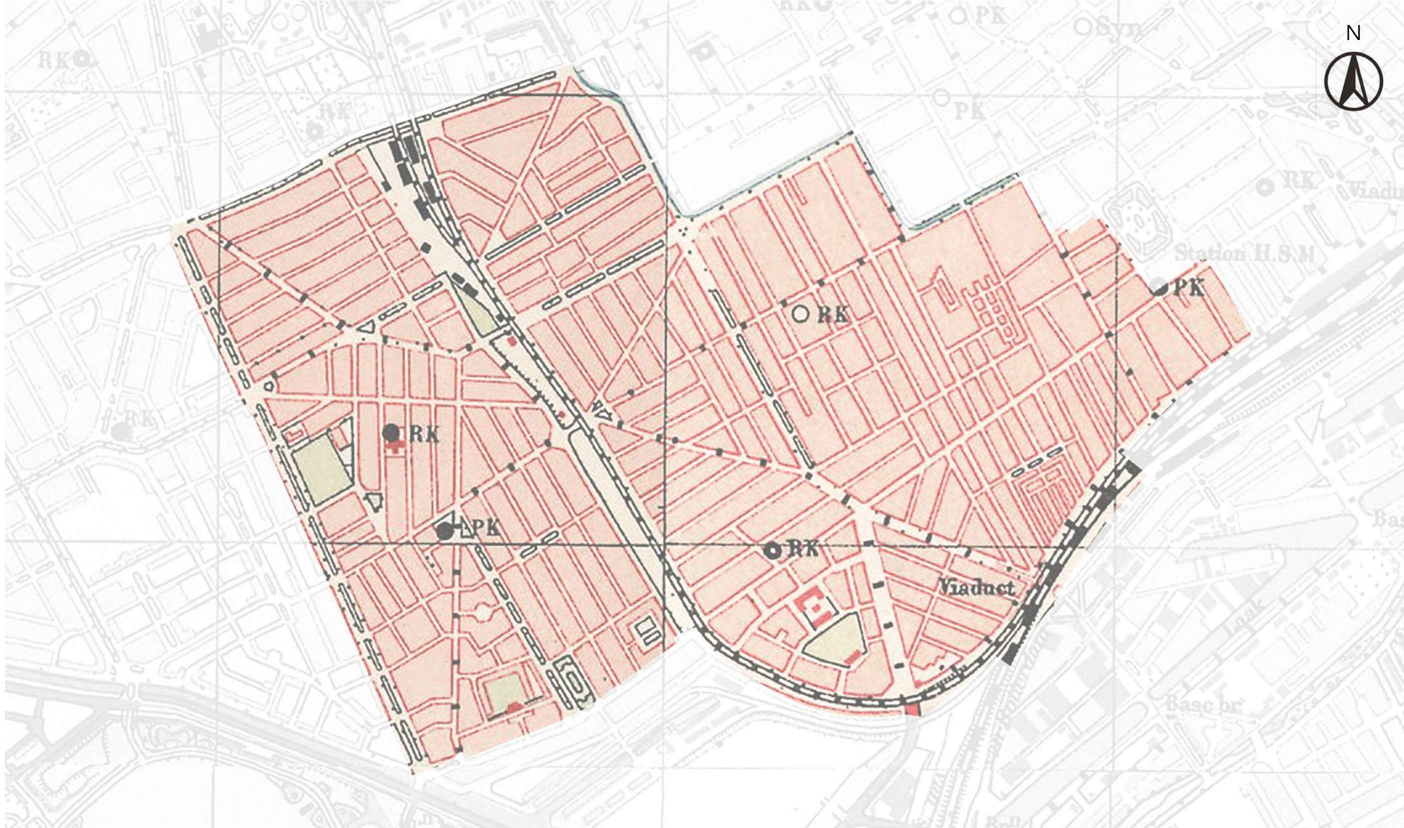


Figure 3.25. Schildersbuurt and Transvaalkwartier in 1940s

Source: https://www.topotijdreis.nl/.

Figure 3.26. The year of construction of the buildings in the study areas.

Source: https://code.waag.org/buildings/.

3.3.1 Introduction of the Study Areas

After the analysis on The Hague, the neighborhoods Schildersbuurt and Transvaalkwartier have been chosen as study areas. In this chapter, more analysis from spatial and microclimate perspectives will be conducted to have a further understanding of the study areas.

Data

Historical maps of Netherlands (https://www.topotijdreis.nl/); The years of construction of buildings in the Netherlands (https://code.waag.org/buildings/); OpenStreetMap; Health situation per neighborhood, district and municipality in the Netherlands (https://www.rivm.nl/media/smap/); Map of 100 by 100 meters with statistics, CBS 2018; Den Haag in Cijfers ('The Hague in number' in English) (https://denhaag.incijfers.nl/).

History

After 1860 The Hague grew rapidly and private developers took the lead of new extensions. 'The correlation between the quality of a housing estate and its subsoil was obvious. Those on the sand, north and west of the old center, were spacious and green. Those on south of the center, mainly on the peat soils, were monotonous working-class neighborhoods, often marked by poor living conditions' (Rutte & Abrahamse, 2016). The neighborhoods Schildersbuurt and Transvaalkwartier are the ones built on the peat soils after 1860s and some parts of them were bad maintained. Both of the neighborhoods were tackled through urban renewal since 1970s, which resulted in almost the same typology of buildings with '1940s neighborhoods' but the buildings are relatively new (Figure 3.25 & 3.26).

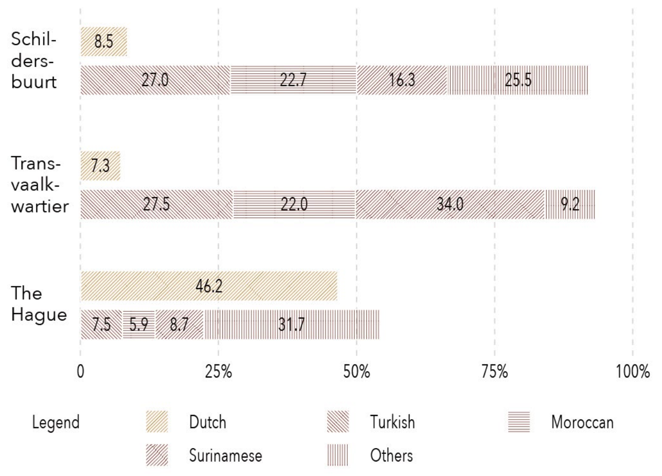


Figure 3.27. Migration background of population in study areas, (Den Haag in Cijfers, 2018).

Source: Reproduced by author.

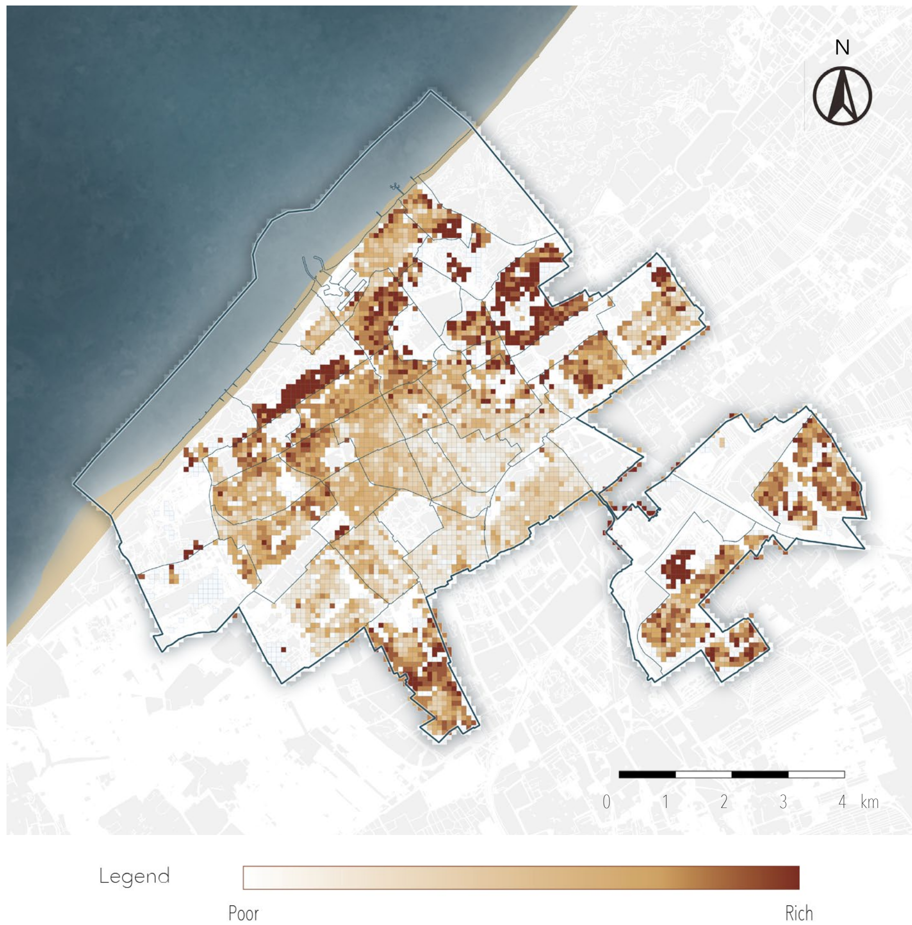


Figure 3.28. Spatial distribution of income level in The Hague.

Source: Produced by author.

	Schildersbuurt	Transvaalkwartier	The Hague	Netherlands
Population	31255	16160	519988	16979120
Good experience health	52%	57%	70%	75%
Long-term disorders	46%	42%	38%	35%
Risk of depression	68%	67%	52%	45%
High risk of depression	24%	22%	12%	7%
Physical limitation	37%	34%	20%	16%
Restriction on movement	29%	26%	14%	11%
Restriction in hearing	11%	11%	5%	5%
Restriction in seeing	19%	17%	9%	6%
Loneliness	65%	65%	53%	44%
Severe loneliness	25%	24%	16%	10%

Table 3.4. Comparison between the health situation of the people in the study areas, The Hague and the Netherlands, (RIVM, 2016).

Source: Reproduced by author.

Current situation

Spatial distribution of income level among the citizens has still been following the pattern that rich people live in the buildings constructed on the sand and citizens with lower income level live in the neighborhoods on the peat soils. The neighborhoods Schildersbuurt and Transvaalkwartier are located in the peat soils and people living in them have relatively low income (Figure 3.28). Moreover, the residents in the study areas have abundant migration backgrounds and more attention should be focused on the demands from people with different culture (Figure 3.27).

The RIVM has collected and calculated health and lifestyle figures for all neighborhoods in the Netherlands in 2016 and some categories related to the topic of the thesis have been selected (Table 3.4) and more explanation of the categories could be found in the appendix (Appendix V). It is obvious that the physical and mental health of the people who live in the neighborhoods Schildersbuurt and Transvaalkwartier is worse than the average of those in The Hague, which also highlight the social issue.

Conclusion

The neighborhoods Schildersbuurt and Transvaalkwartier are the places facing mores challenge from local residents, which makes it more complex to apply interventions and attention should be focused on not only protecting the elderly but also balancing the interests between stakeholders.

3.3.2 Analysis from Spatial Perspective

A series of analysis from spatial perspective have been conducted on the neighborhoods Schildersbuurt and Transvaalkwartier. The results have been demonstrated with several analytical maps in the following pages.

Data

NASA, Landsat 8, 27th May 2017; OpenStreetMap;

Method

The photos have been taken during the site visit. Mapping and illustration were done by software QGIS and Illustrator based on the data from remote sensing as well as OpenStreetMap.

Figure 3.29. Building functions in the study areas.

Source: Produced by author.

Building Functions

The functions of buildings in research areas are mainly residential buildings with some public buildings along the main streets (Figure 3.29 & 3.30). The public functions of buildings are divided into four categories according to the demands of senior citizens. 'Food & drink' refers to the places where the elderly can purchase or have foods and drinks such as supermarket, bakery, cafe, greengrocer and so on. 'Medical' refers to the places where the elderly could get medical treatment like clinic and hospital. The buildings with the function 'Food & drink' and 'Retail' are mainly located at north-west and center of the research areas which shows the probable areas where the elderly usually pay a visit to and more attention should be focused on these areas to protect them from extra heat in outdoor spaces.

Figure 3.30. Buildings with public functions in the study areas.

Source: Produced by author.

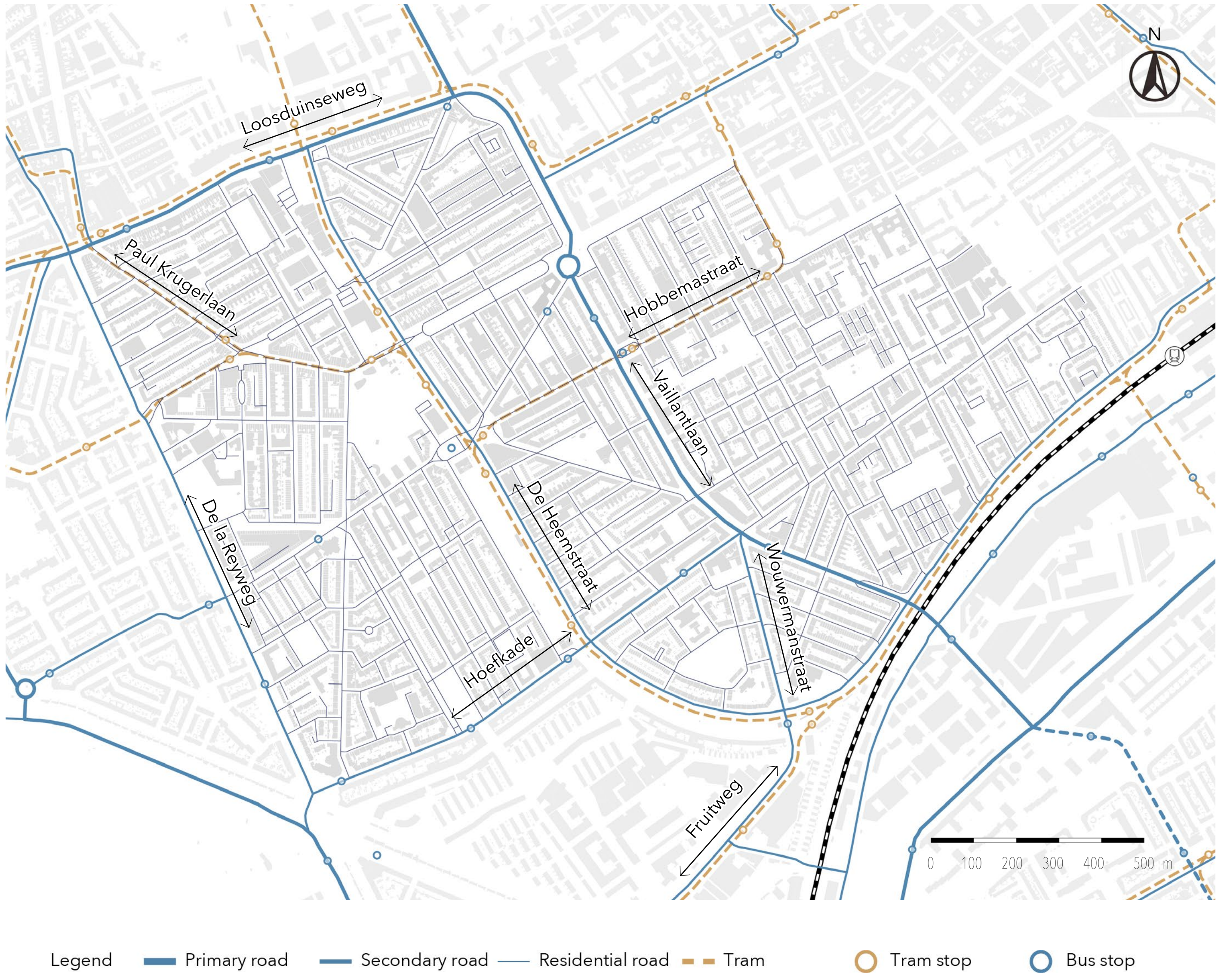


Figure 3.31. Roads and public transport in the study areas.

Source: Produced by author.

Roads & Public Transport

When it comes to roads structure, there is some difference between selected neighborhoods. For the neighborhoods Schildersbuurt, there are one primary road going through it while for the neighborhood Transvaalkwartier, several secondary roads are located around it. Moreover, the research areas are divided by two north-south oriented roads into three parts.

When it comes to public transport, there are trams and buses going through two neighborhoods. The railway station 'The Hague HS' is also located to the east of the neighborhood Schildersbuurt. Most areas have been covered by tram and bus stops except for the east part of the neighborhoods Schildersbuurt (Figure 3.31).

Legend Open Space Vegetation Water body Buildings in sites 5 mins walking from O.S.

Figure 3.32. Open spaces in the study areas.

Source: Produced by author.

Legend Open Space Vegetation
10 mins walking from O.S.

Figure 3.33. Buffer zone of 10 minutes walking from open spaces.

Source: Produced by author.

Open space with playing facilities for kids

Open space with playing facilities for kids

Speelplein

Open space with basketball court

Wijkpark Transvaal

De Haagse Markt

Figure 3.34. Photos of open space in the study areas.

Source: Taken by author.

Open Space

There are several open spaces with various sizes inside and around study areas and two of them are remarkable. One is an urban park called 'Zuiderpark' to the south-west of research areas and the other is a neighborhood park named 'Wijkpark Transvaal'. Burton and Mitchell argued in their book 'inclusive urban design, street for life' that a park or other form of open space, which is referred to secondary services and facilities, should be no further than 800 meters (around 10 minutes walking) from the homes of the elderly if they cannot be within 500 meters (around 5 minutes walking) (Burton & Mitchell, 2006). However, other research argues that the forementioned distance was made based on non-elderly population and one should add 10 and 20 minutes respectively to that (Santinha, Costa, & Diogo, 2018). Based on the forementioned knowledge, the buffer zones which are 5- and 10-minutes walking from all of the open spaces have been mapped and most of the areas could be located in 5 minutes walking from open spaces (Figure 3.32 & 3.33).

When it comes to the content in each open space, there are some common characteristics among them such as impervious and dark-colored pavements, boarded-up green spaces and small trees (Figure 3.34), which are more likely to cause heat stress for the people during hot summers. Moreover, the activities in most of open spaces are designed for kids and teenagers such as football and basketball and less consideration has been taken into account for the elderly. There are benches or public seating in the open spaces but most of them are placed far away from trees or could not get benefits from the shades of trees.

Legend Buildings with orientations that cause high risk of enduring extra solar radiation due to sunset

Figure 3.35. Analysis of building risks from the perspectives of facade orientation.

Source: Produced by author.

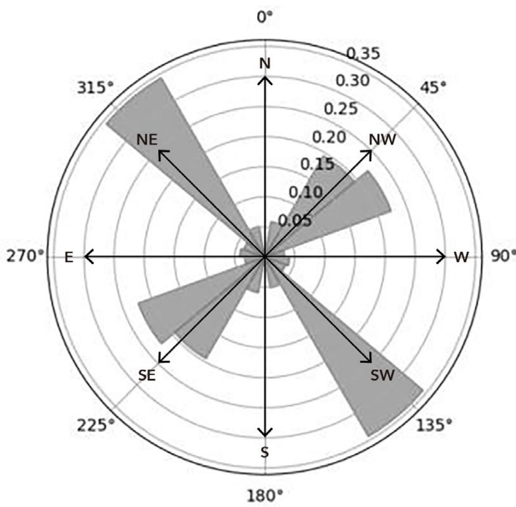


Figure 3.36. Statistical orientations of streets.

Source: Produced by author.

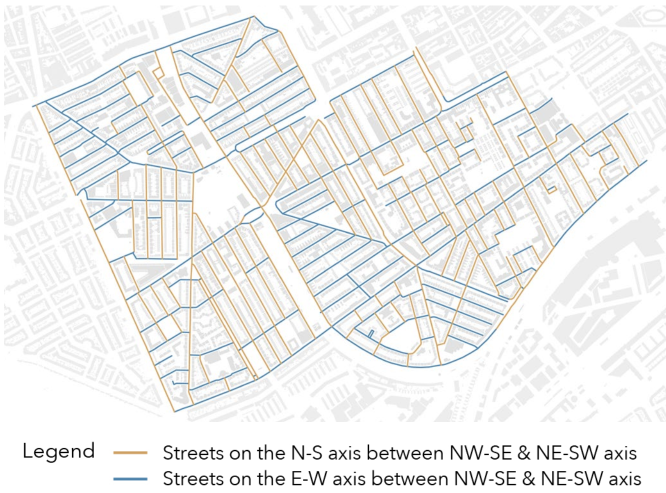


Figure 3.37. Orientations of streets in the study areas.

Source: Produced by author.

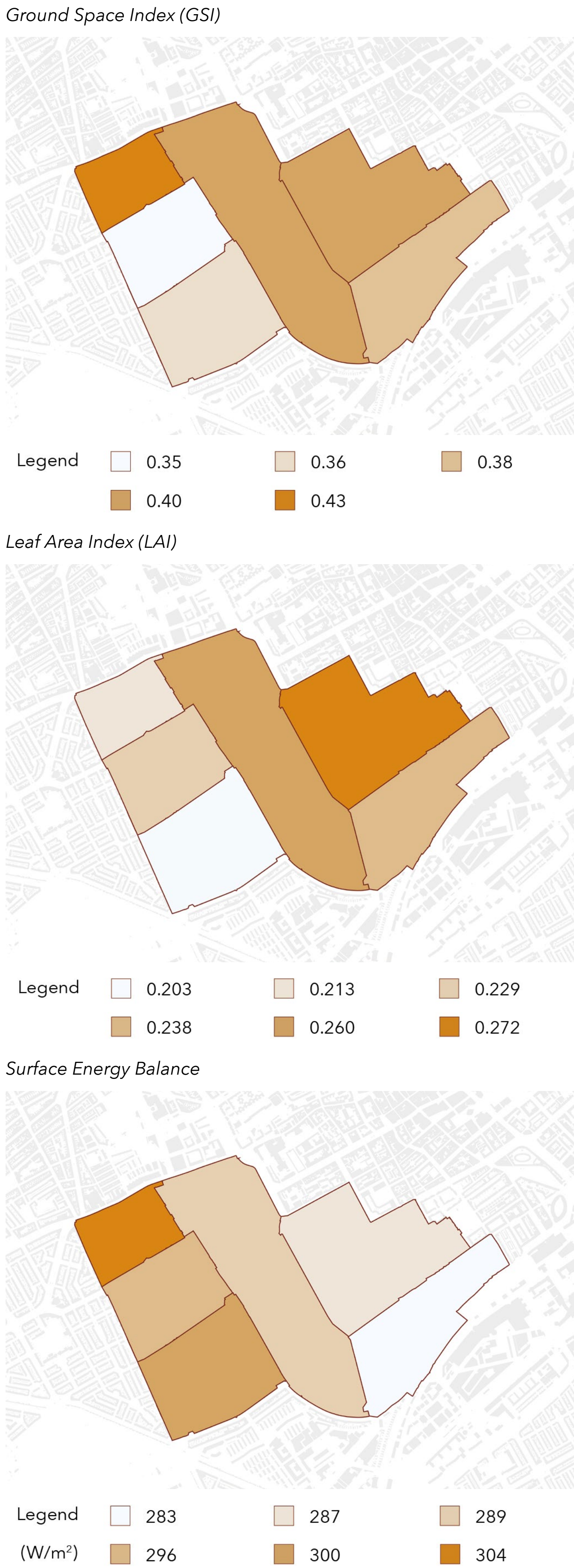


Figure 3.38. GSI, LAI and surface energy balance of study areas on buurten scale on 27th May 2017 (From top to bottom).

Source: Produced by author.

3.3.3 Analysis from Microclimate Perspective

Data

NASA, Landsat 8, 27th May 2017, 26th July 2018 & 2nd August 2018; OpenStreetMap;

Method

The orientation of the facades of buildings have strong effects on the indoor thermal performance especially during the sunsets. The buildings with the facades towards west will endure the most solar radiation which will further affect the indoor temperature during the night.

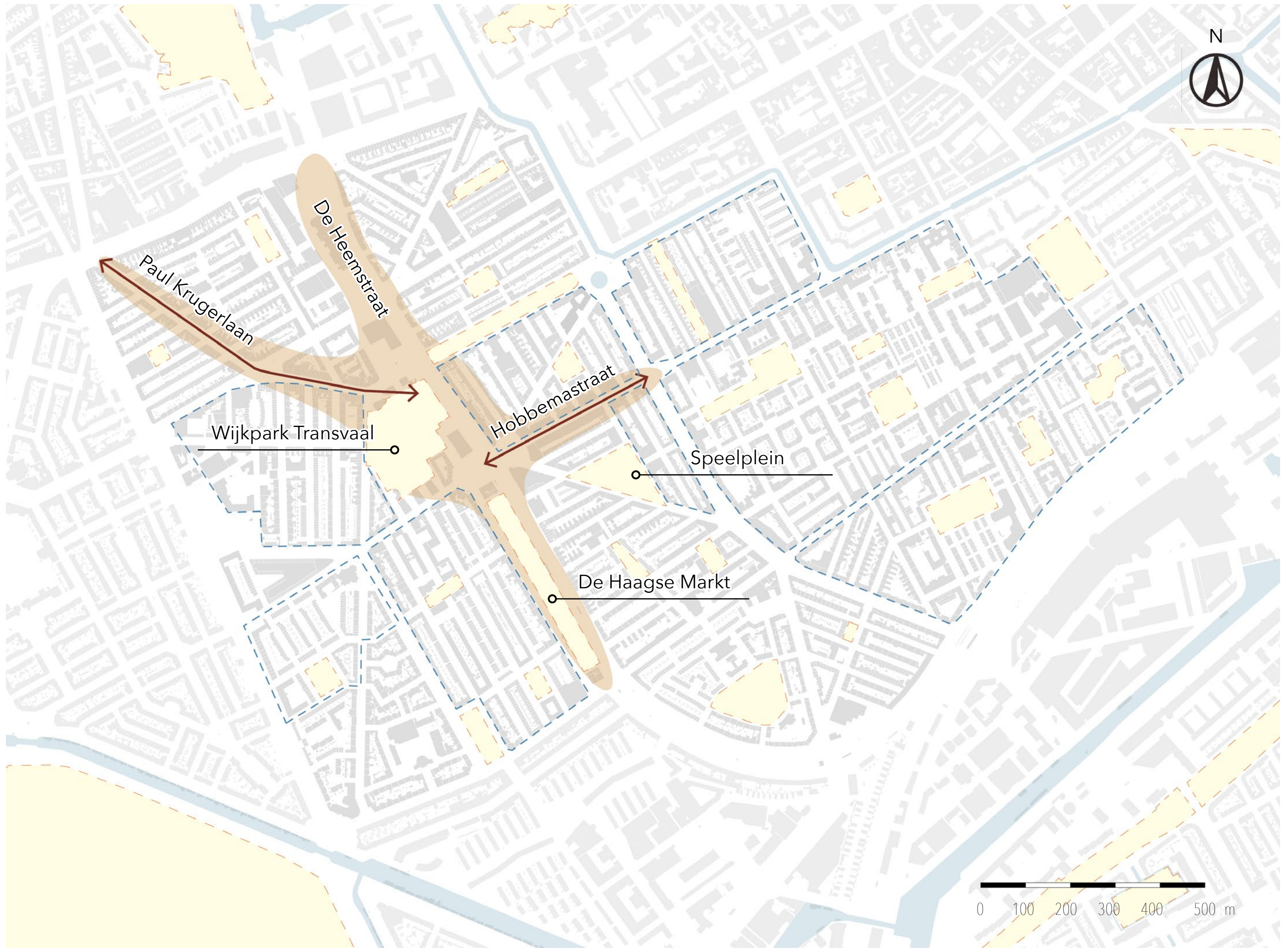
Since most of the buildings in the research areas are residential buildings with facade along the streets, the orientation of the street has been used as an indicator to evaluate the risk from the perspective of microclimate. The effect of the orientation of facades on the indoor thermal performance is strongest when the facades of buildings along the streets are towards east or west, which means the orientation of streets are on the N, S, NE - SW and NW - Se axes. Therefore, the streets in the research areas with orientations between NE - SW and NW - SE axes towards north or south have been marked as relatively high risk in the analysis (Figure 3.36 & 3.37). Afterwards, the orientation of the facades of building are sorted into two categories, high risk and low risk respectively, based on the orientations of streets (Figure 3.35). The geometry of streets and the orientations of buildings were calculated and illustrated by software QGIS and Illustrator.

Moreover, ground space index, leaf area index and surface energy balance (27th May 2017) have been mapped with the same approach 'Join attributes by location' as the analysis on The Hague based on 'buurten' scale (Figure 3.38). The data has been collected on each polygon and then visualized in the software QGIS.

Result

According to the statistics (Figure 3.36 & 3.37), most streets in research areas are on or around the NE - SW and NW - Se axes and half of the streets are marked with high risk. Similarly, almost half of buildings are with high risks considering solar radiation and some clusters are apparent on the map due to the typology of buildings and orientations of streets (Figure 3.35).

When it comes to GSI, LAI and surface energy balance, some clues such as the areas with relatively high value of GSI and low value of LAI are usually hotter even though the difference is not much (Figure 3.38).



Legend: Open space; Relatively public areas; Residential clusters with high risks of high indoor temperature; Streets with retails, food and beverage

Figure 3.39. Conclusion for analysis on the study areas.

Source: Produced by author.

3.3.4 Conclusion for Analysis on the Study Areas

From the perspective of spatial perspective, the neighborhood park 'Wijkpark Transvaal' is like a center and knot for the areas and buildings with public functions. The buildings with functions like retails, supermarket and cafe are mainly located along the street 'Hobbemastraat' and 'Paul Krugerlaan'. The open spaces could cover most of the areas with the distance of 5 minutes walking by the elderly as well (Figure 3.39). However, the food stores along the street 'Paul Krugerlaan' are mainly fast-food stores, which are seldom visited by the elderly and the microclimate on pedestrian level along the street 'Hobbemastraat' is relatively good due to the contribution of the arcades (Figure 3.41 & 3.42) (Appendix V). Moreover, most of the open spaces are designed for the teenagers (Figure 3.40) and less attention has been be drawn on making them more friendly to the elderly especially during hot summer.

From the perspective of microclimate, the streets with the orientation NE-SW and NW-SE are prevailing in the study areas. As a consequence, almost half of the buildings have the potentials to be overheated during sunset and some strategies should be introduced to protect citizens from high indoor temperature (Figure 3.39).

Considering the relatively poor health conditions in the study areas such as around one-third of the people with difficulty to walk 400 meters in one time (Table 3.4) and common courtyard block dwellings (Taleghani, Tenpierik, & van den Dobbelsteen, 2014) with three or four floors, more attention should be focused on the places inside neighborhoods such as neighborhood streets, courtyard blocks and small open spaces to offer more options to the elderly and protect the elderly from heat stress both in indoor and outdoor spaces.

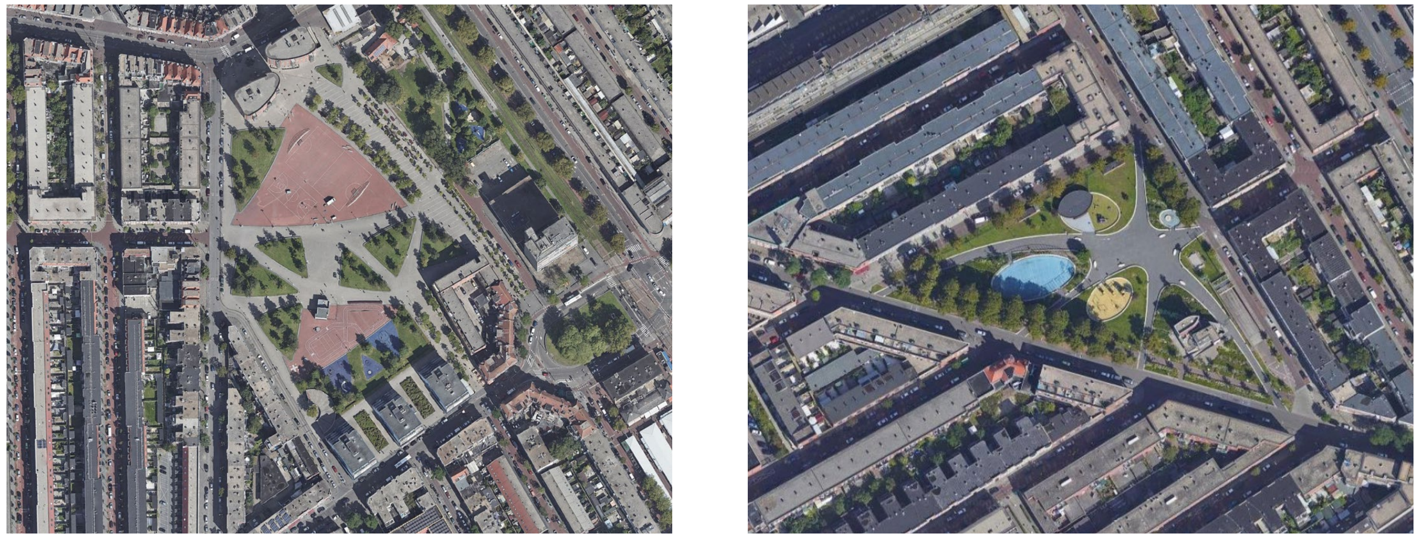


Figure 3.40. Satellite images of Wijkpark Transvaal and Speelplein (From left to right).

Source: Google Map.

Figure 3.41. Street view of the street Hobbemastraat.

Source: Produced by author.

Figure 3.42. Street view of the street Paul Krugerlaan.

Source: Google Map; Produced by author.

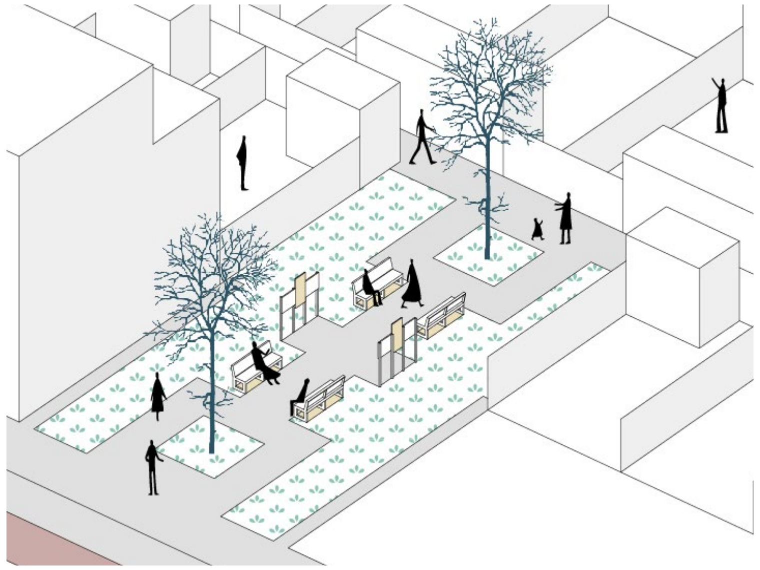


Figure. Designing of 'cooling haven' within the block.

Source: Produced by author.

4 RESEARCH

The chapter 'Research' consists of two parts which are 'research by design' and 'research for deign' to learn about the effect of building configuration and vegetation on outfoor thermal comfort. The sub-question 2 (***causation***) will be uncovered partially by the research of courtyard block dwellings in the chapter.

- Livability from Microclimate Perspectives
- Typology Study from Microclimate Perspective on Courtyard Block Dwellings
- The Effect of Vegetation on Microclimate
- Prevailing Wind during Heat Waves
- Spatial Interventions on Courtyard Block Dwellings
- Conclusion

The concept of 'livability' has risen as a guiding principles in urban planning and design and it is nowhere more prevalent that in the context of cities where the majority of human are living (Ruth & Franklin, 2014). It is projected that 68 percentage of the population in the world will reside in urban areas by 2050 (Ritchie & Roser, 2020). Ruth and Franklin argued that the notion of a livable city requires two elements in sense of 'fit to live in' and 'inhabitable'. One concerns the aspects those goods and services that citizens could rely on such as shelter, energy, food and water, health and safety and so on, which has been given much attention historically. The other element concerns the urban environments which is defined by its physical and biological characteristics known as the built infrastructures and ecosystems that provide citizens with goods and services. These characteristics such as greenery, water body and public spaces not only generate amenities and economic values but also contribute to local climate and air quality (Ruth & Franklin, 2014).

Microclimate, which is known as local atmosphere conditions that differ from the rest of surrounding areas, has been largely shaped by urban environments on different scales and it has effects on comfort and health of well beings (Moonen, Defraeye, Dorer, Blocken, & Carmeliet, 2012). Each of the microclimate components – solar radiation, daylight, wind, air quality and sound – has influence on the physical well-being of citizens individually or together with each other. Some of them have both positive and negative effects while others only have negative impact. The livability from microclimate perspective has been affected by the combination of microclimate components as well as physiological and psychological factors such as culture and health situation, which could be interpreted as thermal comfort for citizens. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) define thermal comfort as 'the condition of the mind in which satisfaction is expressed with the thermal environment' (ASHRAE, 2010) and it will be influence by intrinsic and extrinsic factors such as mood, culture, health situation, clothing, urban environment and much more. Each person staying in a similar area with same background and climate conditions will also propose various opinions on thermal performance due to the combination of a mass of factors, which reveals that there is no absolute standard for thermal comfort.

There are several thermal indices to estimate indoor and outdoor thermal performance and they can be divided into physical environmental variables and subjective comfort sensation. Physical environmental variables include air temperature, mean radiant temperature, relative humidity, wind speed and so on while other models such as predicted mean vote (PMV), comfort sensation vote (CSV) and thermal sensation vote (TSV) are predicting subjective comfort and thermal sensation (Kim, Min, & Kim, 2013; Yau & Chew, 2014). In the thesis, indoor thermal comfort is evaluated by comfort temperatures based on the ASHRAE 55-2010 standard, which are the values between 17.5 and 24.5 °C in the Netherlands (Taleghani, Tenpierik, & van den Dobbelsteen, 2014) and outdoor thermal performance is estimated by physiological equivalent temperature (PET) (Hoppe, 1999). Both of forementioned indices applied in the thesis are based on the unit Celsius degree, which makes them more preferable than other indices since they make the results more comprehensible to urbanists (Matzarakis, Mayer, & Iziomon, 1999). The physiological equivalent temperature (PET) is defined as 'the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed' (Hoppe, 1999). It helps people to compare outdoor thermal environments with their own indoor experience. The physiological equivalent temperature (PET) is calculated based on four thermally relevant climate parameters which are air temperature, mean radiant temperature, wind speed and relative humidity and it could not be used as an absolute measure of thermal comfort since subjective characteristics such as clothing activities and health situation will also influence individual assessment of thermal comfort (Hoppe, 1999).

In order to evaluate and then improve the livability from microclimate perspectives, the physiological equivalent temperature (PET) has been applied as a main indicator in the thesis. Due to the limitation of the schedule and data of the graduation project, the evaluation of the outdoor thermal performance has been relying to a great extent on the results from the simulation in the software ENVI_MET. ENVI_MET is a software that can simulate climates in urban environments and assess the effects of atmosphere, vegetation, architecture and materials (ENVI_MET GmbH, 2020). The results from the simulation in ENVI_MET could not be recognized as the absolute situation for outdoor environments since the accuracy of calculations depends heavily on grid size, details in the model and input parameters and some process are simplified or standardized in ENVI_MET because of the complexity of modeling microclimate. For example, the validation for ENVI_MET with field measurements in Delft, the Netherlands by Taleghani et al. illustrates that the influence of different materials on air temperature can be calculated with an accuracy of about 80% and with an average deviation between 0.74-0.94 °C (Taleghani, Tenpierik, van den Dobbelsteen, & Sailor, 2014).

The impact of the limitations of the simulation in ENVI_MET and the physiological equivalent temperature (PET) from subjective characteristics have been minimized by comparison between the values of PET and its determining parameters before and after spatial interventions based on an assumed individual (Table 4.1). Since the starting point of the thesis is the Dutch elderly, the individual who is 'experiencing' outdoor thermal environments in study areas is assumed as a 70-year-old woman with the weight of 70.5 kilogram and the height of 1.65 meter. The values for weight and height of the assumed female elderly are the average values of the weight and height of the Dutch women between 65 and 74 years old from a survey by Statistics Netherlands (CBS) (CBS, 2005). Therefore, the results from simulation in the thesis could be recognized as a reference for the Dutch elderly.

In the following contents, the research has been conducted based on the mapping, simulation and literature review and it consists of two parts which are 'research for deign' and 'research by design'. The research of the typology of courtyard block dwellings, prevailing wind during heat waves and the effect of vegetation is included in 'research for design' and the aims of them are to instruct designing and strategy making. Moreover, some spatial interventions have been applied within the blocks of courtyard dwellings to test the effect of design on microclimate through the method 'research by design'.

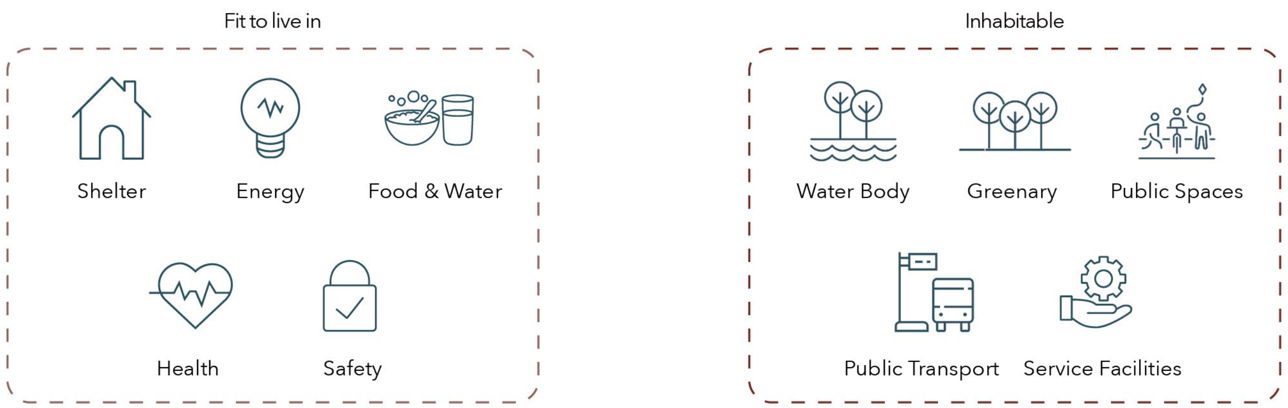


Figure 4.1. The notion of a livable city requires two elements in sense of 'fit to live in' and 'inhabitable'.

Source: Produced by author.

Personal parameters of assumed individual		
Content	Value	Unit & Reference
Body parameters		
Age of person	70	year
Gender	Female	-
Weight	70.50	m
Height	1.65	m
Clothing parameters		
Static clothing insulation	0.90	clo
Body metabolism		
Basal rate	62.18	W
Work metabolism	80.00	W
Summary		
Sum metabolic work	142.18	W

Table 4.1. Personal parameters of assumed individual for the simulation in ENVI_MET.

Source: Produced by author.

4.2 Typology Study on Courtyard Block Dwellings

The common three or four-floor buildings with courtyard form are common in the study areas and the dominant function of courtyard buildings is residential. The form of courtyard is one of the most commonly used building archetypes in hot climates since the courtyards could provide shading and enhance the ventilation through the stack effect to contribute to a cool microclimate inside the building blocks. However, the thermal behavior of courtyard buildings in temperate regions such as West Europe has rarely been studied (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b). When it comes to the contents in the Netherlands, the courtyards exist mainly as urban blocks, which is named as urban courtyard block dwellings (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b). Since the courtyard block dwellings are popular in the study areas, they have been selected as the object of the research to learn about the impact of building configuration on the microclimate within the courtyards as well as that on the streets.

4.2.1 Indoor Thermal Comfort In Courtyard Block Dwellings

Taleghani have been leading in several research on the urban courtyard block dwellings including indoor thermal performance, energy performance as well as some strategies to improve the thermal comfort and the research on indoor thermal comfort with regard to the orientation of the courtyards offers inspirations for further research and methods in the thesis (Taleghani, Kleerekoper, Tenpierik, & Van Den Dobbelsteen, 2015; Taleghani, Tenpierik, & van den Dobbelsteen, 2014b, 2014a; Taleghani, Tenpierik, van den Dobbelsteen, et al., 2014).

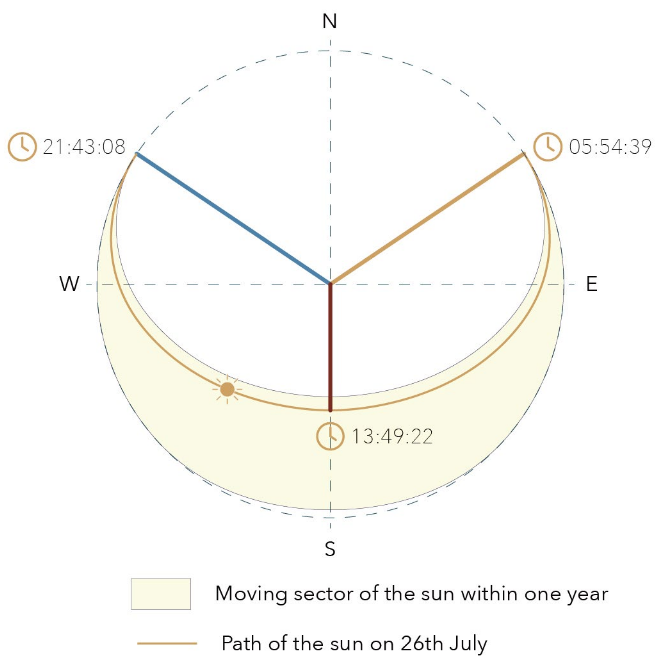


Figure 4.2. Solar path on 26th July 2018.

Source: Produced by author.

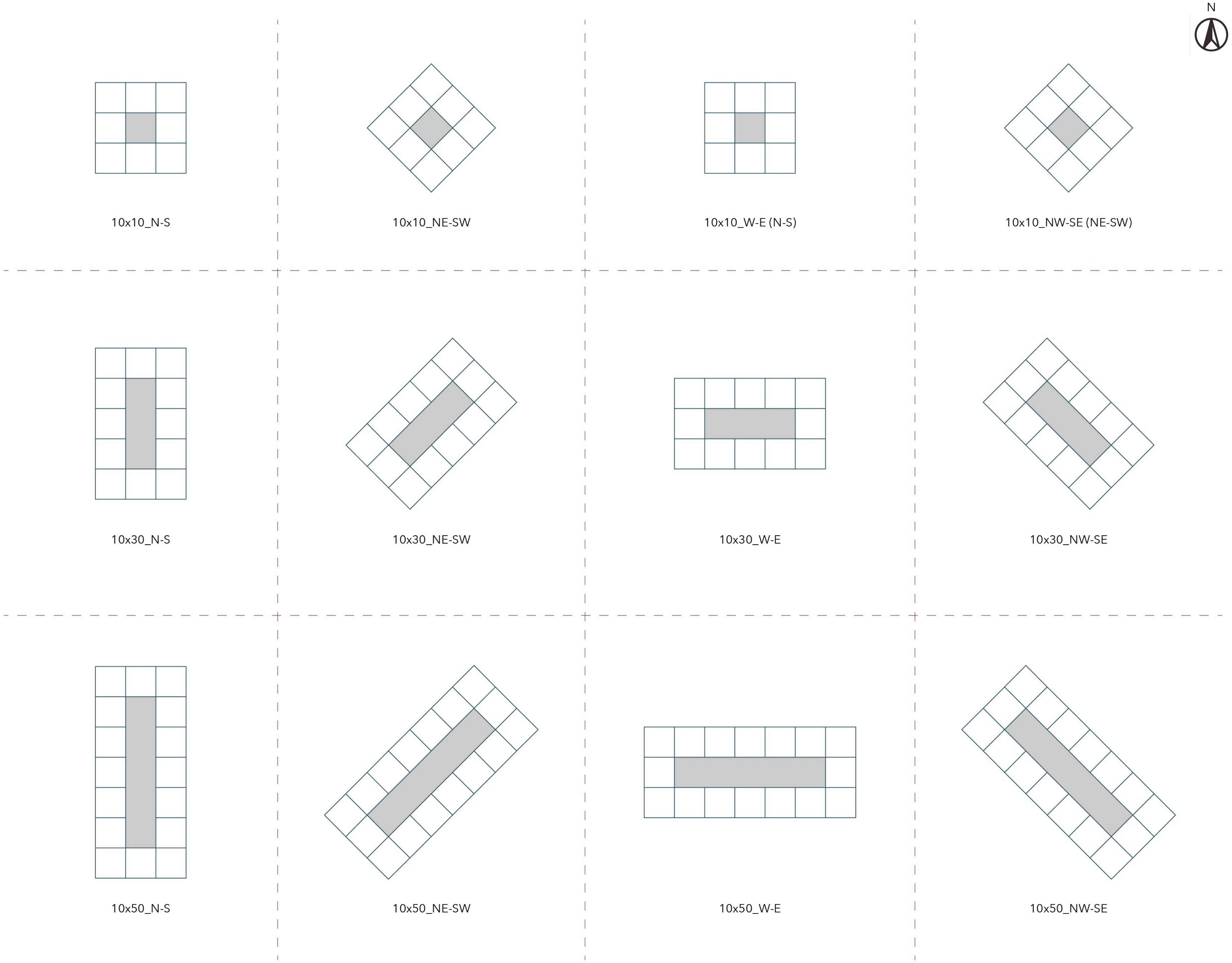


Figure 4.3. 10 models of the courtyard block dwellings simulated in the typology study.

Source: Produced by author.

The research on the indoor thermal comfort has been conducted on the courtyards with different orientations and lengths (The courtyard models vary in length 10 to 50 meters with steps of 10 m and have four main orientations N-S, W-E, NW-SE, and NE-SW.) and the percentage of discomfort hours which are the hours that the indoor temperature exceeds 24.5 oC has been referred to evaluate the indoor thermal comfort. When it comes to the courtyards with different orientations, the gains of solar radiation witness a positive linear relationship with the value of discomfort hours. The warmest model corresponds to the model 10x50_N-S that receives the most solar radiation with 90% of the time uncomfortable and the coolest model 10x50_W-E shows the least discomfort hours corresponding with the least solar radiation entry (with 50% of the time uncomfortable). The rotated models 10x50_NW-SE and NE-SW also have a high percentage of discomfort hours (74% and 85%, respectively) and the overall result shows that the orientation W-E is more comfortable among all of the studied orientations (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b).

The study on how the sun path works could help to explain the impact of the courtyard orientation on the solar heat gains of the buildings. During the 26th July which is the hottest day during heat waves on 2018, the sun rose from the North-East and set in the North-West. The maximum sun angle is 57.32 degree between 13:00 and 14:00 at The Hague local time (Figure 4.2). This sun path affects mostly eastern facades in the morning, roofs and southern facades at noon and western facades in the afternoon and evening (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b). With this principle, buildings with the courtyards of the orientation N-S have higher solar heat gains on facades while the buildings with courtyard of the orientation E-W witness lower solar heat on facades.

4.2.2 Outdoor Thermal Performance of Courtyard Block Dwellings

Inspired by the research of indoor thermal comfort in urban courtyard block dwellings by Mohammad (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b), the typology study based on the idea of control variable method has been delivered to understand how building blocks with courtyards of different orientations and aspect ratios influence the thermal performance inside the courtyards and on the streets. 10 models of the courtyard block dwellings have been set up to evaluate the outdoor thermal comfort and the results from the simulation have been analyzed and compared in the following contents (Figure 4.3).

Data

OpenStreetMap; Past Weather in The Hague, Netherlands (Source: https://www.timeanddate.com/weather/netherlands/the-hague/historic?month=8&year=2018).

Method

Ten courtyards buildings have been studied for their outdoor thermal performance in courtyards and on the streets on 26th July, which was the hottest day during heat waves in 2018. The parametric study has been done with computer simulation by using ENVI_MET and various parameters have been investigated including wind speed, air temperature, mean radiant temperature, relative humidity as well as physiological equivalent temperature. The 'Beginner level' in ENVIguide (Appendix VI) has been chosen for the simulation of typology study and the same weather parameters (Table 4.2) have been applied for 10 models. The width of the houses surrounding the courtyard is 10 meters and the courtyards are designed as 10x10m, 10x30m and 10x50m respectively. The building block with

Input parameters for simulation of typology study

Content	Value	Unit & Reference
Start Date	07.08.2018	DD.MM.YYYY
Start Time	06:00:00	HH:MM:SS
Total Simulation Time	24	h
Air Temperature	16 - 34	°C (lowest - highest)
Wind Speed	2.2	m/s
Wind Direction	90	360-N, 90-E, 180-S, 270-W
Chosen Level	Beginner	Boundary Condition - Simple force

Table 4.2. Input parameters for simulation in ENVI_MET.

Source: Produced by author.

the long edge of the courtyard paralleled to W-E axis has been named as 'Model_10x30_W-E' (Figure 4.4).

The courtyard buildings were built with eight same blocks in its surrounding areas and the data was collected for the courtyard of the center block to avoid the deviation of other factors such as different wind speed in windward and leeward blocks (Figure 4.5). The same materials were applied for facades, roofs and pavements in each model.

After simulation of microclimate by ENVI_MET, physiological equivalent temperature (PET) has been calculated by software Biomet and personal parameters were set as following:

Age of person (year): 70
Gender: Female
Weight (kg): 70.5
Height (m): 1.65

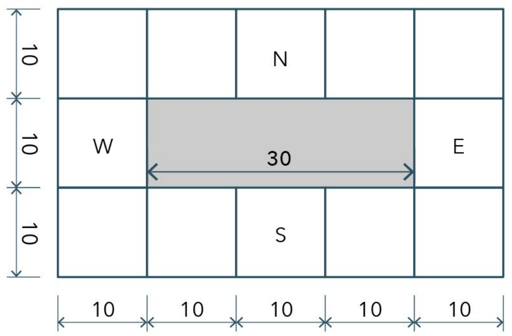


Figure 4.4. Diagram of 'Model_10x30_W-E'.

Source: Produced by author.

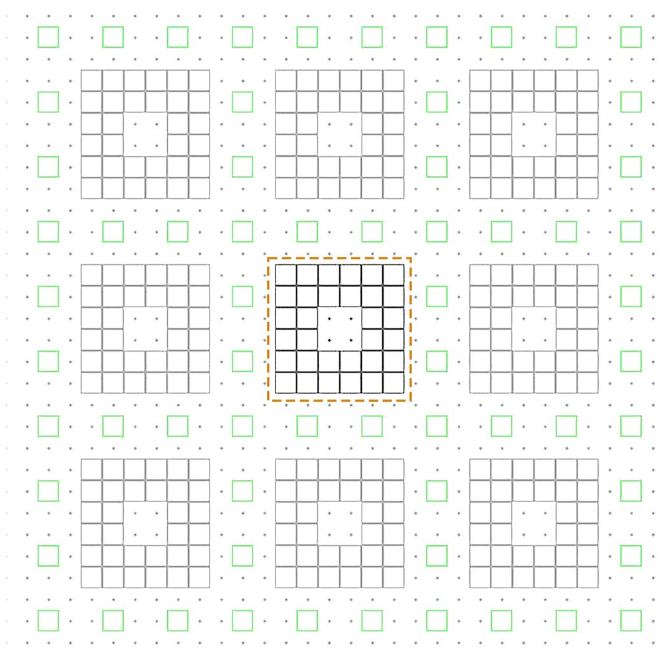


Figure 4.5. The data of the block in the center has been analyzed.

Source: Produced by author.

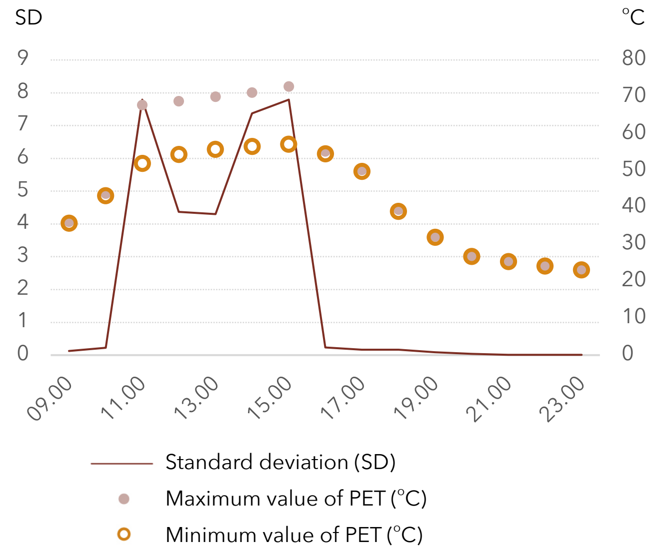


Figure 4.6. The chart of standard deviation (SD), maximum and minimum of the value of PET (°C) at 1.5-meter height among all the grids in the model '10x50_N-S' from 09:00 to 23:00.

Source: Produced by author.

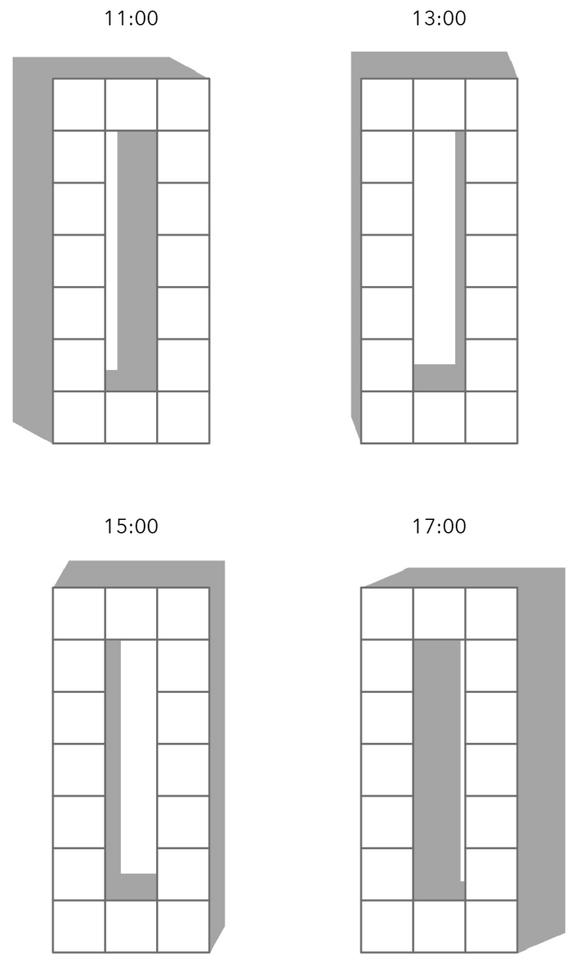
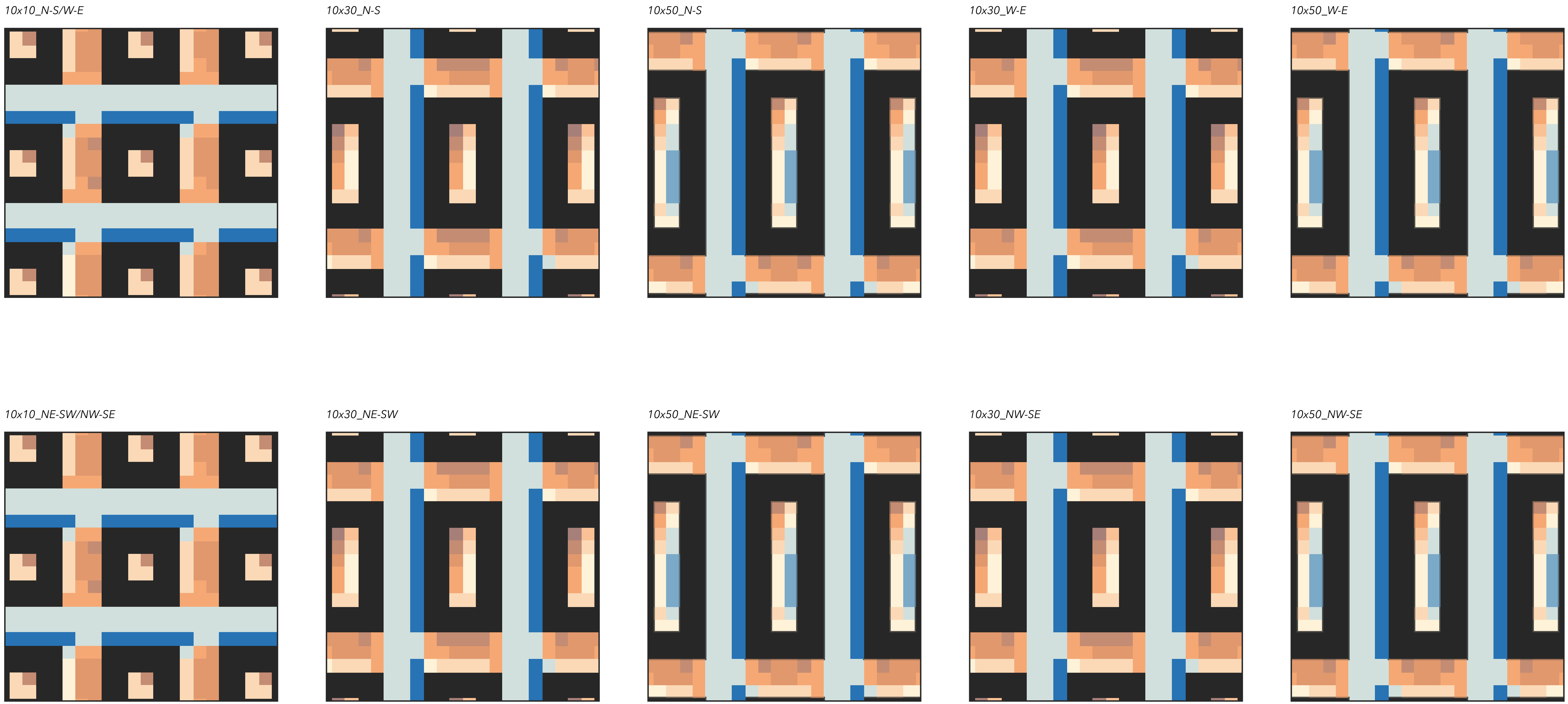


Figure 4.7. Solar exposure analysis on the height of 1.5 meter on 26th July 2018 of the courtyard in the model '10x50_N-S' on 11:00, 13:00, 15:00 and 17:00 respectively.

Source: Produced by author.



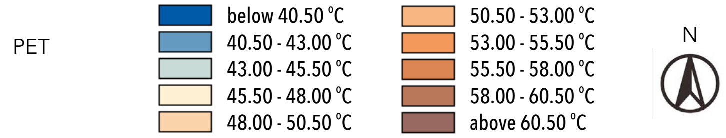


Figure 4.8. Physiological equivalent temperature (PET) of 10 studied models on 14:00 26th July 2018.

Source: Produced by author.

Default parameters are used for other factors and results have been visualized in LEONARDO. The data at 1.5-meter height was collected for each grid and the average value was calculated for each parameter to represent each model during each hour. The standard deviation of the values of physiological equivalent temperature (PET) of the grids in each model have been also calculated to check whether the average value of grids in each model is representative and the maximum and minimum values of PET are collected as well. The solar exposure analysis has also been conducted to understand the causation of the deviation (Figure 4.6, 4.7 & Appendix VIII).

Result

The result of thermal performance which is represented by the values of PET has been illustrated on 14:00 26th July 2018 (Figure 4.8). The standard deviation as well as maximum and minimum of the values of PET at 1.5-meter height have been collected and calculated to check the representation of the average value of PET among each model and the data of 'Model_10x50_N-S' has been visualized as an example (Figure 4.6). Afterwards, the solar exposure analysis on the height of 1.5 meter on 11:00, 13:00, 15:00 and 17:00 has also been visualized (Figure 4.7). It could be discovered that the high value of standard deviation appears when the grids in the courtyard are partially exposed to the sun and the largest difference between maximum and minimum values could reach around 15 °C. Under this situation, it should be kept in the mind that the average value of PET could not represent the thermal comfort in the courtyard completely and there will be large difference between the thermal sensation under the shading and the sun.

The layered area chart illustrates how PET in courtyards is changing from 9:00 in the morning to 23:00 in the evening and the highest value of each model was marked and highlighted for each model (Figure 4.9). PET increases rapidly in the morning after sun rise and reaches the peak value around 13:00 and 14:00 for all of models. A sharp decrease could be seen during the late afternoon when most of the areas are covered by shadow and after 20:00 the PET drops to around 25 Celsius degree.

Moreover, the outdoor thermal performance on the streets has similar pattern with the courtyards of same orientation. The outdoor thermal comfort on the street is better than that inside the courtyard when the urban canyon is paralleling with wind direction since the wind speed is higher on the street than that in the courtyard. The microclimate around the crossing is various due to the main distinction among wind speed and mean radiant temperature.

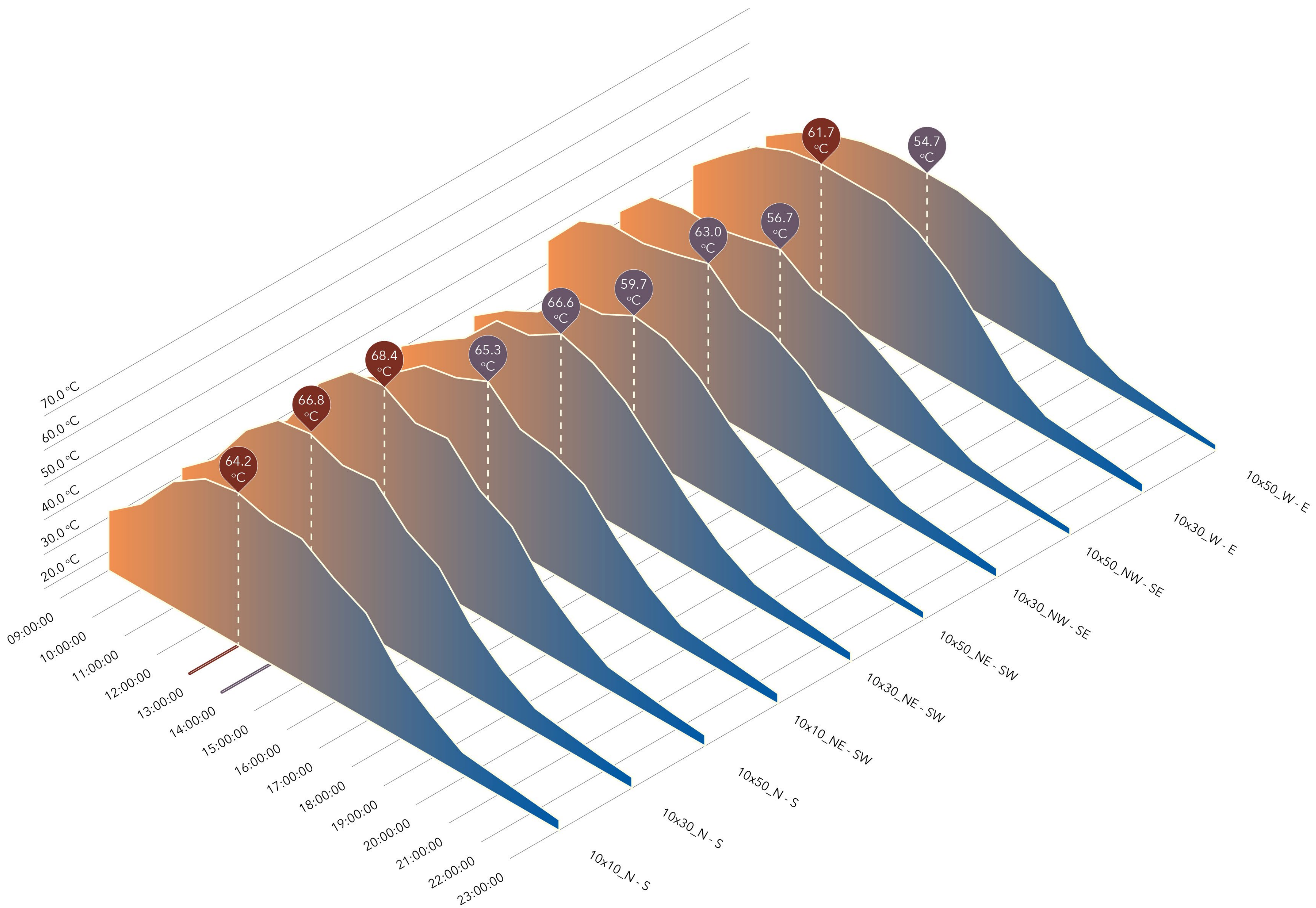


Figure 4.9. Layered area chart for the trend of the average values of PET among the grids in each model. The data has been collected from 09:00 to 23:00 on 26th July 2018 for all of the 10 models.

Source: Produced by author.

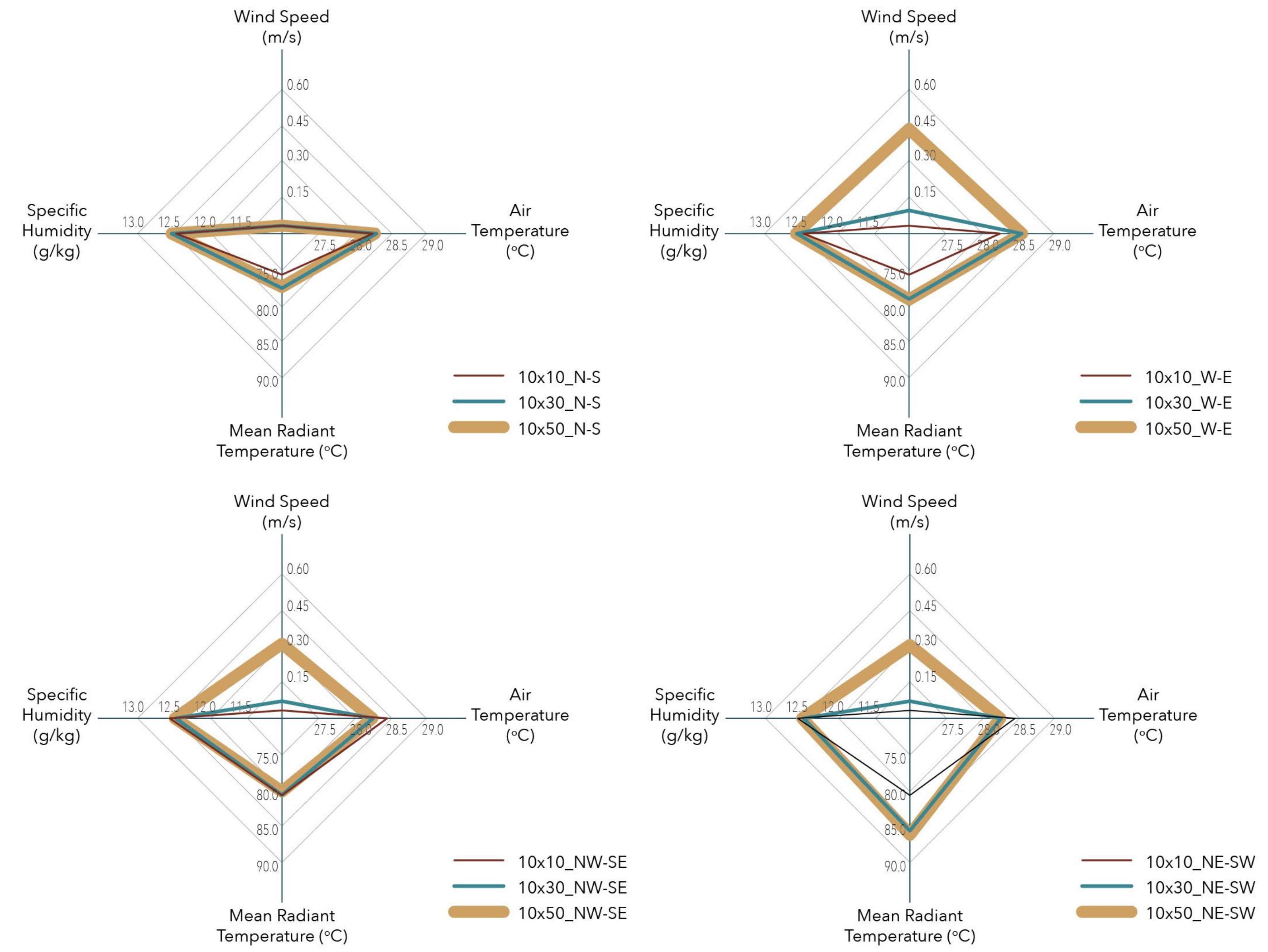


Figure 4.10. Radar charts for selected models to illustrate each parameter on 14:00 to learn about the impact of length of canyons.

Source: Produced by author.

Impact of different length along the orientation

For the courtyards with same orientation but different lengths along the orientation, they have similar trend of the values of PET through the whole day. It seems that thermal performance in courtyard 10x50 is cooler than that in courtyard 10x30 with all of the orientation except for the courtyards with the orientation N-S (Figure 4.9). The radar charts show the difference of wind speed, air temperature, mean radiant temperature and specific humidity, which codetermine outdoor thermal comfort, between different lengths for each orientation on 14:00 (Figure 4.10).

The main distinction of outdoor thermal comfort between courtyards with same orientation but various lengths of canyon axis is mainly determined by the difference among wind speed although there is some difference among mean radiant temperature for all of orientations except for N-S. The wind speed is same in the courtyards with the orientation N-S because the wind direction is set as east for the simulation, which is perpendicular to the canyon axis of the courtyards. The height to width ratio (H/W) is same (H/W = 1) along the wind direction for models with orientation N-S and, therefore, different lengths along the canyon axis do not make difference to wind speed. The distinction between wind speed for the same orientation but different length of courtyards could also be explained by the height to width ratio (H/W) along the wind direction. Normally, higher height to width ratio (0.1< H/W <0.7) will result in higher wind speed (Esch, 2015) but from the study of the courtyard block dwellings lower height to width ration (0.20 for models_10x50m versus 0.33 for models_10x30m) result in higher wind speed inside the courtyard, which is remarkable.

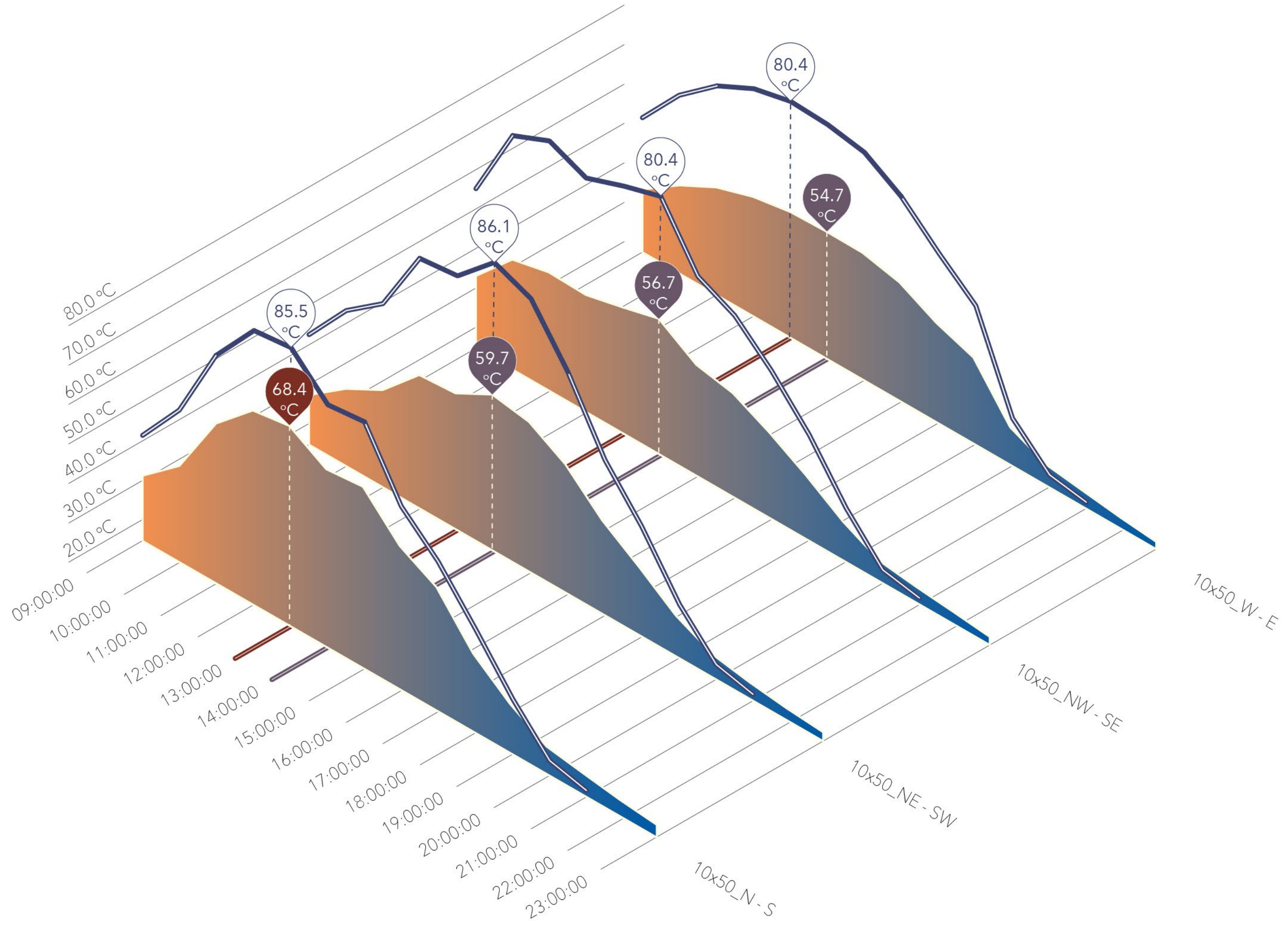


Figure 4.11. Layered area chart for PET & MRT of 4 selected models on 14:00 to learn about the impact of different orientations.

Source: Produced by author.

Impact of different orientations

There is not too much difference of outdoor thermal performance between models 10x10_N-S and 10x10_NE-SW and it is hard to find typology with similar height to width ratio in reality. Therefore, four of the models_10x50 with different orientations have been chosen to analyze the impact of orientation on outdoor thermal performance (Figure 4.11).

By comparing Mean Radiant Temperature (MRT), which is the area weighted average of the various radiation influences on the body (Esch, 2015), with PET for chosen models, the similar variation trends could be discovered especially during daytime. The mean radiant temperature sums up all short and long wave radiation fluxes (both direct and reflected) and is usually measured higher during daytime rather than evening for the same area on a sunny day (Thorsson, Lindberg, Eliasson, & Holmer, 2007). The Mean Radiant Temperature meets the peak point around 13:00 and 14:00 when sun reach the highest point during the whole day but the trend of fluctuation before and after this period is various between each model (orientation). For the courtyard with orientation N-S, MRT witness a sharp increase around 11:00 in the morning and a rapid decrease around 15:00 in the afternoon, between which the values of MRT are higher because most areas in the courtyards are exposed to the sun. The similar trend could be discovered for the courtyard with orientation NE-SW but the period with higher value of MRT is one hour later which is between 12:00 and 16:00. The courtyards with orientation NW-SE meet the period with higher value in the morning and there is a peak value on 11:00 before MRT reach the highest value on 14:00 but it is relatively cooler in the afternoon. When it comes to the model with orientation W-E, although the highest value is lower than the courtyards with orientation N-S and NE-SW, the periods with higher value are the longest among all orientations.

Figure 4.12. Risks map of building blocks from the perspectives of building configuration and microclimate.

Source: Produced by author.

4.2.3 Conclusion

To conclude for the typology study of outdoor thermal performance of courtyard dwellings, the physiological equivalent temperature (PET) increase first in the morning and then decrease in the late afternoon with the peak value between 13:00 and 14:00. During daytime solar radiation plays an important role in shaping hotter outdoor atmosphere on a sunny day so creating more shadow could be an option to decrease heat stress in outdoor space. For the elderly who would like to spend some time in outdoor space, evening, especially the time period after 20:00, is always the best option while early morning is the second choice rather than afternoon. In order to have a lower indoor air temperature, closing the windows and curtains from 9 o'clock in the morning and opening the window after 7 o'clock in the evening to enhance the ventilation to have a more comfortable indoor atmosphere.

Both of indoor and outdoor environments are influenced by many factors and the study mainly focuses on the orientation and length of the blocks, which could be recognized as building configurations. Based on assumption that the elderly or citizens follow the suggestion from health institutions to go outside in the morning and evening and stay at home during the afternoon, the typology with the orientation NE-SW is the best among the researched ones with regard to building configurations since the outdoor atmosphere in the morning is coolest and less solar exposure on the facades before sunset, although it is also the typology that witnesses the hottest outdoor atmosphere in the afternoon due to full expose to the sun. However, the typology with the orientation NW-SE performs worst among all studied orientations and its characteristics of indoor and outdoor thermal performance is just opposite to the one with the orientation NE-SW. The typologies with orientations N-S and W-E have relatively modest performance for indoor and outdoor thermal performance. The typology with orientation W-E has the least solar heat gain on the facades but hotter outdoor atmosphere in the early morning and late afternoon while the typology with orientation N-S, which gains the most solar heat on the facades, has better performance in outdoor spaces in the morning yet most exposure to the sun at noon.

According to the conclusion from the typology study from the perspectives of the building configuration, a heat risk map with consideration of the typology of courtyard block dwellings has been made for the elderly and the building blocks have been divided into groups with high, medium and low risks (Figure 4.12).

4.3 The Effect of Vegetation on Microclimate

Urban design strategies based on vegetations are one of the most common and widely-accepted ones in reducing the intensity of urban heat island in urbanized areas nowadays because of its ameliorative effect against urban heat island, easy implement in existing urban fabrics and other additional benefits such as economic and aesthetics values (University of Wollongong, 2012). Vegetation usually plays an important role in mitigating the urban heat island by warming the air and surface less through two ways – shading and evapotranspiration. Vegetation provide shadow on surface to reduce direct solar radiation gain as well as moderate solar heat gain through evapotranspiration and conversion of incident solar radiation to latent heat (Dimoudi & Nikolopoulou, 2003; University of Wollongong, 2012). Therefore, the application of vegetations in urbanized areas is necessary but it should be applied in a reasonable way such as the cost-effective choices between trees and grass on the streets and open spaces.

Data

Daggegevens van het weer in Nederland ('Daily data from the weather station in the Netherlands' in English) (Source: https://www.knmi.nl/nederland-nu/klimatologie/daggegevens); Haagse Bomen app ('The trees in The Hague' in English) (Source: https://ddh.maps.arcgis.com/apps/webappviewer/index.html?id=26717c16f2ad43678a9bbcc53c90cb03); bgtviewer (Source: https://bgtviewer.nl/4.291298389434815/52.063345479750126/19); Google Map.

Method

Vegetation including but not limited to trees, bushes, grass and climbing plants are quite common in urbanized areas but they have various effects on mitigation of urban heat island and thermal comfort of outdoor environment. In the following contents, the research among the vegetations with regard to grass, hedges and trees has been conducted based on the literature review, simulation with ENVI_MET and mapping of the growth of trees respectively.

The simulation by ENVI_MET of the effect of trees and grass on microclimate have been applied by author. The test in an open space has been done first to compare the effect of grass and brick on thermal comfort to learn about the influence of the grass in a theoretical way. Afterwards, the effects of grass and trees inside the courtyards have been tested by comparing with brick pavement with several simulations by ENVI_MET. The 'Intermediate level' in ENVIguide (Appendix VII) has been chosen for the simulation of all of the forementioned models and the same weather parameters from KNMI website have been applied. The time node of 14:00 on 26th July 2018 has been chosen for all the comparison and the weather condition on 14:00 referring to following table (Table 3). The results have been visualized in LEONARDO and the data was also collected and compared between each model.

Last but not least, in order to understand how trees grow in reality in the courtyards and on the streets, several mappings of the characters of existing trees in The Hague have been conducted based on the website 'Haagse Bomen app', 'bgtviewer' and 'Google Map'. In the last part, some conclusions have been generated to instruct the decision making of the strategies and instruct urban design process.

Result

a. Knowledge from literatures

When it comes to the effect of vegetation on air temperature and PET, Kleerekoper conducted some research and simulation based on ENVI_MET. Different elements such as pavement, grass, hedges and trees have been applied respectively or combined with others on both side of the buildings and four receptors on the north, east, south and west of the buildings have been set up to collect the data from the results of simulation (Figure 4.13). The overall effect of trees during a sunny day is predominantly positive on PET even though they also reduced wind speed which does not usually overrule the cooling effect of air tempera-

Weather condition on 14:00, 26th July 2018		
Content	Value	Unit & Reference
Abs. Temperature	27.1	°C
Relative Humidity	64	%
Wind Speed	4.0	m/s
Wind Direction	360	360-N, 90-E, 180-S, 270-W
Precipitation	0	mm

Table 4.3. Input weather parameters for the simulation on 14:00, 26th July 2018.

Source: Produced by author.

ture and mean radiant temperature on the PET. However, the benefits from trees are locally and trees even increase the PET at the leeward side due to lower wind speed. Grass could also provide lower comfort temperature compared with brick pavement and it can even lower the surrounding paved area with 1°C from the results of the simulation. However, hedges usually have negative impact on thermal comfort since they reduce the wind speed while do not offer shades at pedestrian level (Kleerekoper, 2016).

Urban parks which are the places with large amount of vegetations are cooler than their surrounding areas, which is known as 'park cool island' (PCI). After investigating PCI intensity values for 92 parks in Nagoya, Japan, Cao argued that the areas of trees and shrub inside the park as well as the larger parks contribute to PCI intensity positively while grass and complex shapes such as linear or irregular belt-shape have negative influence on the formation of PCI. It is also argued that the adverse impact of grass is mainly caused by the unfavorable condition of grass growth so the effect of grass highly depends on its growth condition (Cao, Onishi, Chen, & Imura, 2010). The evaporative cooling effect of trees as well as other vegetations is highly depending on the availability of water (Kleerekoper, 2016) and it will not be hard for trees with deep roots to get water in the Netherlands. However, grass should be taken care of with enough irrigation especially during summer with less precipitation. Otherwise, grass will not have proposed effect and could even have negative effect on thermal comfort.

b. Simulation by author to learn about the effect of grass and trees on microclimate

The tests by Kleerekoper are more likely in theory since in reality it is hard to find a place covered totally by grass in cities. Instead, a piece of grassland surrounded by pavements such as bricks is quite common in open spaces in urbanized areas. Therefore, the effect of grass on microclimate in an open space has been tested by 'Model_Pure Bricks' and 'Model_Bricks & Grass' in ENVI_MET. In an open space there will be almost no difference among received solar radiation so four grids with different locations, which are above the grass or bricks and at the leeward or windward side, have been selected to study the influence of grass on microclimate. The grids from north to south are marked as 1,2,3 and 4 for 'Model_Pure Bricks' and 'Model_Bricks & Grass' respectively (Figure 4.14). The data on 1.5-meter-height has been collected and visualized to make the comparison (Figure 4.14, 4.15 & Table 4.4).

By comparison between the grids with same locations on two models, it is remarkable that the application of grass does not seem to reduce the air temperature through evaporation. Instead, the influence of grass on decreasing wind speed could be discovered which would probably result in higher air temperature (Figure 4.15). Mean radiant temperature witness a sharp decrease especially for the grids above the grass with over 6°C difference and it overrules the impact of higher air temperature and lower wind speed on thermal comfort. When it comes to the spatial distribution of the effect of grass on thermal performance, there are not only the decreasing of wind speed from windward side to leeward side of grassland but also the variation of mean radiant temperatures caused by the difference of albedo and emissivity between grass and bricks. In addition to the areas above the grass, the benefits from grass through reducing mean radiant temperature could also be found in surrounding areas especially the opposite side of the grassland referring to the direction of solar incidence (Figure 4.16 & Table 4.4).

Afterwards, the tests of the effect of the grass and trees in the courtyard have been delivered by setting up four models based on a conceptual model which are named as 'Model_Bricks', 'Model_Grass', 'Model_Trees' and 'Model_Trees & Grass' respectively (Figure 4.17). The 'Model_Bricks' has been used as reference model and some grids have been change to grass or trees in the rest of models respectively. The grid between two small sheds which could get benefits from trees on 14:00 has been selected to simulate real situation in the courtyard and learn about the proposed effects of vegetation and the data on 1.5-meter-height has been collected for each model (Table 4.5).

The positive effect from vegetation on thermal comfort of the selected grid is obvious by mainly reducing mean radiant temperatures though there are also some negative impacts from lower wind speed and higher air temperature. Comparing the effect of grass in the courtyards and open space, the influence with same trend on wind speed, air temperature and mean radiant temperature is smaller due to the complexity in the courtyard such as more sources of radiation and more structures to reduce wind speed. When it comes to the effect of trees, the shading from trees is most important to contribute to thermal comfort but the grids which could not be covered by shades are relatively hotter than those in 'Model_Bricks' due to lower wind speed. One small tree is more likely to cause a little worse overall outdoor thermal performance in the garden compared with the situation without trees but the positive effect from trees could be expected in the future. Therefore, the combination of trees and grass in the garden could be one of the best options to improve the outdoor thermal performance in the courtyards now and in the future.

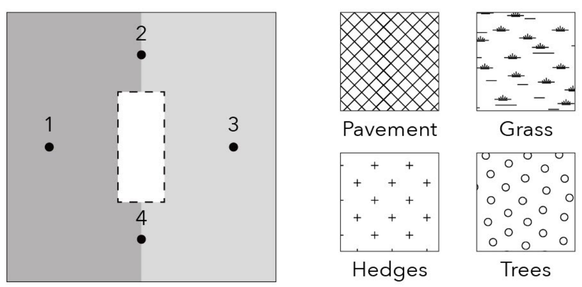


Figure 4.13. Variants with different elements such as pavement, grass, hedges and trees that have been applied respectively or combined with others on both side of the buildings.

Source: Produced by author.

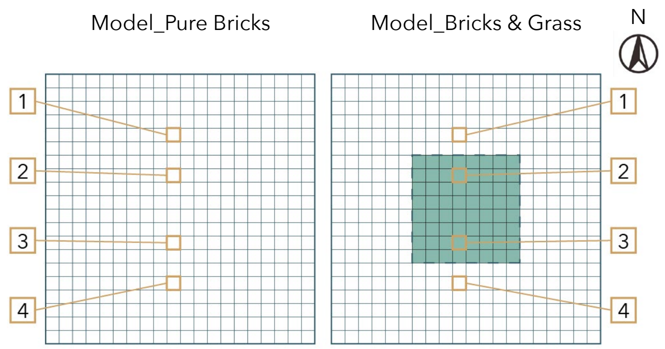


Figure 4.14. 'Model_Pure Bricks' and 'Model_Bricks & Grass' to test the effect of grass on microclimate.

Source: Produced by author.

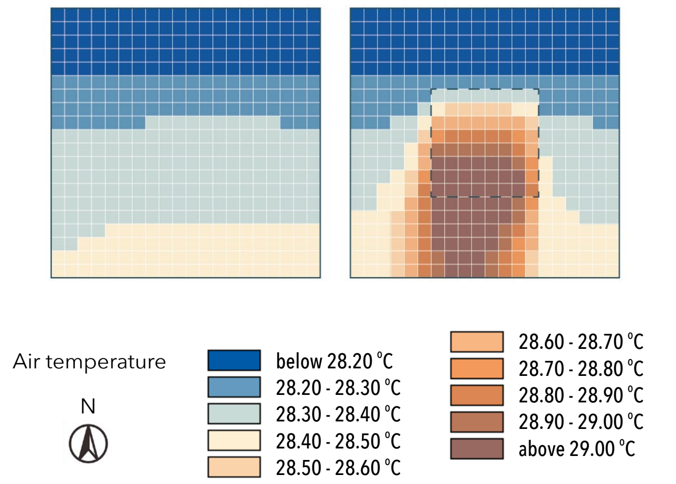


Table 4.15. The values of air temperature at 1.5-meter height of 'Model_Pure Bricks' and 'Model_Bricks & Grass'.

Source: Produced by author.

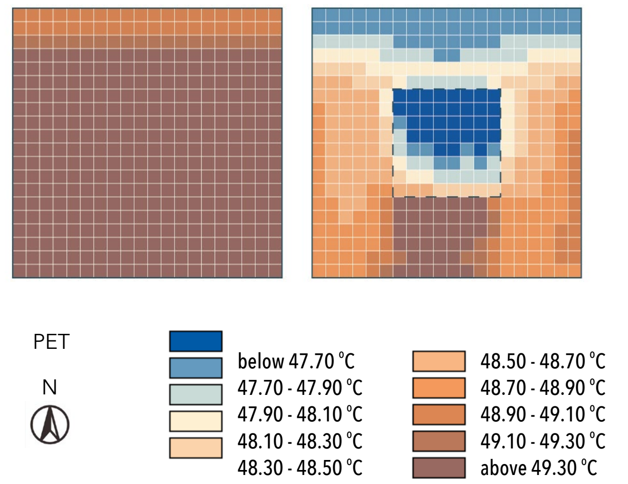


Table 4.16. The values of PET at 1.5-meter height of 'Model_Pure Bricks' and 'Model_Bricks & Grass'.

Source: Produced by author.

Model & Grid No.	PET (°C)	Wind Speed (m/s)	Air Temperature (°C)	Mean Radiant Temperature (°C)	Specific Humidity (g/kg)
Model_Bricks & Grass_1	48.20	2.14	28.17	81.31	14.68
Model_Pure Bricks_1	49.60	2.17	28.17	84.35	14.68
Model_Bricks & Grass_2	47.37	1.95	28.68	77.66	14.70
Model_Pure Bricks_2	50.20	2.07	28.30	84.35	14.68
Model_Bricks & Grass_3	48.00	1.90	29.21	77.82	14.72
Model_Pure Bricks_3	50.00	2.10	28.37	84.35	14.68
Model_Bricks & Grass_4	49.60	1.97	29.18	81.31	14.72
Model_Pure Bricks_4	50.00	2.14	28.40	84.35	14.68

Table 4.4. The simulation results at 1.5-meter height of 4 receptors in 'Model_Pure Bricks' and 'Model_Bricks & Grass'.

Source: Produced by author.

However, not enough quantity and variety of vegetation exists in urbanized areas because large portion of surfaces are occupied by buildings, roads and so on inside courtyards and on the streets. Consequently, trees seem to be more ideal than grass because they can provide more shadow and usually have stronger evapotranspiration mechanism per unit area. Moreover, trees perform better than bushes and grass in mitigating heat stress at the pedestrian level and they are also more effective at improving thermal performance at pedestrian level per unit area compared with facades and roof greening (Chatzidimitriou & Yannas, 2015; Gromke et al., 2015; Li et al., 2019).

To conclude for the knowledge from literatures and simulation, the trees could be one of the best choices to mitigate urban heat island and improve outdoor thermal performance if they are planted properly. It has been suggested that the radius of the root spread of a tree generally equals its height (Flora, 1979). Meanwhile, the cables and pipes which are usually placed underground alone the streets are also forming a competitive relationship with the roots of trees alone the streets and the impact of buildings on the access to solar radiation and wind also limits the growth of vegetation. As a result, trees are hard to flourish alone the streets or inside courtyards and usually shorter than those in the parks or forests. Moreover, it is well-known that roots of trees will seek for water underground and moisture extraction can cause clay soil to shrink so the proposals to restrict tree planting in close proximity to buildings have been made, which should be kept in mind when designing landscape (Flora, 1979).

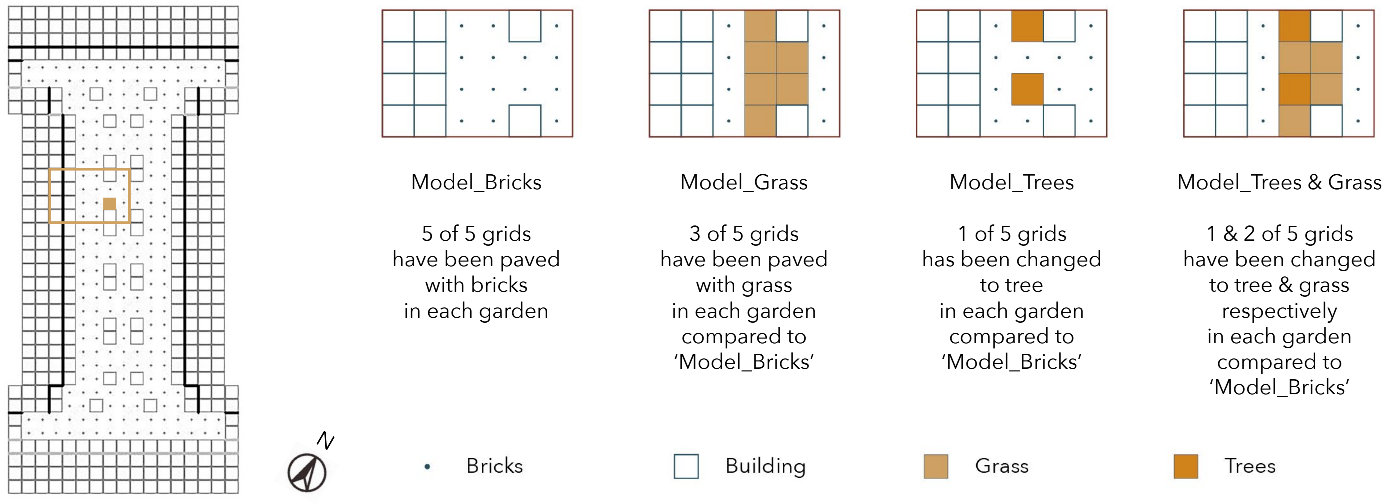


Figure 4.17. The application of grass, trees and the combination of grass and trees in a conceptual courtyard block dwellings to compare the effect of vegetations on microclimate.

Source: Produced by author.

Model	PET (°C)	Wind Speed (m/s)	Air Temperature (°C)	Mean Radiant Temperature (°C)	Specific Humidity (g/kg)
Model_Bricks	58.32	0.32	28.86	82.84	14.68
Model_Grass	57.34	0.32	29.01	80.56	14.69
Model_Trees	56.80	0.30	28.95	77.31	14.69
Model_Trees & Grass	54.80	0.30	29.02	75.25	14.69

Table 4.5. The simulation results at 1.5-meter height of four models on 14:00 26th July 2018.

Source: Produced by author.

c. Mapping of the growth of trees in The Hague

The effect of trees on thermal performance depends on the arrangement of trees, leaf area index, the width of crown as well as the height of trees (Zhang, Zhan, & Lan, 2018). The higher leaf area index, wider crowns and taller trees usually offer more benefits to microclimate with regard to pedestrian level. In order to understand how trees grow in reality in the courtyards and on the streets, six sections of courtyard dwelling buildings and their surrounding streets have been chosen in The Hague, among which lots of greenery could be seen from satellite image. Three of them are located in the studying neighborhood while others are located out of the sites.

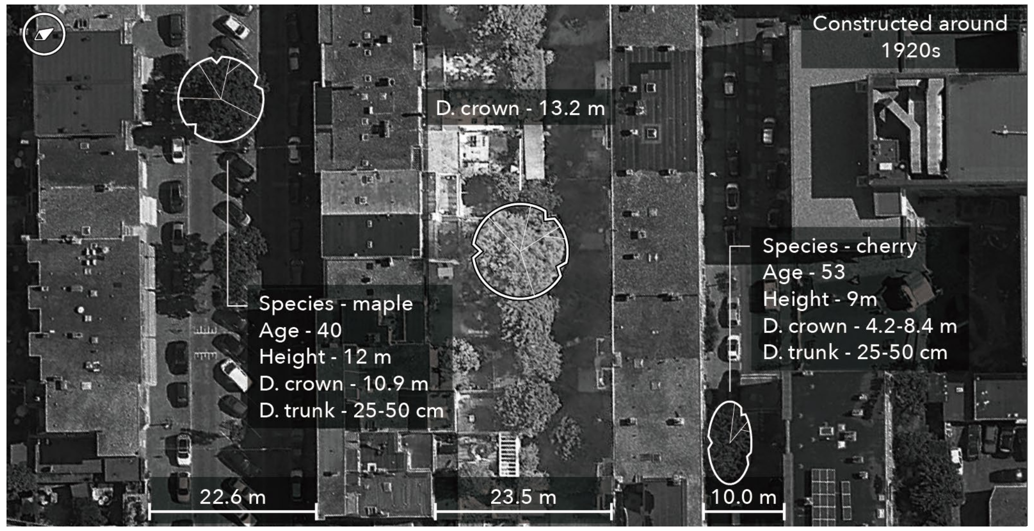
When it comes to existing urban settings in The Hague, there is are an official website called 'Haagse Bomen app' which offers detailed data of each public tree such as species, diameter of trunk, age and so on. Moreover, the website 'bgtviewer' offers some information of buildings in the Netherlands such as construction year and building functions. Combined data of plants from 'Haagse Bomen app', information of buildings from 'bgtviewer' and 'Google Map', several parameters including species, age, height, diameter of crown, diameter of trunk as well as width of urban canyon and construction year of buildings have been mapped to find some clue about the impact of existing urban fabrics on the growth of trees in the neighborhoods with courtyard block dwellings. Due to the missing data of trees in the courtyards, the comparison between trees inside courtyards has been done based on the diameters of crown. The trees with entire and visible crowns among surrounding plants have been highlighted since they are relatively the fittest survivals of the competitive relationships with surrounding trees although there are also some intrinsic factors among the trees such as the species which will determine the size of the crown (Figure 4.18). The comparison between forementioned parameters could help to understand how surrounding urban settings influence the development of trees.

When looking into six mappings of trees in public spaces in existing urban canyons, the trees in wide street canyons or open spaces usually grow better than those in narrow street canyons because of more solar radiation, wind and probably more space for roots underground. The trees on the green belt in the middle of roads usually grow better than those growing on or next to sidewalks because they can get more sunshine as well as more space underground for their roots. The same trend could be found among the trees growing in or next to the gardens on street side. The trees on the streets are usually planted in rows so that there is competition between trees and buildings instead of that between trees and the impact of the buildings on the growth of the trees is recognizable due to the limitation of sunlight and spaces. When it comes to the trees in the courtyard, only the diameters of the crowns have been mapped due to the missing of data and it could be discovered that the trees in the middle of the courtyard are usually with larger crowns than those planted next to buildings. When there are several trees planted next to each other, it is easy to shape a competitive relationship between them and the crown of trees varies a lot. Moreover, both of the trees on the streets and in the courtyard follows the pattern that the elder trees are usually taller with larger crowns in the similar growing environments so planting trees immediately in a scientific way with regard to proper distance against surrounding buildings and trees is necessary.

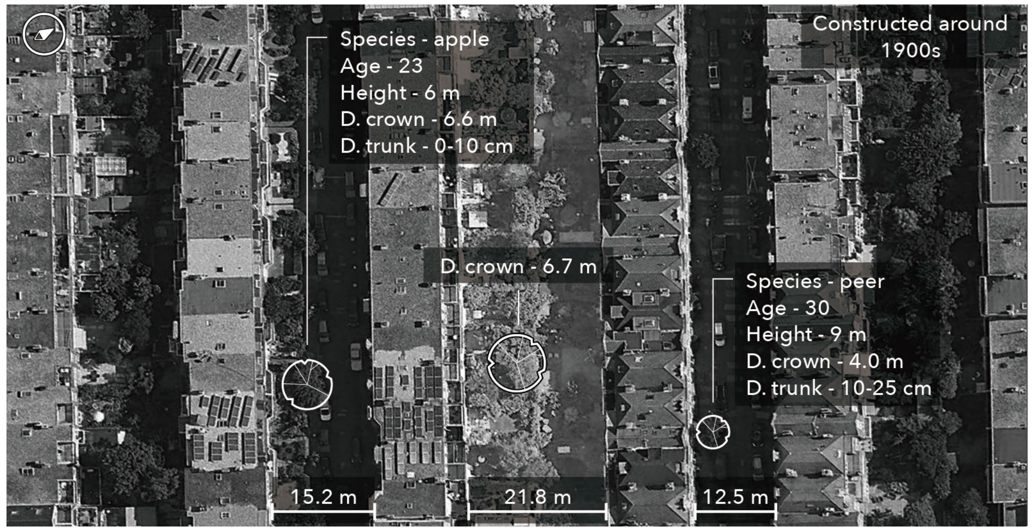
Conclusion

To conclude for the research of the effect of vegetations on microclimate, trees, shrubs and well irrigated grass could have both positive effect through shading and evapotranspiration as well as negative effect through lowing wind speed on thermal comfort. There are some bullet points concluded from literature and research in the following paragraphs:

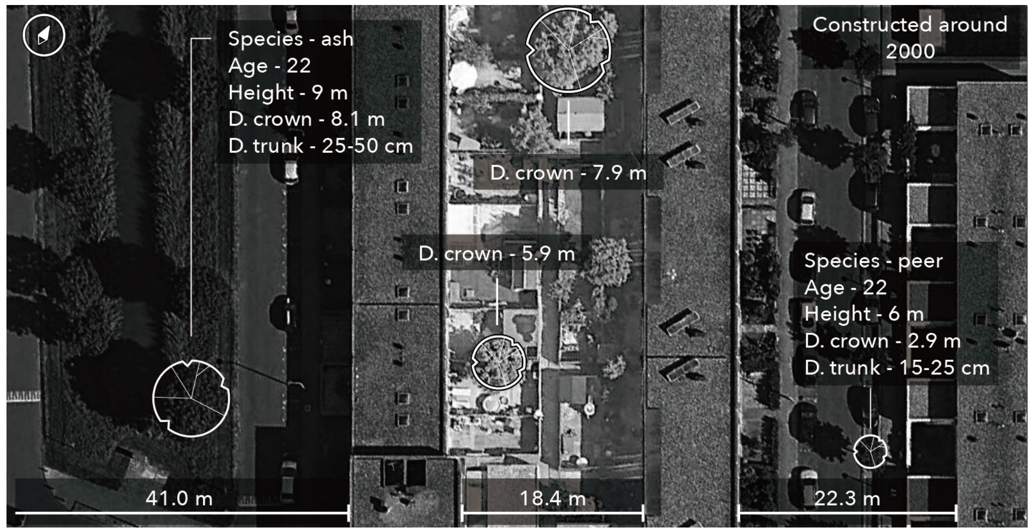
- Vegetations usually have positive effect on the mitigation of urban heat island if they are taken care of properly but from the perspective of outdoor thermal comfort on pedestrian level, the trees and grass are better choices than hedges and bushes.
- Trees need decades of years to grow to have proposed positive effect on improving outdoor thermal comfort as well as mitigation of urban heat island so planting trees from now on in a good location and arrangement.
- The grass has relatively fewer positive effects on outdoor environments compared with large trees but it helps to reduce mean radiant temperatures especially on the opposite side of large grass land against the sun. The design of resting facilities at the north or west side of the grassland in open spaces could improve thermal comfort. The effect of grass on microclimate is also recognizable at night compared with hard pavements since air above grass cool down faster than that above the pavements.
- The combination effect of trees and grass could one of the best choices to improve thermal comfort in public spaces and courtyard. If it is not affordable or possible to apply them both, either of them is always better compared with pavements on microclimate and mitigation of urban heat island.
- Neighborhood parks or pocket parks could be designed with compact shapes as well as clusters of trees inside them in order to enlarge the local effect of trees on better outdoor environments and shape 'park cool island'.



Courtyard block dwellings in the neighborhood Bomen- en Bloemenbuurt



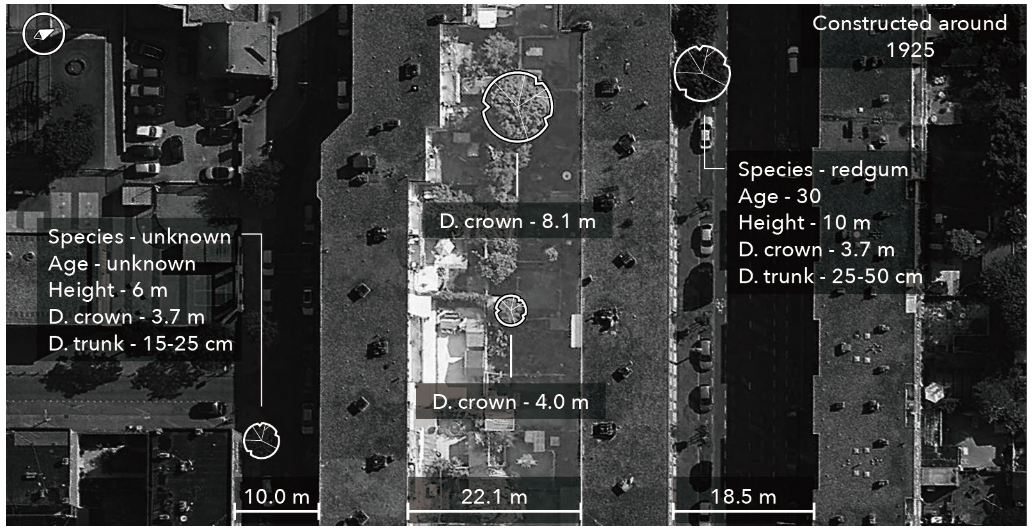
Courtyard block dwellings in the neighborhood Regentesse-kwartier



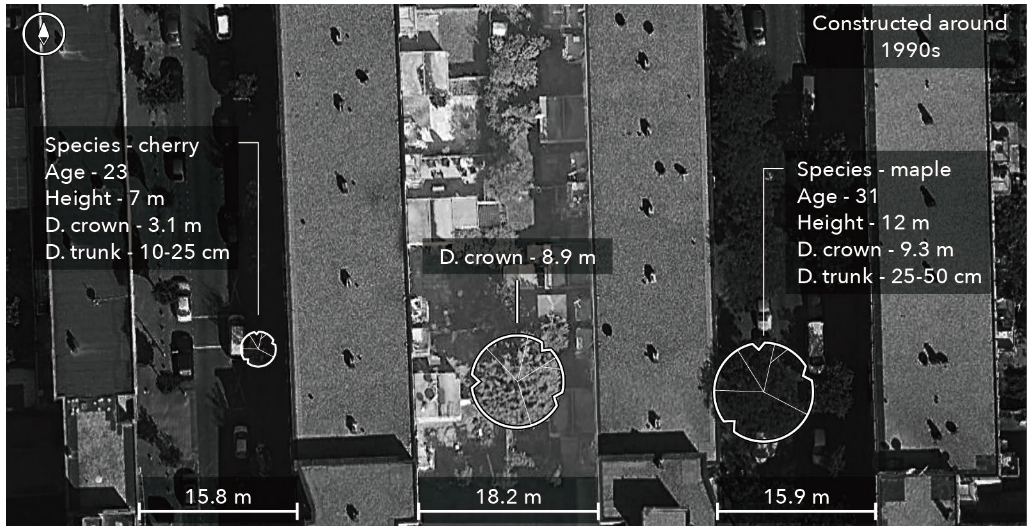
Courtyard block dwellings in the neighborhood Leidschen-veen

Figure 4.18. Mapping of trees in and around six blocks of courtyard dwellings constructed during different decades in The Hague.

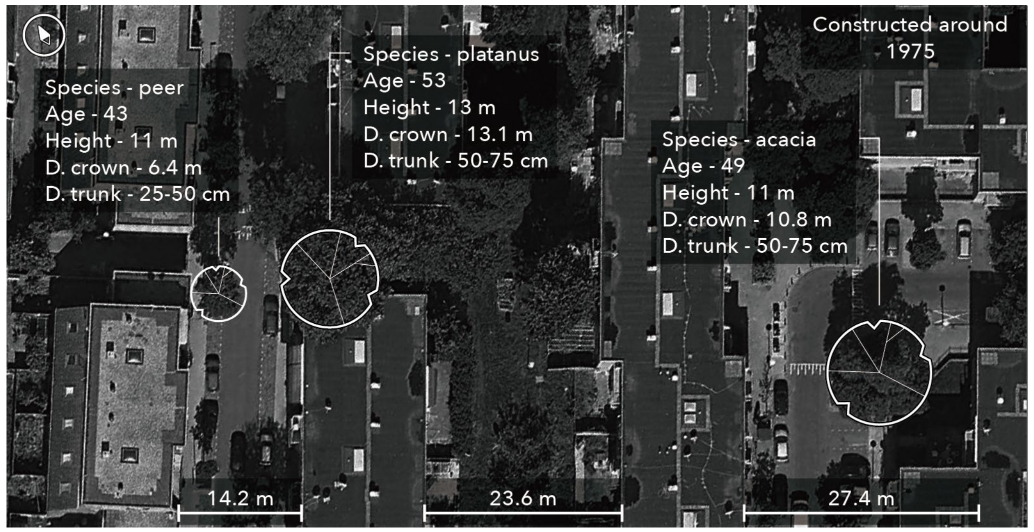
Source: Produced by author.



Courtyard block dwellings in the neighborhood Transvaalk-wartier



Courtyard block dwellings in the neighborhood Transvaalk-wartier



Courtyard block dwellings in the neighborhood Schilders-buurt

4.4 Prevailing Wind during Heat Waves

Wind is one of the factors that influence PET and wind speed in urbanized areas usually have strong relationships with wind direction and urban canyon orientation. For example, the wind direction at roof height with regard to parallel, perpendicular and at an angle to the axis of street canyon will form different patterns in the urban canyon resulting in various air velocity (Figure 4.19) (Erell et al., 2011). Therefore, the pattern of wind direction during heat waves could instruct urban design in order to enhance ventilation.

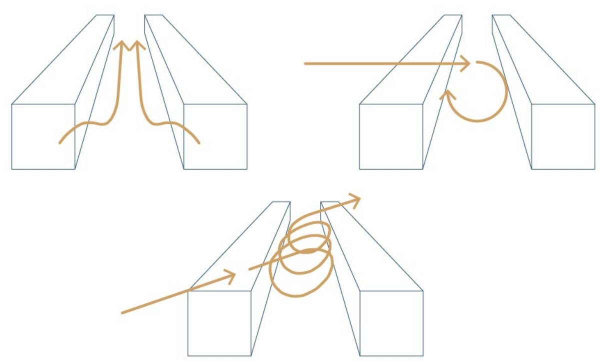


Figure 4.19. Flow patterns in the urban canyon related to the wind direction at roof height with regard to parallel, perpendicular and at an angle to the canyon axis (Erell et al., 2011).

Source: Reproduced by author.

Data

Daggegevens van het weer in Nederland ('Daily data from the weather station in the Netherlands' in English) (Source: https://www.knmi.nl/nederland-nu/klimatologie/daggegevens); Hittegolven ('Heat waves' in English) (Source: https://www.knmi.nl/nederland-nu/klimatologie/lijsten/hittegolven); Waarnemingen ('Observations' in English) (Source: https://www.knmi.nl/nederland-nu/weer/waarnemingen).

Method

The Hague is located on the coastline of the North Sea and it could enjoy the benefits from the cooling effect of the sea. In order to have more accurate understanding of the weather condition in The Hague, the nearest weather station 'Hoek van Holland' which is also one of the weather stations alone the North Sea has been selected to represent the weather situation in The Hague (Figure 4.20). The period between the beginning of 2010 and the end of 2019 has been selected to learn about the pattern of wind direction during heat waves in recent ten years.

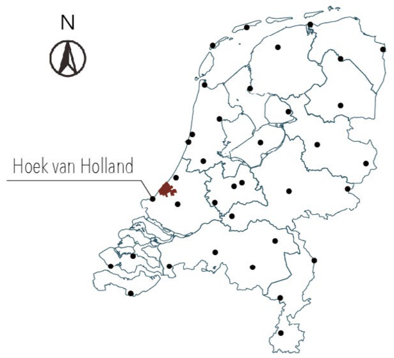


Figure 4.20. Weather station in the Netherlands and the location of the weather station Hoek van Holland.

Source: Produced by author.

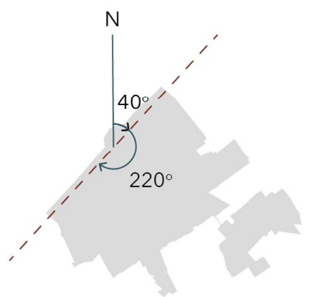


Figure 4.21. Orientation of the coastline of The Hague.

Source: Produced by author.

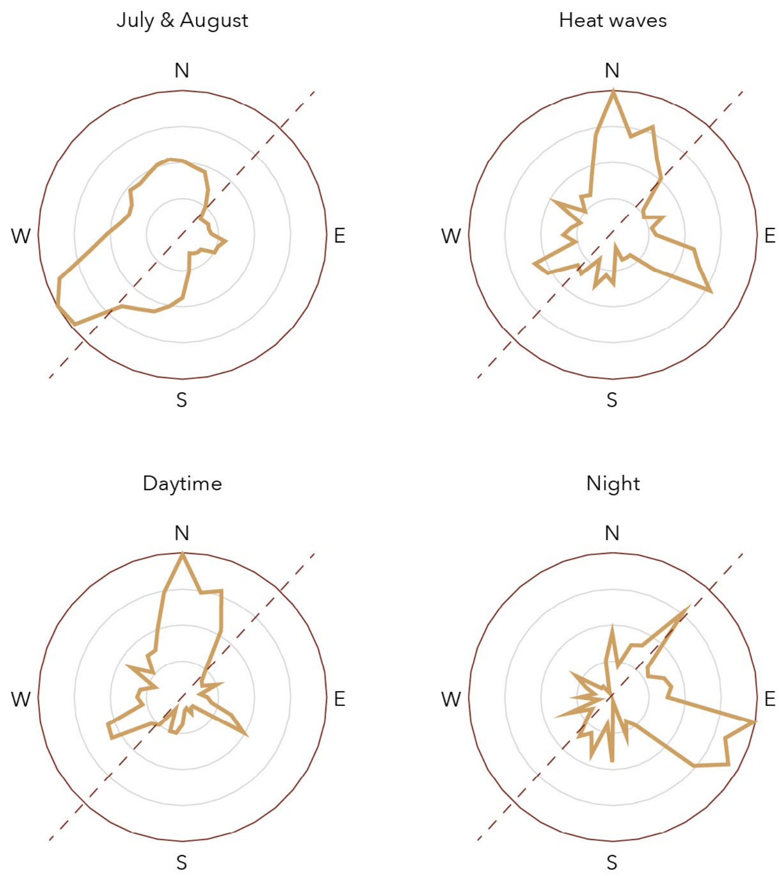


Figure 4.22. Wind rose of weather data measured at Hoek van Holland weather station during July & August, heat waves, the daytime during heat waves as well as the night during heat waves. All of the data is recorded from 2010 to 2019.

Source: Produced by author.

The website 'Daggegevens van het weer in Nederland' offers the weather condition data for all of the official weather stations in the Netherlands recorded from last century towards now while the website 'Hittegolven' recorded all the heat waves since 1901. The weather data measured at weather station 'Hoek van Holland' from 1st January 2010 to 31th December 2019 has been collected to learn about the trend of wind direction in recent ten years. Moreover, there are six heat waves during the same period and the data has been collected from 01:00 on the first day of heat wave to 23:00 on the last day of heat waves.

The coastline of The Hague is alone north east-south west (NE-SW) axis and the orientation of the coastline is rotation clockwise by 40 degree from zero point facing north. So the winds come from the direction which is rotation clockwise by the number between 40 and 220 has been recognized as the wind from land to the North Sea for The Hague (Figure 4.21). The wind roses for months between July and August from 2010 to 2019, days during heat waves since 2010, daytime (06:00 to 21:00) during forementioned heat waves as well as night (22:00 to 05:00 on next day) during forementioned heat waves have been visualized (Figure 4.22). Moreover, two more wind roses with statistics data of wind speed have been made in MATLAB and visualized by Illustrator to learn about the changing or air velocity during heat waves (Figure 4.23).

Conclusion

The prevailing wind direction between July and August is south-west which is same as annual prevailing wind direction while the winds during heat waves in recent 10 years mainly came from north and east. However, due to the limitation of the small amount of days during six heat waves in recent ten years, the prevailing wind direction of heat waves could only be used as a reference. When comparing the popular wind direction on daytime and night during heat waves, it follows the pattern that during daytime the wind comes from the North Sea while at night the wind comes from the land, which is known as sea breeze. When looking into the wind speed during July and August as well as that during heat waves, the lower wind speed could be discovered among heat waves.

Prevailing wind is quite important in the study of how to improve the outdoor thermal performance during hot weathers such as designing wind tunnels. However, the prevailing wind direction during hot summer (July & August) is the same as annual prevailing wind direction and small amounts of days during heat waves with lower wind speed are less compared with the days during hot summers. Therefore, increasing wind speed through designing wind tunnels which will probably compromise the outdoor thermal comfort during winter is not acceptable. Instead, suggestion like not blocking wind when planting deciduous trees or setting up a seasonal fountain is more acceptable during redevelopment of outdoor spaces.

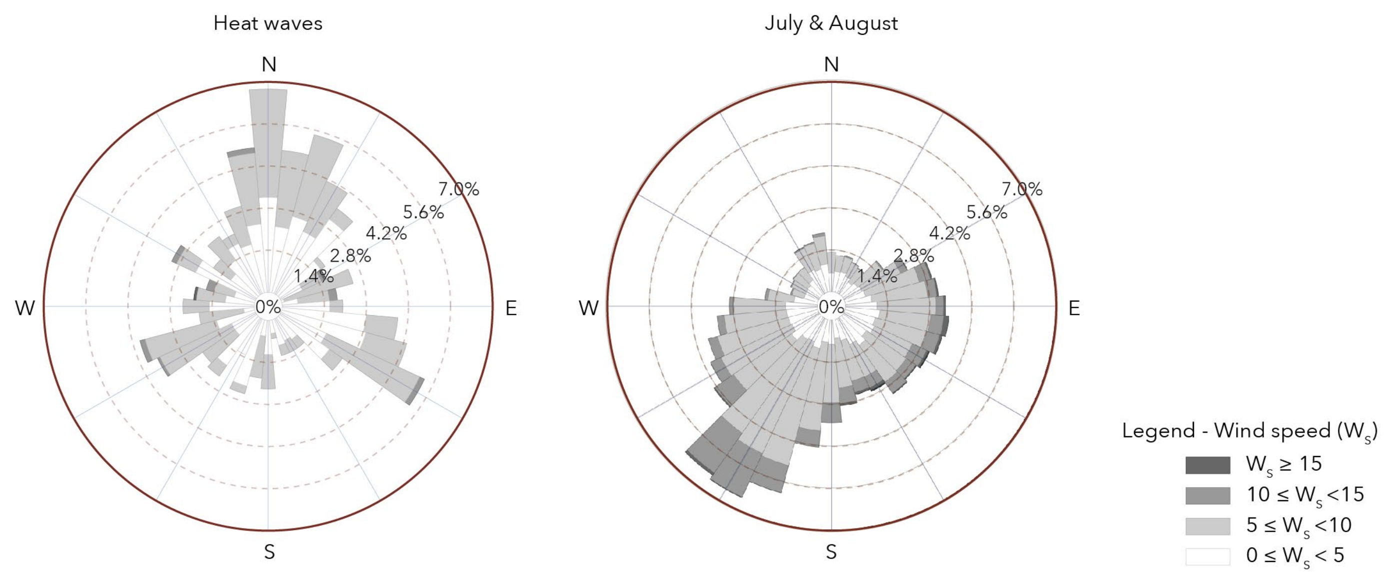


Figure 4.23. Wind rose with the statistics of wind speeds of weather data measured at Hoek van Holland weather station during July & August as well as heat waves from 2010 to 2019.

Source: Produced by author.

The orientation and width of urban canyon in the courtyards and on the streets as well as the materials are playing an important role in shaping various microclimate in urbanized areas. The microclimate in the private courtyards is complicated than that on the public neighborhood streets because of variation among the vegetation, materials and structures in the study areas. Therefore, streets should be the public places to apply more general urban design principles to improve the thermal performance. However, the typology in the study areas is low-rise courtyard block dwellings and Ground Space Index (GSI), which express the density of buildings, is high with the value around 0.40. The streets between blocks are always occupied by brick roads for traffic, parking space and sidewalks so there is almost no potential to apply spatial intervention to improve microclimate on the streets. The streets are also the spaces to place municipal infrastructures such as cables and cubes underground so trees are also limited to spread their roots. As a result, trees are always short and even more time is needed for them to grow to proposed effect on thermal performance. Instead of spatial intervention on the streets, removing pavements and changing materials could one of the best options.

Compared with streets, the space insides the courtyards are private but there is no limitation of underground layer and no need for hard pavement for traffic. If designer could cooperate with the owner of the houses, there will be more potentials to plant vegetations inside courtyard and spatial intervention could also be applied by demolishing and compensating to improve the thermal performance.

Take a look back to the analysis of street orientation (Figure 3.36 & 3.37), the predominant orientation of urban street canyon is along NW-SE axis, followed by NE-SW axis. In other words, the long side of the courtyards in blocks is mainly along the NW-SE and NE-SW axis. From the conclusion of typology study of courtyard block dwellings (Figure 4.12), the typology NW-SE has the worst performance among the studied typologies from the perspectives of building configurations so the courtyard block dwellings with the orientation NW-SE have been chosen (Figure 4.24 & 4.25). There are few vegetations in the courtyard of selected block so it will be relatively easy to simulate the outdoor environments in ENVI_MET and more attention could be focusing on the effects from spatial interventions. Several spatial interventions have been tested on the building configurations and the spaces inside the courtyard based on the idea 'research by design' in order to discover effective ways to improve the outdoor thermal performance.

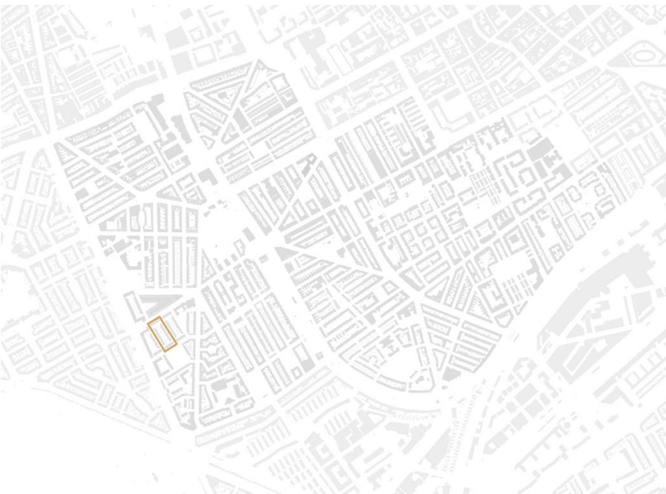


Figure 4.24. Location of the selected block.

Source: Produced by author.

Figure 4.25. Satellite image of the selected block.

Source: Produced by author.

4.5.1 Spatial Interventions in an Ideal Situation

In order to have a better standing of the outdoor thermal performance inside the courtyards of the selected block and the effect of spatial intervention on microclimate, the research and design have been set up in an ideal situation that the influence of vegetations, fences and materials as well as the stakeholders involved in the interventions has been excluded to simplify the comparison between different spatial interventions.

Data

OpenStreetMap; Daggegevens van het weer in Nederland ('Daily data from the weather station in the Netherlands' in English) (Source: https://www.knmi.nl/nederland-nu/klimatologie/daggegevens).

Method

According to the building configurations of selected block, several models have been built in SPACES by ENVI_MET (Figure 4.27). Model_1 (named as 'Actual with storage') has been used to represent the current situation although the fences have not been simulated in the model but Model_Control group (named as 'Actual without storage'), which is simplified by removing small sheds inside the courtyards, has been used as control group. Then Model_2 (named as 'Closed envelop') has been built as a closed envelop based on Model_Control group to learn about the difference of microclimate between buildings with 10-meter height and walls with 3-meter height. Next, some buildings have been demolished at the corner (Model_3, named as 'Open around corners') to test if more openness on the envelop could contribute to a better thermal performance inside the courtyard. Finally, some buildings in the middle of the block have been demolished from Model_Control group (Model_4, named as 'Open in the middle') and a small semipublic space has been created with a tree planting in the center.

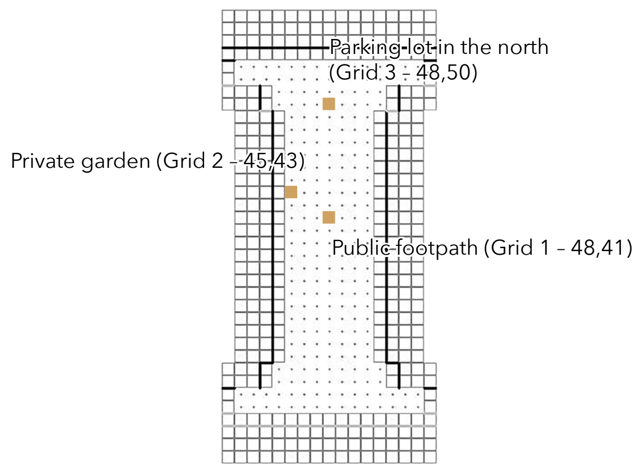


Figure 4.26. Selected grids in models for comparison.

Source: Produced by author.

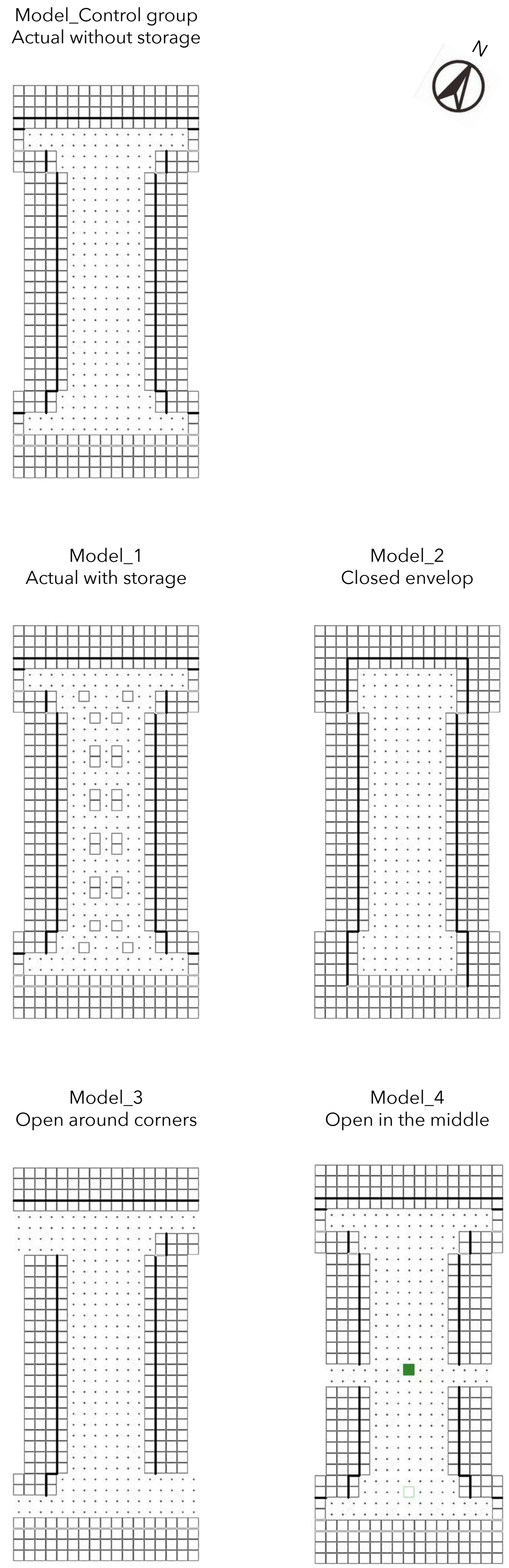


Figure 4.27. Five models for comparison between interventions.

Source: Produced by author.

The 'Intermediate level' in ENVIguide (Appendix VII) has been chosen for the simulation of all of the models and same parameters in 'The Effect of Vegetation on Microclimate' have been applied. The calculations for solar access are conducted with actual weather data for Hoek van Holland. Moreover, same materials were applied for facades, roofs and pavements in each model. After simulation of microclimate by ENVI_MET, physiological equivalent temperature (PET) has been calculated by software Biomet and personal parameters were set to be the same as that in typology study as following:

Age of person (year): 70
Gender: Female
Weight (kg): 70.5
Height (m): 1.65

Default parameters are used for other factors and results have been visualized in LEONARDO. The data of three grids on the 1.5-meter height have been collected to test the effect of spatial intervention, each of which represents the microclimate in public footpath (Grid 1 – 48,41), private garden (Grid 2 – 45,43) and parking lot in the north of the courtyard (Grid 3 – 48,50) respectively (Figure 4.26). After that, the values of PET, MRT and wind speed of the selected grids in Model_Control group (named as 'Actual without storage') have been visualized by charts, which has been used as control group (Figure 4.29). Then the values of the selected grids for each parameter in Model_Control group were subtracted from the values of the same grids in other four models and the results have been illustrated by combined charts in the following pages (Figure 4.30, 4.31, 4.32 & 4.33).

Result

Since there is only spatial distinction in studied models, the difference of the values of air temperature and relative humidity is too small and these two parameters have been excluded from comparison. Firstly, most of the major difference of PET between experimental groups and control group has been caused by the distinction that the grid is under the shadow or exposed to the sun. Either the grids which are located near the locations of interventions or the grids that are relatively further show not much difference between experimental groups and control group. However, apart from the comparison between selected grids, from the comparison between Model_Control group (named as 'Actual without storage') and Model_4 (named as 'Open in the middle') the large difference between the areas under the shading in Model_4 created by demolishing buildings provides inspirations that instead of improving microclimate in the whole courtyard creating 'cooling haven' could also be an option, which will be tested in the following paragraphs (Figure 4.28).

Conclusion

To conclude for the research of the effect of spatial intervention, it is a game between solar radiation and wind speed if the materials and vegetations are controlled as the same situation. When more shading has been created to decrease physiological equivalent temperature (PET), wind speed is always reduced because of the objects that are providing shadow, such as trees, structures, buildings and so on.

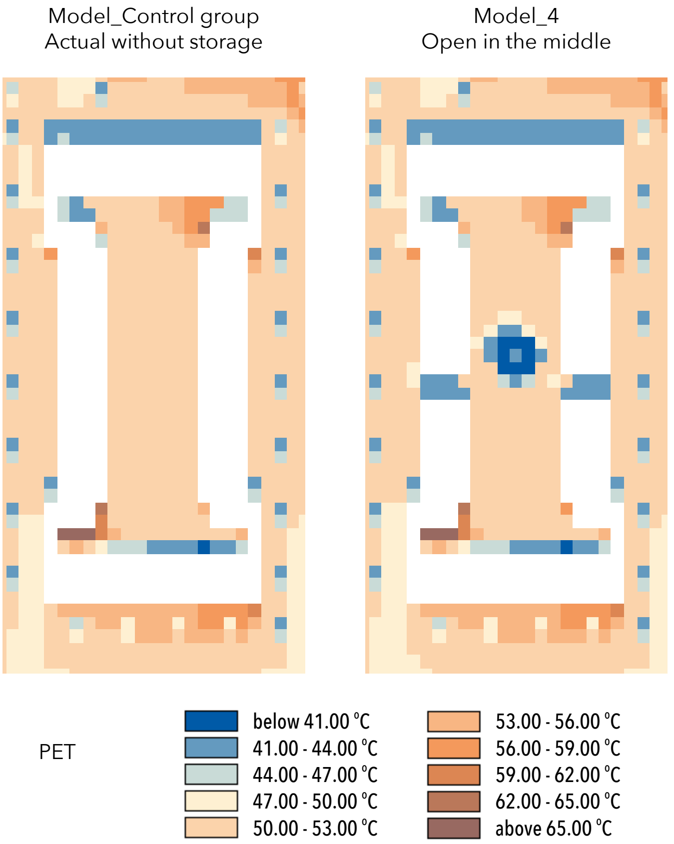


Figure 4.28. PET values on 11:00 26th July 2018.

Source: Produced by author.

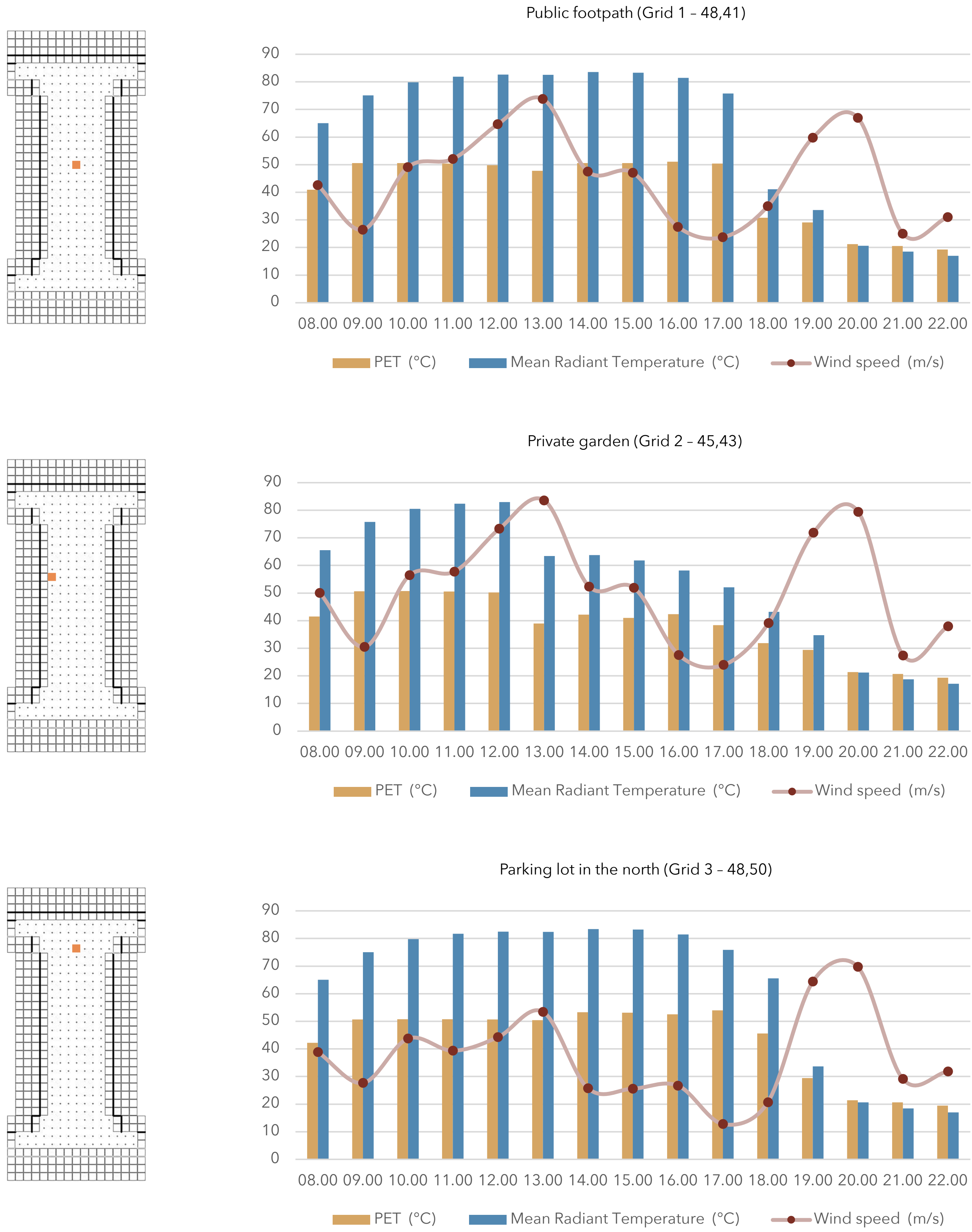
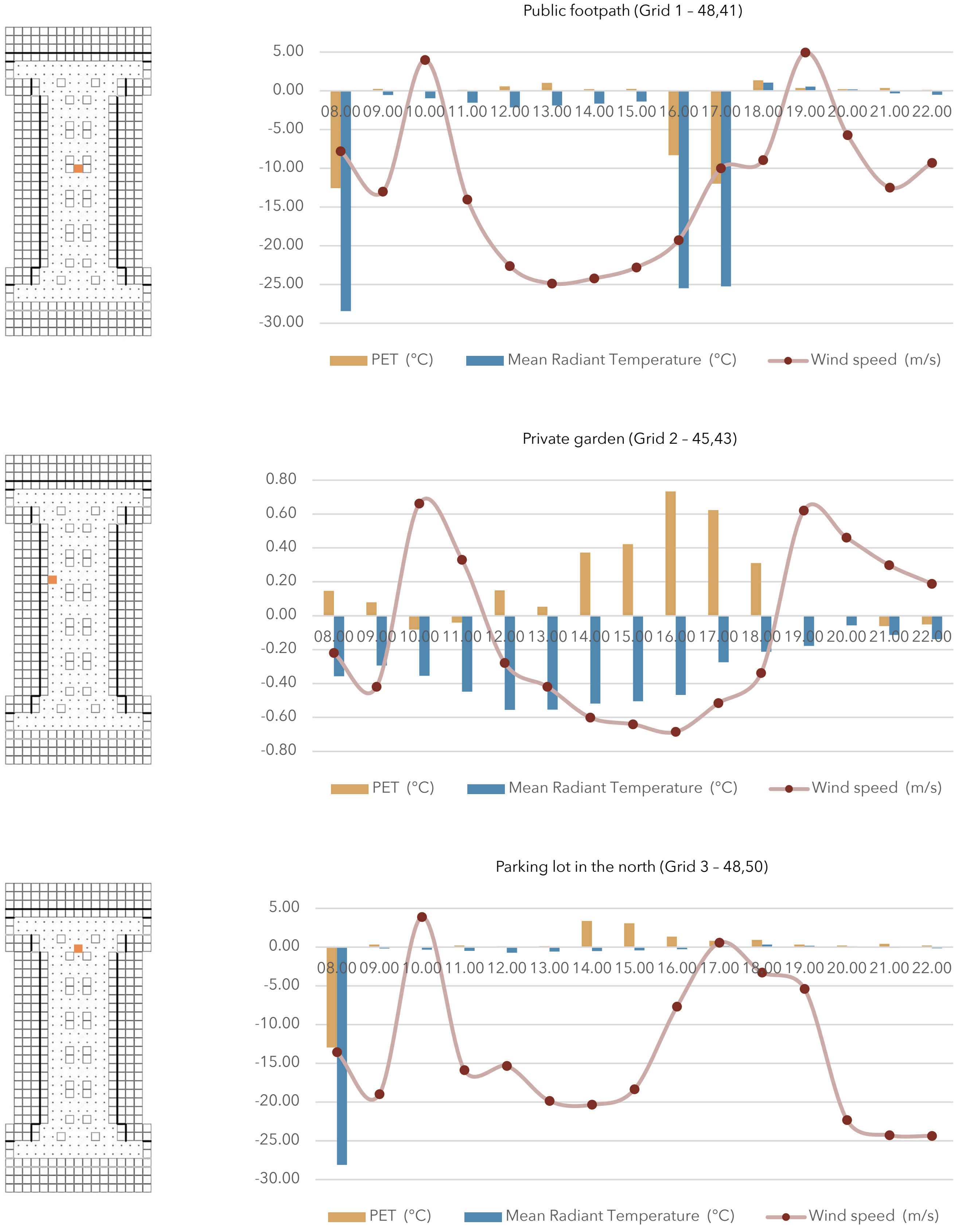


Figure 4.29. PET, MRT & wind speed values among the selected grids on 1.5-meter height in the Model_Control group.

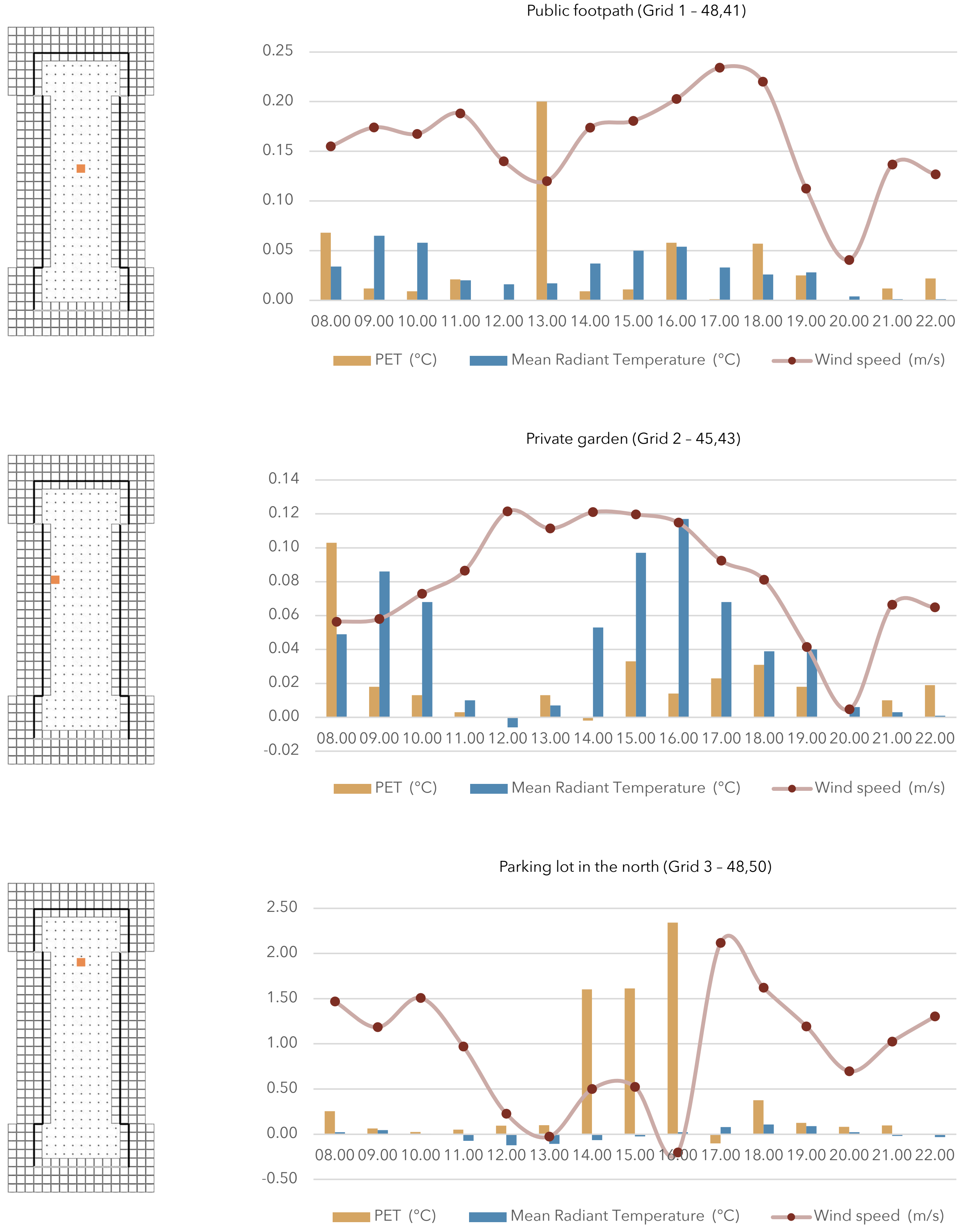
Source: Produced by author.



The large difference between PET value could reach 10 Celsius degree when the grids 'public footpath' and 'parking lot in the north' are covered by the shading from surrounding sheds. The wind speed is also lower for the grids next to the sheds.

Figure 4.30. Comparison between Model_Control group & Model_1 of PET, MRT & wind speed values among the selected grids on 1.5-meter height.

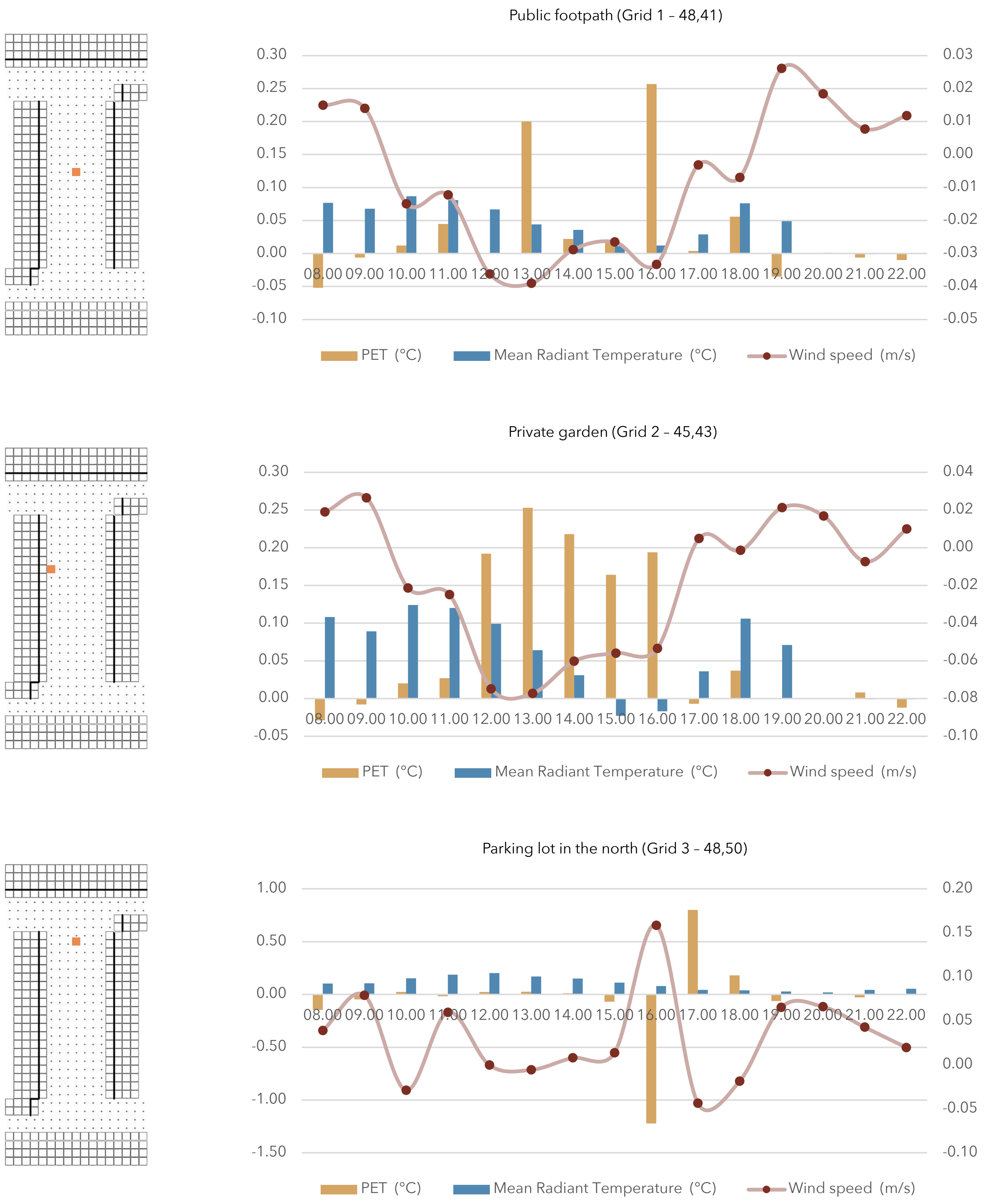
Source: Produced by author.



The closed envelop of the courtyards mainly influence the wind speed among the selected grids but the overall effect on microclimate is not obvious.

Figure 4.31. Comparison between Model_Control group & Model_2 of PET, MRT & wind speed values among the selected grids on 1.5-meter height.

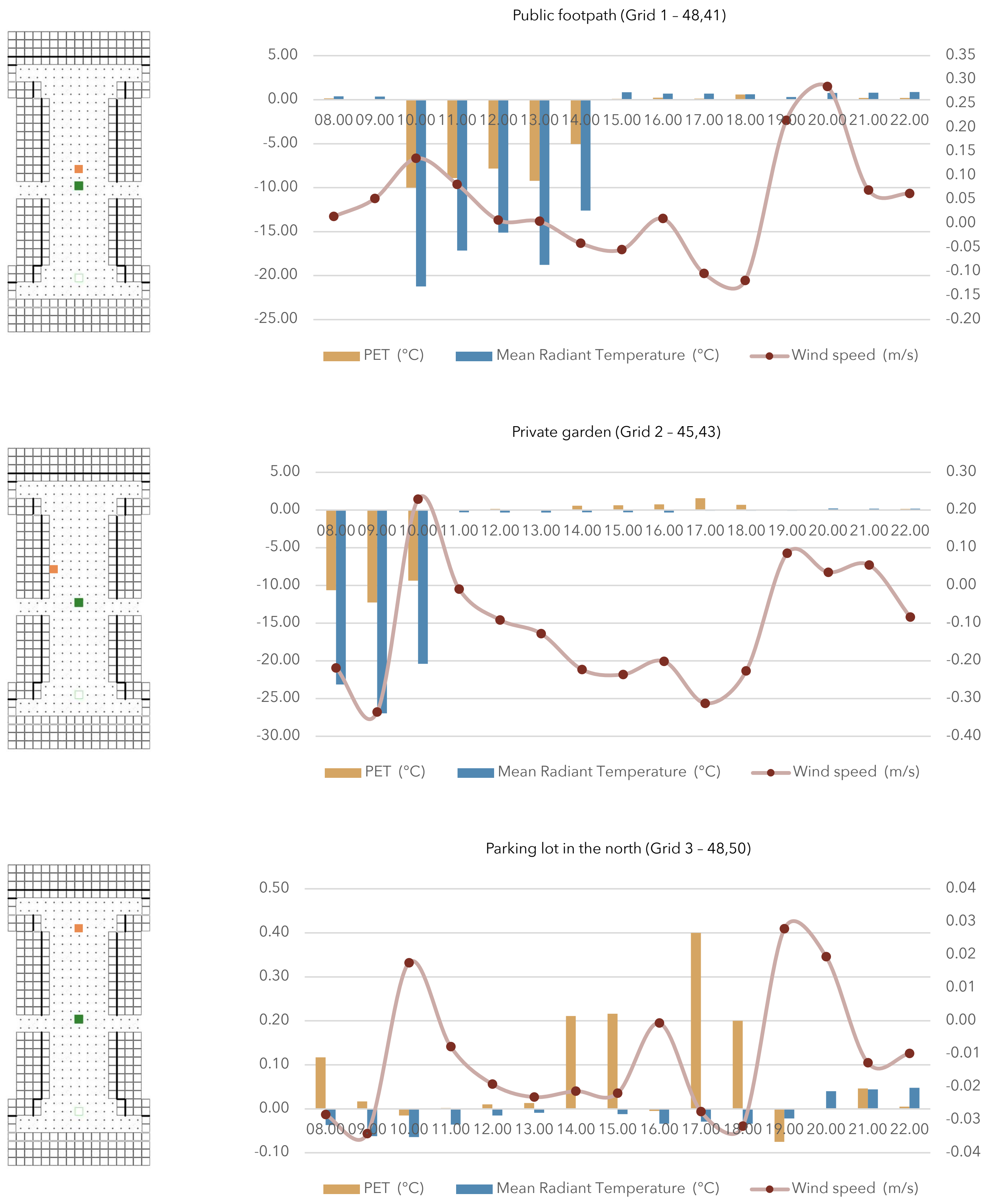
Source: Produced by author.



The openness in the corner makes almost no difference for the thermal comfort among the grids in the public footpath and private garden. The intervention on the envelop has some positive effect on the grid next to openess through increasing wind speed but the effect is still small and transient.

Figure 4.32. Comparison between Model_Control group & Model_3 of PET, MRT & wind speed values among the selected grids on 1.5-meter height.

Source: Produced by author.



The openness in the middle contribute a little to the outdoor thermal comfort but the positive effect from the shading of the tree illustrate large difference around 10 Celsius degree with regard to PET. However, the effect of the tree is local and the tree can not share the benefits to the further grid.

Figure 4.33. Comparison between Model_Control group & Model_4 of PET, MRT & wind speed values among the selected grids on 1.5-meter height.

Source: Produced by author.

4.5.2 Designing 'Cooling haven' & 'Greening footpath' in Courtyards

Compared with streets, thermal comfort in the courtyards could have more potentials to be improved if designer could cooperate with owner of the houses. Among the courtyard block dwellings, the houses or buildings on the short side of the block are always belong to one parcellation and there is no private garden inside the block. For the houses or buildings along the long side of the blocks, they belong to either individuals (left) or one parcellation (right) and there are always separated gardens next to the buildings inside the courtyards (Figure 4.34).

According to different situation of parcellation in the blocks, 'cooling haven' refers to the situation that the buildings belong to one owner such as stakeholders while 'greening footpath' could be applied in the blocks with individual parcellation to improve the thermal comfort inside the courtyard (Figure 4.34).

Designing 'cooling haven'

For the situation with most of buildings belong to one parcellation, such as housing company, some spatial interventions could be applied by demolishing some houses and compensating some floors on existing buildings to balance the interests to create a semi-public space inside the courtyards (Figure 4.35 & 4.36).

Instead of improving the microclimate inside the courtyard, the strategy shows another option to create a small semi-public space between buildings. The wind speed in the semi-public space is more likely to be enhanced a little by the openness on the envelop of the courtyards. Adding vegetations could also improve the thermal comfort by shadow and evaporation. Since this space is covered by shadow from buildings in the morning, it could be the ideal place for the elderly to take a rest and breathe the fresh air out of their houses (Figure 4.37).

The two semi-public gardens with different shapes known as 'cooling haven' have also been tested by ENVI_MET with 'Intermediate level' (Appendix VII) and same parameters in 'The Effect of Vegetation on Microclimate'. The results have been illustrated by LEONARDO (Figure 4.38 & 4.39).

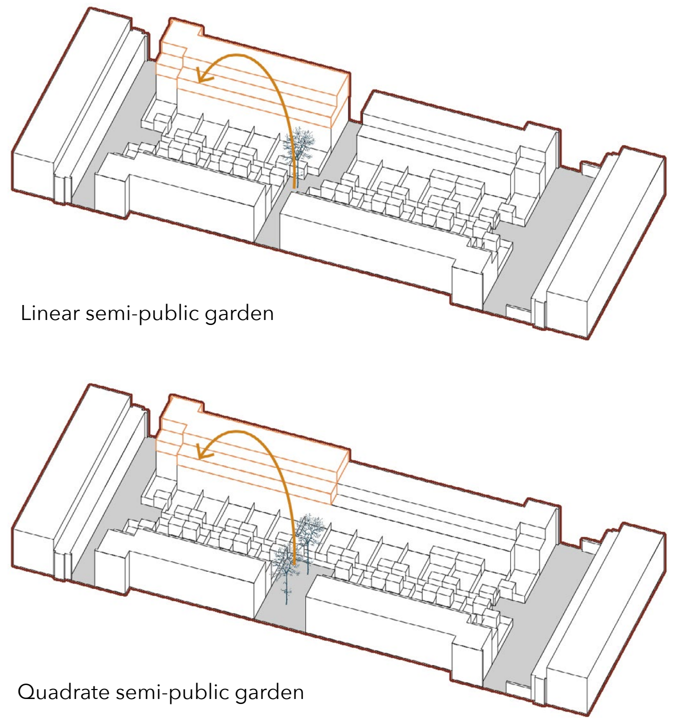


Figure 4.36. Demolishing some buildings and compensating some floors on existing buildings to create a semi-public space inside courtyards.

Source: Produced by author.

From the result of the simulation, it is obvious that both of 'cooling haven' with different shapes can create some spaces which are 10 Celsius degree cooler than surrounding areas inside the courtyard with regard to the physiological equivalent temperature (PET). Moreover, the improvement of microclimate appears not only in the grids created by demolishing buildings but also the grids in surrounding areas. When looking into the factors that determine the physiological equivalent temperature (PET), the difference is hard to find between the values of humidity even though trees are planted in the semi-public gardens. The distinction of air temperature and mean radiant temperature could be found in the grids created by demolishing buildings and the grids besides trees. Although the trees will reduce wind speed, the effect of openness on the envelop will overrule the impact of trees and increase the wind speed a little in the courtyard (Figure 4.38 & 4.39).

To conclude, the design of 'cooling haven' can create some areas besides buildings or trees that are much cooler than the rest areas in the courtyard yet the contribution to better thermal comfort in the courtyard is little. However, it could be an option to provide some spaces within blocks where people can breath some fresh air or have a small talking with others in the morning during hot weathers.

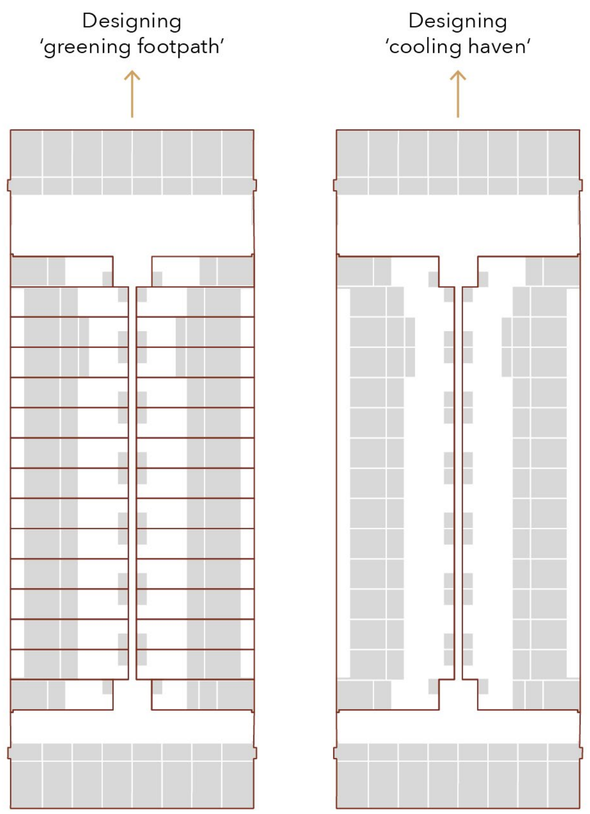


Figure 4.34. Approaches for different situation of parcellation.

Source: Produced by author.

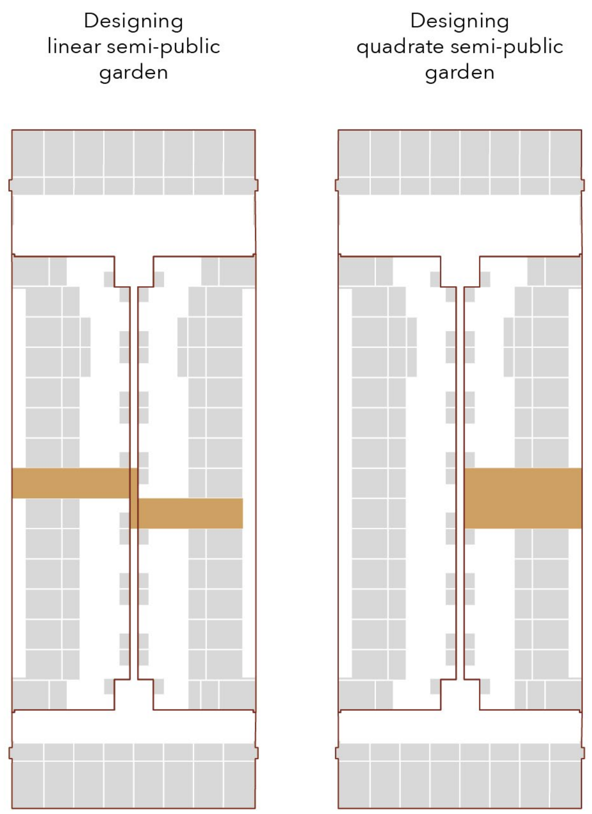


Figure 4.35. Plans of linear and quadrate semi-private garden.

Source: Produced by author.

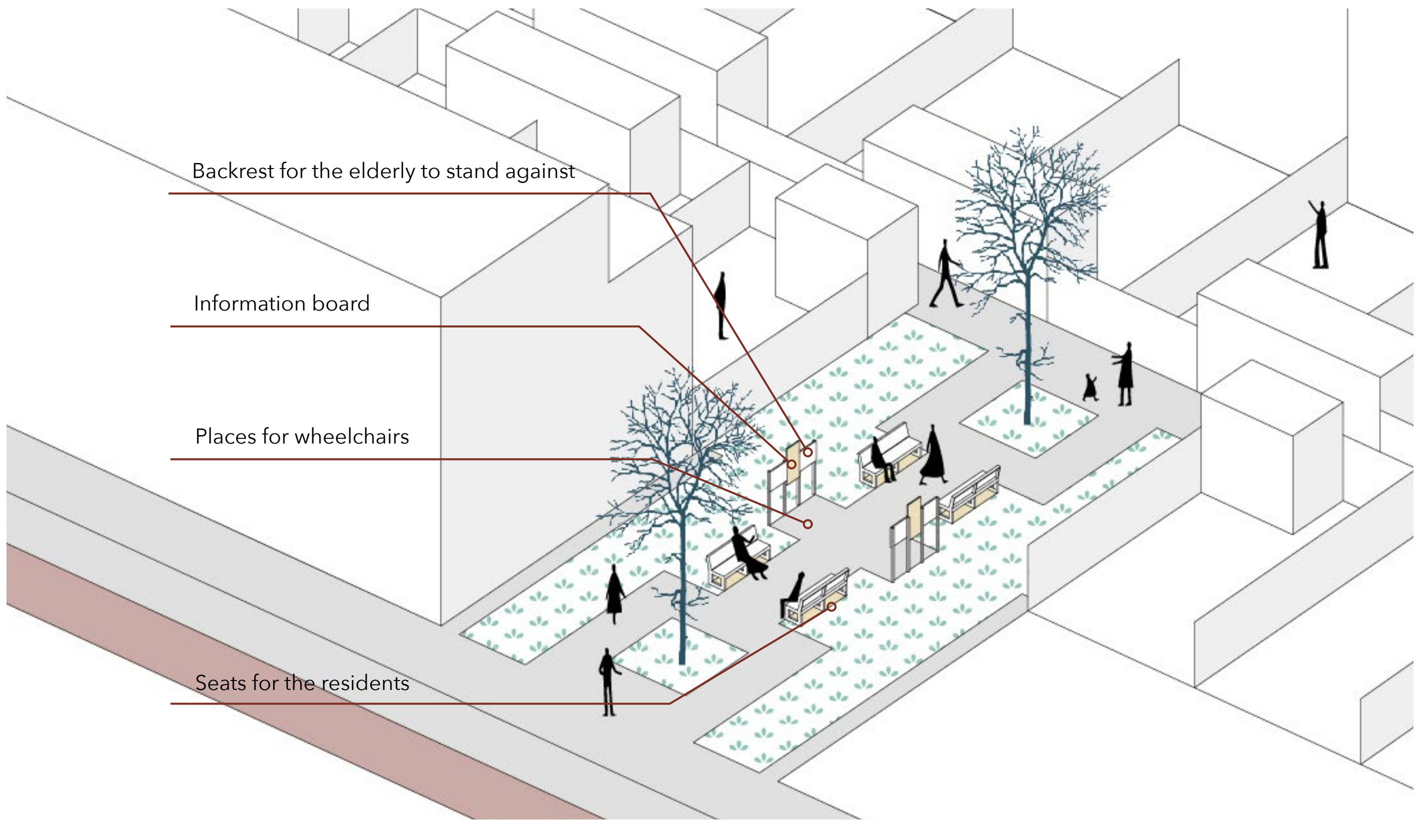


Figure 4.37. Designing of 'cooling haven' within the block for residents with more consideration of the demands from the elderly.

Source: Produced by author.

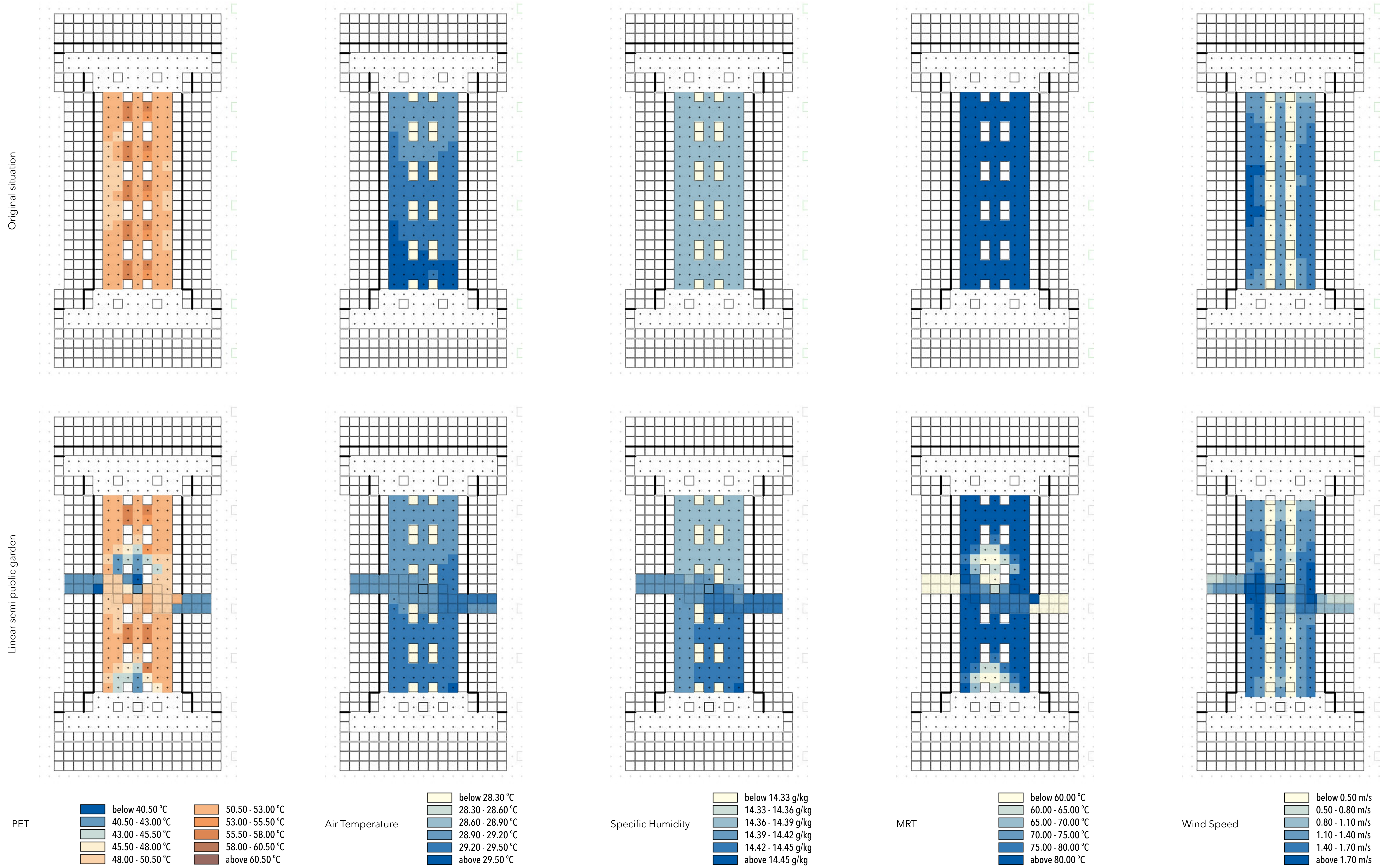


Figure 4.38. Comparison between original situation and linear semipublic garden.

Source: Produced by author.

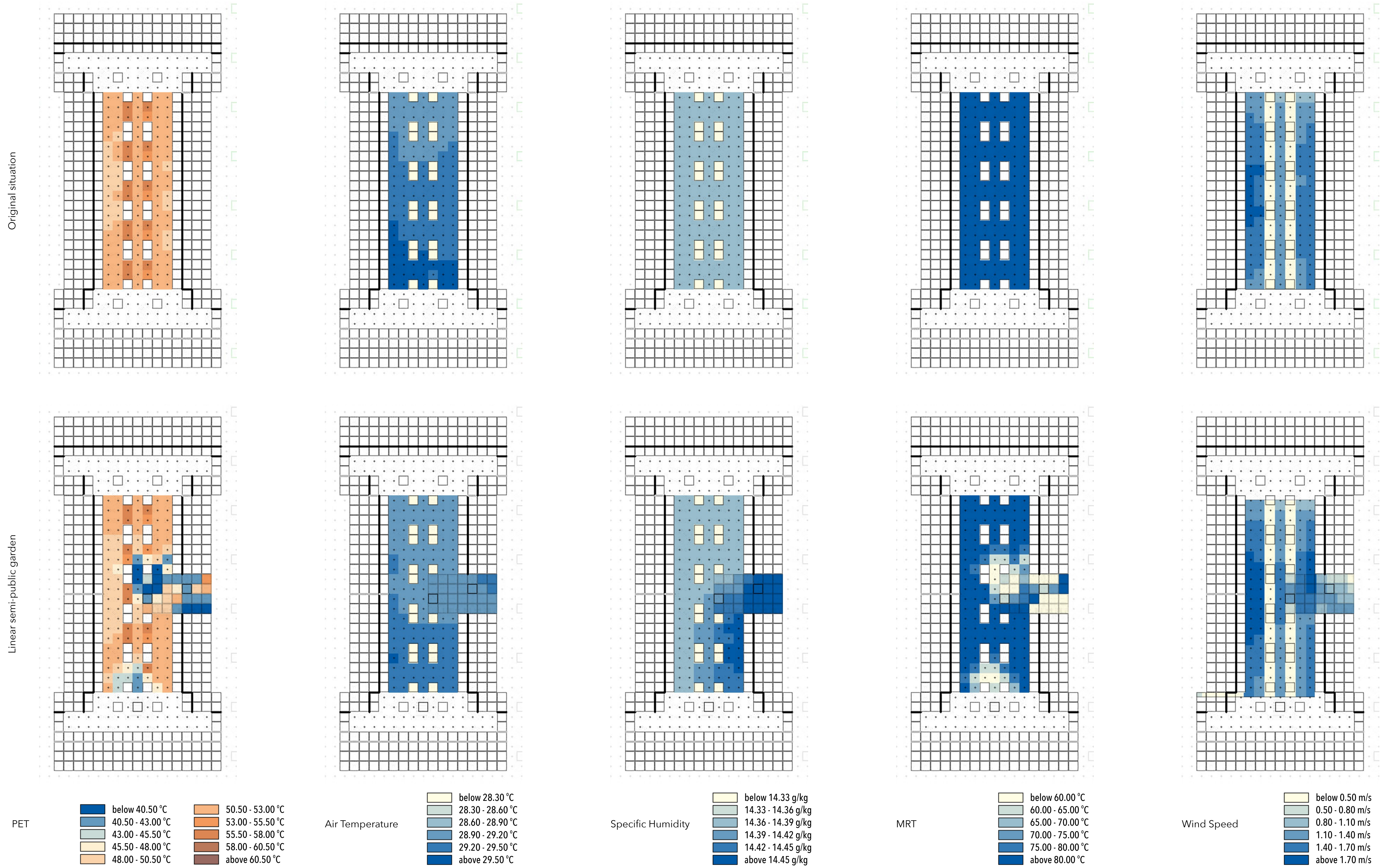


Figure 4.39. Comparison between original situation and quadrate semipublic garden.

Source: Produced by author.

Designing 'greening footpath'

For the situation with most of buildings belong to individuals, it will be easy to convince residents to provide some space inside the courtyards to plant trees instead of demolishing buildings to improve thermal performance inside the courtyards. Usually, there is a narrow footpath in the middle of the courtyards and some private gardens along the footpath. If some spaces could be 'exchanged' or 'borrowed' from residents, a small semi-public garden will exist between private gardens and trees could be planted in order to contribute to a better indoor and outdoor thermal performance during summer (Figure 4.40). As the benefit for residents to exchange, they can have a garden at street side with same size if there are enough spaces for sidewalks or they can get part of the drainage tax free in return besides the benefits from trees.

The strategy has been tested by ENVI_MET with 'Intermediate level' (Appendix VII) and same parameters in 'The Effect of Vegetation on Microclimate' and the results on 11:00 and 14:00h have been illustrated by LEONARDO (Figure 4.41). The effect is obvious that people could get benefits from the shadow created by trees during daytime not only in footpath but also in their private gardens and houses. However, the effect of trees is local and it is not possible to plant more trees to enlarge the local effect of trees in the courtyard with the consideration of the tree arrangement. Therefore, the application of vegetations or other approaches are also needed in private gardens.

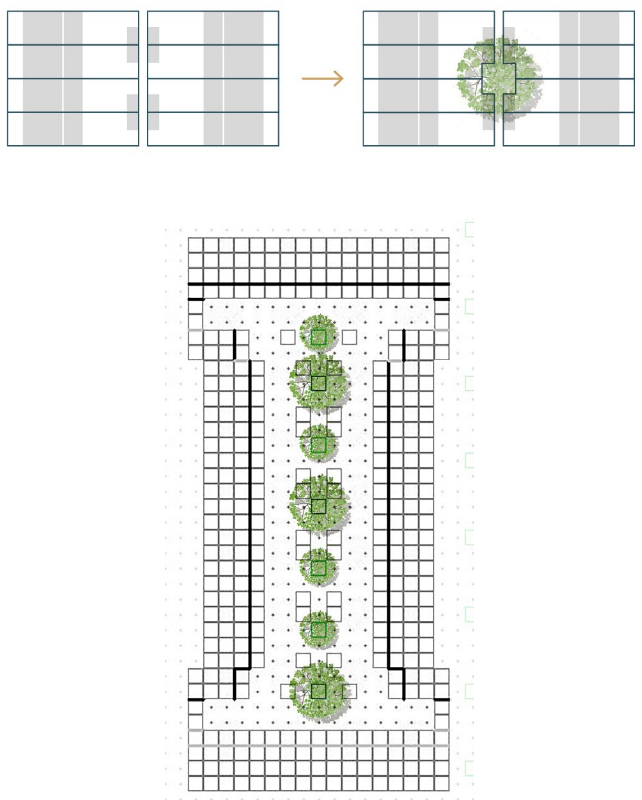
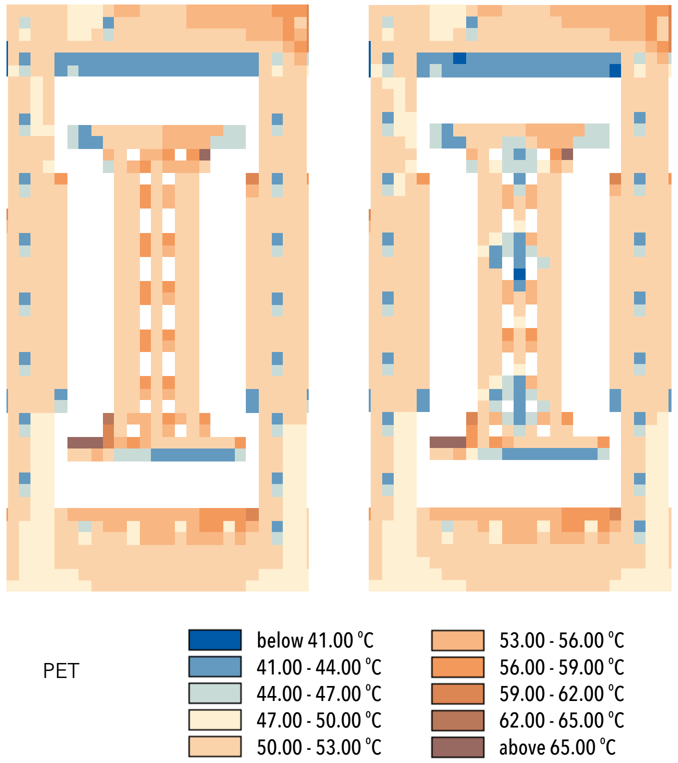


Figure 4.40. 'Borrow' or 'exchange' land from residents to plant trees.

Source: Produced by author.

26th July 2018 - 11:00



26th July 2018 - 14:00

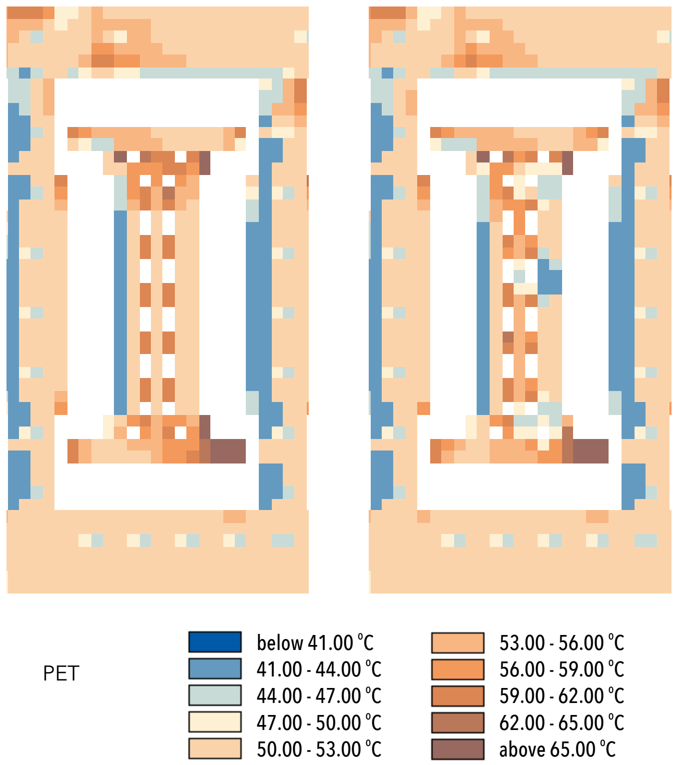


Figure 4.41. Comparison of the PET values between courtyards with trees and without trees.

Source: Produced by author.

4.6 Conclusion

To conclude for the chapter 'Research', the research and studies have been conducted through the approaches of 'research for design' and 'research by design' respectively. The influence of building configurations and vegetations have been studied and the prevailing wind during heat waves and hot summers have been concluded. Furthermore, some spatial interventions have been applied into the courtyard block dwellings and the effect of them have been tested by ENVI_MET.

The main conclusion of the chapter 'Livability from microclimate perspectives' could be summarized as following key points:

- From the perspectives of building configurations, the typology of the courtyard block dwellings with the orientation NW-SE are with high risks.
- The prevailing wind direction during hot summer is the same as annual wind direction while during the heat waves winds usually came from north and east side with relatively lower wind speed.
- The effect of trees and grass on microclimate is positive and the combination of them could be one of the best options.
- The microclimate in the courtyard is more like a game between wind and shading and it is hard to improve them both in the courtyard. The design of 'cooling haven' and 'greening footpath' could be the options to improve the microclimate locally and provide heat refuges for the residents.

Based on the forementioned findings, eight strategies could be concluded totally from the chapter 'Research' and combined with the knowledge from literatures and cases, more strategies could be expected (Figure 4.42).

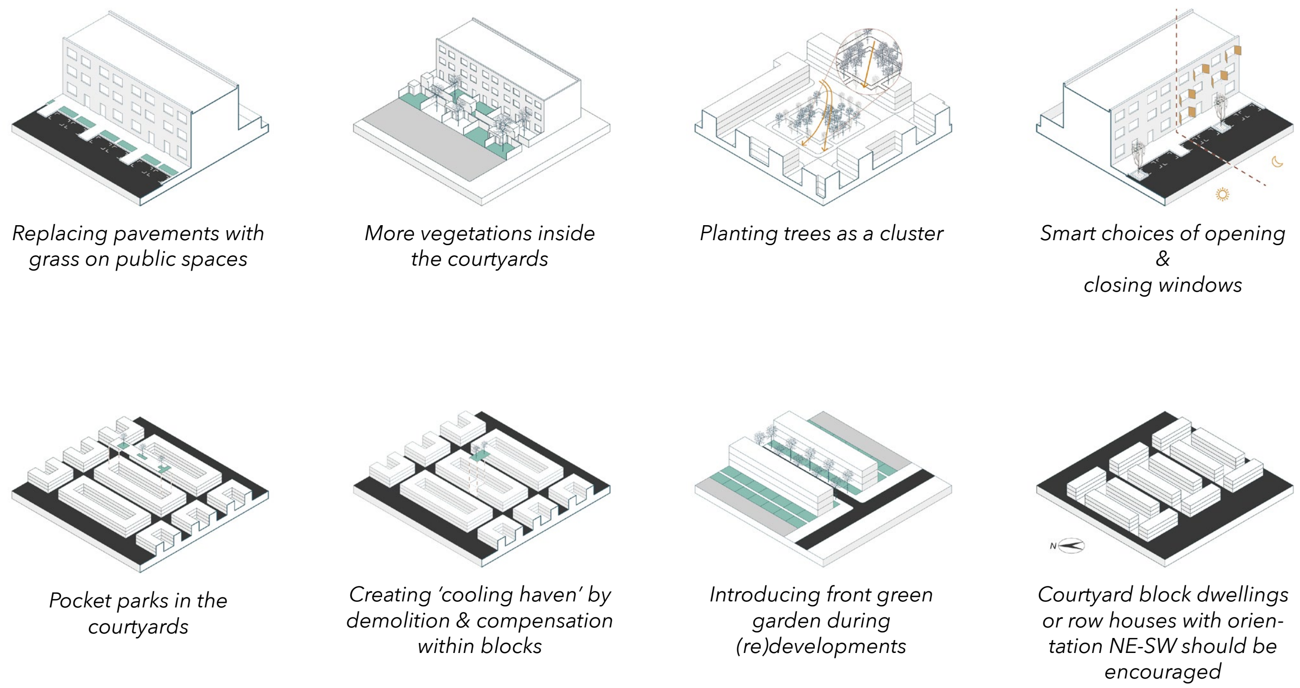


Figure 4.42. Startegies concluded totally from the chapter 'Research'.

Source: Produced by author.

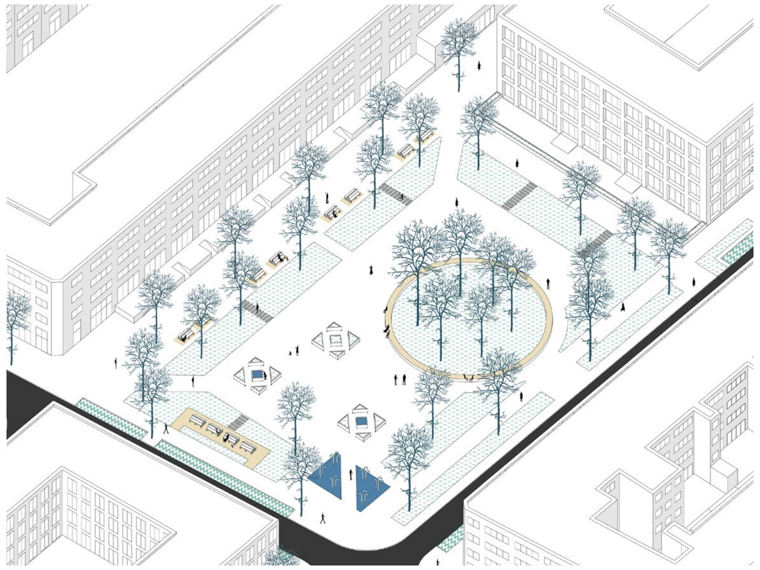


Figure. Redevelopment of Stellenboschplein.

Source: Produced by author.

5 DESIGN & INTERVENTIONS

The chapter 'Design & interventions' introduces strategies from microclimate perspective and urban microclimate design has been applied to test the effectiveness of the strategies. The introduction of 'Cooling sheds' offers another choice to reduce heat stress for the elderly. The sub-question 3, 4 & 5 (***effectiveness, equity & transferability***) will be uncovered by the design and evaluation in the chapter.

- Strategies
- Urban Microclimate Design
- Designing Cooling Sheds
- Conclusion

5.1 Strategies

The strategies from the perspective of microclimate in the thesis have been concluded based on the research through the approached 'research for design' and 'research by design' among a common typology courtyard block dwellings and the effect of vegetations on microclimate in the Netherlands, which reveals the potentials to apply in more areas. Moreover, the aim of the strategies is to improve indoor and outdoor thermal comfort instead of introducing totally new urban design. Therefore, the strategies are with relatively higher hierarchy and following urban microclimate design aims to evaluate the effectiveness of the strategies and show how the strategies could be applied into practice.

Inspired by literatures and the temporal measures in practice to cool down the outdoor environments (Figure 5.1), the strategies have been concluded from the research and studies in the chapter 'Research' as well as the knowledge from literatures and cases. The strategies could be divided into several aspects from the perspectives of vegetations, water, building forms, material and color as well as suggestions for occupants' behavior (Figure 5.2) and some of them are temporal measures which could offer more choices to the stakeholders and protect the citizens during continuous hot weathers. More details about each strategy such as explanation and stakeholders will be introduced one by one in the following pages.

Figure 5.1. Images of temporal measures to imrove outdoor thermal comfort - creating shading by umbrellas over the shopping street (top) & 'Uchimizu' in Japan to cool down the surface.

Source: https://veebrant.com/designer-outlet-malaga/;https://www.flickr.com/photos/worldmeteorologicalorganization/8141832429.

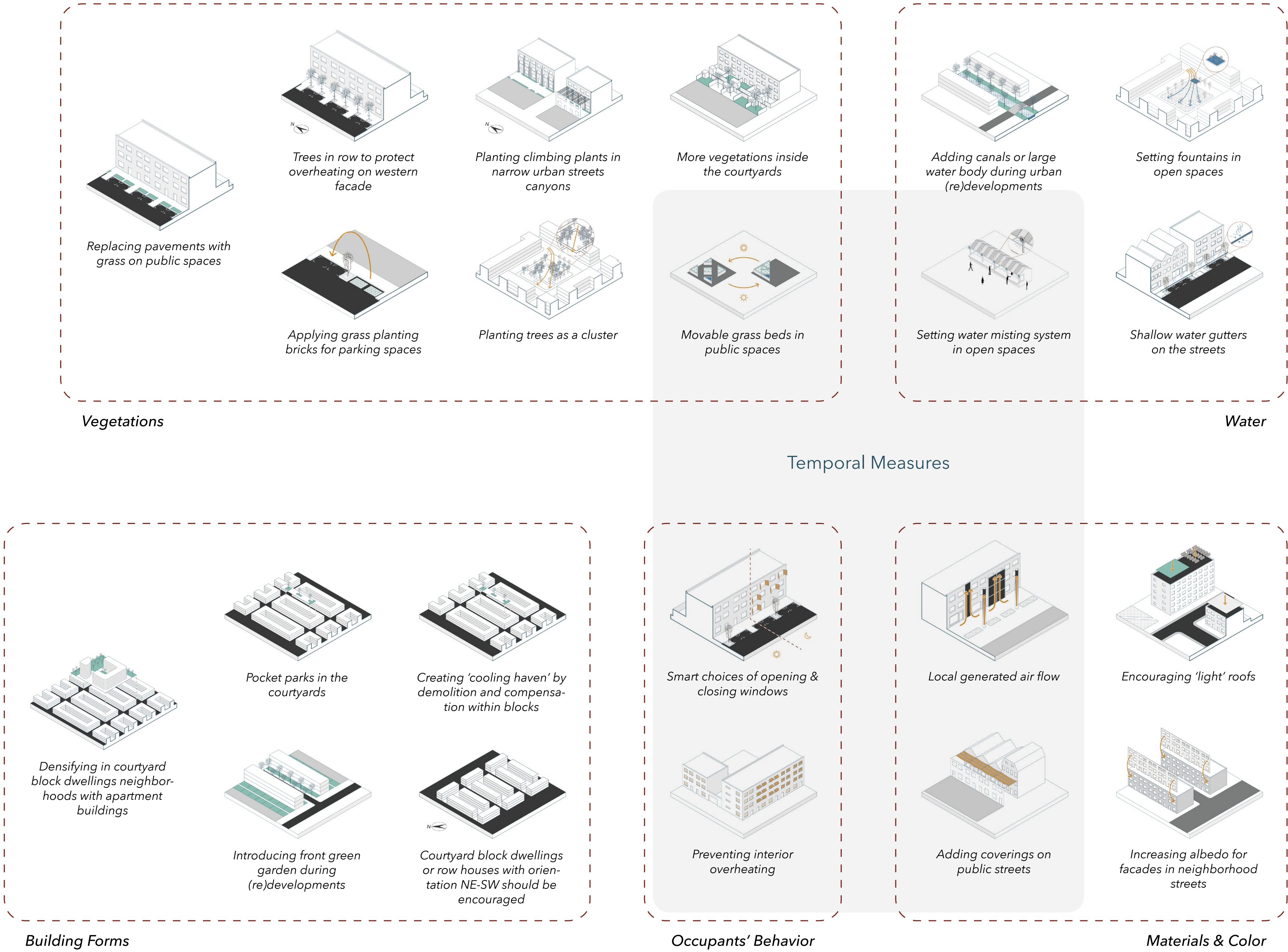


Figure 5.2. Overview of all the strategies.

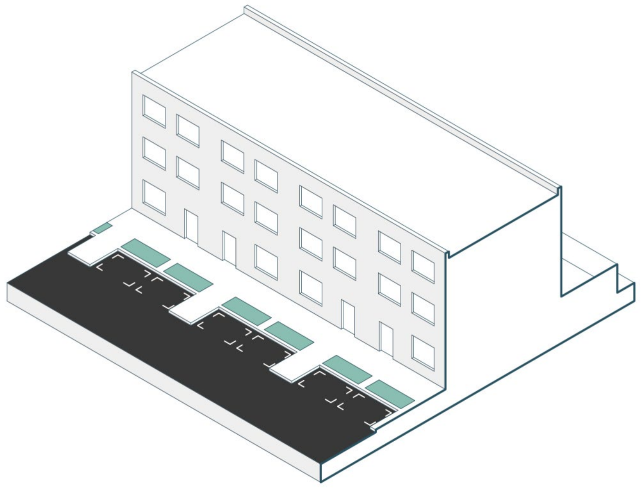
Source: Produced by author.

Replacing pavements with grass on public spaces

Removing extra hard pavements and plant grass on the same location could help to reduce mean radiant temperatures during daytime and night which will further contribute to better outdoor thermal comfort and mitigation of urban heat island.

Municipality should gradually replace some extra hard pavements with grass during the maintenance of the streets and open spaces. For the places facing serious heat risks, high hierarchy of planting grass could be considered and the irrigation of grass could also be taken into account.

Stakeholders: municipality.



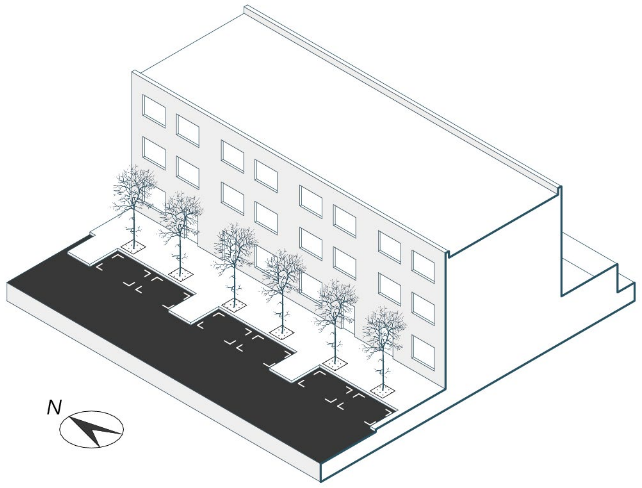
Vegetation

Trees in row to protect overheating on western facade

Deciduous trees should be planted as a row next to buildings along the streets with orientation between NE-SW and NW-SE axis towards north or south in order to prevent indoor temperature from overheating by the sun during afternoon and sunset.

Municipality should convince the residents with the benefits from trees on reducing indoor temperature as well as improving outdoor thermal comfort and then plant trees as a row to provide shades on western facades.

Stakeholders: municipality, residents.



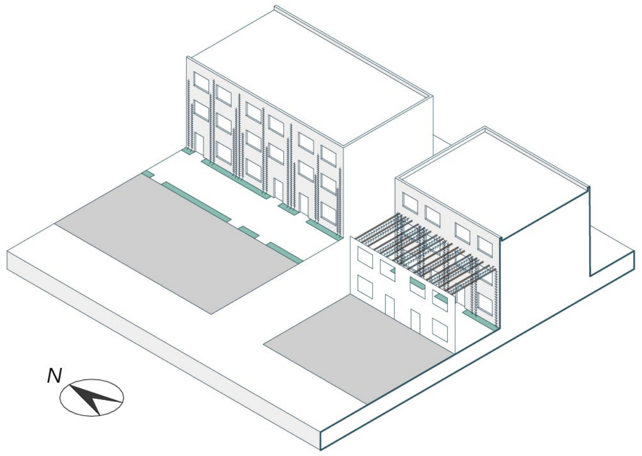
Vegetation

Planting climbing plants in narrow urban streets canyons

Planting deciduous climbing plants in narrow urban streets canyon to create an extra layer on the facades or across the streets as dynamic solar shading devices. Maximum shading occurs in summer to prevent over-exposure to the sun of the facades during sunset and improve thermal performance on pedestrian level while during autumn and winter, sunlight could reach streets canyon and interiors for sufficient daylight.

Municipality could introduce the benefits from deciduous climbing plants and offer consulting, technique and allowance to the residents or housing companies who would like to embrace this approach for better thermal comfort.

Stakeholders: municipality, residents, housing companies.



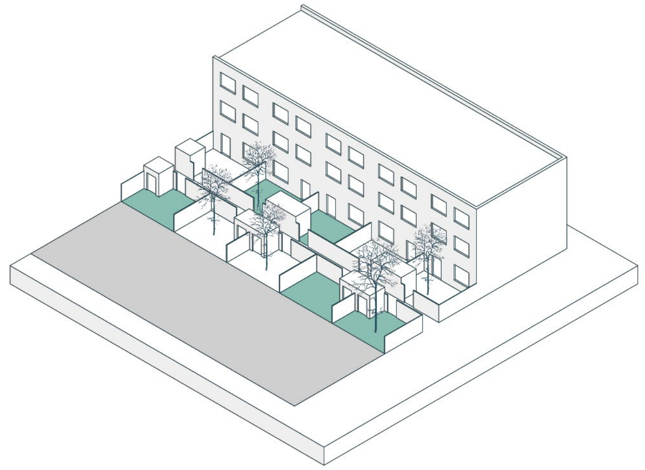
Vegetation

Planting more vegetations inside the courtyards

Residents should plant more vegetations inside their private garden to improve indoor and outdoor thermal comfort. Trees or grass could be options and the combination of them is the best. If it is not affordable, trees will be better than grass since trees will have positive effects in the future while grass need careful irrigation.

Residents and housing companies could be encouraged by municipality to plant more vegetations on their own initiative inside the courtyard by offering cheaper trees or free assistance. Municipality could also 'rent' or 'exchange' some private lands in the courtyard for public trees and invite residents or housing companies to take care of them by setting up rewards.

Stakeholders: municipality, residents, housing companies.



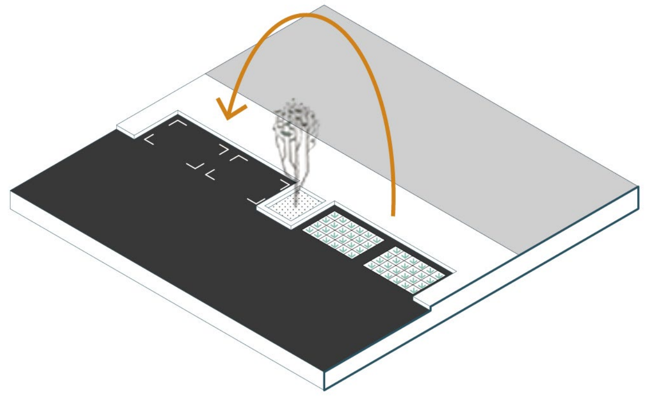
Vegetation

Applying grass planting bricks for parking spaces

Parking spaces with dark color pavements such as asphalt and bricks occupy large spaces in neighborhood streets, which contribute to hot outdoor environments. They could be replaced with grass planting bricks which are light color with grass growing in between in order to increase albedo and decrease emissivity for parking spaces.

Pavements in parking spaces could be replaced gradually by municipality when the possible decrease of car ownership is taken into account in the future, resulting in less demands for parking spaces. The parking spaces on the narrow streets with less vegetation or those on the northern and western side of the streets could be redeveloped first.

Stakeholders: municipality.



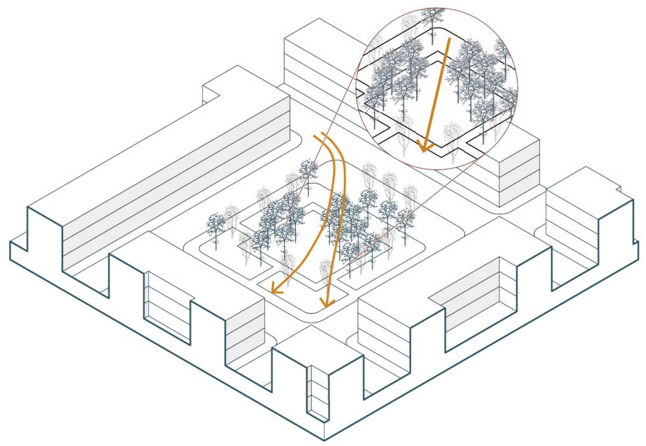
Vegetation

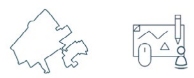
Planting trees as a cluster

Trees should be planted as a cluster in public spaces like square or parks so that the local benefits from trees on microclimate could have effects on broader areas. The combination of trees with grass will be one of the best options. The prevailing wind directions during summer should be taken into account so that trees cluster will not reduce wind speed in public spaces.

The sectors from municipality should be responsive for how to plant as well as taking care of trees in public spaces.

Stakeholders: municipality, designer.





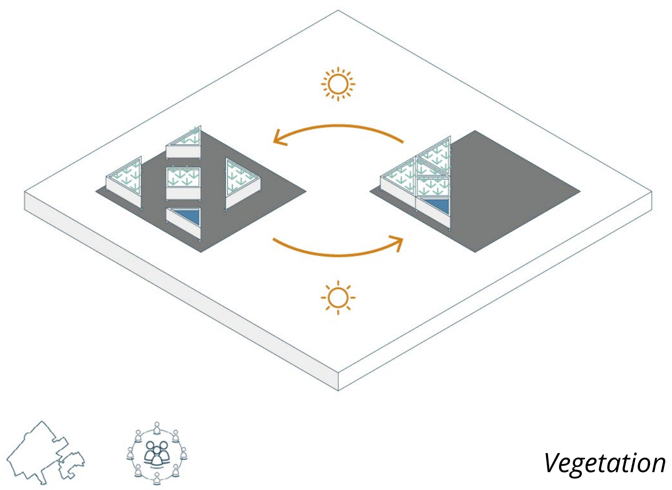
Vegetation

Movable grass beds in public spaces

The pavements in public spaces such as squares and plazas for temporal activities are usually with dark color since pavements with high albedo will cause discomfort for pedestrians. Movable grass beds could be one of the options to reduce the exposure of the hard pavements in public spaces. During the activities, these grass beds could be gathered around the corner. When there is no activity holding, they could be set separately to provide shading and some other elements such as small bushes or water elements could also be added for people to interact with during daytime.

Municipal departments or community centers could be responsible for the distribution and placing of movable grass beds referring to the weather conditions.

Stakeholders: municipality, community center.

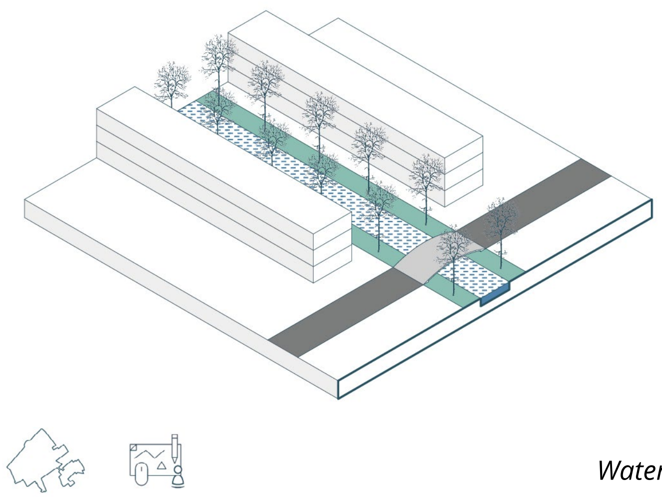


Vegetation

Adding canals or large water body during urban (re)developments

Although water body could heat the air at night during persistent hot weather, the overall psychological and physical cooling effects are positive for outdoor thermal performance. Moreover, vegetations could grow better along the water body with sufficient spaces and water and combination of vegetations and water could have even better influence on thermal comfort.

Stakeholders: municipality, designer.

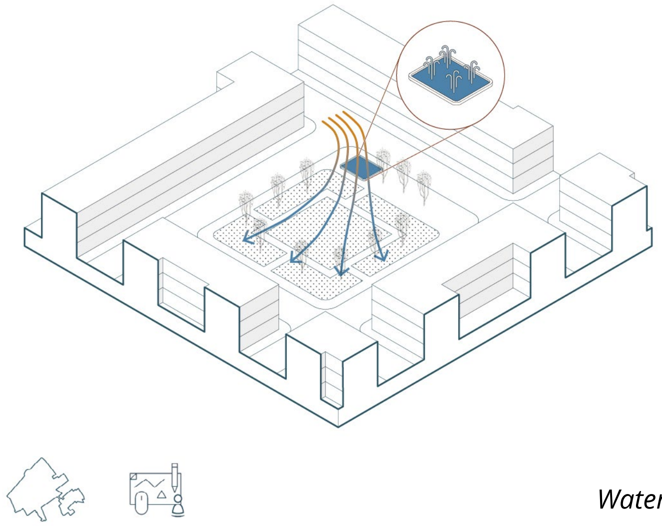


Water

Setting fountains in open spaces

Wind could bring spray of water generated from fountain towards open spaces and contribute to better thermal comfort by increasing humidity and transforming solar radiation to latent heat. The consideration of prevailing wind direction during months with hot weather will expand the positive influence on outdoor thermal comfort from fountains.

Stakeholders: municipality, designer.

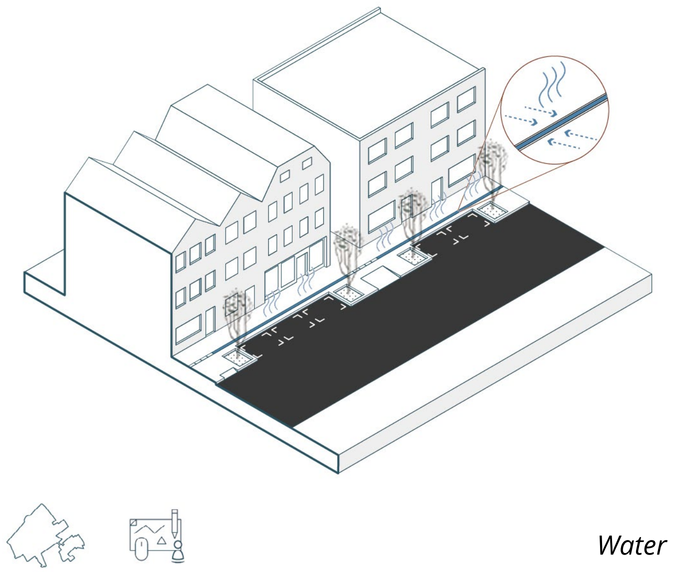


Water

Shallow water gutters on the streets

Shallow water gutter on the streets could reduce air temperature and increase humidity through evaporation to improve outdoor thermal comfort. This approach could be applied on the streets with buildings with public functions while there are few potentials to add vegetation on the street profile. The water could be collected from storm water or pumped up from nearby water elements.

Stakeholders: municipality, designer.

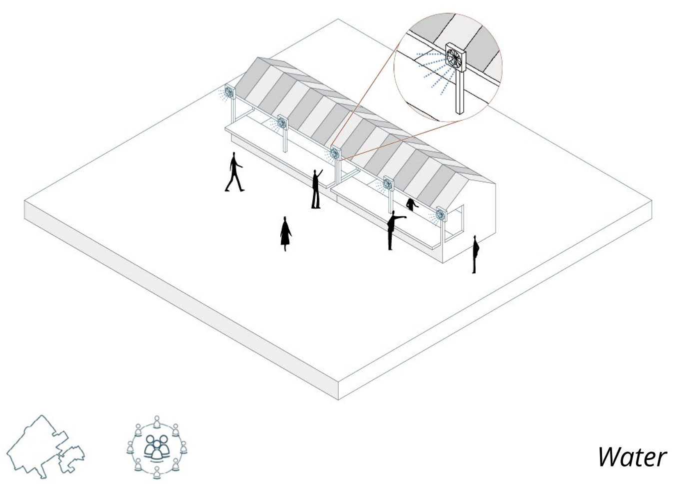


Water

Setting water misting system in open spaces

Water misting system such as water mist fans which converts water into water mist with pressure could mainly increase humidity and consume latent heat in public spaces. The setting of water misting system in the places like squares, plazas, open market and so on will be more effective and efficient in reducing heat stress among the public in outdoor spaces.

Stakeholders: municipality, community center.



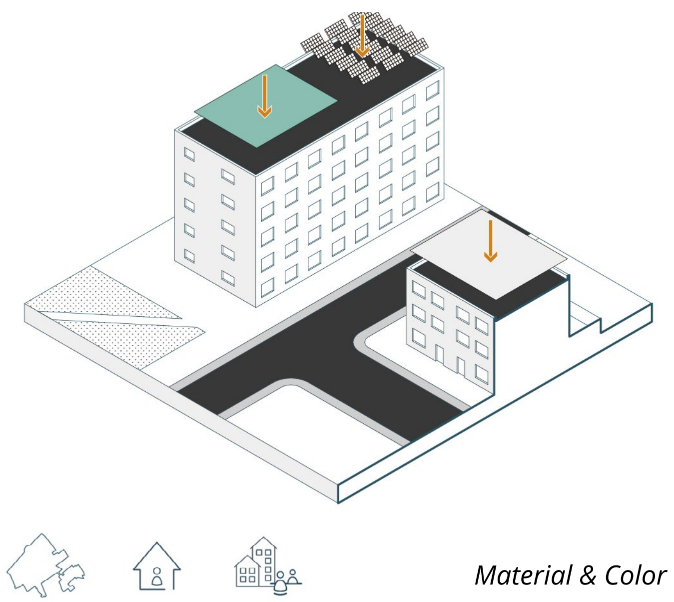
Water

Encouraging 'light' roofs

Roofs with light color usually have a positive effect on mitigation of urban heat island and indoor temperature of upper floor. Gradually changing the materials of roofs to the material with light color when the materials of roofs are going to reach the end of their lifespan or applying solar panels on the roofs could be the most cost-effective solutions. Greening roofs could also be a choice especially for the building with public functions.

Municipality could encourage residents and housing companies to change dark-colored roofs into roofs with light-color materials or green roofs as well as setting solar panels on roofs by offering free advisory services and various levels of subsidy.

Stakeholders: municipality, residents, housing companies.



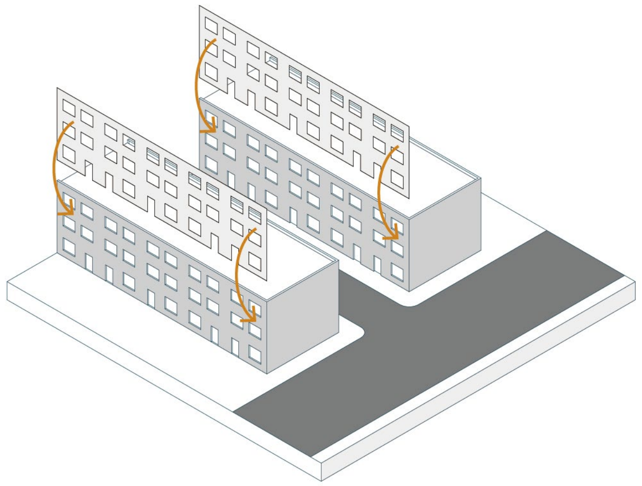
Material & Color

Increasing albedo for facades in neighborhood streets

Although materials of facades with high albedo could probably increase mean radiant temperatures on the streets, the positive effect on reducing outdoor temperature at night and indoor temperatures during the whole day can overrule the impact of materials with high albedo in neighborhood streets when people spend most time indoor.

Municipality should replace the dark-colored pavements with vegetations in the neighborhood streets as much as possible during the redevelopments and encourage the increasing of facades' albedo by offering subsidy or reducing tax among residents and housing companies.

Stakeholders: municipality, residents, housing companies.

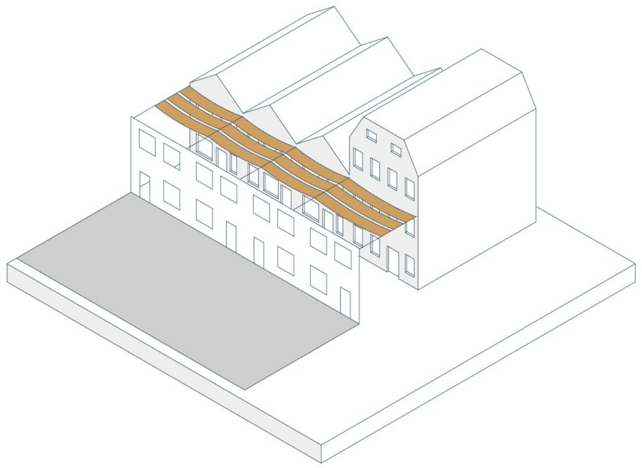


Material & Color

Adding coverings on public streets

A temporal layer created by canvas sheets or climbing plants on top of the streets could provide shading on the facades or ground on hot summers with some additional attachment structures. Coverings could be placed on the north side of the streets or using light color materials if sufficient daylight is needed.

Stakeholders: municipality, community center.

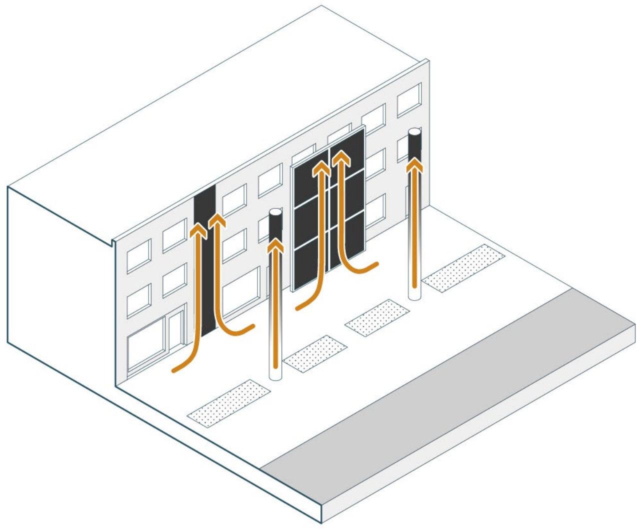


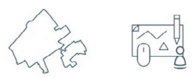
Material & Color

Local generated air flow

Large difference of surface temperature could generate air flows so structures or facades with surface of dark color in the open space could help to increase local wind speed in order to improve outdoor thermal comfort. Moreover, setting solar chimneys could also be a choice to make a better outdoor environment temporally.

Stakeholders: municipality, designer.



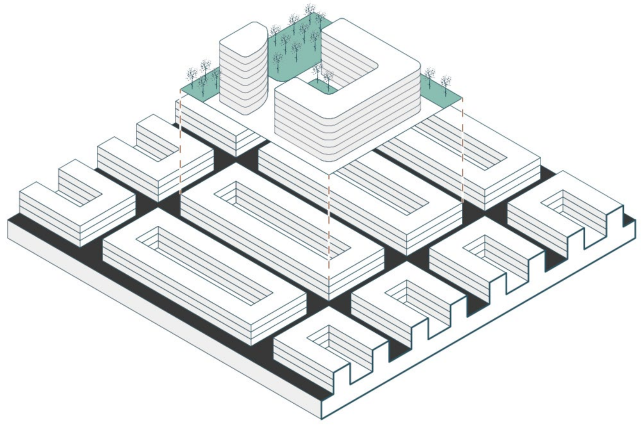


Material & Color

Densifying in courtyard block dwellings neighborhoods with apartment buildings

Redevelopment with apartment buildings could achieve more gross floor areas compared with courtyard block dwellings with same floor areas. More open soil and vegetation could be provided to contribute to better outdoor thermal performance.

Stakeholders: municipality, designer, developers.



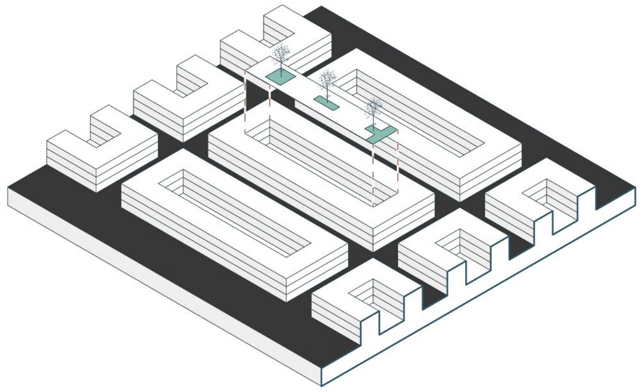
Building Forms

Pocket parks in the courtyards

Creating small semi-public spaces with vegetations in the blocks of courtyard dwellings to provide more shading and less emission in order to improve surrounding outdoor environments.

Small semi-public spaces between buildings or private gardens could be created by 'lending' or 'exchanging' from residents or housing company through rewards. Residents or tenants could get benefits from rewards and plants while vegetations could also contribute to the mitigation of urban heat island.

Stakeholders: municipality, residents, housing companies.



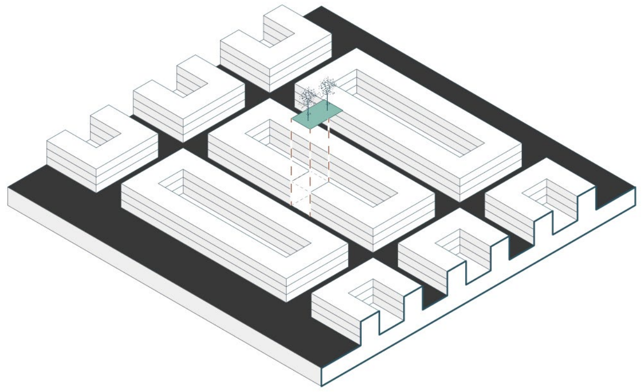
Building Forms

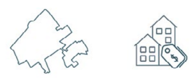
Creating 'cooling haven' by demolition and compensation within blocks

Creating small open spaces with shading from plants and buildings or with better ventilation in the blocks of courtyard dwellings to provide 'cooling haven' for the residents as well as improve surrounding outdoor environments. The spaces could be achieved by demolishing some buildings and compensating with same or more floors on other buildings within blocks.

Considering the ownerships of the buildings in the Netherlands, small open spaces would be easier to be created with the cooperation of housing companies. More storeys or gross floor areas are allowed to be added reasonably by the housing companies on other owned buildings as rewards.

Stakeholders: municipality, housing companies.



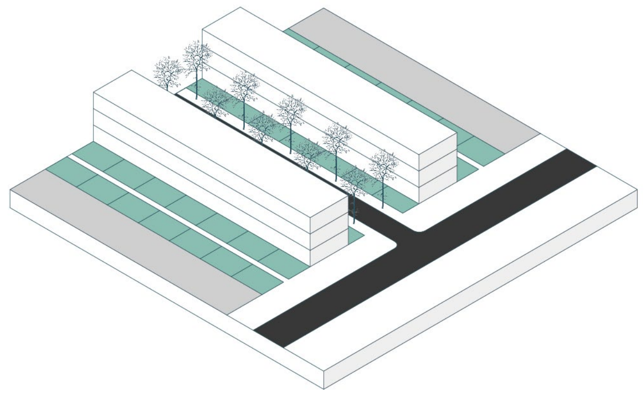


Building Forms

Introducing front green gardens during (re)developments

Front green gardens between buildings and roads can add more vegetations and provide more spaces for trees to grow in urban streets canyon, resulting in better indoor and outdoor environments. The typology of row houses or block courtyard dwellings with front gardens should be introduced for new developments and redevelopments.

Stakeholders: municipality, designer, developers.

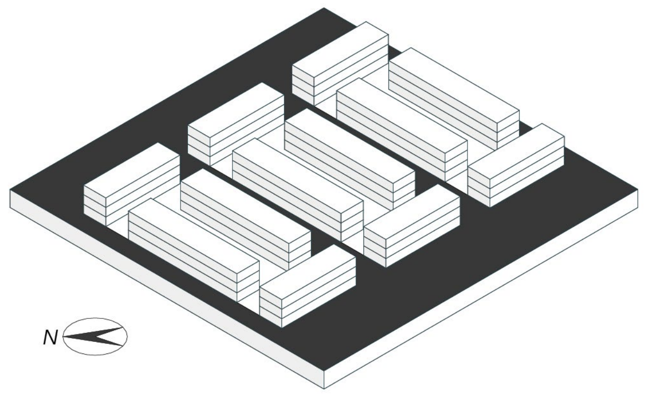


Building Forms

Courtyard block dwellings or row houses with orientation NE-SW should be encouraged

When new developments of courtyard block dwellings or row houses are on the agenda, the building blocks with the long edge paralleled to NE-SW axis should be encouraged when climate change that the summer is getting hotter while winter is getting warmer is taken into account. The buildings with forementioned orientation usually have better outdoor thermal comfort on the streets and in the courtyards in the morning and less solar gain on the facades and inside the rooms during afternoon and sunset.

Stakeholders: municipality, designer, developers.

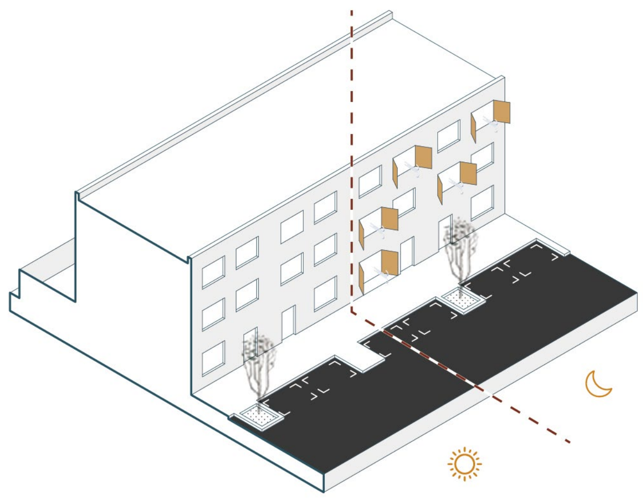


Building Forms

Smart choices of opening & closing windows

The variation of indoor air temperature is usually smaller than that of outdoor air temperature and indoor air temperature is usually higher than surrounding outdoor air temperature in the morning and night. Therefore, smart choice of time to open the window to enhance the ventilation when indoor air temperature is lower is necessary to relief indoor heat stress. Generally speaking the periods before 9:00 or after 19:00 could be the best options to open the windows during hot summer and live weather information could help to make the most rational choice of opening windows.

Stakeholders: residents.

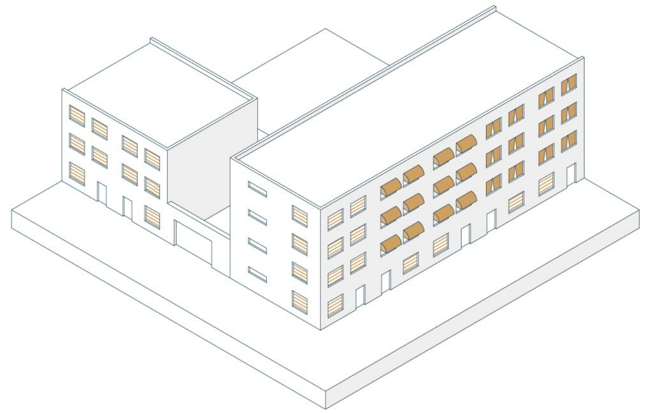


Occupants' Behavior

Preventing interior overheating

Taking measures to prevent over-exposure of interior spaces to the sun could reduce the chance of overheating inside the building on a sunny day in hot summers. Shutters could be the best choices followed by shading devices. Closing curtains could also be a choice if shutters or shading devices are not affordable. Smart facades could also be applied to buildings especially for the buildings with public functions to improve indoor thermal comfort and save energies.

Stakeholders: residents.



Occupants' Behavior

5.2 Urban Microclimate Design

Figure 5.3. Satellite image of selected building clusters.

Source: Produced by author.

Figure 5.4. Location of selected building clusters in the study areas.

Source: Produced by author.

In the part of urban microclimate design, the aim is to introduce how to apply strategies into practice as well as test the effectiveness of the strategies. The building clusters with high risks with regard to building configurations have been selected from the neighborhood Transvaalkwartier (Figure 5.3 & 5.4) and urban design will be introduced from the perspectives of the streets and open spaces respectively to show the possibility of application in public domains. Last but not least, the design of cooling sheds from the distributive justice perspective could offer more choices to the elderly especially the ones with disability or bad health situation.

5.2.1 Urban Design on Neighborhood Streets

The neighborhood streets are the places where the residents usually pay a visit to with high frequencies but short dwell time and the urban settings such as pavements and vegetations are usually influencing not only outdoor thermal comfort during daytime and night but also the indoor thermal comfort with regard to the shading from trees and outdoor air temperature. Therefore, it is necessary to apply spatial interventions on the neighborhood streets.

When it comes to existing urban settings in selected building clusters, all of the neighborhood streets are with the orientation along the NW-SE axis and the street profiles could be concluded into two types named as 'wide street' and 'narrow street', which shows in the following images and diagrams (Figure 5.5 & 5.6). From the middle to the edge of the street along the street canyon axis, the functions and pavements are gray bricks for sidewalks, brown bricks for sidewalks and red bricks for parking spaces and roads in the wide street profile and trees are planted in line with light brown pavements. However, for narrow street the light brown bricks for sidewalks disappears and the trees are growing in line with parking spaces. In the following paragraphs, the analysis and design will be introduced based on the two types of street profiles.

Figure 5.5. Street view of wide street (Wolmaransstraat) and narrow street (Wesselsstraat).

Source: Produced by author.

Figure 5.6. Conceptual plan and section of the current situation of the wide street (left) and narrow street (right).

Source: Produced by author.

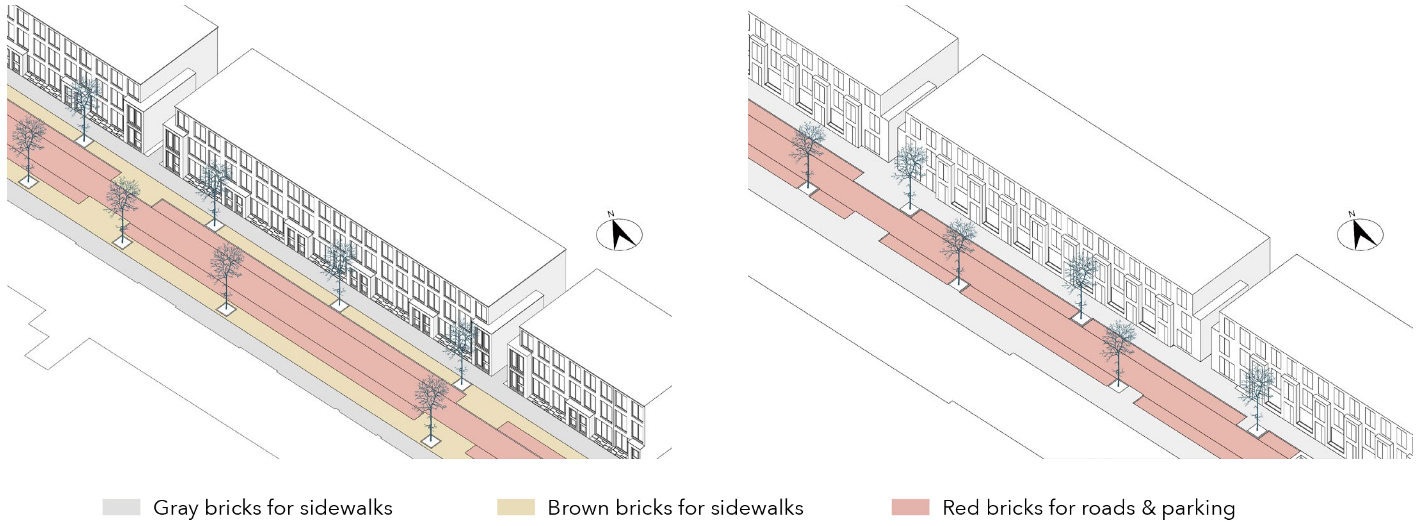


Figure 5.7. Illustration of different functions and pavements within street canyons for wide street and narrow street.

Source: Produced by author.

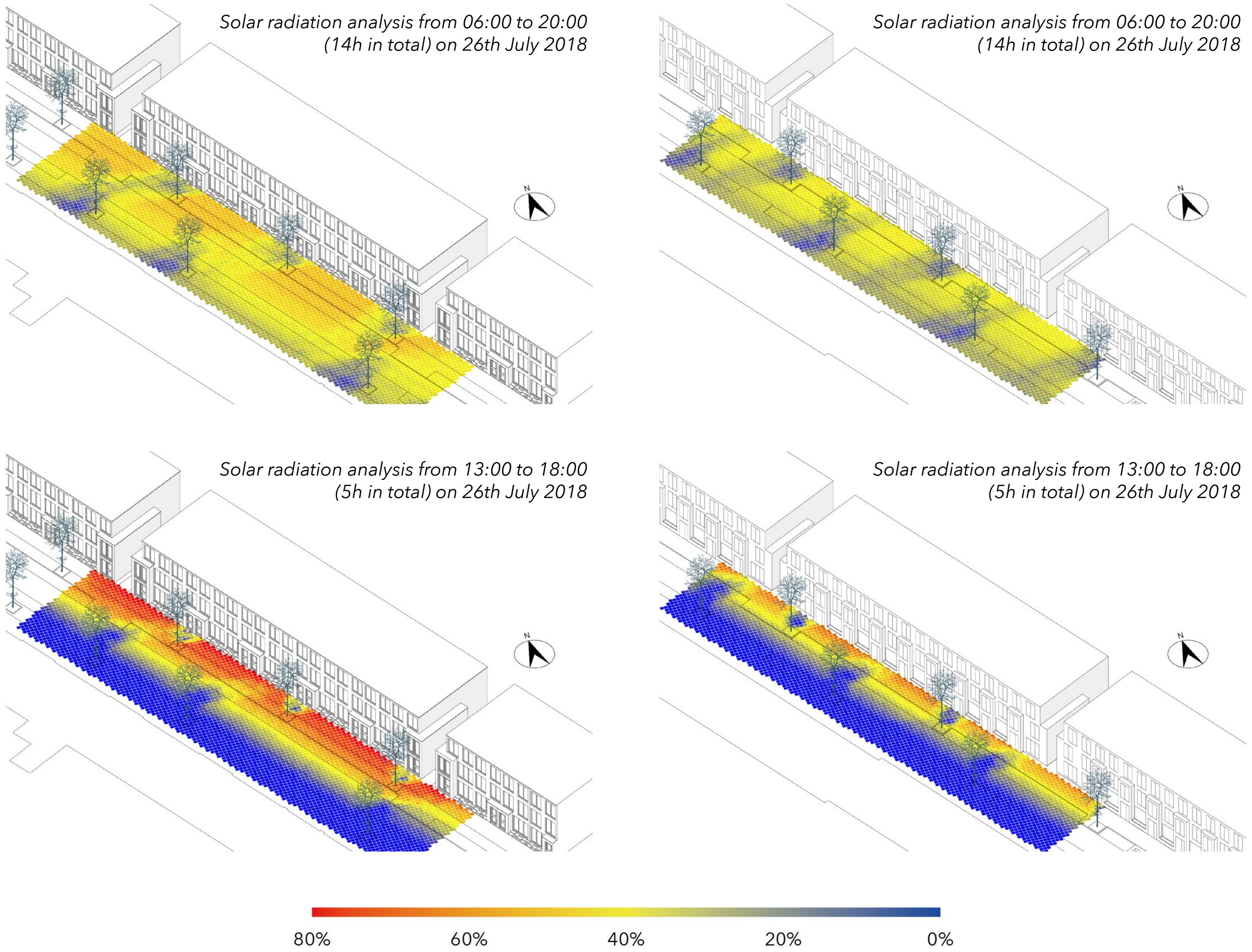


Figure 5.8. Solar radiation analysis on wide street and narrow street during daytime and afternoon respectively.

Source: Produced by author.

Analysis of solar radiation on street profile

The solar radiation on 26th July 2018 has been conducted on the wide street and narrow street from 06:00 to 20:00 (14 hours in total) and from 13:00 to 18:00 respectively. Comparison between the functions (Figure 5.7) and solar radiation analysis (Figure 5.8) illustrates the main difference between solar gain appears in the afternoon and the surface on the wide street gains more radiation on the north-east side of the street. The parking spaces and sidewalks are the places with potentials to be improved to contribute to better outdoor environments. When it comes to the vegetations in the urban street canyon, the effect of trees is quite local and the arrangement of trees is fine with the consideration of the spaces for the roots. Therefore, other spatial interventions are required instead of planting more trees.

Spatial interventions on neighborhood streets

Several factors, including the width of street canyons, the homogeneousness of street profiles, the consideration of finance from municipality and the demands of traveling and parking from the residents, limit the application of considerable interventions for all of the neighborhood streets and it is even hard to pick several streets for totally new redevelopment due to the homogeneousness of street profiles in selected building clusters. Therefore, the strategies 'Replacing pavements with grass on public spaces' and 'Applying grass planting bricks for parking spaces' (Figure 5.9) as well as some small interventions could be one of the best solutions.

The parking spaces and extra pavements for the sidewalks could be the areas for application of the selected strategies since they are more likely exposed to the sun during daytime when residents probably go to other places for work. Changing the pavements of the parking spaces into grass planting bricks with light color could reduce the solar radiation absorption during daytime and heat release during night. Moreover, the extra pavements for the sidewalks on wide street could also be replaced with grass to reduce mean radiant temperature and store storm water (Figure 5.10, 5.11 & 5.12). With the consideration of funds from the municipal sectors, the sidewalks and parking spaces on the north-east side of the street could be considered with high hierarchy for redevelopment.

If there could be more funds from municipality or the concentration of the elderly could be found along one wide street, a new street profile could be introduced to wide street to contribute to the livability on the neighborhood street (Figure 5.11 & 5.12).

The functions of the spaces of the wide street are still following previous ones with roads and parking spaces in the middle and sidewalks at the border. A stripe of grassland could be created on the south-west side of the street between parking spaces and sidewalk by removing extra pavements for sidewalks on both side of the street. Some resting facilities for the elderly such as benches could be placed in the grassland and share the benefits from shading of buildings during the afternoon. More trees could be planted on the grassland and storm water could also be stored in the soil to benefit the growth of trees. An extra layer created by canvas sheets on the north-east side of the street can protect the pedestrians from overexposure to the sun. The pavements of the sidewalks and roads could still be remained for them for sustainability and grass planting bricks should be applied to parking spaces (Figure 5.11 & 5.12).

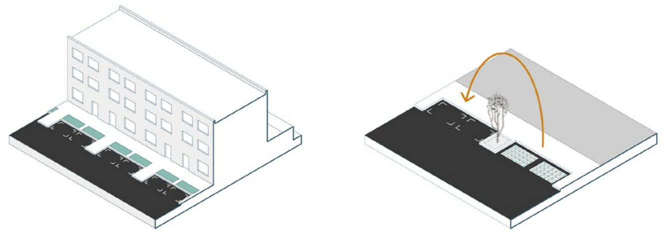
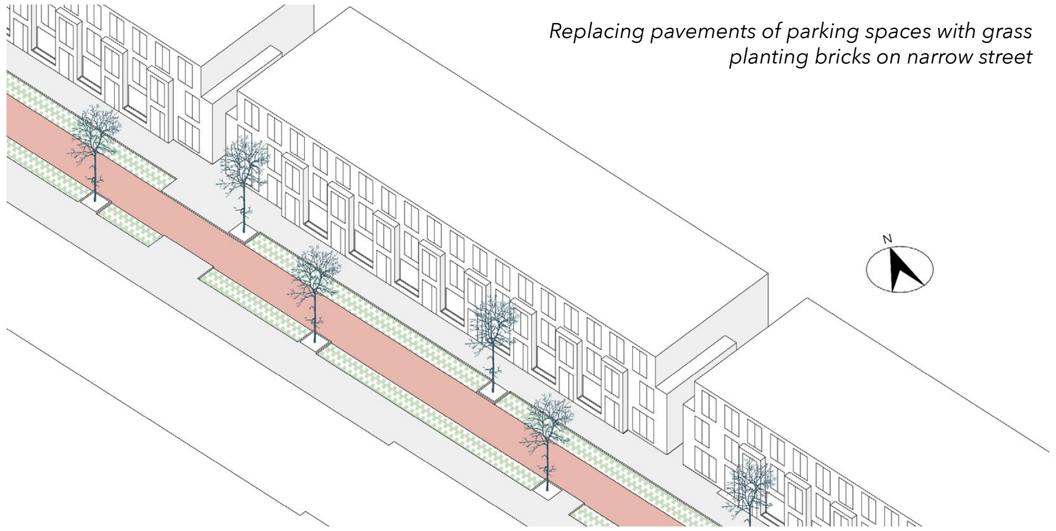


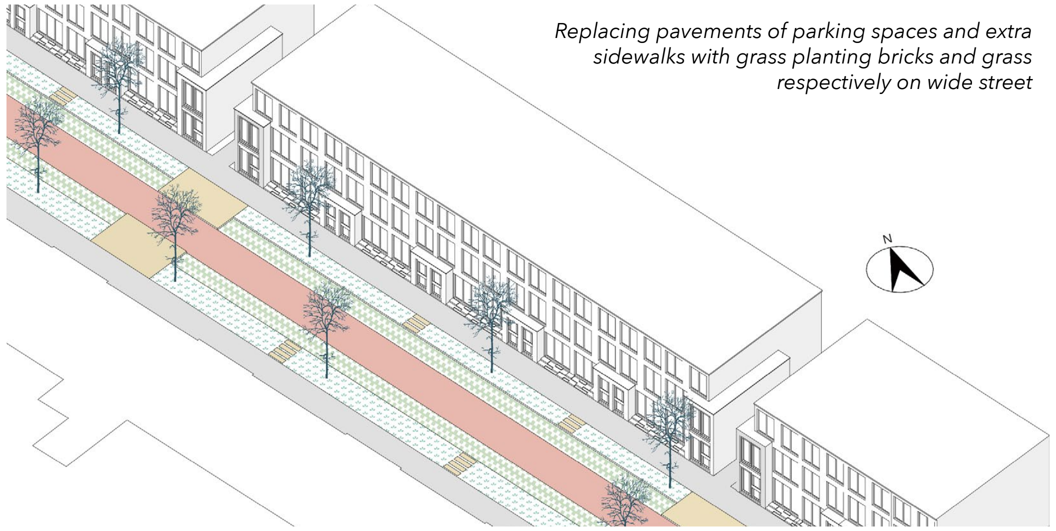
Figure 5.9. Selected strategies for spatial interventions on neighborhood streets.

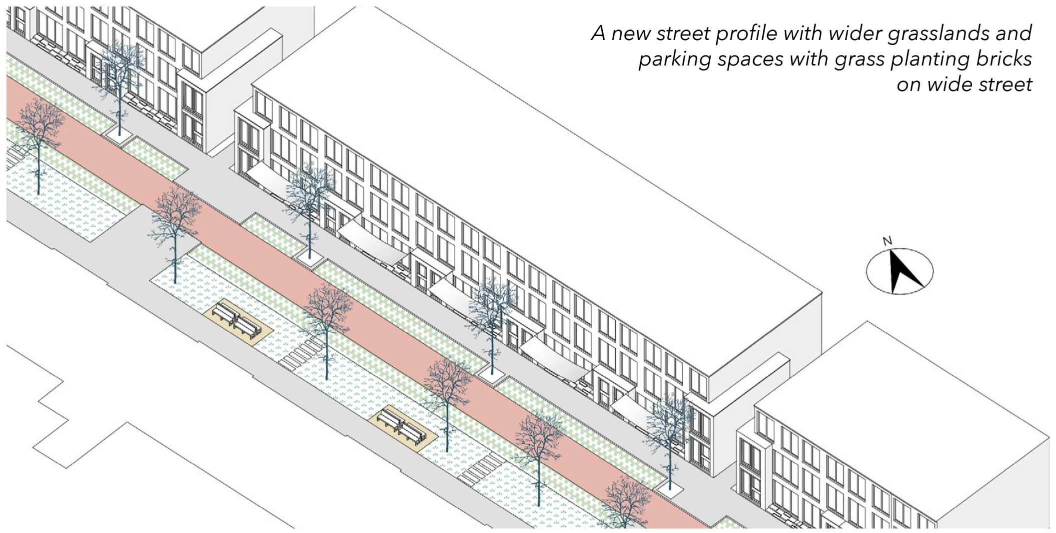
Source: Produced by author.

Figure 5.10. Grass planting bricks.

Source: Produced by author.







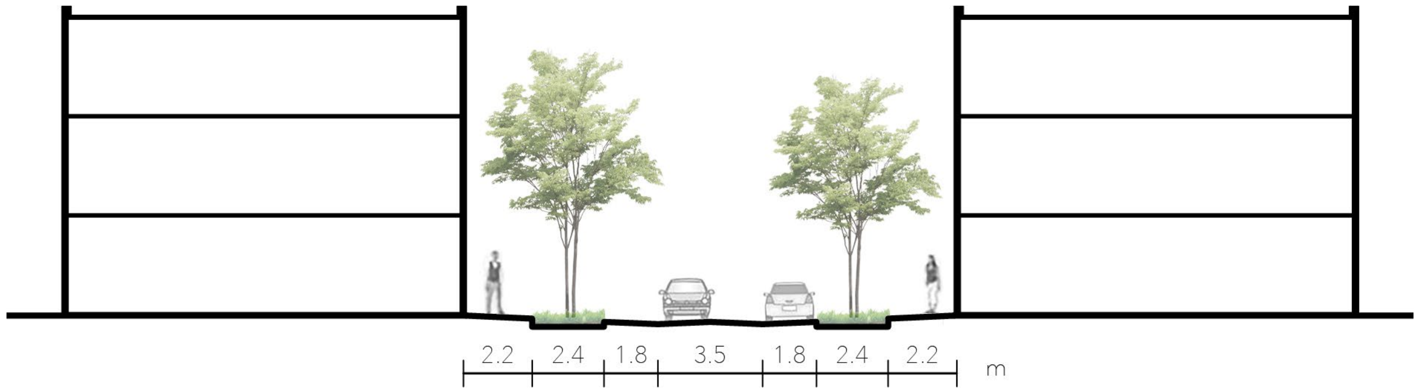
Legend — Grass planting bricks — Grass

Figure 5.11. Interventions on the street profiles of 'narrow street' and 'wide street'.

Source: Produced by author.

Replacing pavements of parking spaces with grass planting bricks on narrow street

Replacing pavements of parking spaces and extra sidewalks with grass planting bricks and grass respectively on wide street



A new street profile with wider grasslands and parking spaces with grass planting bricks on wide street

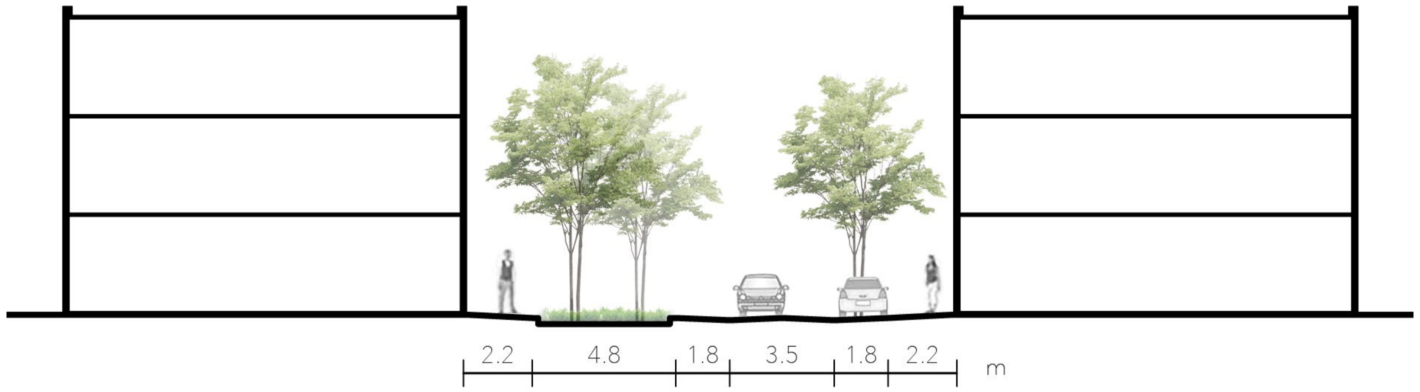


Figure 5.12. Sections of the street profiles of the 'narrow street' and 'wide street'.

Source: Produced by author.

5.2.2 Urban Design on Open Spaces

Open spaces in the neighborhoods are another places which are more likely used by the elderly during daytime. They could spend some time in open spaces talking with others or just having a rest. When it comes to the open spaces inside selected building clusters, there are two neighborhood squares which are Kaapseplein and Stellenboschplein (Figure 5.13). The square Kaapseplein are designed for the kids and teenagers with some facilities for playing and sports and it is obvious that there are several trees with large crowns, which have positive effect on microclimate. However, the square Stellenboschplein looks less green compared with Kaapseplein and there is no activities designed in the square Stellenboschplein. Moreover, the square Stellenboschplein is also the one which is closer to the Haagse Markt. Therefore, the assumption has been made that the elderly would pay a visit to the square Stellenboschplein more frequently than Kaapseplein since it is quiet and close to the Haagse Markt as well.

When looking into the square Stellenboschplein, the ideas behind the design could be interpreted as an open space with red bricks for free activities and surrounding sidewalks with gray bricks for passing pedestrians (Figure 5.14). People in the square Stellenboschplein will either walk along or across the square or stay inside the square (Figure 5.15). From the perspectives of microclimate, the elements such as vegetation and water are hard to find in the square. The trees are planting in a row along the wide sidewalks and a large terrace with the shape of circle are the places where some small trees and bushed are growing. However, over half of the pavements in the square or along the sidewalks will be exposed to the sun, which is not acceptable during hot summers with regard to thermal comfort. Therefore, urban microclimate design is necessary for the square Stellenboschplein.

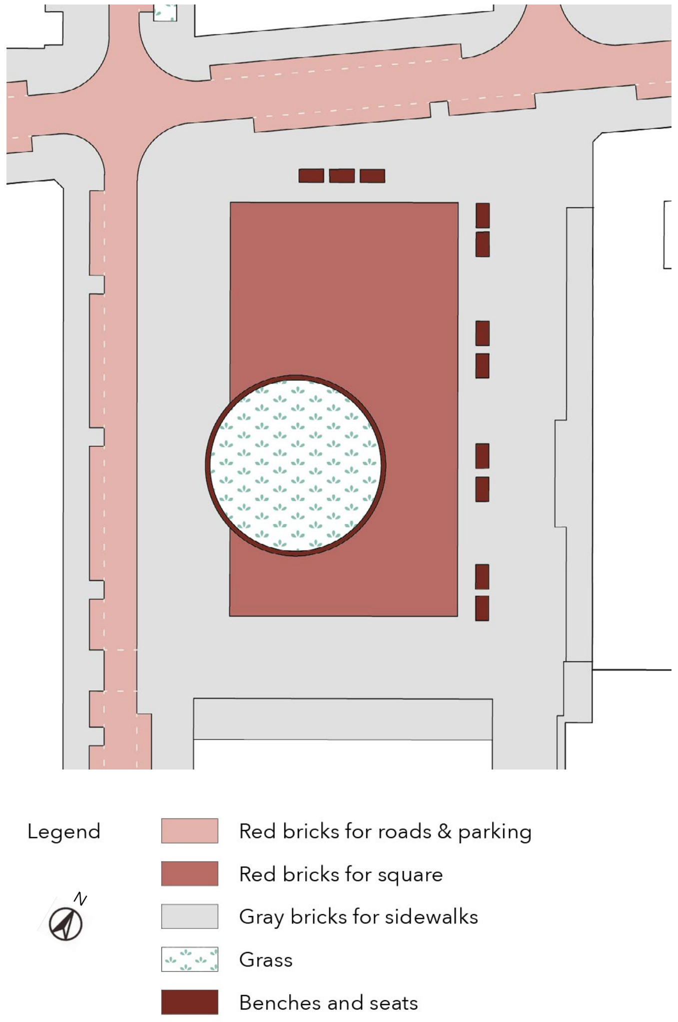


Figure 5.14. Functions and pavements in Stellenboschplein.

Source: Produced by author.

Figure 5.13. Satellite images of two neighborhood squares.

Source: Google Map.

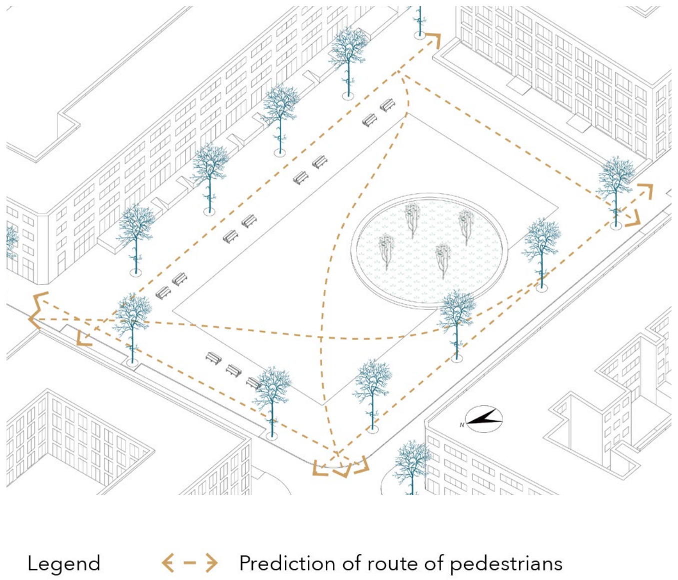


Figure 5.15. Interpretation of pedestrians routes in Stellenboschplein.

Source: Produced by author.

Figure 5.16. Plan of redevelopment of Stellenboschplein.

Source: Produced by author.

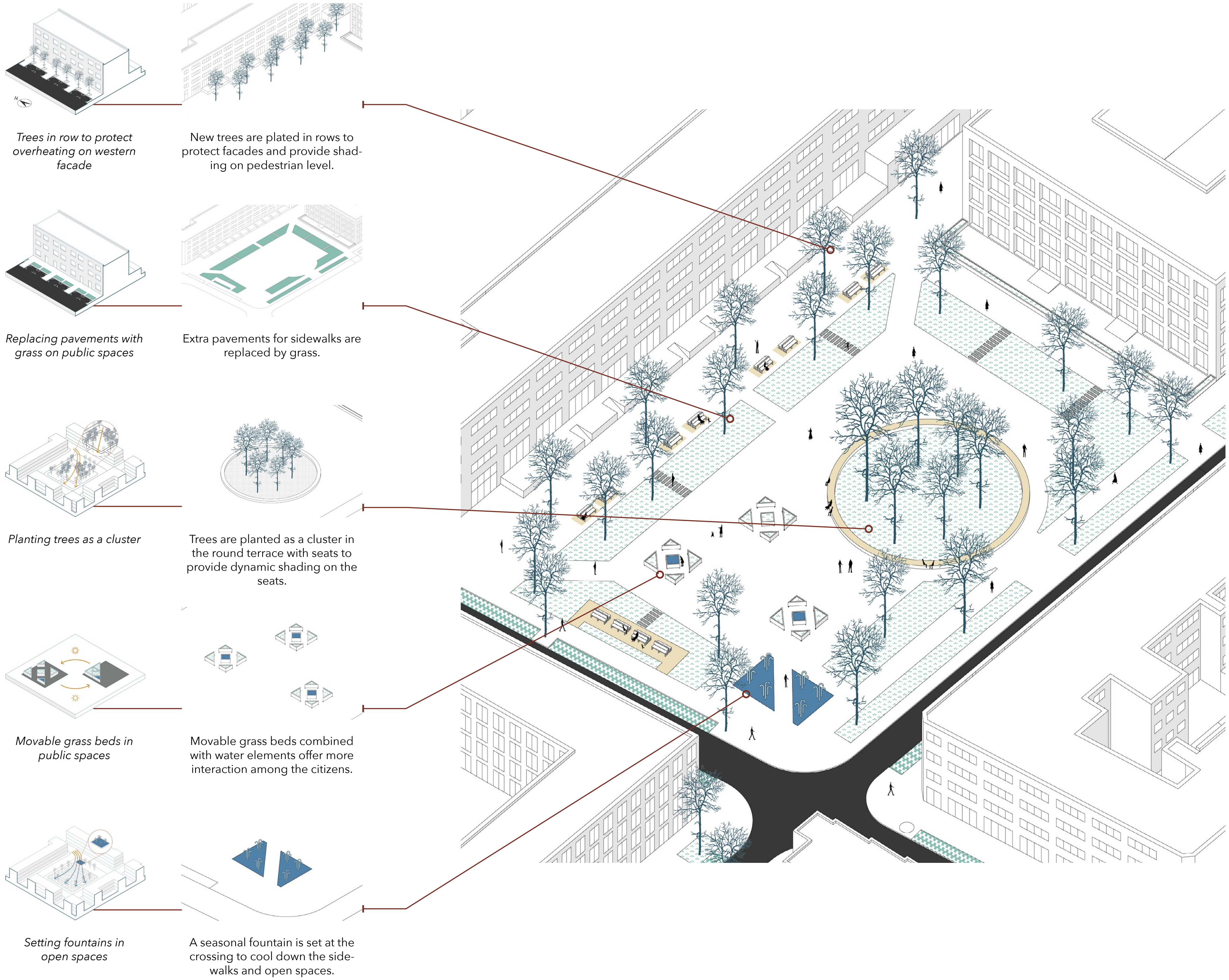


Figure 5.17. Axonometric drawing of redevelopment of Stellenboschplein with the explanation of the selected strategies and application in urban design.

Source: Produced by author.

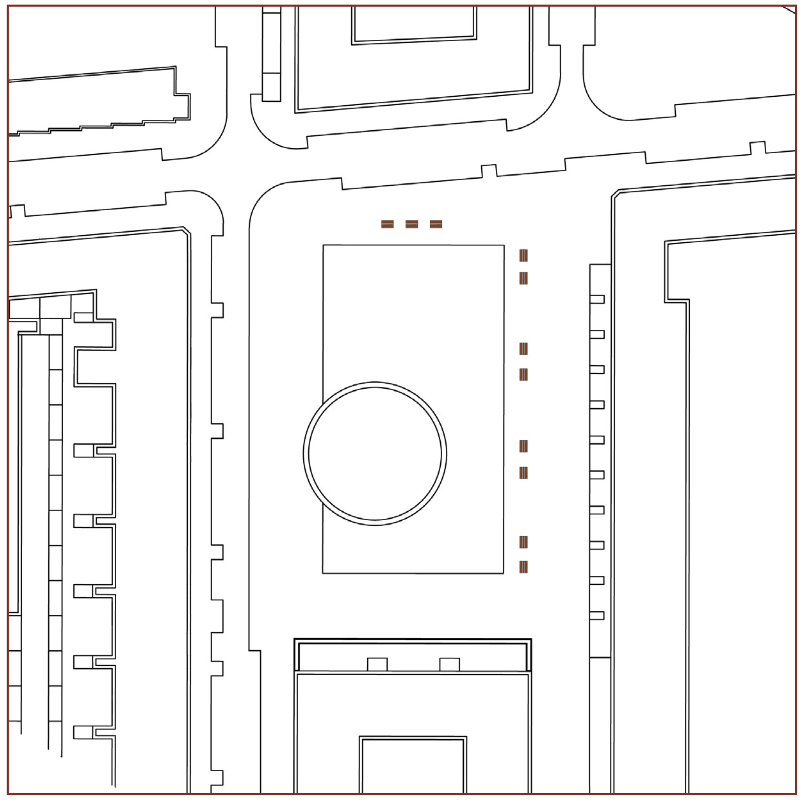
In order to improve the outdoor thermal comfort in the square and protect surrounding western facades from overheating, five strategies which are 'Trees in row to protect overheating on western facade', 'Replacing pavements with grass on public spaces', 'Planting trees as a cluster', 'Movable grass beds in public spaces' as well as 'Setting fountains in open spaces' have been applied into the redevelopment of the square Stellenboschplein (Figure 5.17). More green and blue elements will be added to the square with regard to grass, trees and fountain, which will not only improve the outdoor thermal performance but also contribute to the aesthetics and psychological cooling effect. Large areas of grassland could absorb and store storm water which could further irrigate grass and trees. The water used by fountain could also be collected from surrounding buildings to make a resilient neighborhood (Figure 5.16 & 5.17).

The initial idea behind the urban microclimate design is to redevelop the square with several small spatial interventions and try to keep and enrich the activities inside the open spaces instead of the introduction of a totally new design. The reuse of the material as well as less input materials could also be taken into account such as most of the red bricks for the square will be reused for the square in order to contribute to the sustainability. The reuse of materials and less new materials will also reduce the budget for the redevelopment and the replacement of the pavements could be achieved through maintenance of underground pipes or cables. However, the planting of trees should be put on the schedule as soon as possible since the effect of trees should be expected after decades.

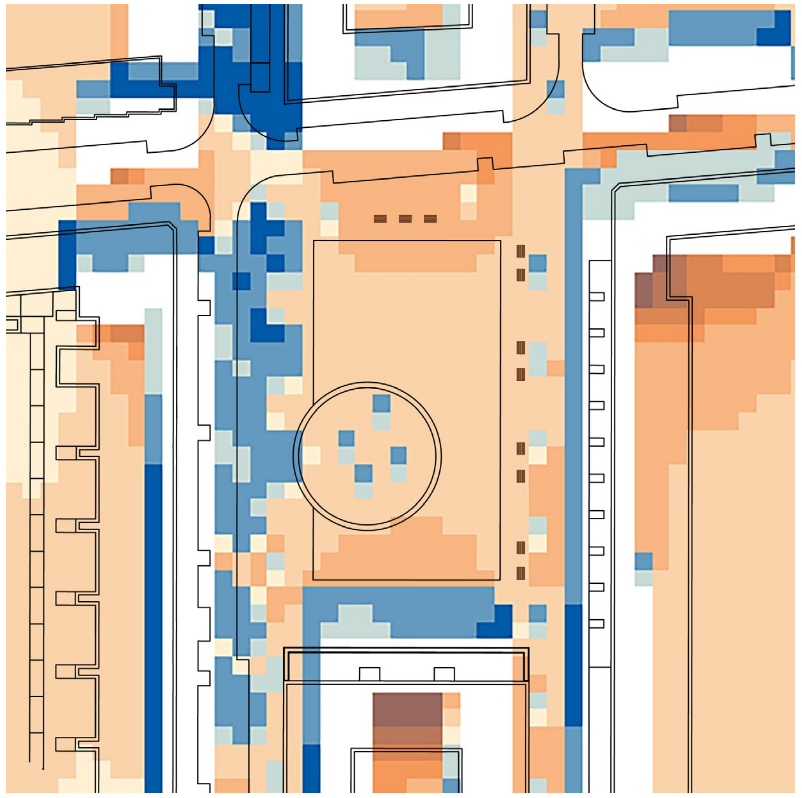
The design outcome has been tested by ENVI_MET with 'Intermediate level' (Appendix VII) and same parameters in 'The Effect of Vegetation on Microclimate' and the results on 11:00 and 14:00h have been illustrated by LEONARDO (Figure 5.18). The comparison between the physiological equivalent temperature (PET) on the open space and inside the courtyards illustrates that the thermal comfort is better on the open space due to higher wind speed although both of them will exceed comfort range during the daytime. When it comes to the effectiveness of design outcome, the difference around 10 Celsius degree in term of PET could be discovered under the shading of trees where seats and sidewalks are located, showing the large contribution of the trees on better thermal comfort.

With regard to the breakout of corona virus, the social distance of 1.5 meters in the Netherlands is also challenging the urban design. Although the benches have been set with distance over 1.5 meters, each bench will become one seat for social distance. Therefore, the flexibility should also be considered during the design process. In the redevelopment of Stellenboschplein, large areas of open spaces designed for free activities have been created under the shading of the trees for citizens to keep a proper distance when enjoying the cooling effect from trees.

Current plan



26th July 2018 - 11:00



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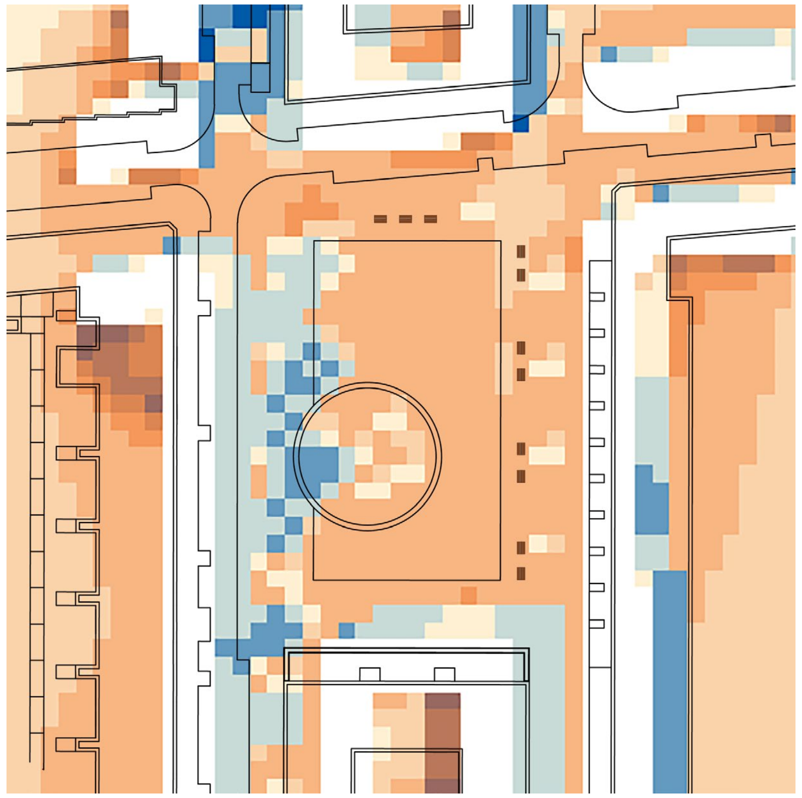
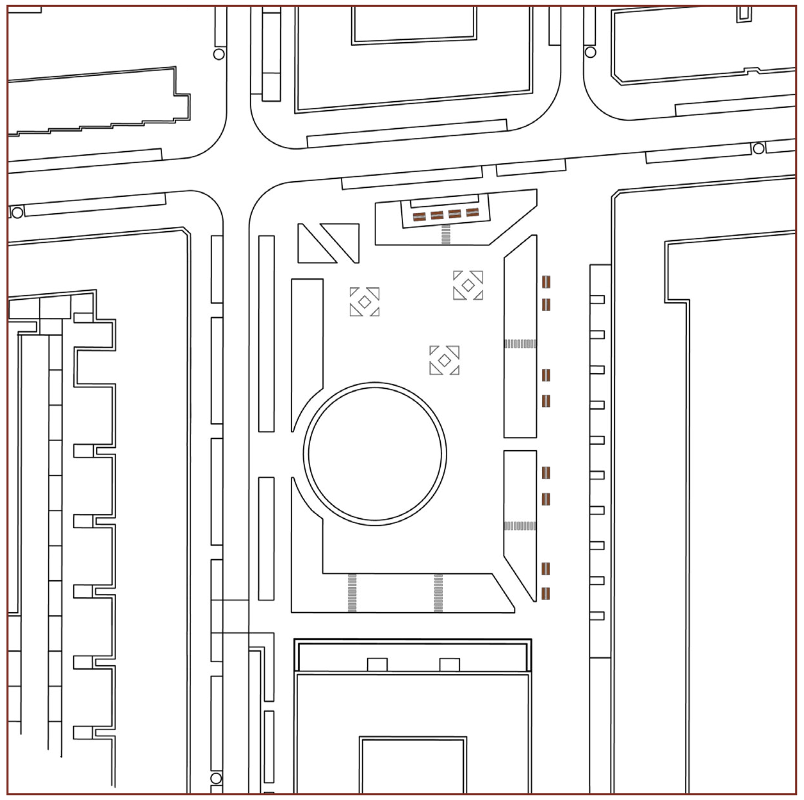


Plan after intervention



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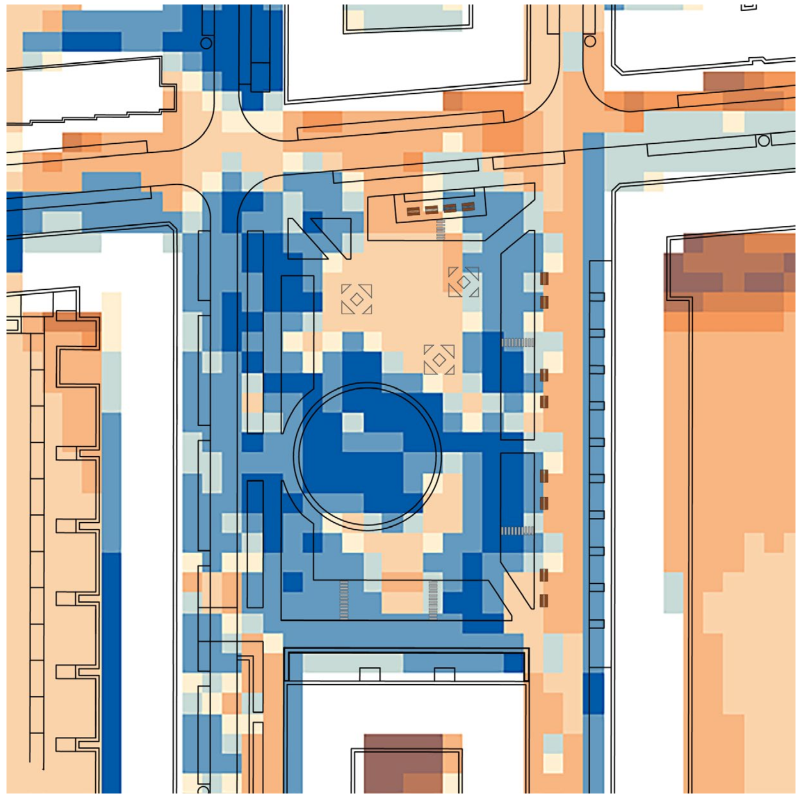

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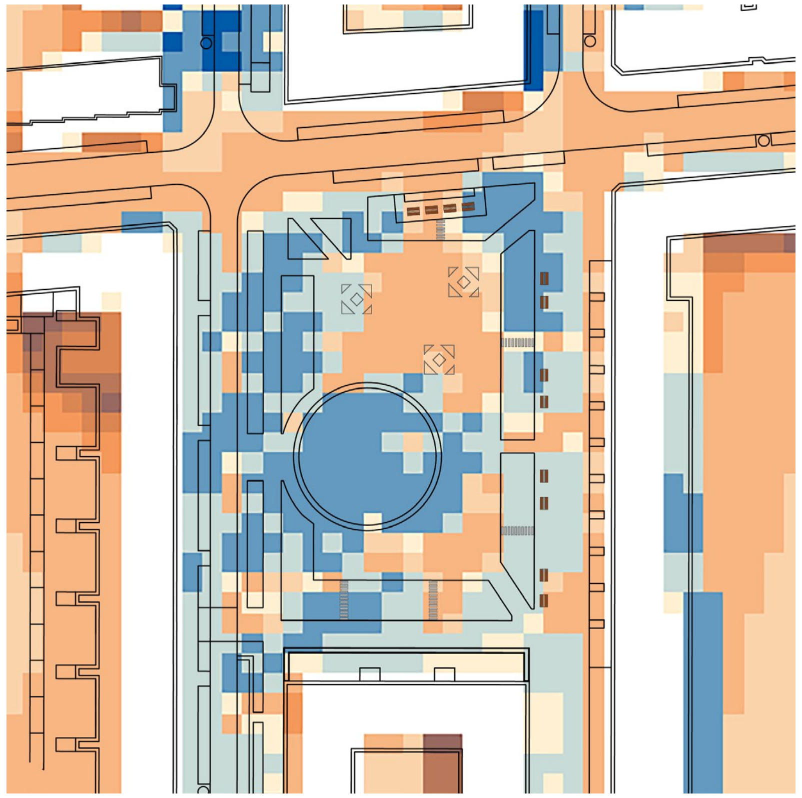


PET

below 36.00 °C
36.00 - 39.00 °C
39.00 - 42.00 °C
42.00 - 45.00 °C
45.00 - 48.00 °C
48.00 - 51.00 °C
51.00 - 54.00 °C
54.00 - 57.00 °C
57.00 - 60.00 °C
above 60.00 °C

Figure 5.18. Comparison of the PET values between the Stellenboschplein before intervention and after intervention.

Source: Produced by author.

5.3 Designing Cooling Sheds

Inspired by temporal measures to improve outdoor environments such as canvas sheets and the project 'City Cell Prototype' by Next Institute (Figure 5.19), a structure that can be movable and easy to fit in various locations could also be a choice to protect the elderly from extra heat during hot summers and heat waves and the design of 'cooling sheds' just comes to the mind.

Not only the open spaces but also the neighborhood streets will be used by the elderly and the initial ideas of 'cooling sheds' are that they could be placed both in open spaces and neighborhood street. However, the spaces in the neighborhood streets are limited and the place on the sidewalks are next to the buildings which will probably cause privacy intrusion. Therefore, the parking spaces could be the best locations for the 'cooling sheds'. The width of parking spaces along the neighborhood street is usually 1.8 meters so the width of the 'cooling sheds' are also designed as 1.8 meters. In order to offer more possibilities for the application of the 'cooling sheds', the ideas of modularity have been introduced to the 'cooling sheds'. The basic model is designed as a square with the size of 0.9x0.9 meter and six of the basic models could occupy half of the parking space for one car (Figure 5.20). Eight kinds of models with different functions have been introduced (Table 5.1 & Figure 5.21).

The diagrams show two of the possible assemble of 'cooling sheds' and how they look like on the neighborhood streets as a heat refuges (Figure 5.22 & 5.23). The consideration of the demands from the elderly has been applied in the design of each model from the distributive justice. The 'cooling sheds' could not only provide cool environments inside it but also improving surrounding areas through shading and evapotranspiration. The 'cooling sheds' could also be assembled with more models and placed in open spaces as temporal measures during continuous hot weathers.

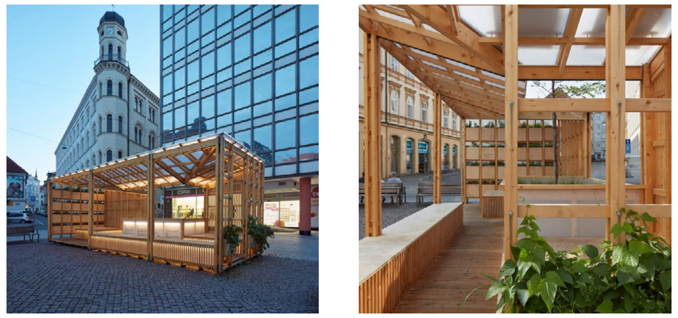


Figure 5.19. City Cell Prototype by NEXT Institute .

Source: https://www.gooood.cn/city-cell-prototype-by-next-institute.htm?lang=cn.

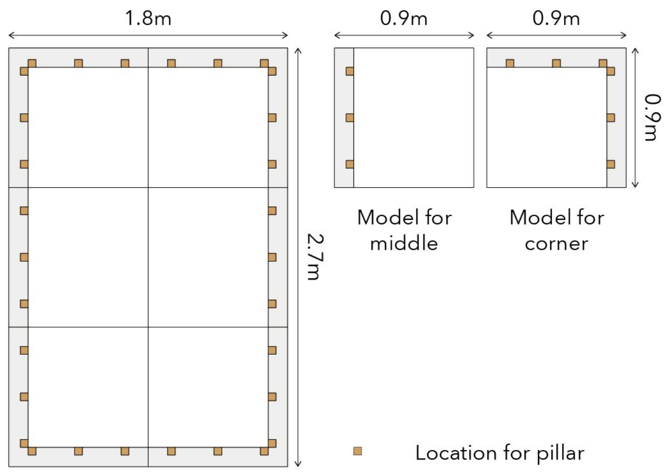


Figure 5.20. Basic models of 'Cooling sheds'.

Source: Produced by author.

Model NO.	Name	Description
A	Flexible seats inside	Flexible seats assembled in the 'cooling sheds'
B	Flexible seats outside	Flexible seats assembled out of the 'cooling sheds'
C	Backrest	Backrest for people to lay again to have a rest inside Flexible seats assembled in the 'cooling sheds'
D	Handle	Handle for the elderly to support themselves to have a rest out of the 'cooling sheds'
E	Solar panels	Solar panels on the top of the 'cooling sheds' to generate electricity for equipments
F	Green wall	Green wall placed out of the 'cooling sheds' to improve outdoor environments and provide shading
G	Water mist fan	Water mist fan generate water mists and increase wind speed to consume latent heat
H	Solar fence	Solar fence to provide shading but not block wind or vision

Table 5.1. Introductions of each model for 'Cooling sheds'.

Source: Produced by author.

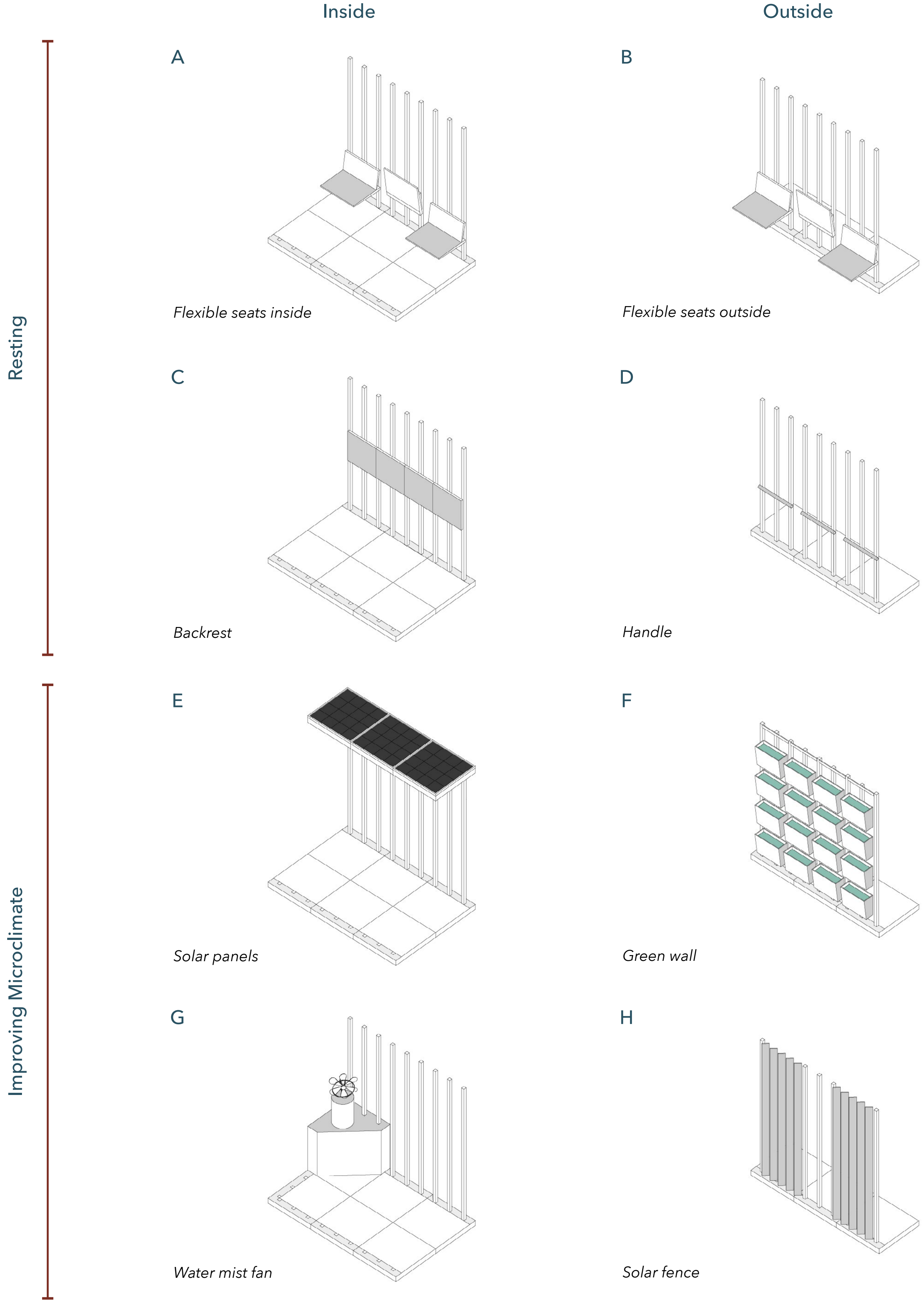
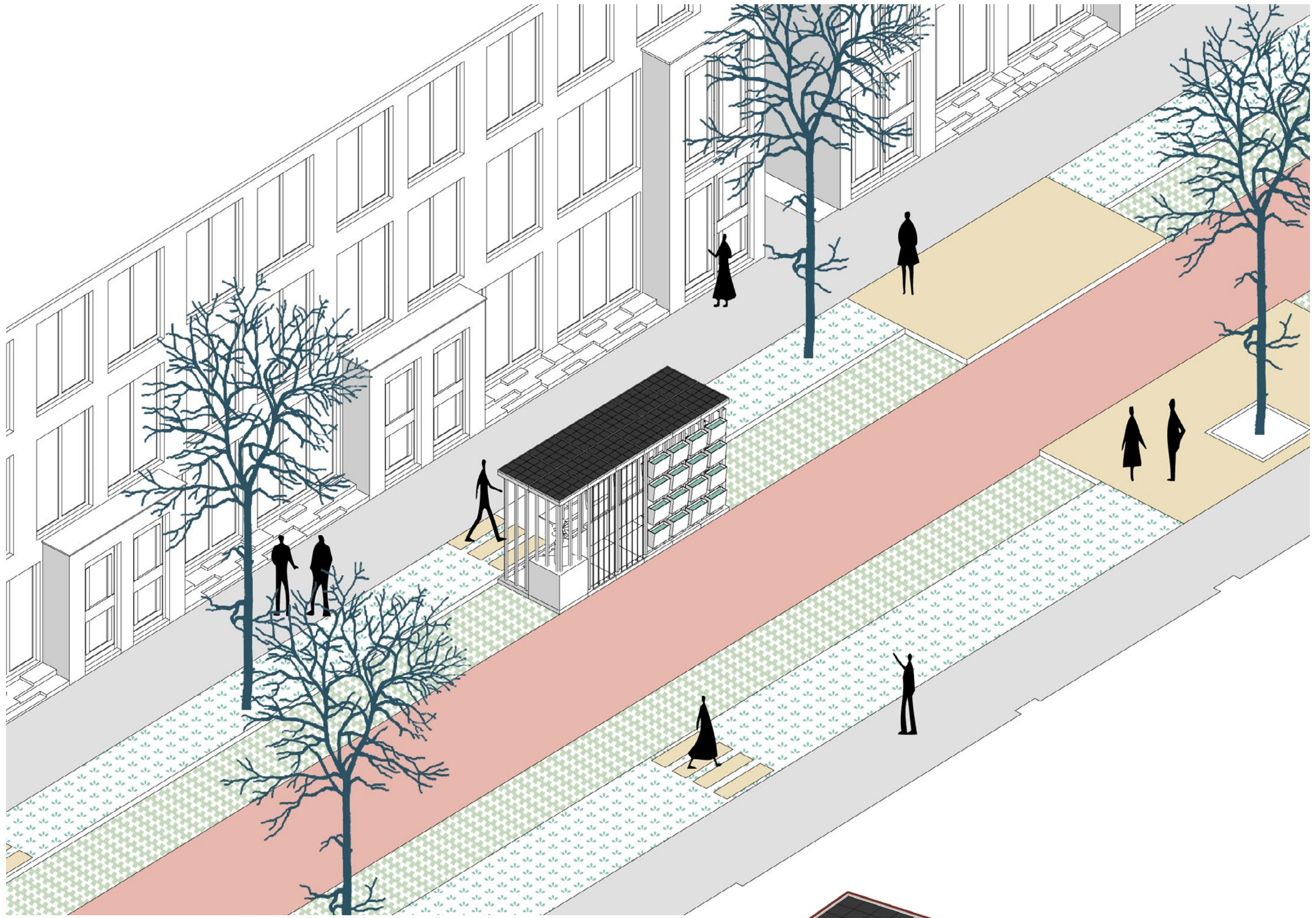
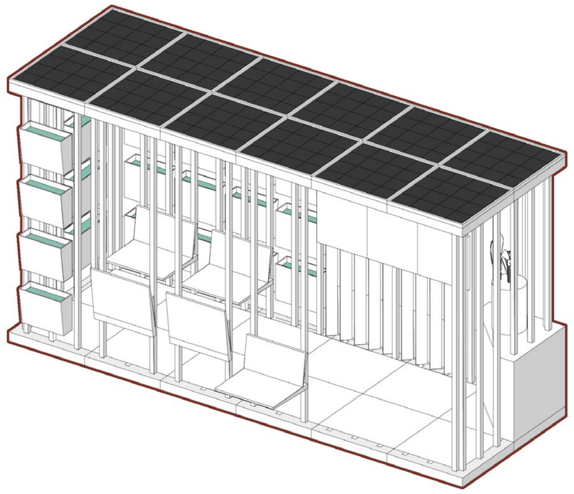


Figure 5.21. Different models of the 'cooling sheds'.

Source: Produced by author.

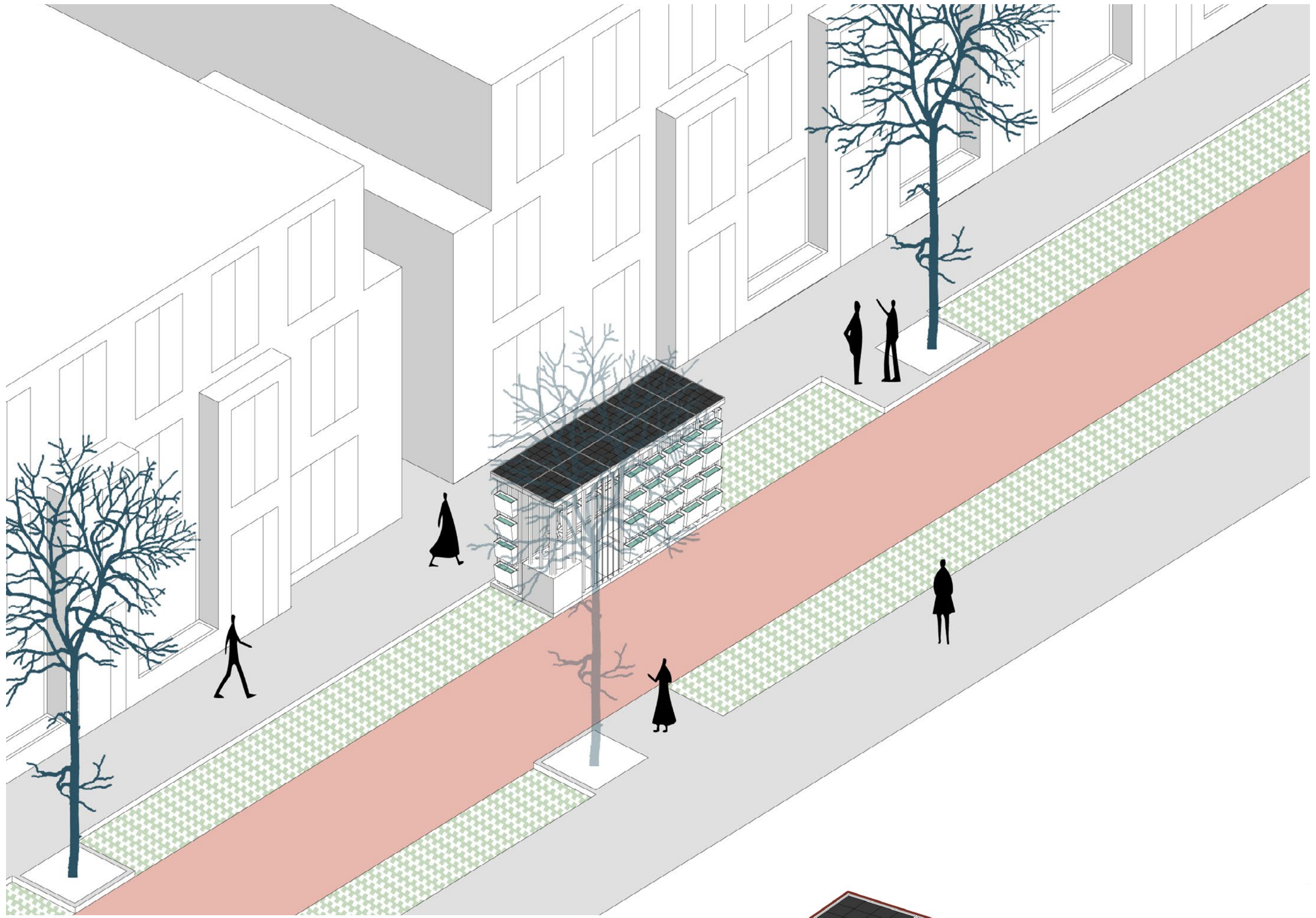


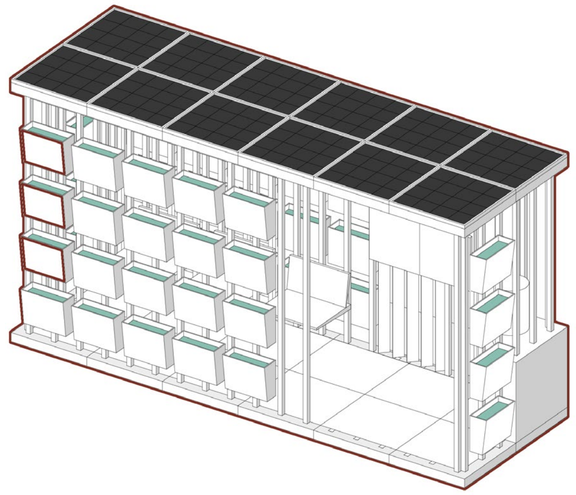


The 'Cooling sheds' with more openness could be placed on the parking space of the 'wide street' next to the stripe of grasslands to offer more interaction between the people inside and outside of the 'Cooling sheds'.

Figure 5.22. Relatively open 'Cooling sheds' on the 'wide street'.

Source: Produced by author.





The 'Cooling sheds' with less openness could be placed on the parking space of the 'narrow street' and shapes a relatively cooler atmosphere inside the 'Cooling sheds'. The vegetations on the 'Cooling sheds' could also help to add the element of plants on the street.

Figure 5.23. Relatively closed 'Cooling shed's on the 'narrow street'.

Source: Produced by author.

5.4 Conclusion

To conclude for the chapter 'Design', the strategies from microclimate perspective, urban microclimate design on the neighborhood streets and open spaces as well as designing of 'Cooling sheds' have been introduced and the effectiveness of the design outcome on the open spaces has been tested by ENVI_MET. The combination of strategies and application of 'Cooling sheds' could help to reduce the heat stress among the public and more consideration has been focused on the elderly.

The overall effect of the urban microclimate design could be expected through urban design on the neighborhood streets and open spaces, designing of 'Cooling haven' inside the blocks as well as the application of 'Cooling sheds' on the neighborhood streets, which could form a net work on different scale in different time to reduce the heat stress both in indoor and outdoor spaces (Figure 5.24). Vegetations, especially large trees, have the most positive effect on indoor and outdoor thermal comfort through consuming latent heat and providing shading on the facades or grounds. Therefore, how to plant more trees and provide better environment for trees to grow should be considered as higher hierarchy for the interventions from microclimate perspectives in the courtyards, neighborhood streets as well as open spaces. Another effective approach is to replace pavements with vegetations or water as much as possible to reduce the heat stored within the street canyon. These two approaches could help to mitigate urban heat island to a great extent in a long term and combining the long term approaches with temporal interventions could reduce the heat risks not only in coming few years but also in the distant future.

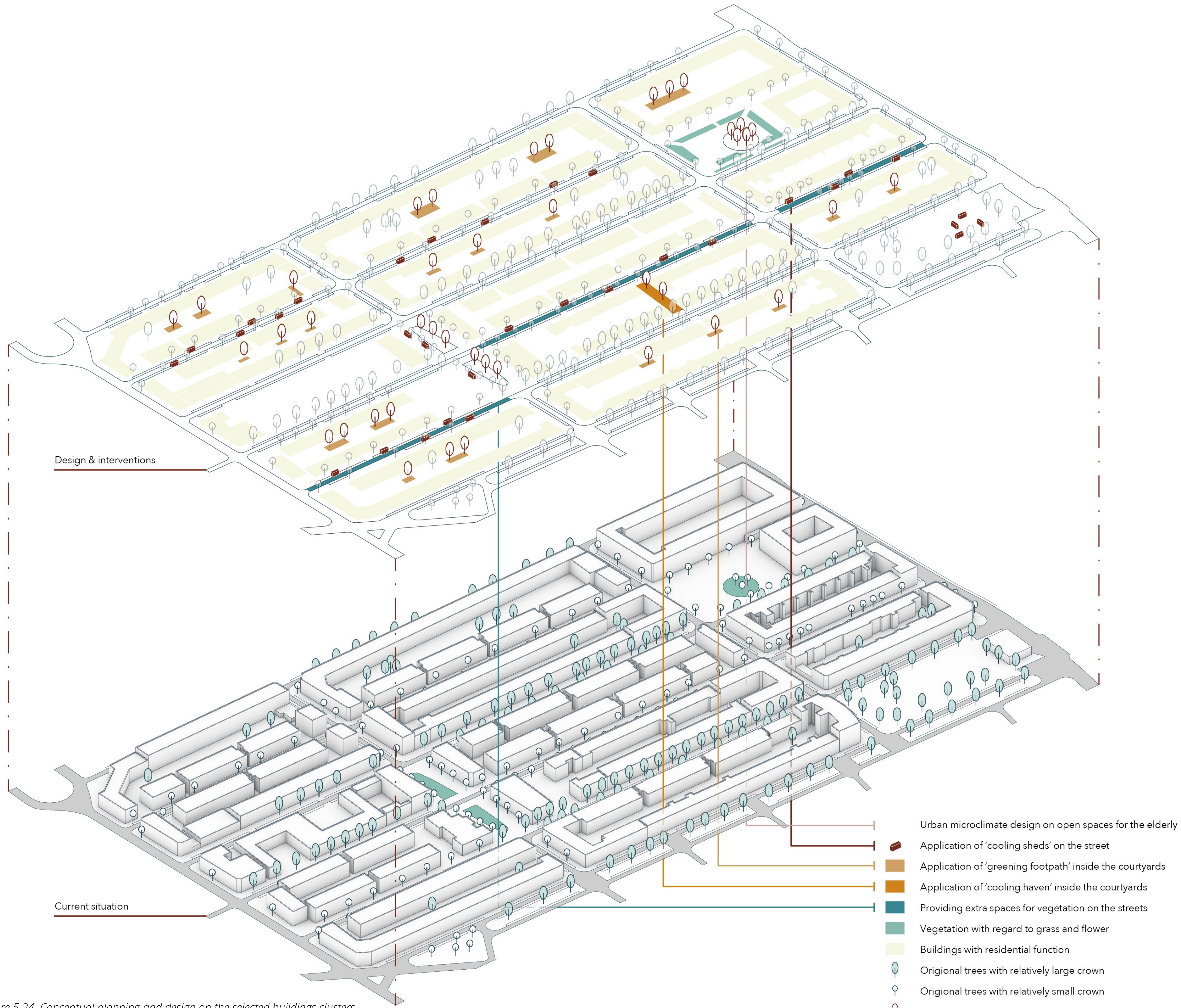


Figure 5.24. Conceptual planning and design on the selected buildings clusters .

Source: Produced by author.

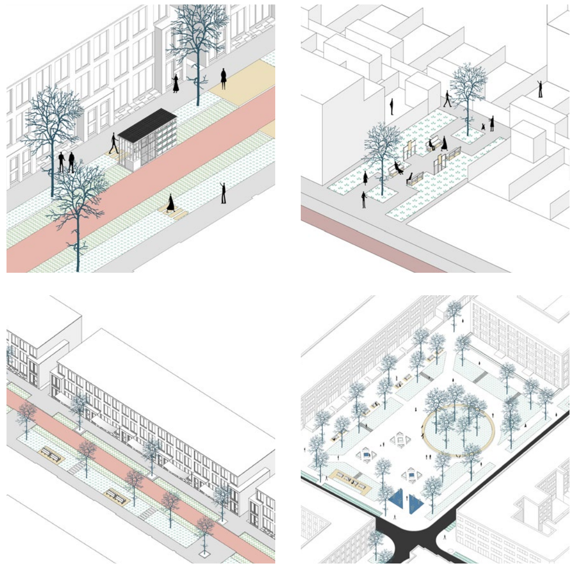


Figure. Redevelopment of Stellenboschplein.

Source: Produced by author.

6 CONCLUSION

The chapter 'Conclusion' consists of conclusion and reflections. The research questions have been answered first and some reflections with regard to research approaches and relevance have been discussed.

- Conclusion
- Reflections

6.1 Conclusion

Global warming and climate changing are placing challenge and pressure to the whole public with regard to more and more extreme weather conditions such as heat wave and intensive storms. Heat waves, which are continuous hot weathers, not only change the behavior of the citizens but also increase the heat risks among the public and millions of economic losses. The thesis has taken the elderly who are proven to be one of the vulnerable groups against heat waves as the starting point and tried to seek for strategies and interventions to reduce the heat risks for the Dutch elderly through urban design process using The Hague as the test field. The research question is:

How could urban design reduce heat stress for the elderly in the Netherlands?

The research question looks simply but challenging as well. Urban design always depends on the situations in the sites so it is relatively harder to apply somewhere else. Then how to introduce urban design which could be applied in the Netherlands to fill in the knowledge gap between public health interventions and urban planning interventions is worth thinking and discussing.

Through the research in The Hague, the places which have been urbanized around 1930s have been discovered as the areas where people are more likely to suffer from heat stress during persistent hot weathers. The typology courtyard block dwellings is common in these areas with relatively higher ground floor index and lower leaf area index and dark-colored roofs as well as large windows also increase the susceptibility on household level. The streets are always occupied by parking spaces and vegetations are hard to witness. The situation will become worse for both indoor and outdoor thermal comfort if the trees are short with small crowns and most of the hard pavements and building facades are directly exposed to the sun, just like the situation in the selected neighborhoods in the thesis. Moreover, the concentration of the vulnerable groups in the 'hot' areas such as the elderly and the people with poor health conditions will also increase the individual susceptibility and place the challenge to the governments and health institutions.

In order to reduce the heat risks among the public and protect the elderly from potential heat stress through urban design in existing urban fabrics, the research of the outdoor thermal performance of courtyard block dwellings, the effect of vegetations as well as the prevailing wind during heat eaves has been conducted and the several ideas of interventions within the block of courtyard buildings have been tested to be effective. The results from the research and tests as well as the empirical knowledge from literatures have been concluded as the strategies that could be applied on various scales and in different times with regard to instructions for urban design in a long term and temporal spatial interventions during persistent hot weathers. Urban design follows the instructions from forementioned strategies and the designing of cooling sheds offers another option to reduce the heat stress for the elderly in the public spaces.

In the following paragraphs, the answers to the sub-questions have been discussed in order to deliver more details and explanation to the readers.

1. How did heat waves influence the life of the public and the elderly respectively?

Through the literature review, the impact of heat waves on the public could be divided into three aspects which are heat-related mortality, morbidity and symptoms respectively and the elderly have been proved to be one of the vulnerable groups to the persistent hot weathers. Both of the mortality and morbidity increase significantly during heat waves in the Netherlands and surrounding countries and the interaction between consisting hot weathers and accompanying air pollution has also been discovered, which will further increase the risks of mortality and morbidity among the public. The adaption and preparation of the public against heat waves could be found in the past few years by comparing the reported death numbers in the Netherlands but it is hard to find some clues among the morbidity due to privacy and the scenario against heat waves and global warming for the future is questionable.

When it comes to the individual level of perceiving extra heat and heat-related symptoms, it is hard to draw some conclusions because of the limitation of data but most of the investigated people have reported perception of heat and could take some proper measures. However, because of some intrinsic factors among the elderly such as less sensitive thermal perception and social segregation they are more vulnerable to heat stress and more attention should be focused on them.

2. What are the reasons that cause uneven distribution of the heat risks among the public or the elderly in The Hague?

Through the research in the thesis and the knowledge from literatures, the factors that cause the uneven distribution of heat risks among the public could be concluded as two aspects which are intrinsic factors and extrinsic factors respectively. The extrinsic factors of urban heat risks in the thesis refer to the characteristics of the existing urban settings such as large windows and dark-colored roofs on building scale as well as less vegetation and more hard pavements on neighborhood scale while the intrinsic factors vary among each individual in terms of income level, culture, education level, health situation and so on.

The selected neighborhoods Schildersbuurt and Transvaalkwartier, which are redeveloped following previous structures with linear blocks and narrow neighborhood streets, are representative with high ground floor index and low leaf area index. In other words, most of the spaces in the study areas are occupied by buildings and infrastructures and less spaces have been left for vegetations in public domain. The private gardens inside the courtyards have been also occupied by small sheds and hard pavements and all of the forementioned elements combined with dark-colored roofs and large windows consist of the extrinsic factors that cause the uneven distribution of heat risks in The Hague.

When it comes to intrinsic factors, they refer broadly to the physical condition of individuals and age is at the forefront among the susceptible explanatory variables of unequal risk distribution (Fernandez Milan & Creutzig, 2015). The elderly who are living at their own homes have been above average in the study areas and the health situation

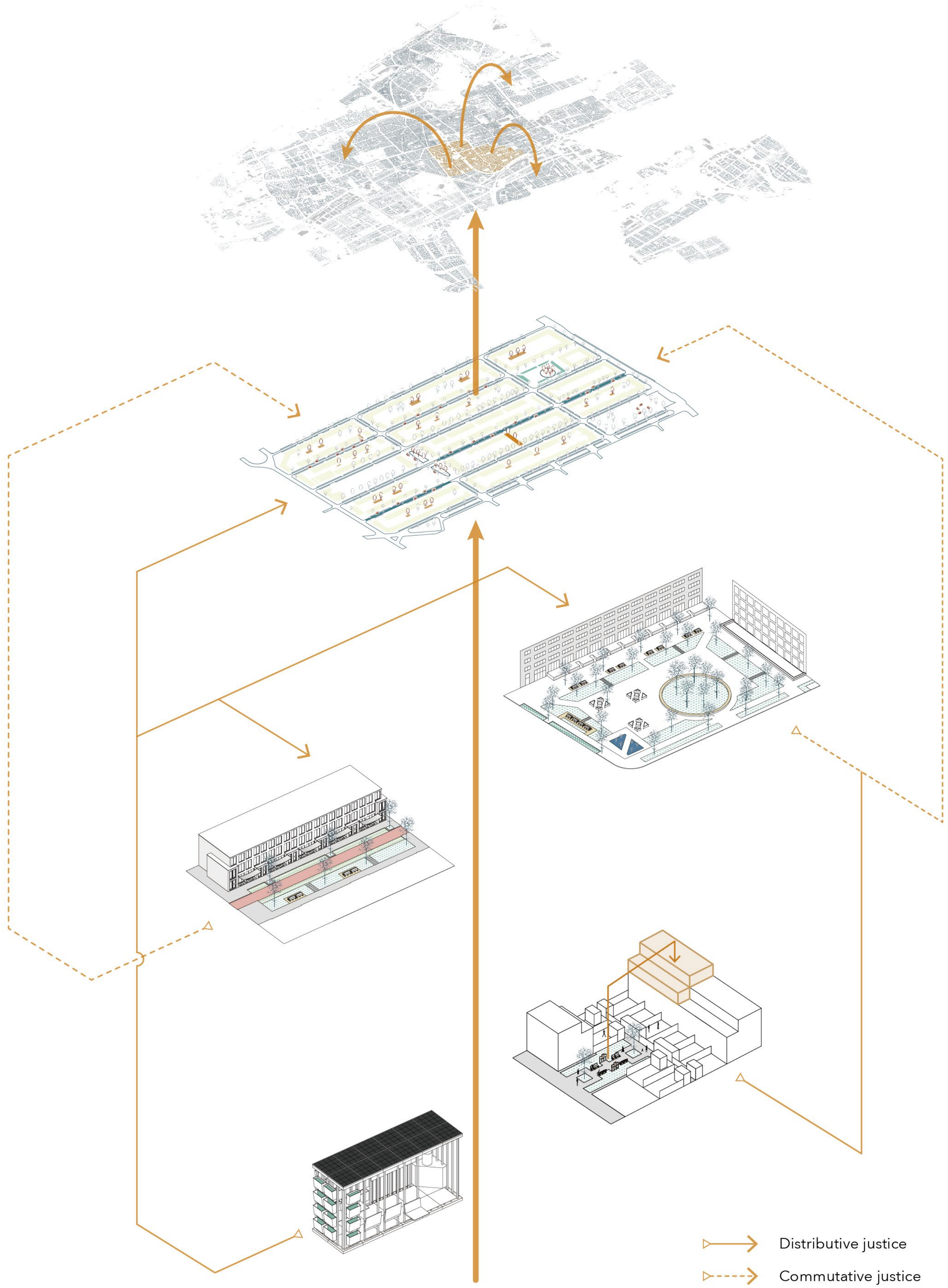


Figure 6.1. Design outcome on different scales to reduce the heat stress among the citizens as well as the elderly taken from the joint of commutative and distributive justice.

Source: Produced by author.

of the citizens in the neighborhoods Schildersbuurt and Transvaalkwartier are worse than the average level in The Hague, both of which highlight the higher level of heat risks with regard to intrinsic factor. Other intrinsic factors such as income level, education level and social segregation will also influence the choices among the citizens to protect them against heat stress during hot weathers, which will further result in uneven distribution of heat risks among the public. Moreover, the less sensitive thermal perception and social segregation of the elderly, especially for the senior citizens who live alone, make them facing even higher heat risks.

3. To what extent could the strategies and urban design improve the outdoor thermal performance to protect the elderly from heat stress in outdoor spaces and contribute to better indoor thermal comfort?

The strategies to mitigate urban heat island and reduce heat stress among the public have been made based on the research and literatures, which makes them convincible. After the introduction of the strategies, urban design, which follows the instructions from strategies has been applied in the selected open spaces and the design outcome has also been evaluated by the simulation by ENVI_MET. The difference around 5 Celsius degree between the value of physiological equivalent temperature (PET) on pedestrian level in the places where the seats and sidewalks are located illustrates the effectiveness of the strategies and interventions. However, the PET values still exceed 36 Celsius degree in the places for seats and sidewalks on the afternoon during heat waves from the results of simulation. It does not reveal the limitation of the design to provide heat refuges for the citizens but highlights that the afternoon is not the proper time to have some outdoor activities during heat waves. To conclude for the effectiveness of the strategies and urban design, the interventions could indeed reduce the heat stress around one level on the heat stress scale (around 5 to 10 Celsius degree) but the outdoor thermal performance is still out of the comfort range. Other measures or choices such as dressing properly or staying in a cool indoor space are also necessary to reduce individual heat stress by the citizens.

4. How could urban design be taken from the joint of commutative and distributive justice perspectives to reduce heat stress among the public?

Commutative justice and distributive justice are the terms from economics to evaluate the equity of welfare or benefits. Commutative justice describes the situation that the goods or services are equally provided to each group while distributive justice considers the prior sharing of the goods or services according to the demands from each individual or group. When it comes to urban planning and design, commutative justice is not as sharply distinguished from distributive justice as it used to be in economics and the discussions between these two terms also depend on the scales. For example, the urban microclimate design on the open space and streets are taken from the perspective of commutative justice on neighborhood and bock scale since people can share the overall benefits of mitigation of urban heat island. The applications of cooling sheds and cooling haven are relatively from distributive justice because more consideration has been focused on the demands of the elderly. The cooling sheds, cooling haven as well as urban microclimate design on the open space and streets could work as a network to offer heat refuges on various scales, which is the way to apply urban design from the joint of commutative and distributive justice perspectives.

5. Is it possible to have the similar effect when the strategies and urban design are applied to some places else in the Netherlands?

The strategies, which instruct urban design process, have been set up based on the research of a common building typology 'courtyard block dwellings', the effect of vegetations on microclimate as well as literatures, which shows their potentials to apply somewhere else in the Netherlands. The research of courtyard block dwellings has focused on the orientation and the size of courtyards instead of materials and pavements, which uncover its potentials to inspire the research of similar typology in other locations. The courtyard block dwellings mainly appeared in the Netherlands around 1920s to 1950s and the strategies from the perspective of building configurations could instruct the renewal process of these blocks from the microclimate perspective. However, the microclimate always depends on the local situation so the research is also necessary for the sites before designing.

To conclude for the thesis and answer the research questions, the design of cooling sheds and cooling havens are taken from distributive justice with more consideration of the demands from the elderly while urban microclimate design following the instructions from strategies on streets and open spaces are applied through commutative justice on street and neighborhood scale respectively. The urban heat risks and existing urban fabrics are interacting with each other on different scales and the strategies in the thesis could be applied on household, building, block and neighborhood scale to reduce the heat stress among the public or the elderly. The combination of the application of strategies through urban microclimate design process and the placing of cooling sheds on neighborhood streets could therefore work as a network on various scales to provide heat refuges for not only the citizens and healthy elderly but also the elderly with restriction of movements in different times (Figure 6.1).

6.2 Reflections

The relation between research & design

The topic of microclimate and heat stress has quite broad coverage since it can be approached with different scales and it also depends on individual characteristics. As mentioned in the chapter 'Livability from microclimate perspectives', microclimate could be interpreted not only on urban canopy layer scale to discuss the atmosphere conditions in cities with surrounding rural areas but also in local thermal environments that differ from surrounding areas. In this thesis, the main research and design focus on neighborhood and block scale to improve thermal performance for the elderly. It is suggested that local microclimate is largely affected by surrounding urban settings which means that microclimate always varies depending on local situation. Therefore, the thesis is made up of research and design while relatively more workloads have been done on research part.

The main research splits into two main parts. The first section is about how heat waves influenced the life of the elderly and how to locate the elderly who were facing serious heat stress during heat waves while the second section focus more on the characteristics of local spatial factors such as orientations and widths of urban canyon once the study area has been chosen. The analytical framework instructed the study of the impact of heat waves on the elderly as well as spatial distribution of urban heat risks. Then the research from the perspectives of microclimate on a common typology in study area called courtyard block dwellings has been delivered to learn about the effect of different factors like size, shape and orientation. Afterwards, the attempt of spatial intervention on courtyard block dwellings through the approach of research by design has been carried out to explore the possibility and then to instruct the design. The strategies based on the results from research to mitigate heat stress on neighborhood and block scale have been introduced and the proposed design solution has been tested. To conclude, research and design are certainly supporting each other in the thesis with the relationship as a vicious circle.

The relation between project topic, the studio of Urban Metabolism & Urbanism

The faculty of Architecture and the Built Environment aims to deliver the research and study on not only urbanised areas but also the relationship between existing urban settings and nature while the track of Urbanism attracts more attention on urban issues and topics such as resilient cities and metropolitan cities. The studio of Urban Metabolism is focusing on developing future urban systems that are less damaging to the environment and more resilient to future changes. Some topics like energy, material and climate will be often mentioned with regard to Urban Metabolism. Different systems and flows will also be discussed in the studio, one of which is climate known as natural flows such as air, heat and storm water. Some discussions about mitigation of urban heat island as well as storm water management have become popular recent years and more attention has been drawn on construction of resilient cities. However, most of strategies on making cities resilience are applied through top-down approach on large scale and less consideration has been focused on microclimate locally. Taking one of the vulnerable groups, the elderly, who were facing threaten from heat waves as a starting point, my graduation project focuses on urban design and spatial intervention of local microclimate which could be considered as the combination of different flows such as air and solar radiation to improve the outdoor thermal performance during hot summers in urban environments. The studio of Urban Metabolism can offer me necessary knowledge, tools and approaches to carry out a thorough and reasonable project.

Methods & approach

The analytical framework which illustrates how the study area in The Hague has been chosen follows linear structure and it helps to reduce the complexity of analysis. Data from different perspectives are also required to support the analysis while the timeliness and accuracy of data are also essential. Luckily, most of data is available on various official websites like CBS and KNMI in the Netherlands and some data could also be obtained from other research projects and reports like Haagse Hitte (Hoeven & Wandl, 2018). However, there is still some unexpected stuff such as deviation among data about average indoor temperature and the missing of data about building quality. Therefore, it posed a challenge that the weight of each factor is hard to define and some missing data is indispensable. In order to avoid the error caused by the accuracy of data, only the demographics from CBS and satellite images have been used to narrow down the ideal study areas to three neighbourhoods. Afterwards, other data such as average indoor temperature and dashboard of age-friendly city has been analysed to make the final decision of study area. Not comprehensive perspectives of analysis have been considered through the decision of the study area as well as only several factors play decisive roles in decision making, which shows the limitation of the analysis on The Hague. For further work on mapping the elderly who were facing heat stress during heat waves, Analytic Hierarchy Process (AHP) could be an option to determine the weights of each factor to achieve a more reasonable result if data from more perspectives could be integrated.

Experienced heat among citizens varies due to individual difference and the study areas which supposed to be relatively hotter in summer have been selected by ignore subjective impressions among citizens. Various factors such as gender, age, health situation and characteristics of surrounding environments will codetermine how each individual experience thermal environments. Consequently, different person will have different opinion on the thermal performance in totally same conditions, which also illustrates the limitation of the selected approach to only use objective data. The investigation among the citizens could help to minimize the impact of the deviation between subjective and objective if a sufficient number of samples could be achieved.

The timeliness of the research and investigation is the challenge but also limitation of this thesis. This thesis with topic about heat waves and hot weather was started from October and most of the research has been finished around January in 2020. There is no hot weather from October to January in the Netherlands so the research and investigation will generally base on literatures and people's memory. It would be better if the investigation could be conducted during summer but the schedule extinguished the possibility. Moreover, the breakout of the coronavirus globally also limited the investigation among the elderly so the study of the elderly has been conducted based on literatures and communication with Dutch people. It could be better to investigate the elderly during summer or even heat waves to support the research and design for the topic.

Last but not least for the research approaches, there is also some limitation about the criteria. Physiological equivalent temperature is a criterion to evaluate the thermal performance with the comfort value between 18 to 23 degree. However, the criterion is based on male adult so there will be limitation when the same criterion has been applied to evaluate the thermal performance of surrounding environments for the elderly. In order to avoid the deviation of criterion among different age groups, the evaluation of design has been conducted by comparison with the thermal performance of study areas before intervention. The difference could tell the effect of design and intervention properly.

Although there is also limitation of outdoor thermal performance between simulation and reality (Taleghani, Tenpierik, & van den Dobbelsteen, 2014b, 2014a), the approach of research by design to learn about the effect of spatial interventions in courtyard block dwellings on outdoor thermal performance is really effective and helpful. The method control variates has been applied to have a comprehensive understanding that how parameters which codetermine physiological equivalent temperature are influenced by space and vegetation. The complexity of microclimate has been simplified and the outcome from research by design instructed the design of heat refuges a lot.

Societal, academic & ethical relevance

European Environment Agency stated that the number of heat waves has substantially increased across Europe in recent years (European Environment Agency (EEA), 2016). Tens of thousands of premature deaths have been caused by heat waves since 2000 and larger economics impacts could be expected such as exacerbate peaks in electricity consumption in summer (Baumert & Selman, 2003; European Environment Agency (EEA), 2016). The impact of urban heat on human life and nature could not be overlooked especially in northern and western European where increasing number of heat waves has been witnessed in the countries with wild weather annually. As a consequence, heat waves and urban heat have already become a societal issue which will cause more unexpected deaths and uneven distribution of heat risks among the citizens (Fernandez Milan & Creutzig, 2015).

Existing urban settings have strong interaction with urban heat island and cause uneven distribution of heat risk. The situation will become even worse when it happens to the elderly who live individually or with a partner in their own homes, which could be uncovered from the statistics of monthly death among different age groups offered by CBS. The risk caused by uneven distribution of urban heat will be enhanced among the elderly when the elderly are dressing improperly or not informed with coming heat waves. Therefore, this thesis focuses on the elderly and propose to design for them to decrease the heat stress.

However, although the elderly are proved to be vulnerable to hot weathers, others such as babies, people who are overweight, people in nursing homes or hospitals and people who are socially isolated are also facing high heat risks (Fernandez Milan & Creutzig, 2015). Due to limitation of privacy and availability of data, the mortality, to which the elderly contribute most, is the few data that reveals the unnegligible impacts of global warming. The influence on other vulnerable group is hard to discover but it is also necessary and crucial to take other vulnerable groups into consideration in the thesis. Therefore, some strategies and design proposed in the thesis also consider about the interests of other people who are vulnerable to hot weathers in order to pursue fairness and equality.

As a thesis of graduation project, the potentials to contribute to the discussion of urban renewal process under the pressure from global warming could be discovered, which reveals the scientific relevance of the topic and project. Most urban microclimate design is on smaller scale compared with urban planning and always depends on the situation in the sites, which shows less potentials of application in other places. The research of typology study and design of temporal spatial interventions could add up to the potentials of urban microclimate design to be applied in more places with a proper adjustment. Besides, some strategies for courtyard block dwellings and temporal spatial interventions in the public spaces could also be an approach that join the public health institutions and urban planning sector and then offer more efficient benefits to the public.

Transferability of results

This thesis focuses on neighbourhood and block scale to discuss about the solution to improve the outdoor thermal performance in the Netherlands which is the blank between public health intervention which is effective on individuals and urban planning which usually focuses on city or regional scale. The approach that the scope narrows down in the selected test field from larger scale to smaller scale and then the results from research and design feedback to larger scale could also be applied in other researches.

The study typology courtyard block dwellings is common in the Netherlands and the researches have been focusing on orientation and the shape of block instead of materials and pavements, which uncover its potentials to inspire the research of similar typology in other locations. Moreover, this representative typology mainly appeared in the Netherlands around 1920s to 1950s, which is facing the challenge of urban renewal in coming years especially under the pressure of rising global temperature. Therefore, the research in this thesis could help to inspire the coming renewal process.

However, the research based on simulation with ENVI_MET also reveals its limitation since the models have been simplified by remove fences and vegetation inside the courtyards in order to reduce the workload of the computer. The actual microclimate should be more complex than the result from simulations and microclimate also varies depending on surrounding urban settings so the result from research and design in this thesis also have limitation to apply to other places with similar typology. Instead, it could help to offer the brief impression to researchers and designers and more analysis should be carried out according to local situation to have a comprehensive understanding of study or design areas.

Discussion of ethical issues and dilemmas encountered

The main challenge encountered during the research and design is the missing investigation among the elderly. Not only the issue of schedule but also the breakout of the corona-virus restrict the investigation among the elderly during heat waves and it is also hard to learn about the demands from the elderly in study areas. The literature review and communication with Dutch people help to minimize the impact of missing data but the outcome of design still seems to be general instead of focusing on the elderly or specific group of the elderly in study areas.

When it comes to potential applications of the design outcome in practice, most of the strategies are flexible which means they have great potentials to apply but the cooperation with stakeholders is challenging. For example, either 'rent' private lands to plant trees inside courtyards or the application of temporal spatial interventions need the coordination with stakeholders like individuals who own the lands or the sponsors such as NGO or municipalities. Moreover, taking plating trees inside courtyards as an example, since the trees will provide shades not only on the ground but also on the facades of buildings, some owners may prefer the sunlight coming into their bedroom instead of being blocked by trees. The stakeholders need to be convinced by the effects of interventions and then application of the design outcomes will be available.

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8 APPENDIX

Heat and the health of well being

Review of the impact of heat waves and hot weathers on the public with more consideration of the elderly

AR3023 Theories of urban planning and design
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Abstract

With global warming forecast to be continued in a vicious circle, extreme weathers and urban heat islands are becoming serious in the urbanized areas which is posing severe stress on the society. The increases in frequency, intensity and duration of warm spell and heat waves are discovered globally and urban heat risks result in not only the increasing rate of heat-related morbidity and mortality but also uneven distribution of risk among populations. The recorded high temperatures across Europe in 2003 resulted in around 40,000 deaths, most of whom are the elderly. Numerous studies have proved that the elderly are vulnerable to the effects of hot weathers and heat waves in terms of direct pressure on the compromised thermoregulatory system and indirect impacts on the daily life of the elderly caused by high indoor and outdoor temperatures. The paper will mainly research how hot weathers and heat waves influence the health and daily life of the public with more consideration on the elderly by reviewing the research paper with the contents about the Netherlands and surrounding countries. Some advice from the urbanism perspective will be proposed in the end to contribute to the livability of the elderly.

Key words

heat wave, hot weather, the elderly, mortality, morbidity.

0 Background

With the continuing emission of greenhouse gas, it is now widely accepted that climate change is occurring and extreme weathers like heavy rains and draughts are becoming common and placing pressure on the public. As one of the consequences of global warming, heat waves are increasing in frequency, intensity and duration across the world (IPCC, 2007) and more extreme heat waves could become commonplace by the 2040s (Christidis, Jones, & Stott, 2015). The increasing mean temperatures and continuous hot weathers are increasing the chance of exposure to high ambient temperatures which will lead to an increase both in mortality and morbidity. One of the most severe heat waves in 2003 across the Europe was estimated to cause around 40,000 deaths in Europe, most of which are the elderly, and it also highlighted the widespread um-preparedness of the society to cope with such large events (García-Herrera, Díaz, Trigo, Luterbacher, & Fischer, 2010). Another research on the impact of heat in fifteen cities across Europe by reviewing the relationships between outdoor temperatures and mortality argued that a significant increase in mortality of almost 2% in the 'north-continental' region of Europe was uncovered, especially for the elderly group, when temperatures increase 1 ° C degree above the specific threshold of the city (Baccini et al., 2008).

Nowadays the population structure is changing as the proportion of the elderly is rising driven by a dramatic increase in life expectancy and a decline in fertility rates (Kulik, Ryan, Harper, & George, 2014; Oudin Åström, Bertil, & Joacim, 2011). Most of the developed countries have already facing the challenge of the aging population and

Europe is currently the oldest region in the world ranked by median age (Kulik et al., 2014). Studies and research have shown that the elderly who are widely defined as the people who are 65 years old and over are most vulnerable to heat waves and high temperatures (Baccini et al., 2008; Li, Gu, Bi, Yang, & Liu, 2015; Sartor, Demuth, Snacken, & Walckiers, 1997; Joris Adriaan Frank van Loenhout et al., 2018). Aging population and heat waves have already interacted with each other resulting in serious issues among the society and more attention from different sections should be focusing on solutions to mitigate the risks with interdisciplinary thinking.

1 Introduction

Netherlands is a coastal country with a typical maritime climate with mild summers and cold winters. As in all other countries with mild weathers, annual mortality related to cold is higher than heat-related mortality in the Netherlands (Garssen, Harmsen, & Beer, 2005). However, during the heat waves in 2003 and 2006, the hot weather in the summer of 2003 led to between 1,000 and 1,400 more deaths while one thousand more people died in July 2006 (CBS, 2003; CBS, 2006). It could be interpreted that the buildings and urban settings in the Netherlands are considered to prepare and design for cold weathers in the winter such as large windows to gain more sunlight and common indoor heating system. However, residential buildings like many other North-Western European countries are 'typically neither equipped with an air-conditioning system, nor with other active cooling systems to reduce the indoor air temperature in hot periods' (van Hooff, Blocken, Hensen, & Timmermans, 2014), which makes the public are more vulnerable to the heat waves with less consciousness and preparation of hot weathers.

The Royal Netherlands Meteorological Institute, which is known as KNMI, has developed four scenarios with equal chance of the occurrence to describe how the climate may change and 'Both the mean temperature and mean precipitation will increase in future in all four scenarios except for summer precipitation.' (Attema et al., 2014) This means that summer in the Netherlands will become hotter and drier and citizens are more likely to experience heat waves in coming years.

In order to have a comprehensive understanding of the impact of hot weathers and heat waves on the health and daily life of the elderly in the Netherlands to support further research, the paper will mainly focus on research and studies within the Netherlands since the variation of weather conditions and the difference of ability to adapt to local climate depend on local situations (Brázdil & Budíková, 1999). Belgium and England will also be taken into consideration as they have similar characteristics such as mild maritime climates, latitude and coastlines along the North Sea, but not limited to them.

2 Heat-related mortality and morbidity

Based on the review of the papers about the content in the Netherlands and surrounding countries with the key words such as heat, heat wave, mortality, morbidity and the elderly, studies are mainly conducted from two aspects. On one hand, the relationships between meteorological data and regional or national mortality are uncovered, on the other hand, heat-related morbidity was studied by comparing hospital admissions during different weather conditions. Heat wave is the word mentioned most in the papers but some research and studies are not only limited on the effects of heat waves, but also attempted to learn about the impact of hot weathers. The definitions of heat wave are varied with location and 'In the Netherlands, a heat wave is a sequence of at least 5 summer days in De Bilt (maximum temperature 25.0 ° C or higher), of which there are at least three tropical days (maximum temperature 30.0 ° C or higher).' (KNMI, 2019) As heat-related health issues may be attributed to many various causes, the relationship between hot weathers and mortality will be discussed first in the following paragraph. Then heat-related morbidity will be reviewed based on hospital admissions.

2.1 Heat-related mortality

Before the most serious heat waves in 2003 and 2006 which attracted most attention from the public, Huynen et al. have already conducted the study to investigate the impact of ambient temperatures on mortality in the Netherlands during 1970-1997 and a V-like relationship between mortality and temperatures with an optimum temperature value of 16.5 ° C for total mortality and mortality among the elderly was found for Dutch population (Huynen, Martens, Schram, Weijenberg, & Kunst, 2001). It was also argued that 'Mortality increased significantly during all of the heat waves studied, and the elderly were most affected by extreme heat' since the health status of the elderly is more compromised with a reduced thermoregulatory system and less sensitive thermal perception (Huynen et al., 2001). Another study about the effect of heat on mortality in fifteen European cities found similar results with V-shape relationships between temperatures and mortality rates as well as 'city-specific threshold' for 'north-continental cities' such as London, Paris and Helsinki (Baccini et al., 2008). For temperatures above the threshold, total mortality increased by 2.72% in the Netherlands for all age group and by 2.1% in the 'north-continental cities' for people aged 75 and over when there is a 1 ° C increase above the threshold (Baccini et al., 2008; Huynen et al., 2001).

2.1.1 Direct causes of deaths

When it comes to the cause of mortality during the heat waves, cardiovascular diseases and respiratory disease are most mentioned when people try to uncover the relationships between heat waves and mortality as well as morbidity and all of the studies found that mortality increased during hot weathers for all cause-of-death groups examined. Respiratory causes were found most contribution to excess mortality during hot weathers from 1970 to 1997 as well as 2003 in the Netherlands and from 1993 to 2006 in England and Wales respectively (Garssen et al., 2005; Gasparrini, Armstrong, Kovats, & Wilkinson, 2012; Huynen et al., 2001). Kunst, Looman and Mackenbach argued that direct effects on the respiratory system are probably more important for heat related mortality while for cardiovascular disease the direct effects are in part the result of increased stress on the circulatory system, which could help to explain why respiratory causes are dominant in excess mortality (Kunst, Looman, & Mackenbach, 1993).

For the cardiovascular causes the increase in mortality was much smaller but comparatively high for arrhythmias and pulmonary heat disease in England and Wales during the summers (June–September) of 1993–2006 (Gasparrini et al., 2012). However, the statistical data about the total number of all-cause mortality during hot weathers not only in the Netherlands but also across the Europe showed that deaths from cardiovascular causes contribute most to the heat-related mortality followed by respiratory diseases and the effect of heat on mortality was particularly large in the elderly (Baccini et al., 2008; Huynen et al., 2001).

2.1.2 Interaction between air pollution and hot weathers

Besides the studies about the relationships between hot weathers and mortality, there are also some studies about the impact of hot weathers interacting with air pollution which prevailed during heat waves on the mortality (Filleul et al., 2006; P. Fischer, Ameling, & Marra, 2008; P. H. Fischer, Brunekreef, & Lebret, 2004; P. H. Fischer, Marra, Ameling, Janssen, & Cassee, 2011; Sartor et al., 1997; Sartor, Snacken, Demuth, & Walckiers, 1995; Willers et al., 2016). The strong interactions between air pollution and high temperatures were discovered in three research papers by analyzing the data of daily mortality, air pollution and high temperatures in the Netherlands and taking the heat wave in 2003 as an example, a significant proportion of deaths during the heat wave with an excess of around 400 to 600 deaths could be reasonably explained as the consequence of air pollution (P. Fischer et al., 2008; P. H. Fischer et al., 2004, 2011). Similar conclusion could be found in the research about the heat wave in 1994 in Belgium about the temperatures, ozone concentration and mortality (Linares & Díaz, 2008; Sartor et al., 1995).

High temperatures are associated with increased mortality since ozone 'is readily formed under warm and sunny conditions' while PM10 concentrations also tend to rise during hot weathers (P. H. Fischer et al., 2004). Moreover, the upward trends were discovered in respiratory-related causes of death for PM 10 during the period from 1992 to 2006 in the Netherlands while increasing number of total and cardiovascular deaths were found for O3 (P. H. Fischer et al., 2011), which can further explain the effects of air pollution during hot weathers on mortality. The elderly are also vulnerable to the interactions between high temperatures and air pollution and a study found that 'Single living elderly were the most vulnerable group' (Willers et al., 2016). A statistical association between daily mortality and ambient ozone concentration among the elderly during the hot summer of 1994 in Belgium, during which there is a recorded heat wave from June 27 to August 7 was observed as

'When mean daily temperature ranged from 15 to 20°C, ozone level contributed to a linear increase of the daily mortality. When mean daily temperature exceeded 20.3°C, the effect of ozone on daily mortality appeared to be enhanced by temperature.'

The study about the temperature, ozone and mortality in nine French cities during heat wave of 2003 confirmed that 'in urban areas O3 levels have a non-negligible impact for the public health, even if this impact is low in terms of individual risks' and contribution of ozone and temperature in mortality was heterogeneous among cities with regard to local specific characteristics (Filleul et al., 2006). Spatial differences in temperatures and air pollution could also result in different risks between not only cities but also neighborhoods. For example, mortality risks which varied substantially between neighborhoods with a difference up to 7% were found in Rotterdam due to spatial characteristics (Willers et al., 2016).

2.1.3 Impact of intensity and duration of heat waves on mortality

In addition to the accompanying air pollution during hot weathers, the intensity and duration of heat waves also play an important role in increasing mortality. Huynen et al. found that the increase in mortality was highest in 1994 during the longest heat wave between 1970 and 1997 (Huynen et al., 2001). Besides persistent hot days during heat waves, the sharp change in temperature at the beginning or end of the heat waves can also contribute to high risks of death and illness. Guo and other scholars found that a significant change in temperature of more than 3°C either positively or negatively in neighboring days has an adverse impact on mortality (Guo et al., 2011).

2.1.4 Lag effect of heat waves

When compared the mortality after heat waves with the same period during other years without heat waves, forward displacement of deaths, which is also known as harvest effect of heat, was always discussed in the papers (Baccini et al., 2008; Garssen et al., 2005; Huynen et al., 2001). Baccini et al. found evidence of harvesting in 'north-continental cities' after researching heat effects in fifteen European cities and argued that 'The mortality displacement partially compensates for the effect of heat observed during the first week after exposure' (Baccini et al., 2008). In the research of the heat wave of 2003 in the Netherlands, some forward shift may have taken placed but did not fully compensate the excess mortality caused by heat (Garssen et al., 2005). However, the results from the research by Huynen and others on heat-related mortality in the Netherlands are inclusive relating to harvest effect of heat since some heat waves showed a decline in mortality after the extreme heat while others did not show the decrease (Huynen et al., 2001). Therefore, it is hard to define the relationship between heat waves and forward displacement of deaths, especially in the content of the Netherlands although mortality was found to decrease after some heat waves.

2.2 Heat-related morbidity

Due to the limitation of data and privacy, there are a few literature studying the effect of heat on morbidity focusing on the relationships between temperatures and hospital admissions and it is argued that an increase in respiratory admissions could be found during the heat waves while for circulatory disease, the tendency seems to be negatively related or even not related to heat at all (Kovats, Hajat, & Wilkinson, 2004; Mastrangelo et al., 2007; Michelozzi et al., 2009; Joris Adriaan Frank van Loenhout et al., 2018). However, Linares and Diaz suggested that 'In heat wave the people die rapidly from circulatory diseases before they can be admitted to hospital' (Linares & Díaz, 2008) which could help to explain the missing relationship between the hospital admissions of circulatory disease and heat waves. Moreover, hospital admissions for heat diseases such as disorders of fluid and electrolyte balance, acute renal failure, and heat stroke were also found rising during the heat waves in Italy (Mastrangelo et al., 2007) and the sharp rising of heatstroke and sunstroke was discovered during the heat wave of 2013 in England (Elliot et al., 2014).

When it comes to the research on the content of the Netherlands, the relationships between increasing temperature and hospital admissions were also found positively in several papers. A recent study based on emergency room admissions in the Netherlands found a positive relationship between increasing temperatures above 21 °C and the relative risk for urgent emergency room admissions for the disease categories 'Potential heat-related diseases' which consists of subgroups such as 'Disorder of electrolyte, fluid, acid-base balance', 'Acute renal failure' and 'Effect of heat and light' as well as 'Respiratory diseases' (Joris Adriaan Frank van Loenhout et al., 2018).

The elderly are proved as one of the risk groups for heat stress as well. The research based on emergency room admissions in the Netherlands found that the 85+ aged group had the highest relative risk for 'Potential heat-related diseases' and 'Respiratory diseases' (Joris Adriaan Frank van Loenhout et al., 2018) and another study based on GP (general practitioners) consultations in the Netherlands illustrated 'an increase of 5.4% in the number of consultations on general heat related illness' during hot weathers (Hondema, 2019). The study in London during the heat waves of 2003 also illustrated the increase in the respiratory disease among the people who are over 74 years old (Mastrangelo et al., 2007), which reinforced that the elderly are more vulnerable to hot weathers.

The intensity and duration of hot weathers and heat waves not only have effects on increasing the mortality among the public but also result in high morbidity. Loenhout et al. argued that 'the impact of a single day with extreme heat is comparable to the impact of several days with moderate heat' (Joris Adriaan Frank van Loenhout et al., 2018), which emphasized that the impact of duration and intensity of heat waves on the morbidity of the society could not be overlooked.

3 Heat-related symptoms and self-response

The impacts of individual perceiving heat on the daily life of the person have been studied by experiments and questionnaires on a group of people in different municipalities in the Netherlands (Appendix 1.1). There are only three research papers focusing on the heat-related symptoms, two of which also study how the investigated residents responded to heat waves and hot weathers (Daalen, Radboud, & Nijmegen, 2010; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; J. A.F. van Loenhout et al., 2016). Due to the limitation of research such as age groups, individual health situations and so on, the conclusion from these papers are inconclusive, but some points in common could be found from the results.

In the investigation of heat-related symptoms, most people reported the perception of extra heat during heat waves and sleep disturbance is most reported followed by tiredness and feeling exhausted (Daalen et al., 2010; Huynen M.M.T.E., de Hollander A.E.M., Martens P., 2016; J. A.F. van Loenhout et al., 2016). When it comes to unpromoted measures to reduce heat stress, drinking more water, reducing physical activities and more natural ventilation are the most common among the investigated residents, which revealed that most people were aware of extra perceived heat during hot weathers and could take some proper measures to reduce heat stress. However, during the investigation in Arnhem and Groningen the scholars also found that 'one in four participants in this period reported not to usually undertake any measures' (J. A.F. van Loenhout et al., 2016) and the difference of indoor temperatures between the locations in Tilburg was found in the houses in the inner city and outside the center (Daalen et al., 2010), which emphasize the importance of the role of public health institutions and urban planning in mitigating heat risks among the public.

4 Discussion

This review paper focus on the topic on the heat waves and its impact on the society. There are a large amount of papers studying the effect of heat waves and hot weathers on mortality and morbidity with the contents about Netherlands and surrounding countries while the research and studies on heat-related symptoms are less. None of research and studies which reported social, medical and environmental susceptibility is found through this literature review and it is also argued by a review paper that 'Few studies reported social, medical and environmental susceptibility factors' (Oudin Åström et al., 2011). It could be interpreted as the privacy and limitation of data and there should be more research and studies on individual perceived heat as well as susceptibility factors especially for the contents about the Netherlands.

To conclude for the discovery in the review paper, mortality and morbidity increase significantly during heat waves and consisting hot weathers in the Netherlands and surrounding countries and the elderly are proved to be vulnerable to hot weathers. Besides the impact of intensity and duration of heat waves on mortality and morbidity, the interaction between increasing temperatures and accompanying air pollution should not be overlooked. Hot weathers associate with urban heat islands in the urbanized area which leads to uneven distribution of heat risk among the public (Fernandez Milan & Creutzig, 2015). However, the difference of air pollution levels with the locations during heat waves could also enhance the relative risk when it was accumulated with uneven distributed heat risks (Fernandez Milan & Creutzig, 2015; Willers et al., 2016).

When it comes to the individual level of perceiving extra heat, most people have reported perception of heat and could take proper measures such as more natural ventilation and reducing physical activity to reduce heat stress. However, a quarter of the investigated elderly took less action against heat stress during the heat wave in Arnhem and Groningen (J. A.F. van Loenhout et al., 2016). The elderly are more vulnerable to heat stress due to less sensitive thermal perception (Huynen et al., 2001) and social segregation among the elderly, especially for the ones who live alone is more likely to enhance the relative risk of hot weathers. For example, the elderly living alone may not be informed coming heat wave and could not take proper measures to reduce heat stress, which is more likely to result in high risk of heat-related issues. Moreover, the indoor temperature also play an important role in shaping the risk for individuals since people usually spend most of time inside the buildings (J. A.F. van Loenhout et al., 2016).

The increasing temperatures in the Netherlands have already drawn the attention from the public and the public health institution in the Netherlands, known as RIVM, implemented the 'National Heat Plan', which is a warning for everyone to be aware of the risks posed by persistent heat and also a calling on everyone to pay extra attention to each other, especially for groups of vulnerable people (Hagens & Bruggen, 2015). However, after reviewing the literatures about public health, heat risk reduction and relative urban planning, Fernandez Milan and Creutzig argued that 'urban planners' potential to address heat waves in the field remain largely untapped' and the joint of public health interventions and urban planning strategies could have better effects (Fernandez Milan & Creutzig, 2015).

5 Conclusion

Some advices from the conclusion of the review paper are proposed for the field of urbanism in order to contribute to the livability of citizens. Firstly, more attention should be focused on the prevention of overheating of indoor temperatures from the joint of architecture and urbanism

	Region & Cities	Number & Population	Heat-related Symptoms	Self-response to Reduce Heat Stress
Loenhout et al.	Arnhem Groningen	113 (the elderly)	Thirst (42.7%); Sleep disturbance (40.6%); Excessive sweating (39.6%);	Drinking more water (69.8%); Reducing physical activity (62.5%); More natural ventilation (50.0%); Going outside (24.0%); Mechanical ventilation (16.7%); Leaving the city (13.5%`)
Huynen	Province of Limburg	588 (adult)	Sleep disturbance (35.0%); Tiredness (around 33%); Swollen legs, feet or hands (14.3%); Feeling exhausted (13.4%); Respiratory problems (9.7%); Heart complaints (3.4%);	Drinking more water (94.0%); Wearing appropriate clothing (93.0%); Opening windows at night (91.0%); Avoiding strenuous activity (65.0%); Staying inside (60.0%); Taking a cool shower (58.0%);
Daalen et al.	Tilburg	316 (the elderly)	Sleep disturbance (61.7%); Fatigue (61.1%); Stuffiness (28.5%); Headache, dizziness, skin complaints, muscle cramps and problems with concentration (Around 20 to 25%);	—

Appendix 1.1 Heat-related symptoms and self-response to reduce heat stress.

perspectives. Urbanists could not only design and intervene in public space to create more 'green and blue' to cool down the ambient temperature, but also cooperate with architects to cool down inside temperatures. Secondly, not only uneven distribution of perceiving heat in the urbanized area but also the difference of air pollution levels with locations should be considered when evaluating the heat-related risk or making urban heat risk maps for further research and interventions. Finally, public health interventions are effective on individual scale with high time efficiency while urban planning strategies and interventions are more effective on larger scales with relative low time efficiency (Fernandez Milan & Creutzig, 2015). The association of the interventions from two aspects could be a solution to reduce urban heat risk for the society. For example, some temporal spatial interventions, which are designed by urbanists, could be applied during hot weathers by public health institutions in the places with high heat risks. The idea of the joint of public health interventions and urban planning will be tested in the graduation project called 'Designing Heat Refuges for the Dutch Elderly' by the author.

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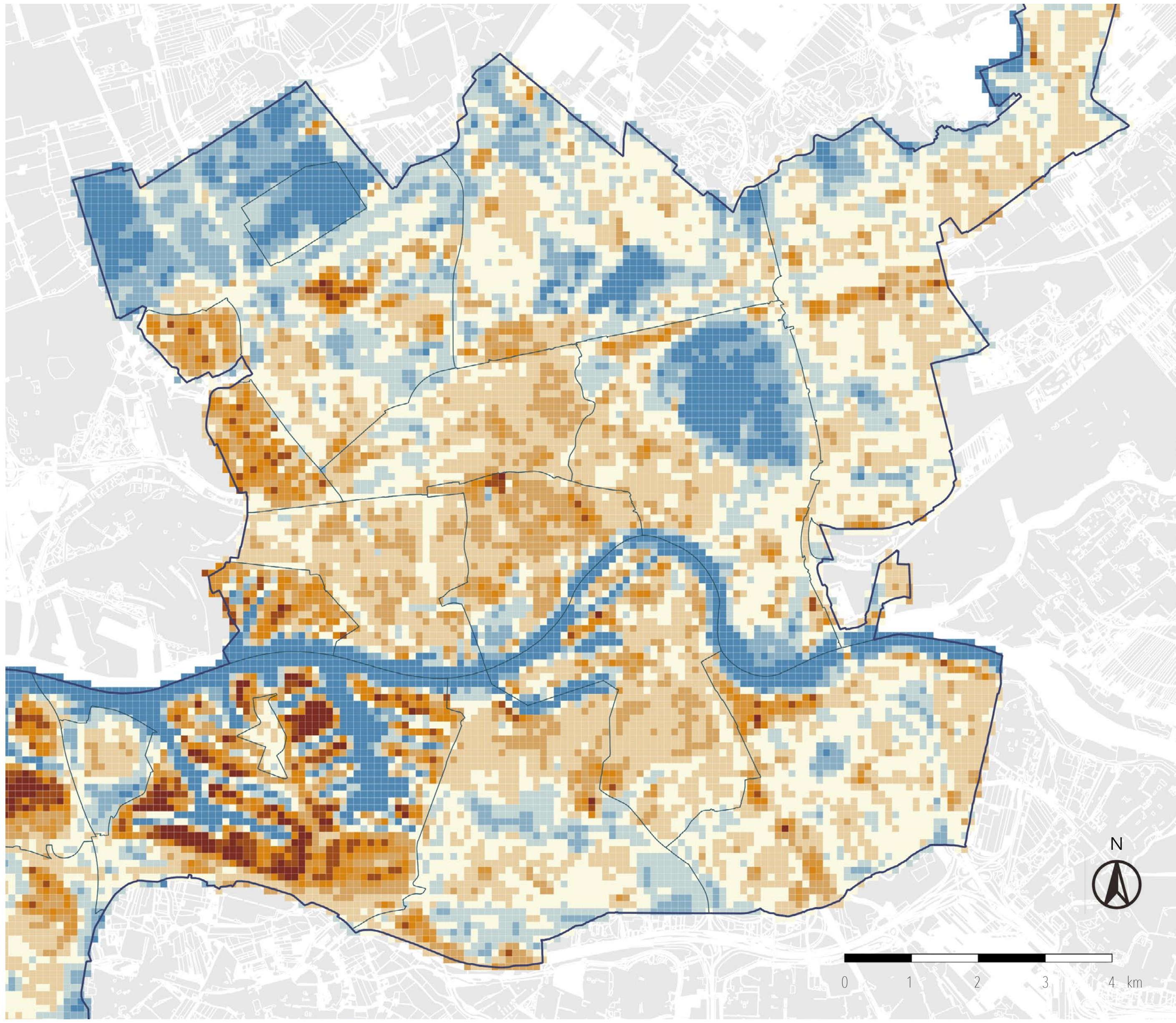
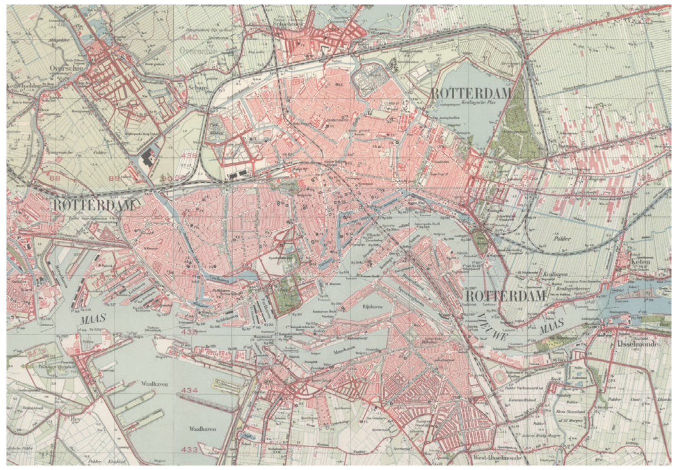
Appendix II Surface Energy Balance in Rotterdam on 27th May 2017



Surface energy balance measured on 27th May 2017.

Source: Produced by author.

Legend (W/m²)
75 125 175 225 275 325 375 425 475

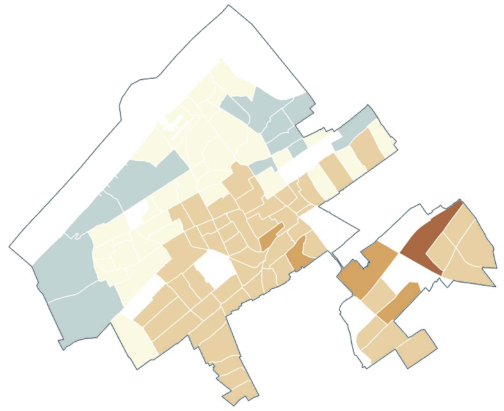


Historical map of Rotterdam in 1940s.

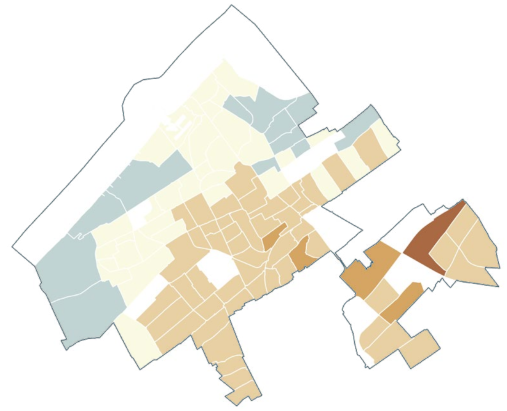
Source: Source: https://www.topotijdreis.nl/.

Appendix III Average Indoor Temperature on Two Hottest Days during Heat Waves on 2018

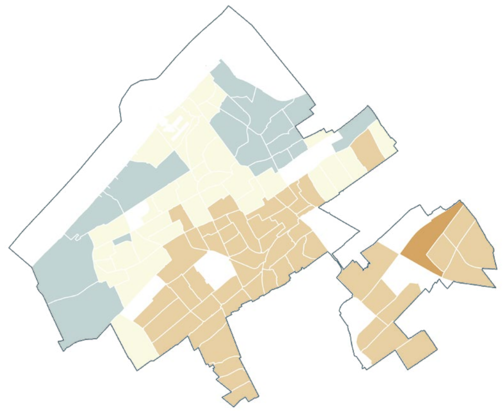
July 26th 2018 - 00:00



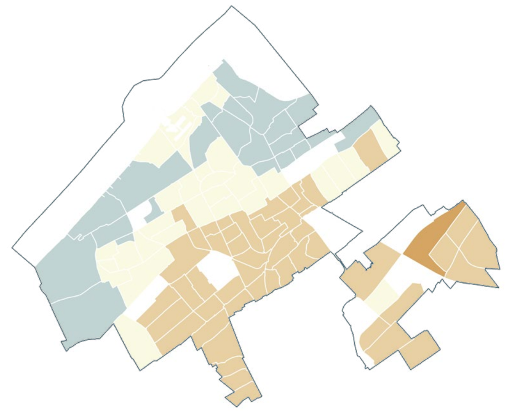
July 26th 2018 - 01:00



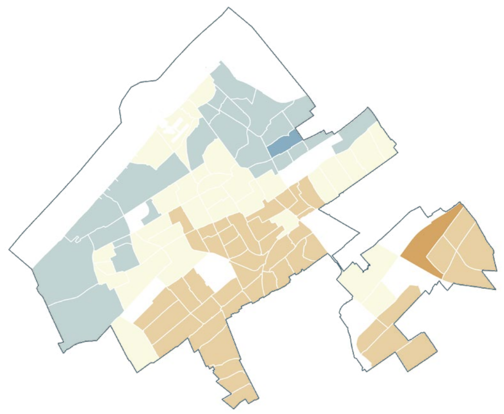
July 26th 2018 - 02:00



July 26th 2018 - 03:00



July 26th 2018 - 04:00



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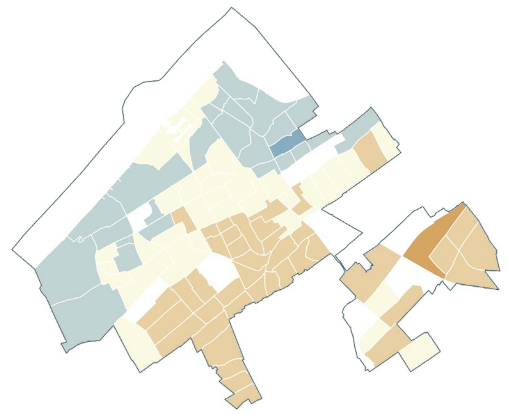
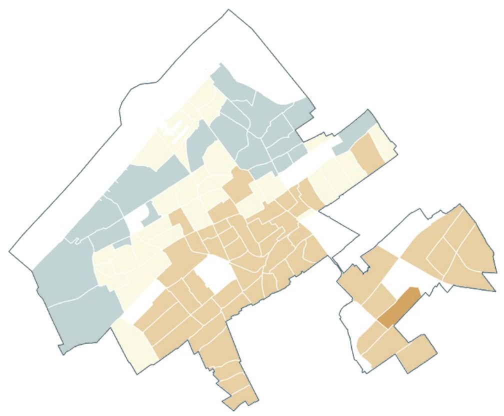
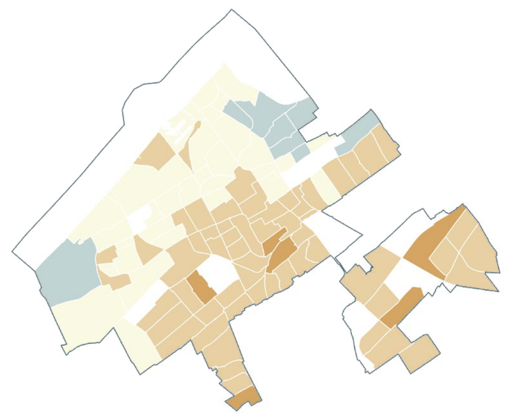


July 26th 2018 - 06:00

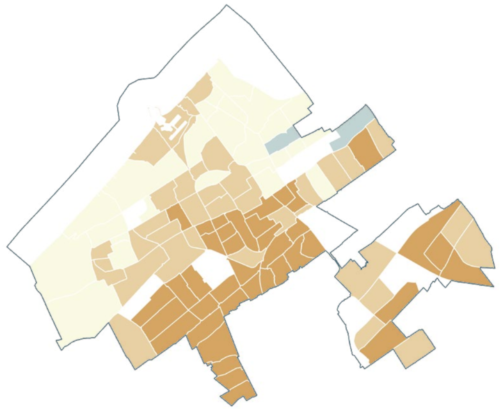


July 26th 2018 - 07:00

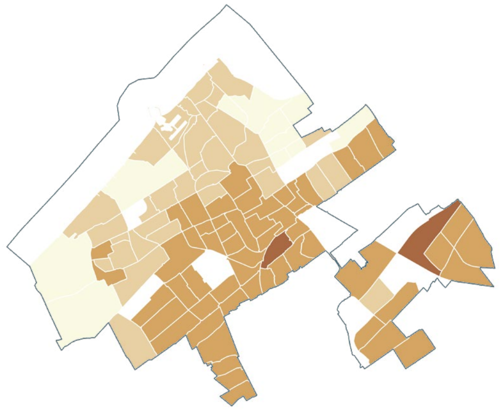


Legend (°C)
23 24 25 26 27 28 29 30 31

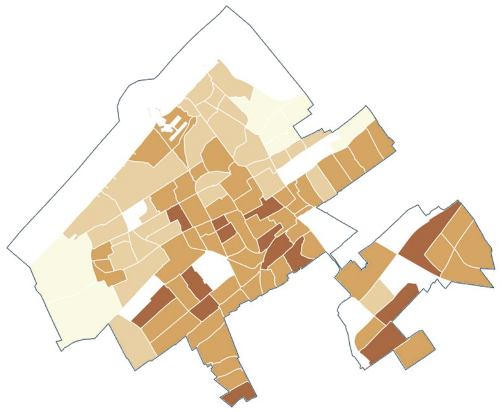
July 26th 2018 - 08:00



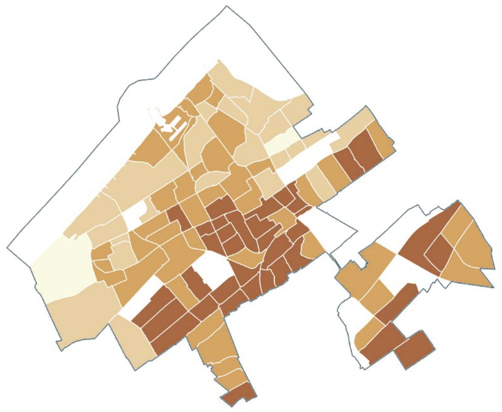
July 26th 2018 - 09:00



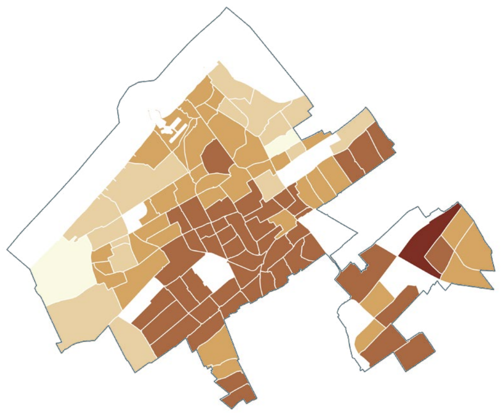
July 26th 2018 - 10:00



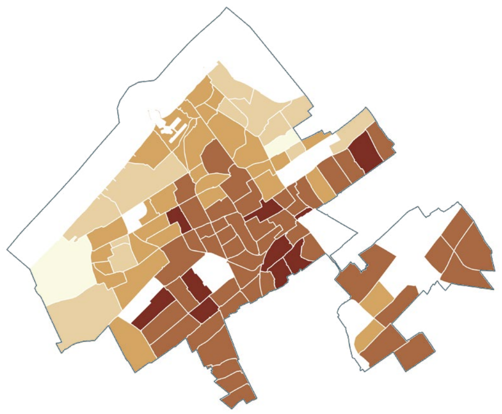
July 26th 2018 - 11:00



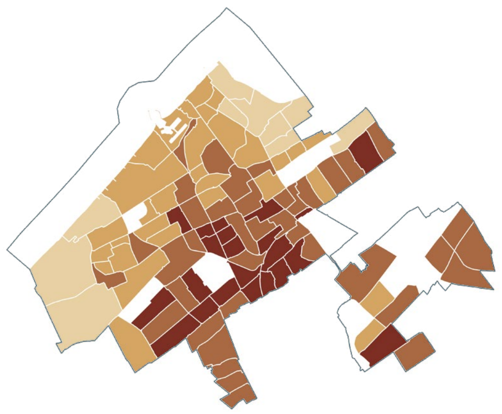
July 26th 2018 - 12:00



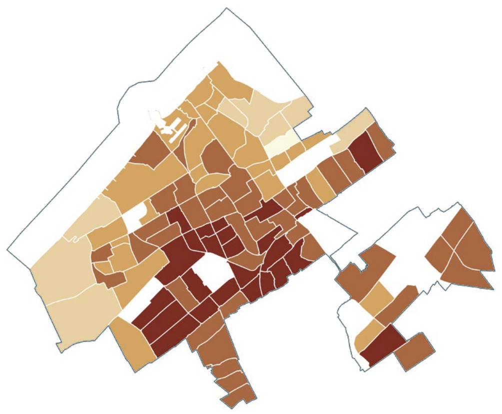
July 26th 2018 - 13:00

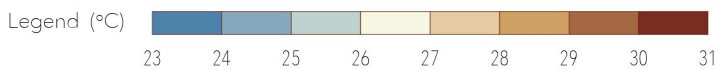


July 26th 2018 - 14:00

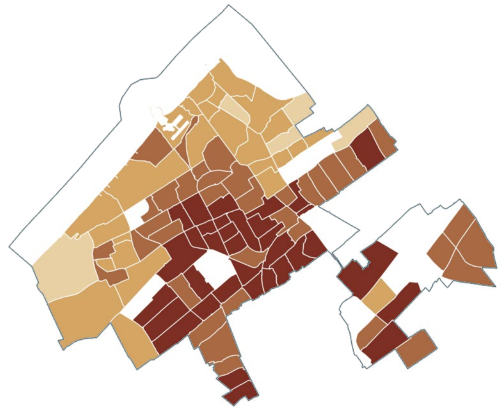


July 26th 2018 - 15:00

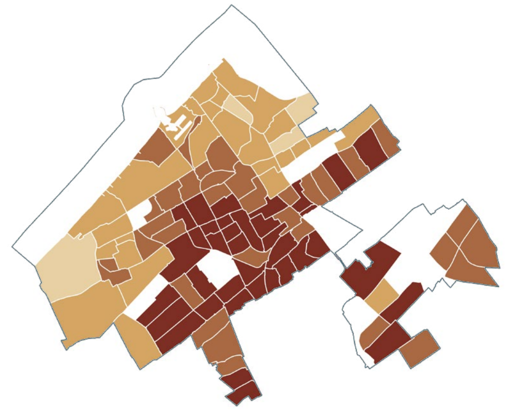




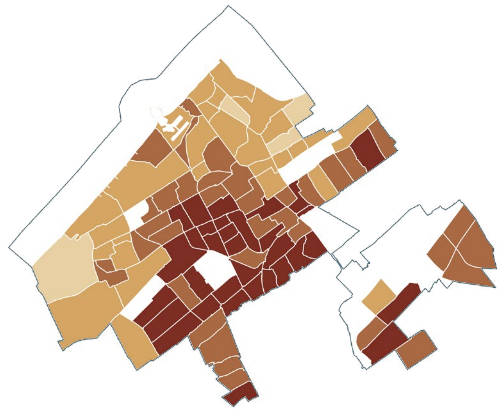
July 26th 2018 - 16:00



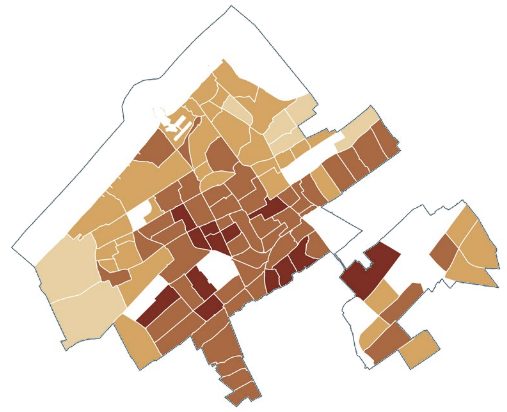
July 26th 2018 - 17:00



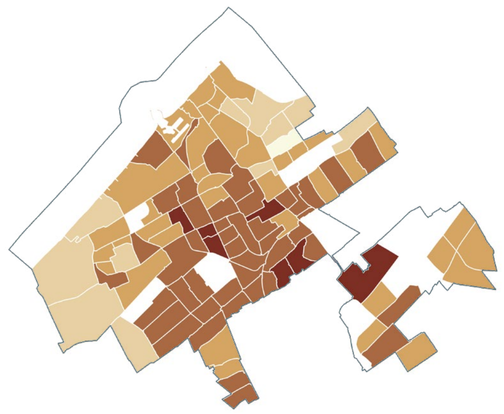
July 26th 2018 - 18:00



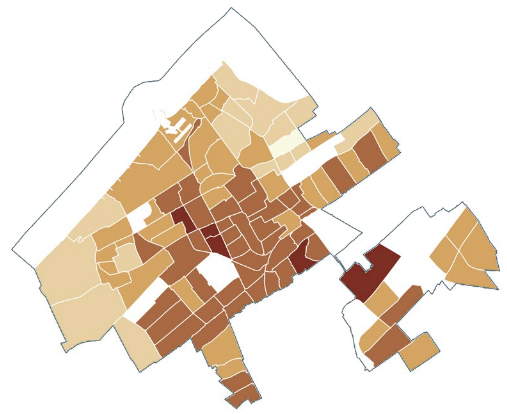
July 26th 2018 - 19:00



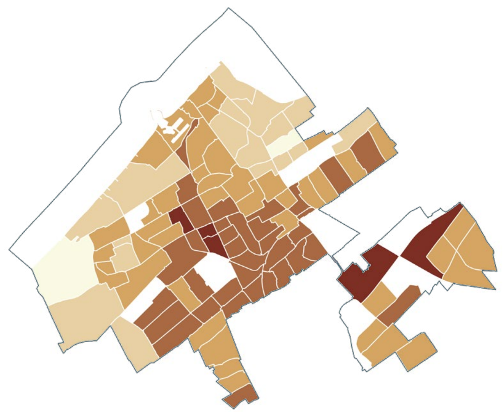
July 26th 2018 - 20:00



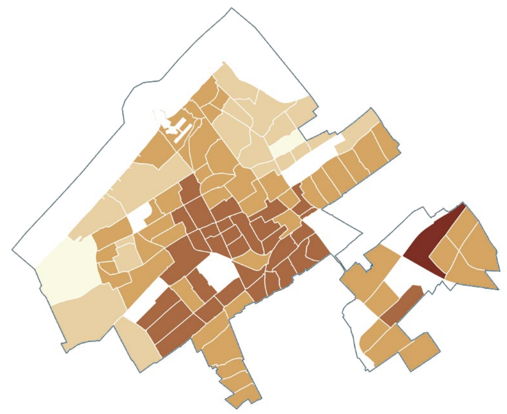
July 26th 2018 - 21:00

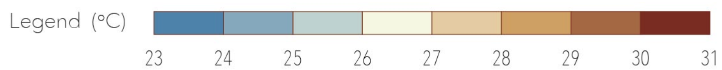


July 26th 2018 - 22:00

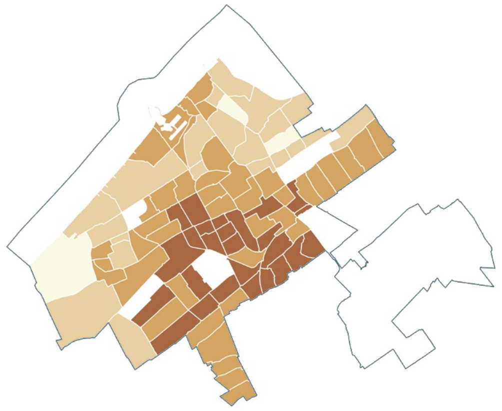


July 26th 2018 - 23:00

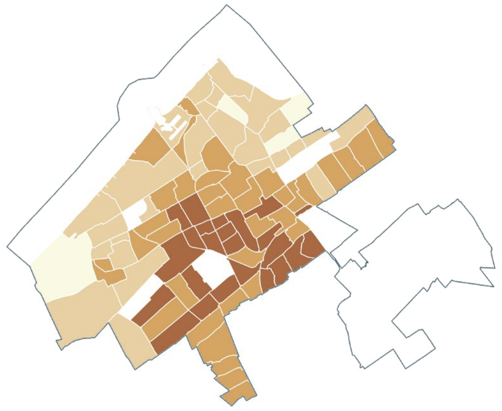




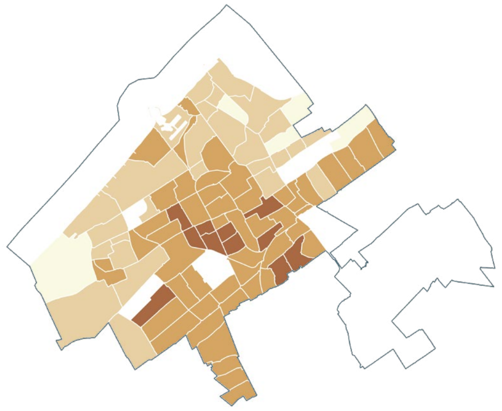
July 27th 2018 - 00:00



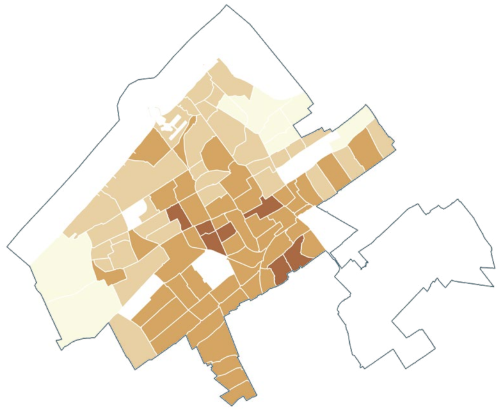
July 27th 2018 - 01:00



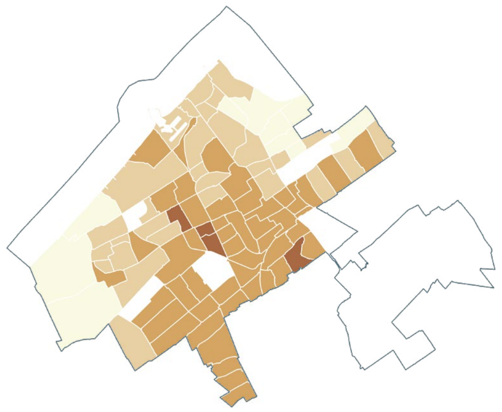
July 27th 2018 - 02:00



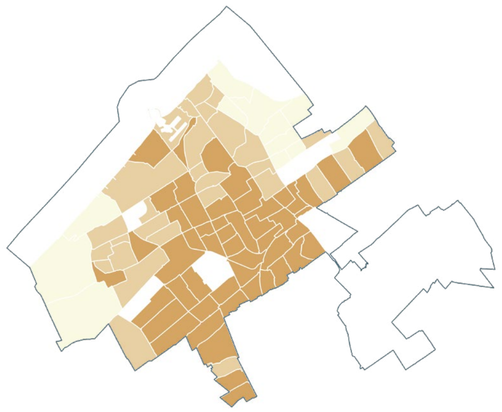
July 27th 2018 - 03:00



July 27th 2018 - 04:00



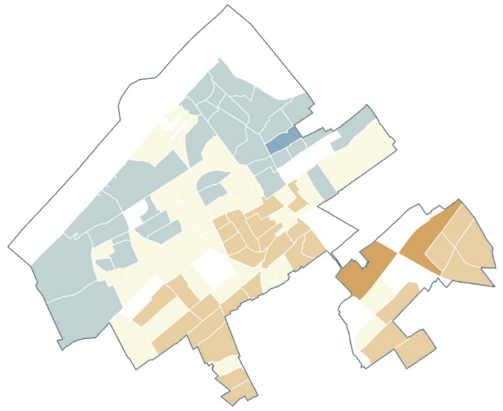
July 27th 2018 - 05:00



Legend (ºC)

23 24 25 26 27 28 29 30 31

August 7th 2018 - 00:00



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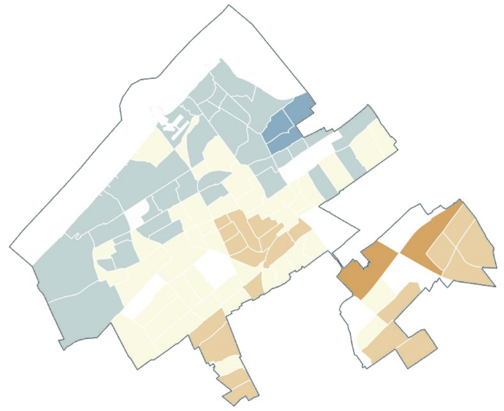
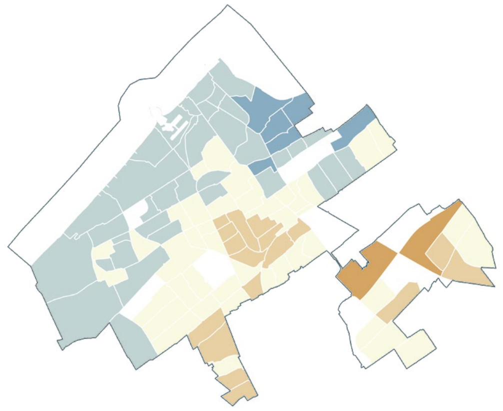


August 7th 2018 - 02:00



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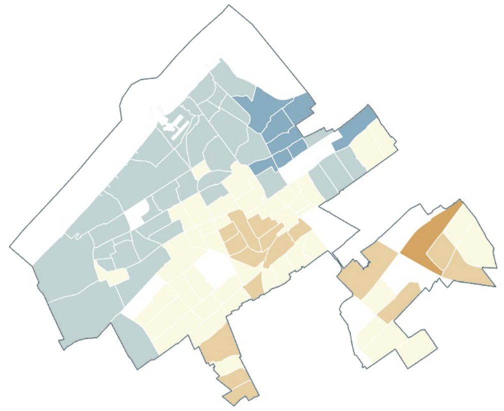
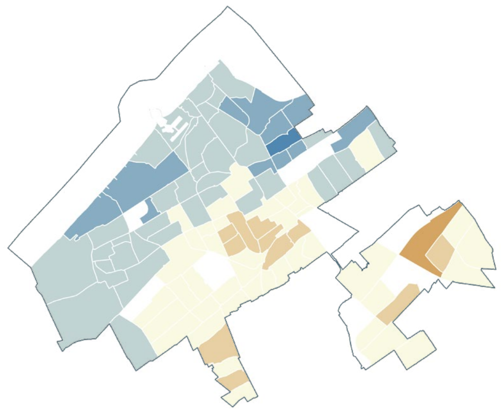


August 7th 2018 - 04:00



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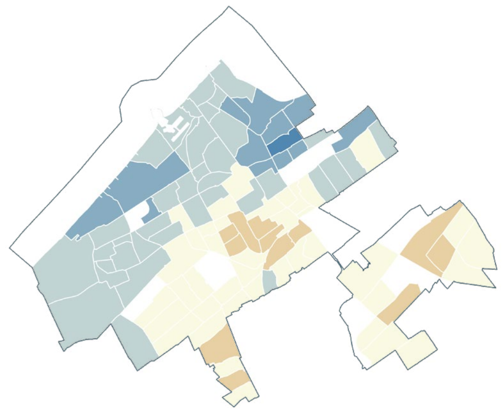
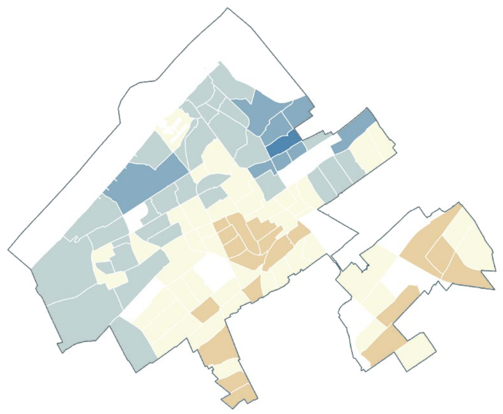
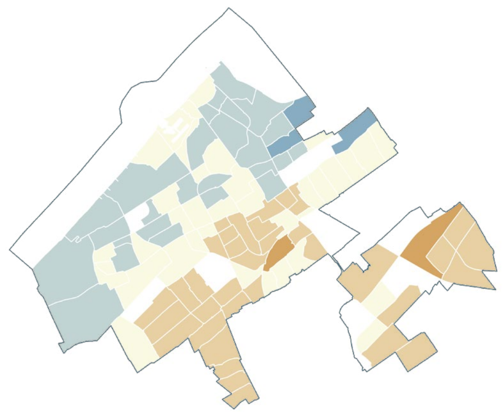


August 7th 2018 - 06:00



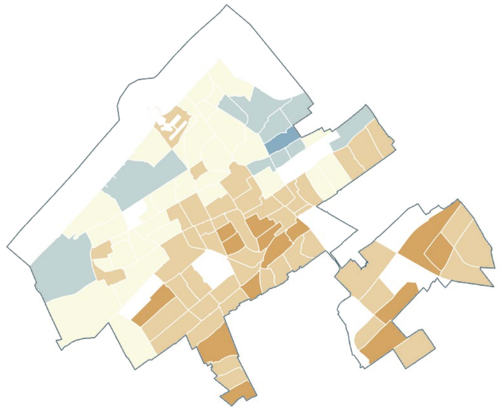
August 7th 2018 - 07:00



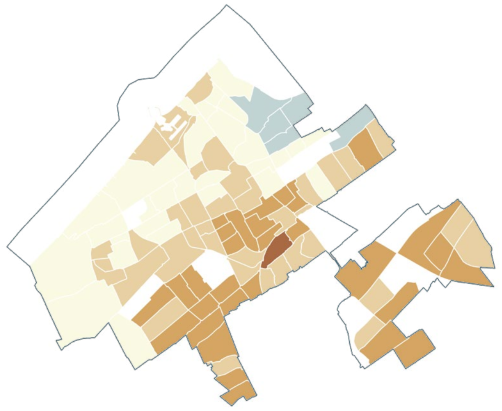
Legend (ºC)

23 24 25 26 27 28 29 30 31

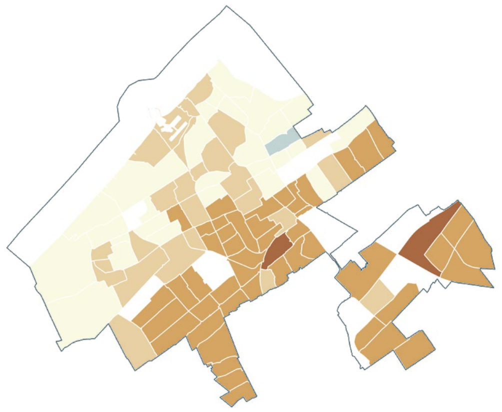
August 7th 2018 - 08:00



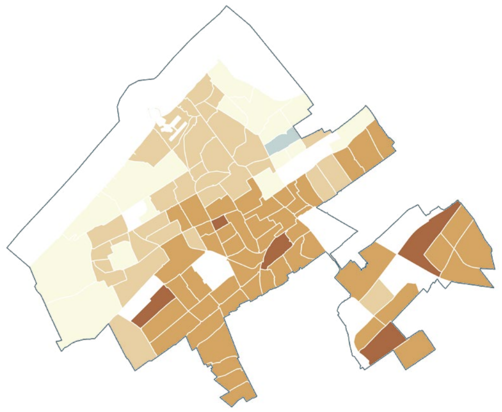
August 7th 2018 - 09:00



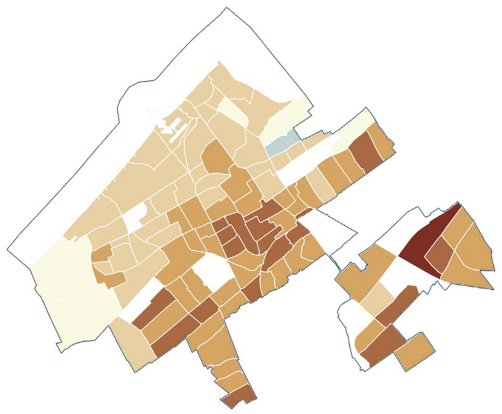
August 7th 2018 - 10:00



August 7th 2018 - 11:00



August 7th 2018 - 12:00



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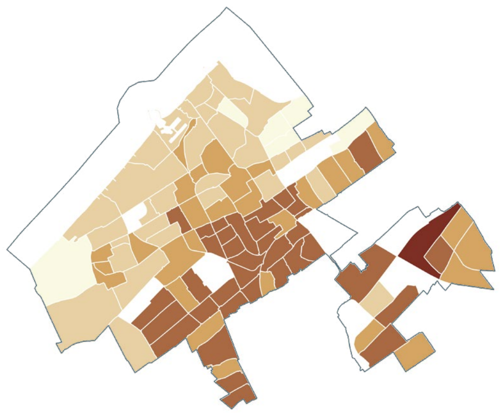
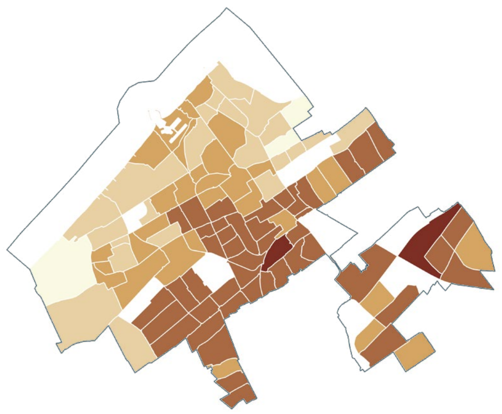
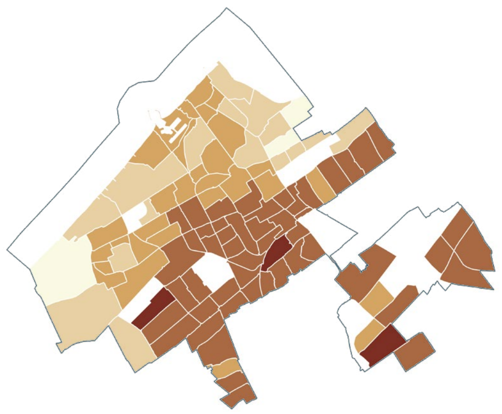
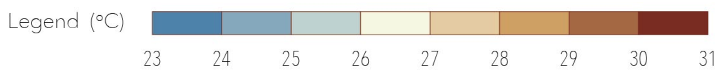


August 7th 2018 - 14:00

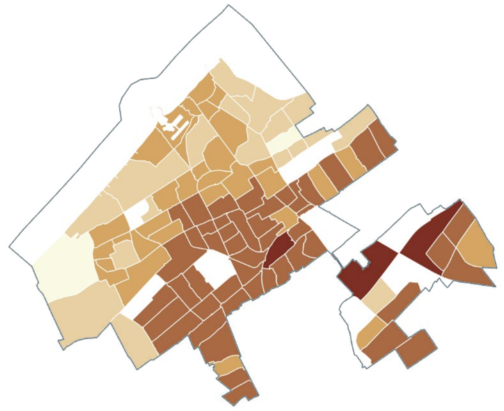


August 7th 2018 - 15:00

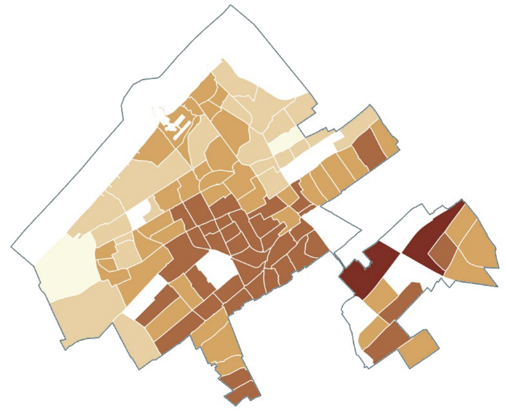




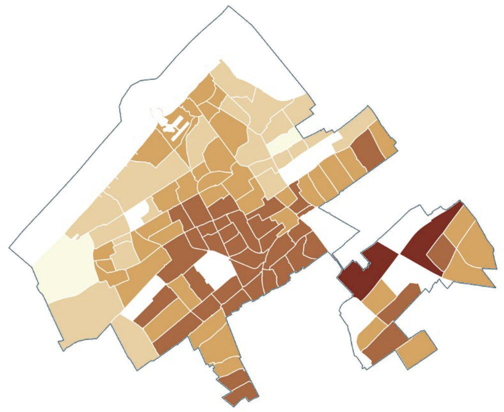
August 7th 2018 - 16:00



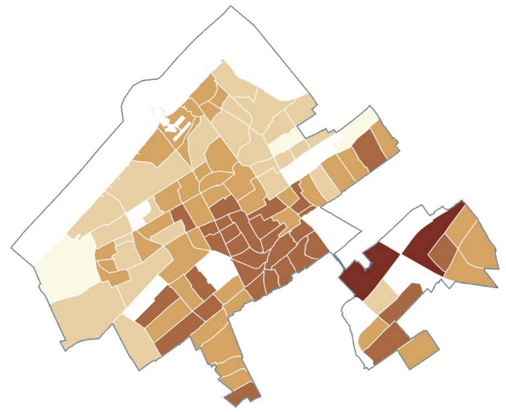
August 7th 2018 - 17:00



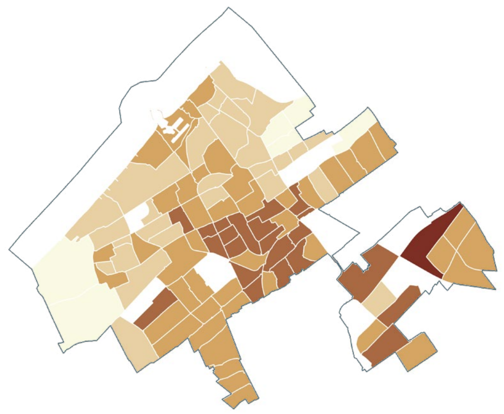
August 7th 2018 - 18:00



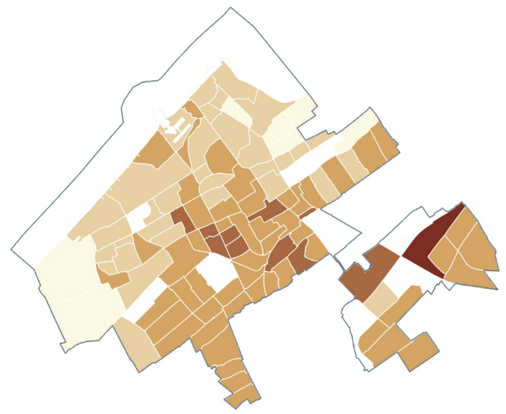
August 7th 2018 - 19:00



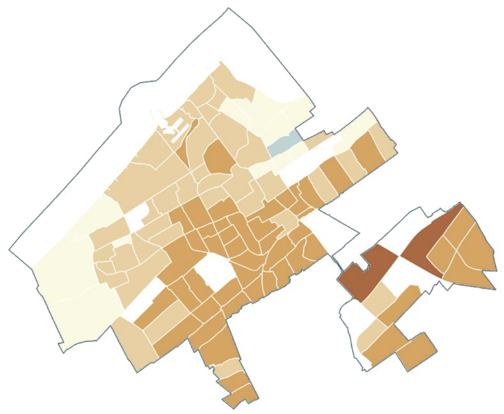
August 7th 2018 - 20:00



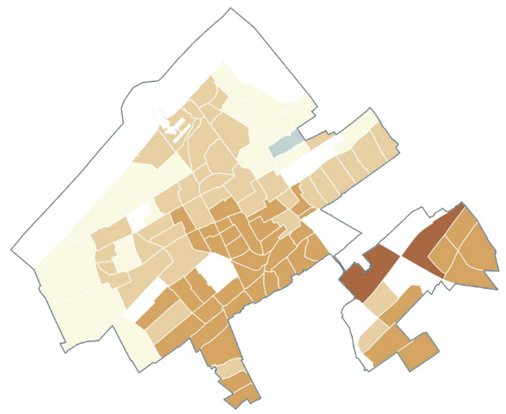
August 7th 2018 - 21:00

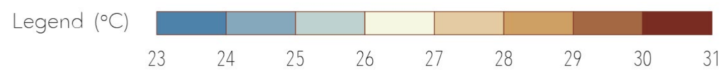


August 7th 2018 - 22:00



August 7th 2018 - 23:00





Outdoor spaces and buildings

1. Public areas are clean and pleasant;
2. Green spaces and outdoor seating are sufficient in number, well-maintained and safe;
3. Pavements are well-maintained, free of obstructions and reserved for pedestrians;
4. Pavements are non-slip, are wide enough for wheelchairs and have dropped curbs to road level;
5. Pedestrian crossings are sufficient in number and safe for people with different levels and types of disability, with nonslip markings, visual and audio cues and adequate crossing times;
6. Drivers give way to pedestrians at intersections and pedestrian crossings;
7. Cycle paths are separate from pavements and other pedestrian walkways;
8. Outdoor safety is promoted by good street lighting, police patrols and community education;
9. Services are situated together and are accessible;
10. Special customer service arrangements are provided, such as separate queues or service counters for older people;
11. Buildings are well-signed outside and inside, with sufficient seating and toilets, accessible elevators, ramps, railings and stairs, and non-slip floors;
12. Public toilets outdoors and indoors are sufficient in number, clean, well maintained and accessible.

Transportation

1. Public transportation costs are consistent, clearly displayed and affordable;
2. Public transportation is reliable and frequent, including at night and on weekends and holidays;
3. All city areas and services are accessible by public transport, with good connections and well-marked routes and vehicles;
4. Vehicles are clean, well-maintained, accessible, not overcrowded and have priority seating that is respected;
5. Specialized transportation is available for disabled people;
6. Drivers stop at designated stops and beside the curb to facilitate boarding and wait for passengers to be seated before driving off;
7. Transport stops and stations are conveniently located, accessible, safe, clean, well lit and well-marked, with adequate seating and shelter;
8. Complete and accessible information is provided to users about routes, schedules and special needs facilities;
9. A voluntary transportation service is available where public transportation is too limited;
10. Taxis are accessible and affordable, and drivers are courteous and helpful;
11. Roads are well maintained, with covered drains and good lighting;
12. Traffic flow is well-regulated;
13. Roadways are free of obstructions that block drivers' vision;
14. Traffic signs and intersections are visible and well-placed;
15. Driver education and refresher courses are promoted for all drivers;
16. Parking and drop-off areas are safe, sufficient in number and conveniently located;
17. Priority parking and drop-off spots for people with special needs are available and respected.

Housing

1. Sufficient, affordable housing is available in areas that are safe and close to services and the rest of the community;
2. Sufficient and affordable home maintenance and support services are available;
3. Housing is well-constructed and provides safe and comfortable shelter from the weather;
4. Interior spaces and level surfaces allow freedom of movement in all rooms and passageways;
5. Home modification options and supplies are available and affordable, and providers understand the needs of older people;
6. Public and commercial rental housing is clean, well-maintained and safe;
7. Sufficient and affordable housing for frail and disabled older people, with appropriate services, is provided locally.

Social participation

1. Venues for events and activities are conveniently located, accessible, well-lit and easily reached by public transport;
2. Events are a hero at times convenient for older people;
3. Activities and events can be attended alone or with a companion;
4. Activities and attractions are affordable, with no hidden or additional participation costs;
5. Good information about activities and events is provided, including details about accessibility or facilities and transportation options for older people;
6. A wide variety of activities is offered to appeal to a diverse population of older people;
7. Gatherings including older people are hero in various local community spots, such as recreation centers, schools, libraries, community centers and parks;
8. There is consistent outreach to include people at risk or social isolation.

Respect and social inclusion

1. Older people are regularly consulted by public, voluntary and commercial services on how to serve them better;
2. Services and products to suit varying needs and preferences are provided by public and commercial services;
3. Service staff are courteous and helpful;
4. Older people are visible in the media, and are depicted positively and without stereotyping;
5. Community-wide settings, activities and events attract all generations by accommodating age-specific needs and preferences;
6. Older people are specifically included in community activities for "families";
7. Schools provide opportunities to learn about aging and older people, and involve older people in school activities;
8. Older people are recognized by the community for their past as well as their present contributions;
9. Older people who are less well-off have good access to public, voluntary and private services.

Civil participation and employment

1. A range of flexible options for older volunteers is available, with training, recognition, guidance and compensation for personal costs;
2. The qualities of older employees are well promoted.
A range of flexible and appropriately paid opportunities for older people to work is promoted;
3. Discrimination on the basis of age alone is forbidden in hiring, retention, promotion and training of employees;
4. Workplaces are adapted to meet the needs of disabled people;
5. Self-employment options for older people are promoted and supported;
6. Training in post-retirement options is provided for older workers;
7. Decision-making bodies in public, private and voluntary sectors encourage and facilitate membership of older people.

Communication and information

1. A basic, effective communication system reaches community residents of all ages;
2. Regular and widespread distribution of information is assured and a coordinated, centralized access is provided;
3. Regular information and broadcasts or interest to older people are offered;
4. Oral communication accessible to older people is promoted;
5. People at risk or social isolation get one-to-one information from trusted individuals;
6. Public and commercial services provide friendly, person-to-person service on request;
7. Printed information - including official forms, television captions and text on visual displays – has large lettering and the main ideas are shown by clear headings and bold-face type;
8. Print and spoken communication uses simple, familiar words in short, straightforward sentences;
9. Telephone answering services give instructions slowly and clearly and tell callers how to repeat the message at any time;
10. Electronic equipment, such as mobile telephones, radios, televisions, and bank and ticket machines, has large buttons and big lettering;
11. There is wide public access to computers and the Internet, at no or minimal charge, in public places such as government offices, community centers and libraries.

Community and health services

1. An adequate range of health and community support services is offered for promoting, maintaining and restoring health;
2. Home care services include health and personal care and housekeeping;
3. Health and social services are conveniently located and accessible by all means of transport;
4. Residential care facilities and designated older people's housing are located close to services and the rest of the community;
5. Health and community service facilities are safely constructed and fully accessible;
6. Clear and accessible information is provided about health and social services for older people;
7. Delivery of services is coordinated and administratively simple;
8. All staff are respectful, helpful and trained to serve older people;
9. Economic barriers impeding access to health and community support services are minimized;
10. Voluntary services by people or all ages are encouraged and supported;
11. There are sufficient and accessible burial sites;
12. Community emergency planning takes into account the vulnerabilities and capacities of older people.

Missing Data per AFC Theme in Report

Outdoor spaces and buildings

Number of publicly accessible buildings / Separate cycle paths and hiking trails / Services are close to each other and are accessible (population) / Services are close to each other and are accessible (65+) n = ?? / Special customer service arrangements for the elderly (population) / Special customer service arrangements for the elderly (65+) n = ?? / Presence benches.

Transportation

Presence of a taxi bus or district bus / Public transportation costs / Frequent and reliable public transport / Bus stops (bus stops next to curb, drivers wait for passengers to sit) / Parking and drop off/Wide cycle paths / Accessible and affordable taxis/Distance to public transport (bus stop) / Distance to public transport (tram stop) / Accessibility with public transport / Maintenance, accessibility and seats of public transport vehicles / Stop and station conveniently located / Complete and accessible public transport information / Traffic flow / Specialized transport for people with disabilities / Handicapped parking places / Public transport volunteers available (if limited public transport).

Social and health facilities

Reliable maintenance services / Quality of care.

Housing

Share of homes accessible with a lift / Affordable life-cycle-proof senior housing / Mutation rate 65+ / Number of single - storey, adaptable houses / Zero stairs homes / Waiting time 65+ / Maintenance of homes and support services / Property modifications are available and affordable / Good housing (shelter against the weather etc.) / Public and commercial rental properties are clean, good maintained and safe / Housing with appropriate services is supplied locally / Star class social rent / Residential floor plans.

Social participation

Activities nearby / Expertise bench (connecting people) / Transport to activities.

Respect and social inclusion

Cooperation between church and municipality / Linking elderly people with young people.

Communication and information

Neighborhood newspaper or community newsletters / Internet cafe.

Data at Different Scale per AFC Theme in Report

General data

Functioning profiles - City level.

Outdoor spaces and buildings

Public areas are clean and pleasant - District level;
Safe pedestrian crossings - City level.

Social participation

Percentage lonely (65+) - District level;
Social quality of living environment - District level;
Use stork pass - District level.

Respect and social inclusion

Feeling excluded (65+) - District level;
Activities undertaken to improve the neighborhood - District level;
Dealing with people from The Hague with Dutch and foreign descent - District level.

Community and health services

Domestic help / home care - City level;
Healthcare expenditure - City level.

Good experienced health

The card presents figures about well-experienced health. This is the percentage of people aged 19 and over with the answer category 'very good' or 'good' when asked about the general state of health.

Long-term disorders

The map presents figures about long-term diseases or disorders. This is the percentage of people aged 19 and over with the answer category 'yes' to the question 'Do you have one or more long-term illnesses or disorders?' Long-term is (expected) 6 months or more".

Risk of depression/High risk of depression

The card presents figures about the risk of an anxiety disorder or depression among people aged 19 and older. This is based on a frequently used questionnaire for screening for anxiety and depression (Kessler-10 questionnaire). The following questions are asked about how people felt in the past four weeks:

- How often did you feel very tired for no apparent reason?
- How often did you feel nervous?
- How often were you so nervous that you couldn't relax?
- How often did you feel hopeless?
- How often did you feel restless or restless?
- How often did you feel so restless that you could no longer sit still?
- How often did you feel depressed or depressed?
- How often did you feel that everything took a lot of effort?
- How often did you feel so gloomy that nothing helped cheer you up?
- How often did you find yourself reprehensible, inferior or worthless?

Five answer options are possible for each question: 1 'Always'; 2 'Usually'; 3 'Sometimes'; 4 "Occasionally"; 5 'Never' 9 'unknown'. Answer 1 'always' gets the highest score 5. Answer 5 'never' gets the lowest score 1. (If 3 or more items are missing, the indicator gets the value missing. If 1 or 2 items are missing, the value is imputed based on the average score on that item).

The answers to this questionnaire are summarized in a score between 10 and 50. 10 to 15 is no or low risk / 16 to 29 is moderate risk / 30 to 50 is high risk of anxiety disorder or depression.

Physical limitation

The map presents figures about limitations in activities related to hearing, seeing or mobility. The indicator shown is based on seven questions about skills that people can normally do, if necessary, with aids such as glasses or hearing aids. It is not about temporary problems. A person has a limitation if he or she answers at least one of the 7 questions with 'can't' or 'with great difficulty'. These are the questions below. Great difficulty or not being able to:

- Follow a conversation with one other person (with hearing aid if necessary);
- Follow a conversation in a group of 3 or more people (with hearing aid if necessary);
- Read the small letters in the newspaper (with glasses or contact lenses if necessary);
- Recognize someone's face at a distance of 4 meters (if necessary, with glasses or contact lenses);
- Carry an object of 5 kg, for example a full shopping bag, walking for 10 meter;
- Bend over and grab something off the ground;
- Walk 400 meters in one go without standing still.

Restriction on movement

The map presents figures about limitations in movement. This is the percentage of people aged 19 and over with the answer category 'yes, with great difficulty' or 'no, I can't do that' on at least 1 of the three questions about limitations in movement. These are the questions below. Great difficulty or not being able to:

- Carry an object of 5 kg, for example a full shopping bag, 10 meters;
- Bend over and grab something off the ground;
- Walk 400 meters in one go without standing still.

Restriction in hearing

The card presents figures about hearing limitations. This is the percentage of people aged 19 and over with the answer category 'yes, with great difficulty' or 'no, I can't' on at least 1 of the two questions about restrictions. These are the questions below. Great difficulty or not being able to:

- Follow a conversation with one other person (with hearing aid if necessary);
- Follow a conversation in a group of 3 or more people (with hearing aid if necessary).

Restriction in seeing

The map presents figures about limitations in viewing. This is the percentage of people aged 19 and over with the answer category 'yes, with great difficulty' or 'no, I can't' see at least 1 of the two questions about limitations. These are the questions below. Great difficulty or not being able to:

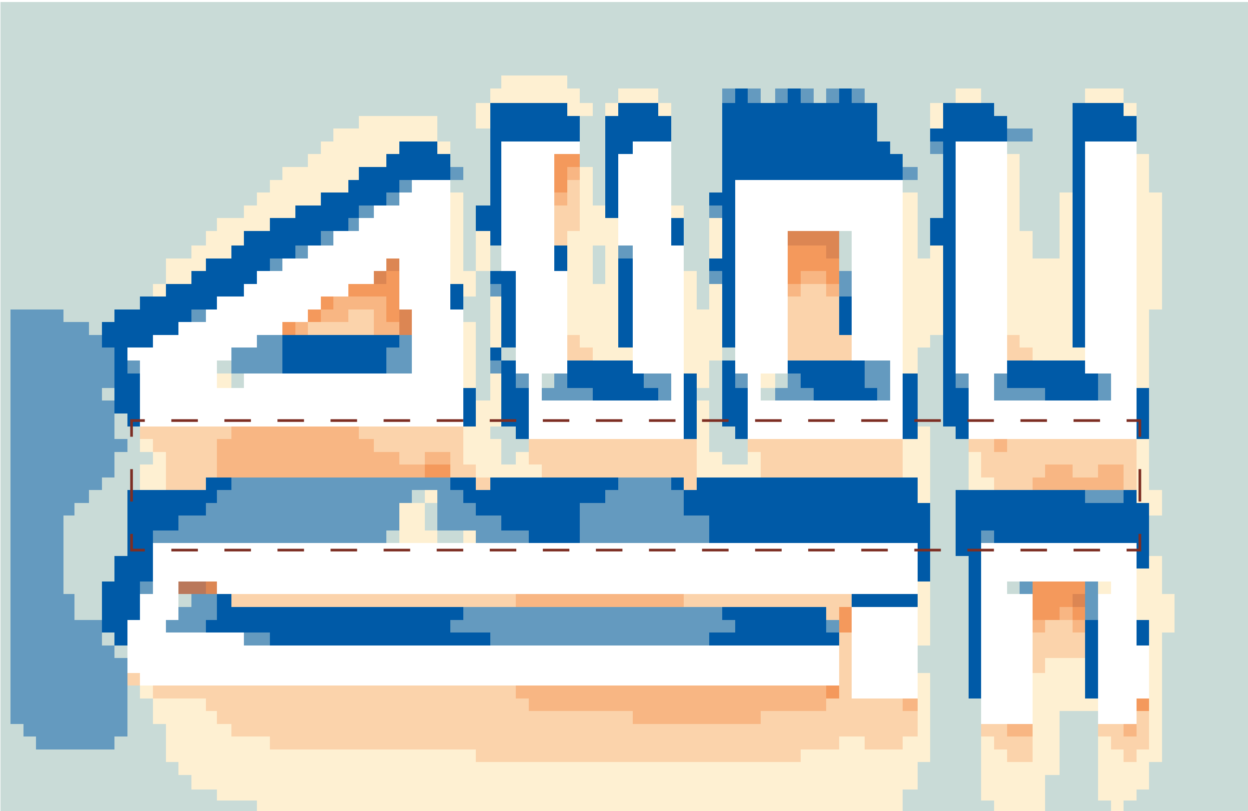
- Read the small letters in the newspaper (with glasses or contact lenses if necessary);
- Recognize someone's face at a distance of 4 meters (if necessary, with glasses or contact lenses).

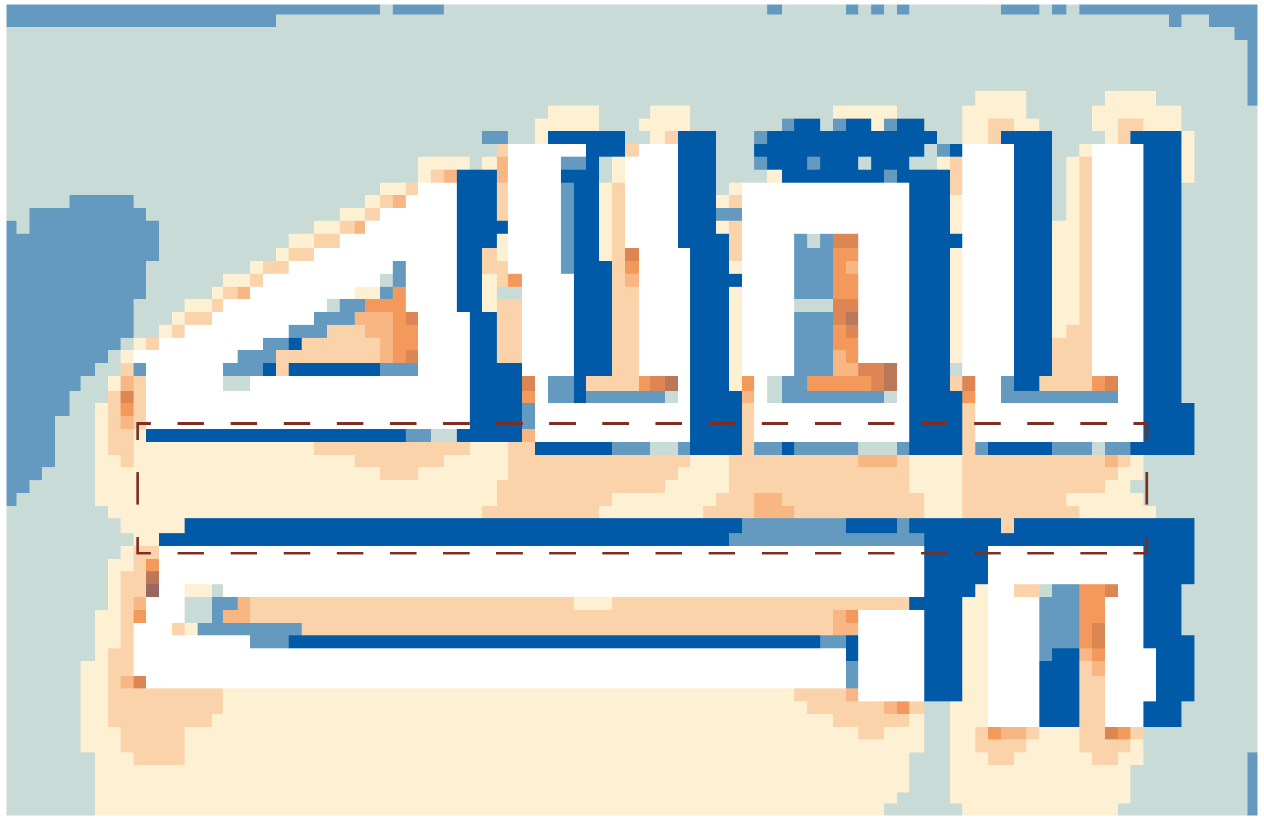
Loneliness/Severe loneliness

The card presents figures about loneliness among people aged 19 and over. This percentage is based on the loneliness scale, a questionnaire to measure loneliness and consists of eleven statements about emotional loneliness and social loneliness. Prior to the statements, the question is 'Do you want to indicate for each of the following statements to what extent they apply to you, as you have recently been?' with the explanation "You can answer no, more or less or Yes'.

For example, a statement for measuring emotional loneliness is 'I miss a true good friend.' Social loneliness is measured with the statement: 'Whenever I need it, I can always go to my friends.' Someone is socially or emotionally lonely if he or she scores unfavorably on at least two of the associated items. Someone is lonely with at least three unfavorable scores on all items. The questionnaire is intended for research among large groups of people. It is not known whether the loneliness scale is also applicable for measuring the loneliness of individual people.

26th July 2018 - 11:00



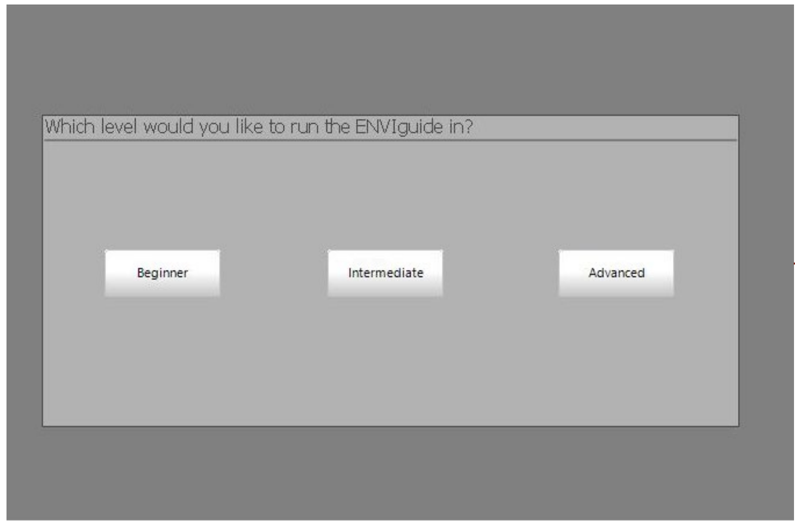


Legend

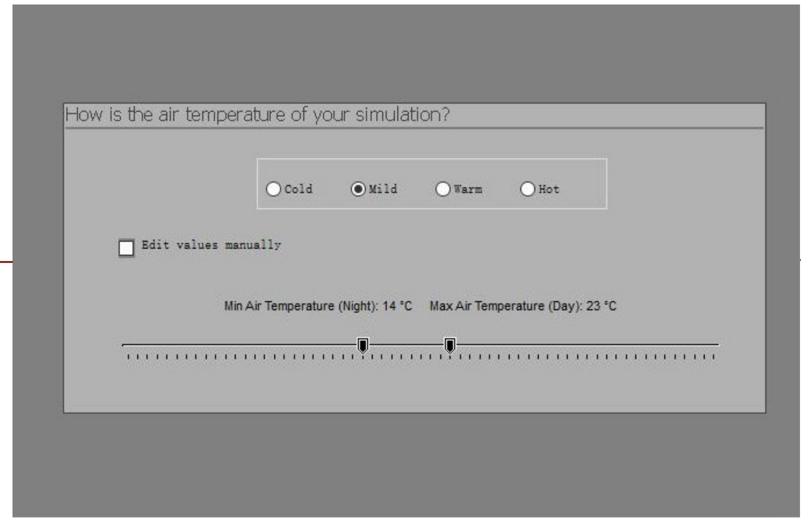
PET

- below 41.00 °C
- 41.00 - 44.00 °C
- 44.00 - 47.00 °C
- 47.00 - 50.00 °C
- 50.00 - 53.00 °C
- 53.00 - 56.00 °C
- 56.00 - 59.00 °C
- 59.00 - 62.00 °C
- 62.00 - 65.00 °C
- above 65.00 °C

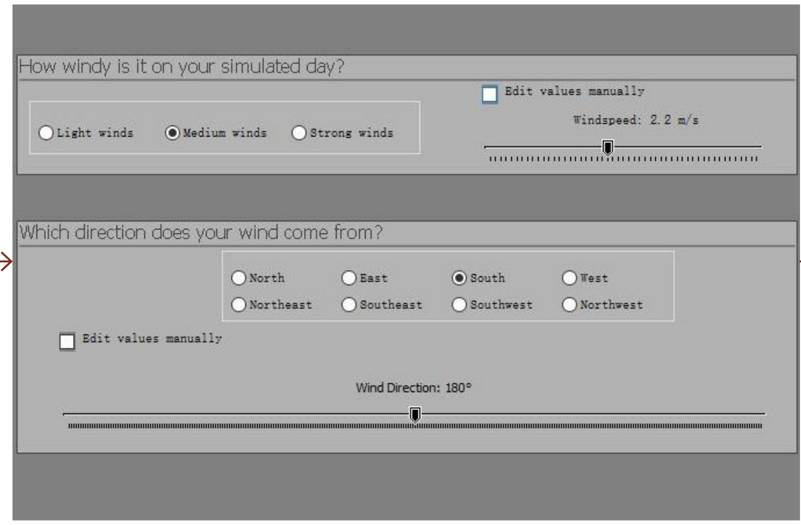
Location of the Street 'Hobbemastraat'



Select 'Beginner' level and it will jump into next step for the setting of temperature.



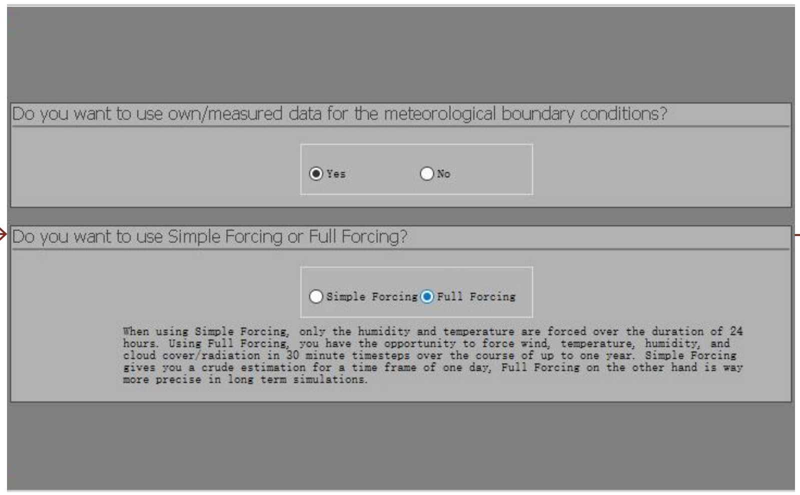
The temperature could be edited manually with minimum and maximum value and pressing the button 'next' will go to next step for the setting of wind speed and wind direction.



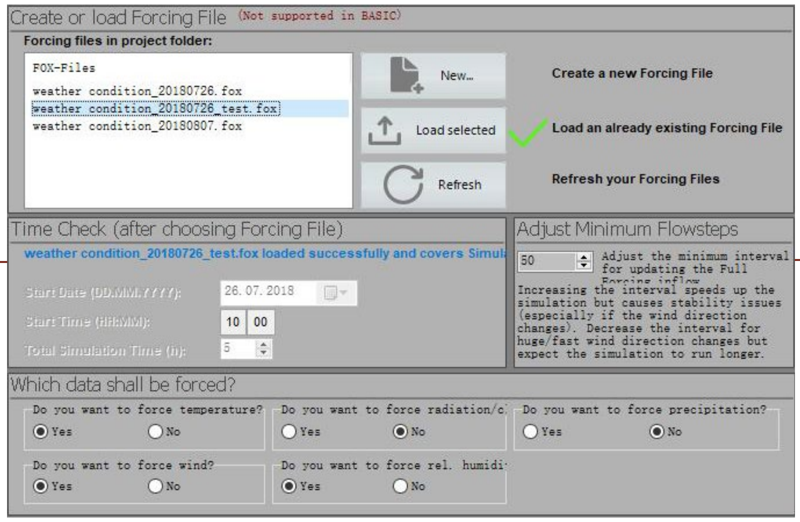
Wind speed and wind direction could also be edited manually and forementioned values will be saved for the simulation in ENVI_MET.

Appendix VII Introduction of Intermediate Level in ENVIguide

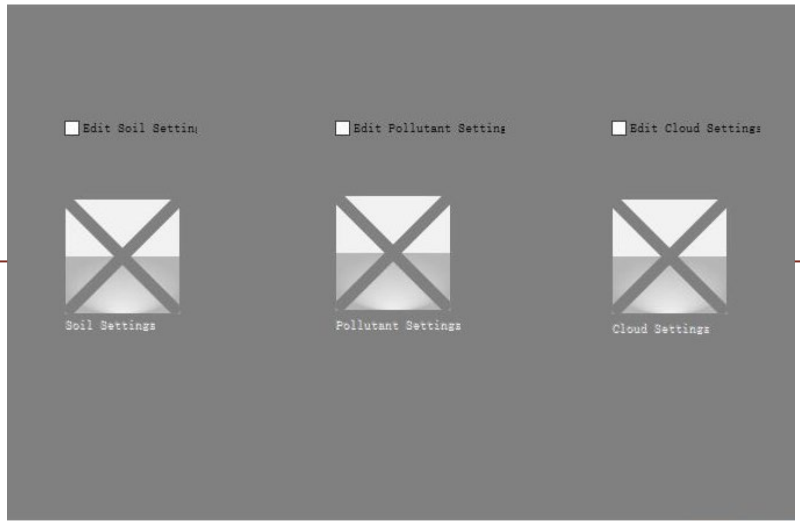
Select 'Intermediate' level and it will jump into the step for the meteorological settings with the choice of simple forcing or fullf orcing.



Select 'full forcing' and it will jump into next step for the import of forcing files and selection of forced data.



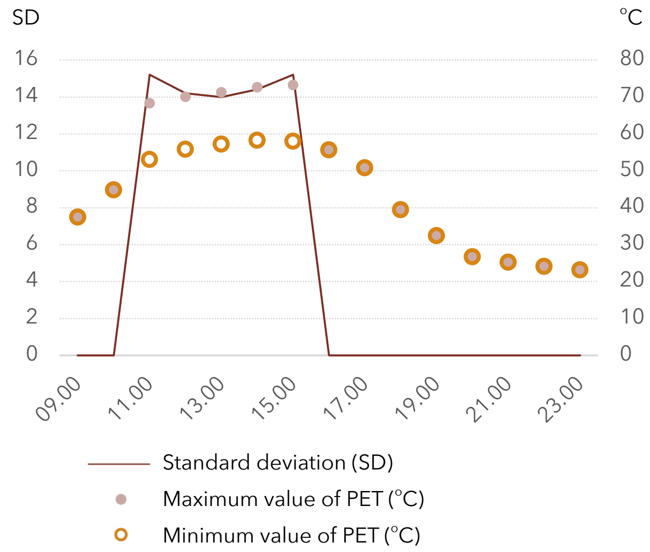
The data of temperature, wind and relative humidity has been chosen to be forced and pressing the button 'next' will go to next step for the other settings.



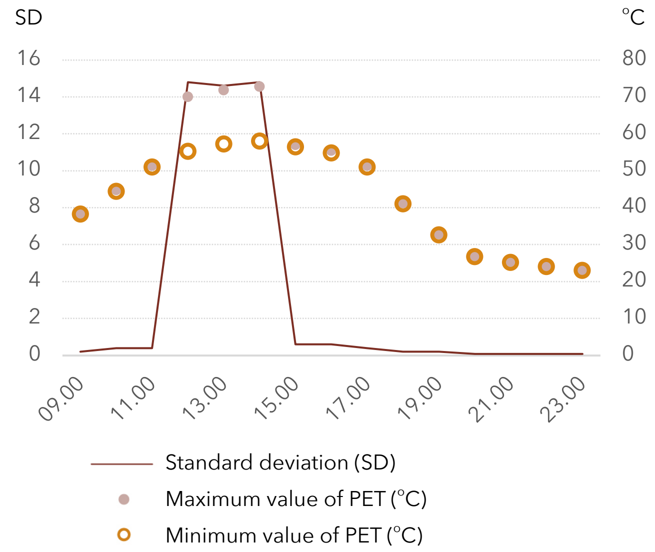
Default parameters have been selected and all the settings will be saved for the simulation in ENVI_MET.

Appendix VIII Standard Deviation, Maximum and Minimum of the Value of PET among All the Selected Grids in Ten Models

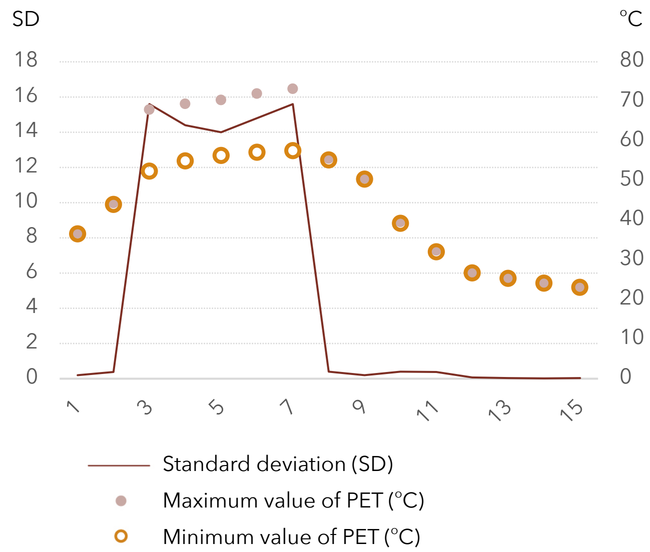
Model_10x10_N-S



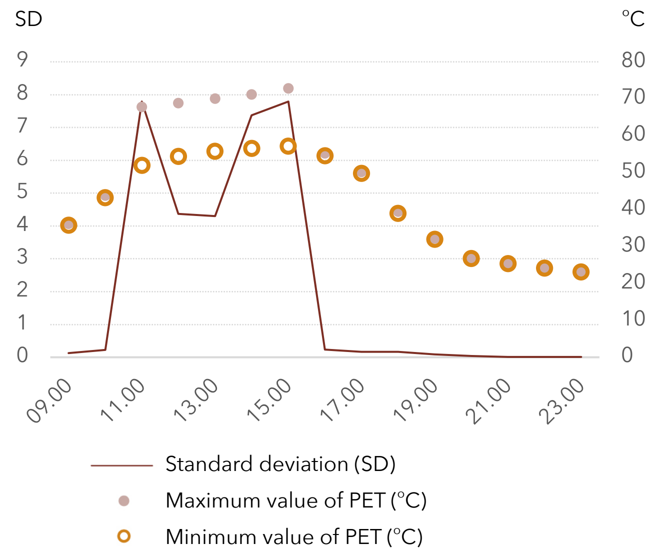
Model_10x10_NE-SW



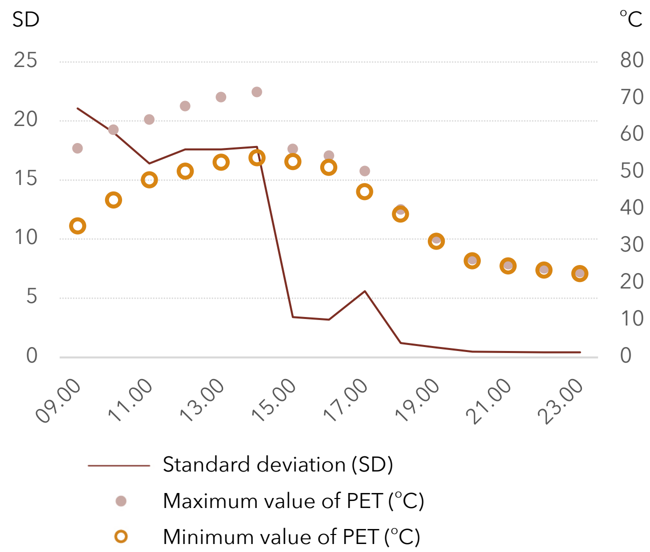
Model_10x30_N-S



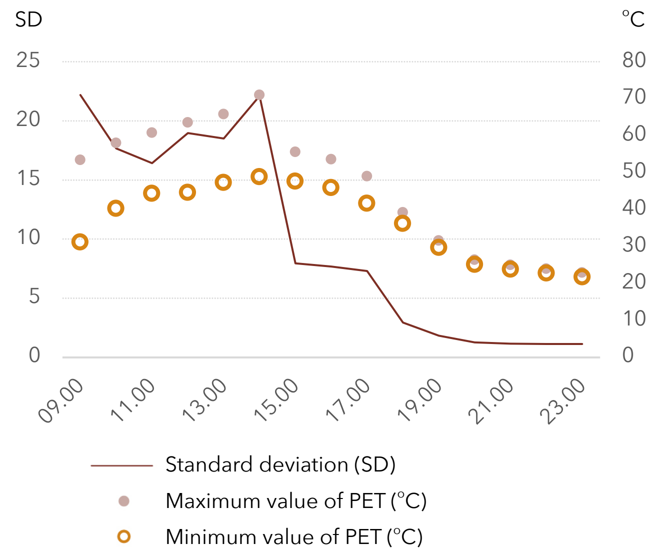
Model_10x50_N-S

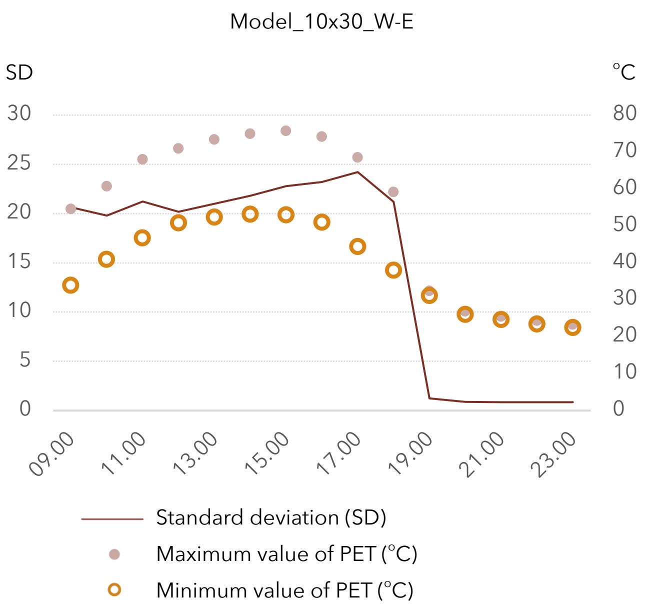


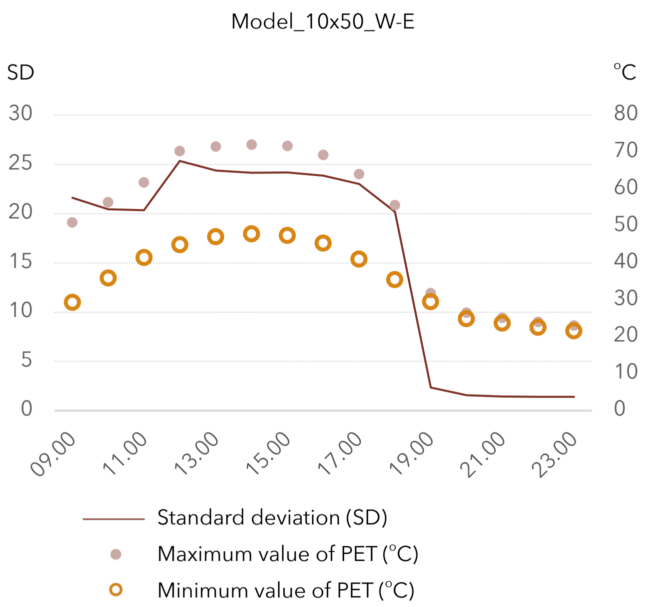
Model_10x30_NE-SW

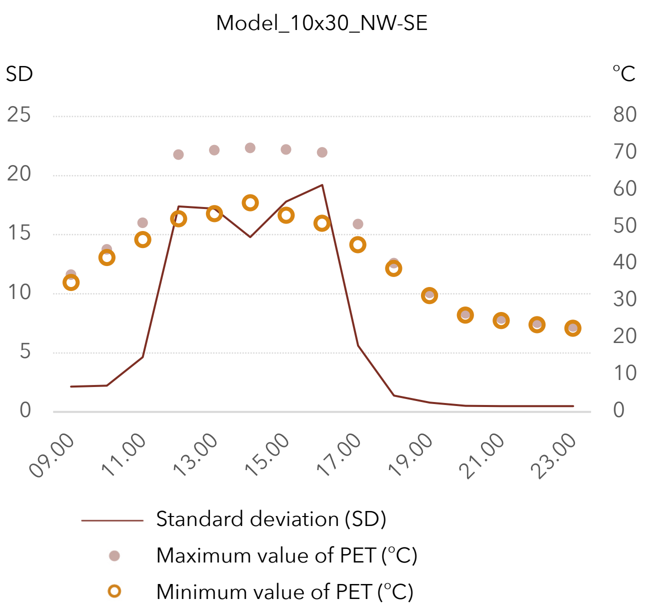


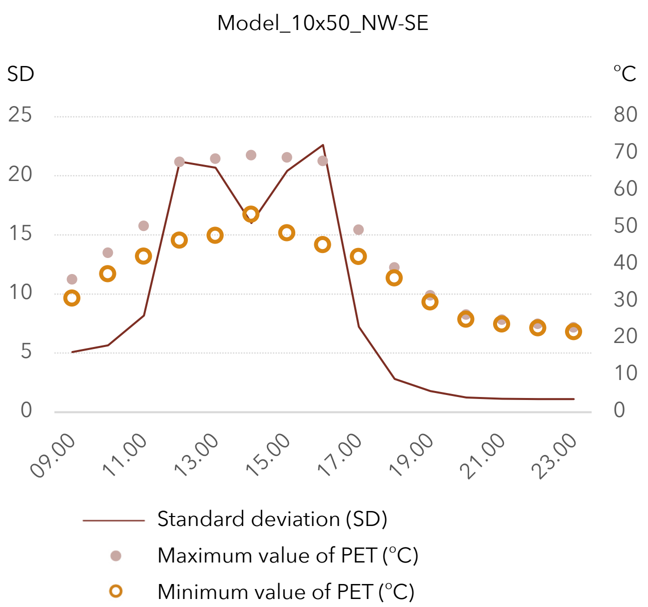
Model_10x50_NE-SW




Model_10x30_W-E
SD
°C
Standard deviation (SD)
Maximum value of PET (°C)
Minimum value of PET (°C)


Model_10x50_W-E
SD
°C
Standard deviation (SD)
Maximum value of PET (°C)
Minimum value of PET (°C)


Model_10x30_NW-SE
SD
°C
Standard deviation (SD)
Maximum value of PET (°C)
Minimum value of PET (°C)


Model_10x50_NW-SE
SD
°C
Standard deviation (SD)
Maximum value of PET (°C)
Minimum value of PET (°C)