THERMALLY COMFORTABLE RUNNING ROUTES IN AMSTERDAM

Katarzyna Starzycka
Msc Thesis Landscape Architecture
August 2017
Wageningen University

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COLOPHON

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ABSTRACT

Even though running is one of the most popular sport activity in the Netherlands and represents one of the most rapidly growing leisure activity in cities during the last 35 years, this open-air physical activity and its patterns are reduced due to the microclimatic conditions. Regularly raising air temperature, more frequent and serious heat waves, and severe UHI effect result in more heat stress in the urban environment. As a consequence, the urban microclimate, which has a strong impact on thermal comfort of runners, is affected.

Therefore, the issue that this thesis addresses is heat stress in the urban environment and its negative effects on running patterns. The city of Amsterdam serves as a case study. Issues that impact running such as urban microclimate and sensory experience are explored. The objective of the thesis is to inquire possible spatial interventions that improve thermal comfort and sensory experience of runners on running routes.

To conduct the research, research-for-design and research-through-designing are used as the main research strategies. Both qualitative and quantitative research methods are used. The study develops an integrated design toolbox and criteria that are used to test and evaluate the design models for the most avoided routes by runners. As a result, the design guidelines are generated.

Keywords: urban microclimate; urban heat stress; running; research-through-designing; climate responsive design; Amsterdam;

PREFACE

During my masters studies at Wageningen University I became fascinated about sustainability and innovation in landscape architecture. By following the course 'climate-responsive design and planning', I had a chance to implement these fascinations into design practice. During this course I got acquainted with the microclimate knowledge and became aware of how important is to design urban environments with regard to local microclimates.

Gladly, by conducting this research I took another step to deepen my knowledge on sustainable, innovative and climate-responsive landscape architecture. In this study I searched for climate-responsive design solutions that reduce heat stress and enhance running activities in cities. Therefore, this thesis did not only fulfill my academic fascinations but also met my personal hobby which is concerned with outdoor activities.

I hope that this thesis report will not only make my readers aware of the issue concerned with heat stress in the urban environments, but also fascinate and inspire to search for solutions for sustainable landscape and climate-responsive designs.

ACKNOWLEDGEMENTS

This academic journey and the progress of this thesis would not have been possible without the help and support of my supervisor, professors, family, and friends.

Foremost, I would like to thank to my dear thesis supervisor Sanda Lenzholzer for your professional support and guidance, critical eye and feedbacks, conversations and encouragement that greatly assisted the entire thesis process.

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Warm thanks to my dear university friends Kamila, Antonia, Veronika, Lukasz, Julia, Carlo, Thanos, Kathrine, Wojtek, Pawel, friends from the International Catholic Community, and Droevendaal 95 not only for giving your input into my research and supporting me during difficult times but also for giving inspirations and motivation to carry on, sharing your passions and daily life, for all good moments, travels, dinners, conversations, advices, well-wishes, and finally for your friendship.

Last but not least, thanks to my family and my best friends from Poland to whom I dedicate this thesis. Thank you for sharing your love, care, patience, support, passions, wisdom and life experience. Thank you for being always next to me, giving your honest advises, inspiration and encouragement to follow my dreams and passions.

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INTRODUCTION

1

1 INTRODUCTION

In this chapter, the larger relevance of research on climate change, public health and running is introduced. The dependencies between these three aspects are explained in global and local scale, for which Amsterdam serves as a study case.

1.1 CLIMATE CHANGE

According to the Intergovernmental Panel on Climate Change (2014), the changes in climate will occur in many extreme weather and climate events. The IPCC (2014) presents climate change scenarios for possible future situations and they slightly differ for different countries. It is very likely that the global mean surface temperature will increase, and there will be more frequent hot and fewer cold temperature extremes on the global scale. Climate change is expected to raise air temperatures about 1-2°C worldwide by 2050 (KNMI, 2014), double the number of summer days reaching 25°C, and triple the number of summer days reaching over 30°C in the Netherlands (van der Hoeven & Wandl, 2015). Moreover, heat waves are expected to last longer and occur more frequently by 2050, and therefore the Urban Heat Island (UHI) effect will be also strengthened (IPCC, 2014; KNMI, 2014).

1.1.1 Heat stress in the NL

The rising air temperatures, more frequent heat waves and ongoing process of urbanization will add to the UHI effect and enhance the problem of heat stress in the urban areas (Koopmans et al., 2012; Lenzholzer, 2015; Rahola, van Oppen, & Mulder, 2009). The UHI effect in the Netherlands is presented as a severe problem of many Dutch cities (Klok et al., 2012; Rahola, van Oppen and Mulder, 2009; van der Hoeven & Wandl, 2015). The difference in surface temperatures between urban areas of Dutch cities and their rural surroundings are 2.9°C during daytime, and 2.4°C during night-time (Klok et al., 2012). These measures are predicted to be worsen.

The problem of heat stress has been also identified in Amsterdam (Kolk et al., 2012; van der Hoeven & Wandl, 2015). Based on experience of heat waves in July 2006, Amsterdam faces a significant UHI effect that negatively affects people's well-being, health and comfort (Kolk et al., 2012; van der Hoeven & Wandl, 2015). The surface temperatures in Amsterdam are higher than national average (fig. 1). The surface temperature in the city of Amsterdam is 3.0°C higher than its rural surroundings during the daytime, and 3.9°C during the night-time (Klok et al., 2012). Following the findings of Oke (1982) and Amsterwarm project, *"it seems that the Amsterdam UHI is in the upper range of what can be expected in European Cities"* (van der Hoeven & Wandl, 2015, p. 72).

1.1.2 Impact of climatic conditions on physical open-air activities

Proven by many studies, physical outdoor activities are correlated with climatic conditions. Warm and dry weather stimulates choices for active open-air modes whereas rainy, snowy, windy, cold or extreme hot weather conditions have opposite effects. The study conducted by Böcker, Prillwitz and Dijst (2013a) demonstrates the dominance of temperature over precipitation when deciding on open-air activity. Therefore, active transport modes increase in winter, and decrease in summer (Böcker, Prillwitz, & Dijst, 2013).

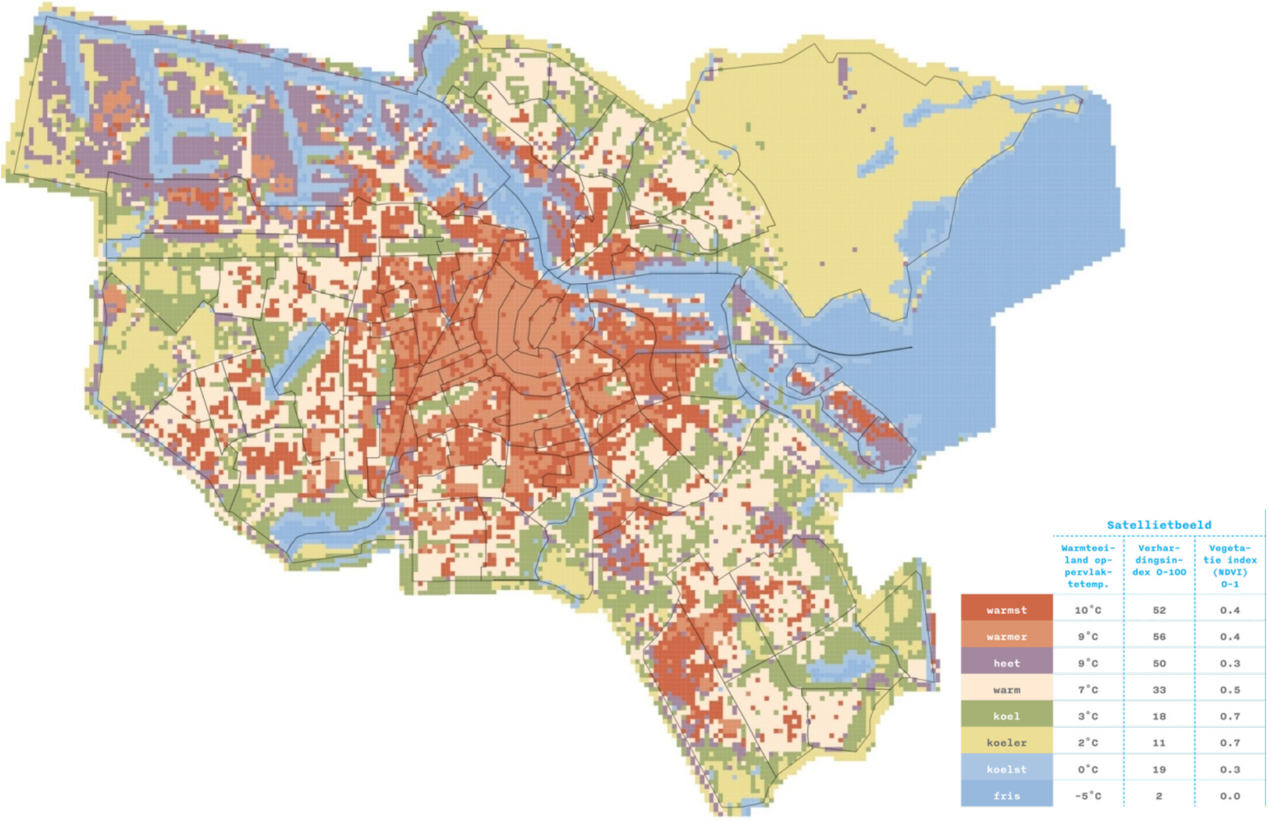


Fig. 1 Land surface temperature UHI on the 16-07-2016 in Amsterdam (van der Hoeven & Wandl, 2015)

1.2 PUBLIC HEALTH

1.2.1 Physical activity: facts and figures

Due to sedentary lifestyle, lack of physical activities during leisure time, increased use of passive modes of transportation, and exreme weather conditions, the level of physical inactivity is rising and bringing major implications for general health of people worldwide and for the prevalence of NCDs, overweight and obesity (RIVM, 2014; WHO, 2008). The study commissioned by WHO (2016) presents that 80 % of the world's adolescent's population (5-17 years old) and 25 % of the world's adults population (18-64 years old) are insufficiently physically active, and predicts that this ratio will increase.

Physical inactivity has become a global issue in public health and has been identified as the fourth leading risk factor for global mortality that is responsible for 6% of global deaths (WHO, 2010). Due to the problem of insufficient physical activity, the World Health Organization addresses the significance of physical activity on public health, and encourages to daily health-enhancing physical activities (Branca et al., 2007). WHO (2010) provides Global Recommendations on Physical Activity for Health as a guideline to primary prevention of NCDs and how to bring health benefits to the people worldwide.

1.2.2 Overweight and obesity in the NL

According to the study by WHO (2013), the number of NCDs, weight excess and obesity threat is also increasing in the Netherlands. The forecast predicts that 8% of men and 9% of women living in the Netherlands will be obese by 2030 (WHO, 2013), what will be mostly caused by physical inactivity and increased food intake. According to Bernaards

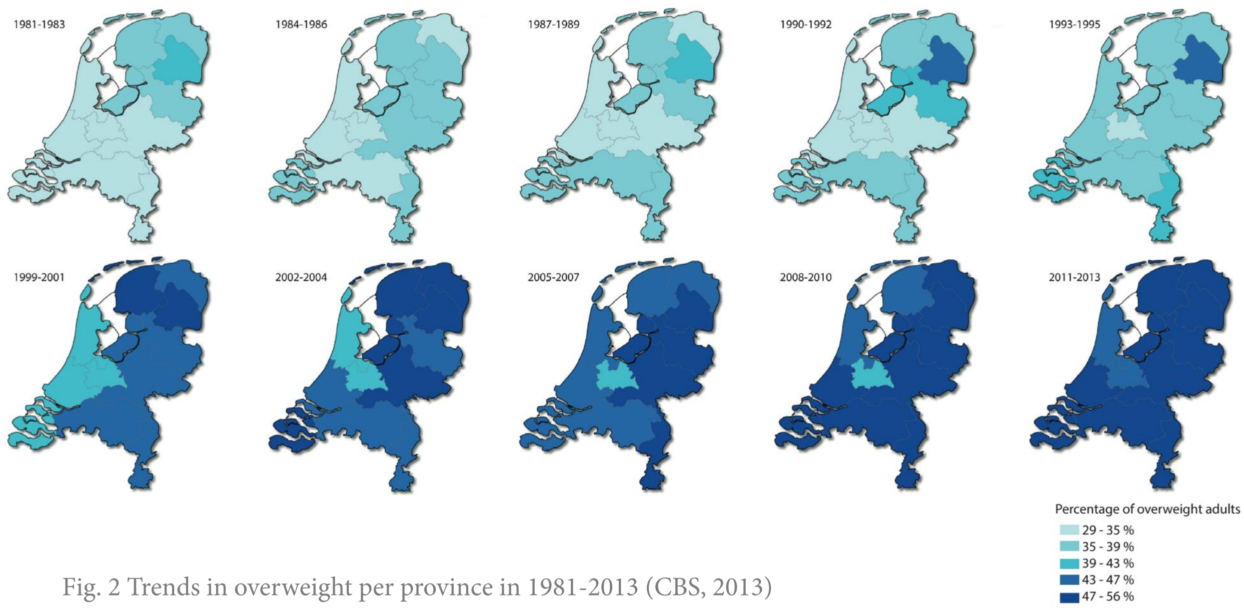


Fig. 2 Trends in overweight per province in 1981-2013 (CBS, 2013)

(2010), the prevalence of physical inactivity in Dutch adults is slowly declining, however, older adults and adolescents need urgent attention. Moreover, sedentary behaviour is increasing and adolescents are at special risk.

Over the last 30 years, the percentage of overweight and obese adults in Amsterdam has increased significantly (fig. 2), and it is predicted that these numbers will be increasing (CBS, 2016; WHO, 2013).

Therefore, Dutch National Institute for Public Health and the Environment (RIVM, 2014) pays special attention to the importance of improving public health and promotes physical activities among Dutch population. The city of Amsterdam set up several strategies to fight against the obesity. Investing and investigating in youth sports and activities is one of them.

1.2.3 Benefits of physical activities

Physical activity brings significant health benefits. It does not only reduce the risk of getting obese and prevalence of NCDs (Pretty et al., 2005; WHO, 2010), but is also associated with better quality of life, desirable health outcomes, positive effects on physical health and better mood states (Penedo & Dah, 2015).

According to the study by Pretty et al. (2005), exposure to nature and 'green exercises' in both rural and urban environments have positive significant effects on participants' mood measures. Moreover, recent studies show that participants engaged in outdoor physical activities display greater enjoyment and satisfaction with an outdoor activity, and declare a greater intent to repeat the activity later (Blair, Cheng, & Holder, 2001; Pretty et al., 2005).

1.2.4 Sport in leisure time

Even though the world's population is not sufficiently physically active, and physical activities are not regularly practiced among the western societies (WHO, 2010), a trend of doing sport in cities during the leisure time is increasing.

Because of rising awareness of health problems and importance of healthy lifestyle among citizens, sport is getting popular in the urban areas and becoming an essential part of the urban life (Gemeente Amsterdam, 2015). The popularity and intensity of specific sports partly depend on type of the environment (fig. 3). The urban environment is more inviting to do fitness, swim and run, while the non-urban environment is more pleasant for cyclists and hikers. Over the last few years, recreational running became a very popular urban sport.

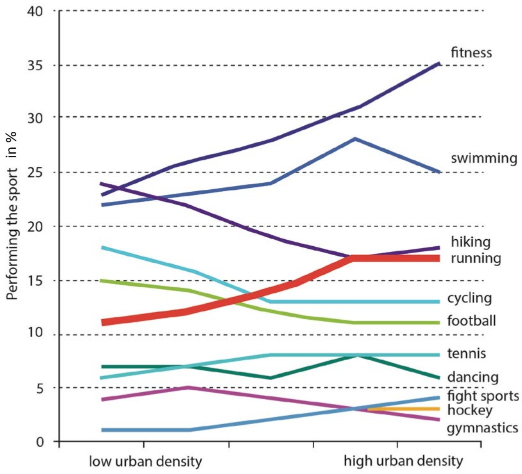


Fig. 3 Running participation in Europe Sport performance according to the urban density (Bernaards, 2010)

1.3 RUNNING

1.3.1 History of running

Running as a sport has a long history, however, a recreational running is a relatively new invention. Originally, only competitive athletes practiced running in private tracks and field clubs. The recreational running along streets was considered as a strange activity until the 1960's. The cultural revolution that had arrived in the 1960's and the 1970's, significantly influenced the sport trends, and recreational running became a public physical activity (Schreerder & Breedveld, 2015).

Recreational running started being practiced not only along public roads but also in parks and woods. Running became an individual, independent, and well-pursued sporting activity, which turned to be a mass movement. People started spending their leisure time on running. Running created a balance between work and private life, and had many positive impacts on runners' health and well-being. Running became a part of healthy and cultural life, and thus many cities started to organize annual marathons and running competitions that were open to everyone (Schreerder & Breedveld, 2015).

Currently, recreational running is one of the most popular sporting activities worldwide. The number of European runners exceeds 50 million. Running became a part of a daily life of many people, and it plays important role in cultural, social, health-oriented and economic dimensions. Runners appear in urban and rural environments, in parks, streets, at running competitions, and marathons. The number of runners, running clubs and federations grows every year and it is expected to keep increasing (Schreerder & Breedveld, 2015).

1.3.2 Running in the NL: facts and figures

Running is the fourth most common sport activity in the Netherlands. Running is practiced in every district of Amsterdam, and it is the second most popular sport in Amsterdam among other sports such as fitness, swimming, hiking (fig. 4) (Breedveld & Schreeder, 2015; CBS, 2013; Selten, Greven, & Bosveld, 2013).

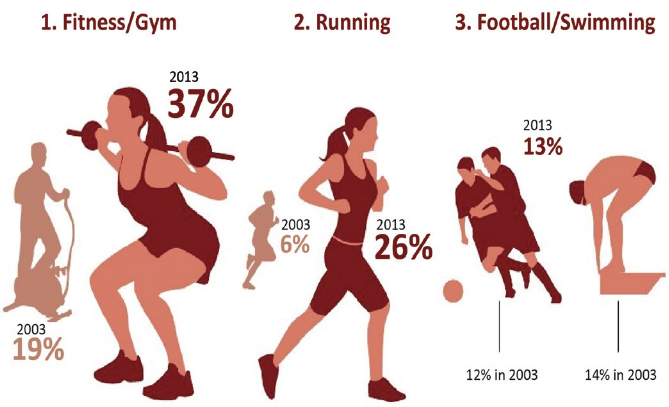


Fig. 4 The most popular sports in Amsterdam (Selten, Greven, & Bosveld, 2013)

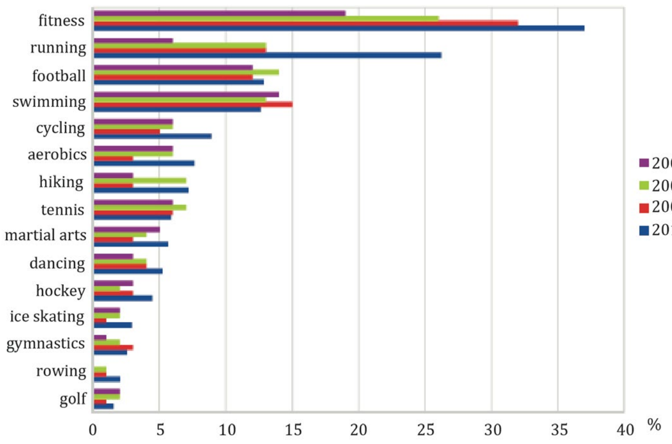


Fig. 5 Trends in sport (Raaphorst et al. 2014)

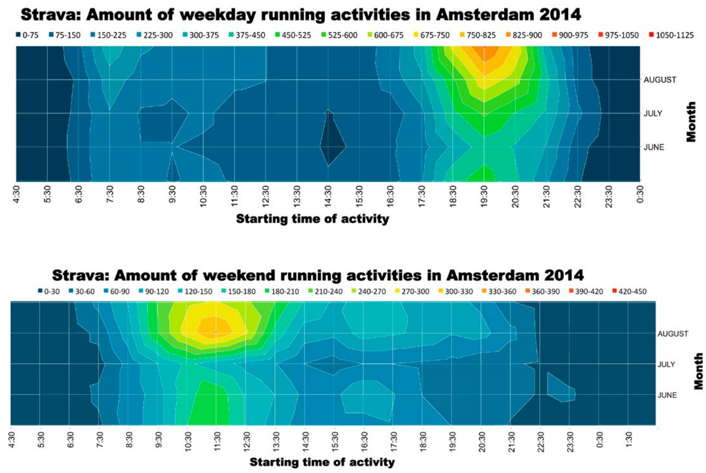


Fig. 6 Running activities in Amsterdam during weekdays and weekends (Dolders & Reiling, 2015)

Running is the most rapidly growing leisure activity during the last 35 years (Raaphorst et al. 2014). Between 2009 and 2013 the number of runners doubled (fig. 5), and it is expected that the running trend will continue (Selten, Greven, & Bosveld, 2013).

According to the study of Dolders and Reiling (2015), there are many factors that determine running patterns and runner's behaviour in Amsterdam. Running is strongly influenced by both personal and natural-rhythms, however, it has been observed that the natural places (urban parks) or water structures generally attract more runners than densely built urban environments. The areas of Vondelpark, Amsterdamse Bos, Amstel river and IJ are very attractive for runners. However, the distribution of the runners and intensity of the use of these places are variable. The running performance in Amsterdam depends on planned training distance, time, week day, urban tissue, spatial configuration, size of green and water structures along the route, and air temperature (Dolders & Reiling, 2015).

Runners of Amsterdam prefer running during weekdays and in the evenings (Dolders & Reiling, 2015). Most of the running activities occur between at 8.00 - 11.00 during the weekends, and at 17.00 - 21.00 during the weekdays (fig. 6). According to the statistics of CBS (2013), runners at the age of 18-34 (38% of all runners) and 35-54 (32% of all runners) actively run in Amsterdam. People below the age of 18 do not practice running. Running is the same popular among men and women.

1.4 RUNNING IN CITIES AND MICROCLIMATE

In the light of climate change, public health and rapidly increasing running activities in the urban environment, cities face a big challenge to provide safe and comfortable environment to run, especially during warm summer days.

Since running is embodied in the urban life and it is a very popular sport in recent years, running draws a lot of attention of researchers. Even though there is still a limited number of research about an impact of environment and landscape on running involvement, the potential relevance of the built environment to running has been recognized (Allen-Collinson & Hockey, 2007a; Cook, Shaw, & Simpson, 2016; Ettema, 2015; Qvistrom, 2016).

In recent years sport and medicine science draws special attention to heat stress arising from the thermal environment, and concerns about increasing number of heat-related illnesses among open-air physically active people (Barrow & Clark, 2007; Brotherhood, 2007; Howe & Boden, 2007; Porter, 1984). Heat stress and duration of outdoor exercise influence a runner's physiology, perception of effort, well-being and performance (Brotherhood, 2007). Regarding the study of Dolders and Reiling (2015), significant dependency between air temperature and running has been observed. The performance of runners on warm days reaching above 20°C is significantly lesser than on colder days.

Therefore, running in the urban environment in hot temperatures is a significant issue to be addressed.

1.5 AMBITIONS OF AMSTERDAM

The city of Amsterdam addresses the environment, climate, health, mobility and sustainability as prior concepts to be developed. These concepts are included within the ambitions of the city, and respond to the issues that city is facing with. To keep the running trend growing and getting this sport activity more popular in coming years, the city of Amsterdam set up a new Sportaccommodatieplan 2015-2020 (Gemeente Amsterdam, 2015). In this plan, Amsterdam presents ambitions to improve outdoor sport facilities in the city and host more sporting events, which will not only be a practical method to fight against obesity but also a business card to promote Amsterdam as healthy, sporty and attractive city on the international scale (Penninx et al., 2015). With regard to the ambitions of becoming healthy, climate-proof and sport-friendly, the result of this study can contribute to fulfill these ambitions.

1.6 THESIS OVERVIEW

This thesis addresses the issue of heat stress in the urban environment and its negative effects on running patterns. The city of Amsterdam serves as a case. The research outline and its objectives are defined (chapter 2). This thesis is to find the answer to the MRQ: *What spatial interventions could improve thermal comfort and sensory experience of runners on running routes?* The theoretical framework and themes of running, urban microclimate, and sensory experience are explored (chapter 3). Research-for-design and research-through-designing are used as the main research strategies. Both qualitative and quantitative research methods are used (chapter 4). The study develops design guidelines, which improve both thermal conditions and sensory experience of runners on the most avoided running routes (chapter 5). Finally, conclusion of this thesis (chapter 6), general observations and recommendations for further research are provided (chapter 7).

RESEARCH OUTLINE

2 RESEARCH OUTLINE

This chapter presents problem statement, theoretical lens and worldview, knowledge gap and research objective. Research questions are presented together with applied research strategy and methods.

2.1 PROBLEM STATEMENT

On the basis of the information from chapter 1, this thesis focuses on heat stress in the urban areas and its negative effects on running patterns in Amsterdam, and searches for design solutions to improve thermally conditions of runners on running routes.

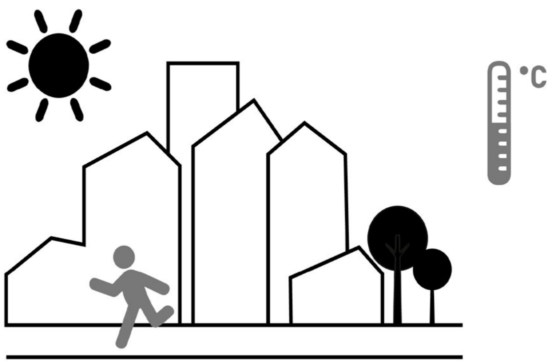


Fig. 7 Problem statement

The developed design guidelines will not only improve the local microclimate in the urban environment, but probably also positively affect the running patterns in Amsterdam and decrease the number of runners who struggle with heat-related discomfort. By doing this research and design, I generate design guidelines in order to improve local microclimate and thermal comfort of runners on the running routes.

This problem will be specifically addressed for the city of Amsterdam. Following the Amsterwarm project and findings of Oke, the city of Amsterdam already struggles with heat stress and *"it seems that the Amsterdam UHI is in the upper range of what can be expected in European cities"* (van der Hoeven & Wandl, 2015, p. 72). Moreover, the study conducted by Dolders and Reiling (2015) provides coherent data about running patterns in Amsterdam and introduces the problem of decreasing number of runners when it is warm. Therefore, Amsterdam will serve as a case. Additionally, the city of Amsterdam has ambitions to be "healthy" and "climate-proof" (chapter 1.5), being more reasons for the choice of this study case.

2.2 THEORETICAL LENS & WORLDVIEW

This section defines the theoretical lens and the worldview used in this research. They both direct the research and types of the methods to be used.

2.2.1 Theoretical lens

This research is conducted through the lens of a landscape architect, who sees and experience the landscape as a complex system. The landscape-based approach introduced at Wageningen University inspired me to look at the landscape as a layered system in which all layers influence and depend on each other.

This study investigates design solutions that reduce heat stress in the urban environment and positively influence running activities. The concepts presented in this thesis are assigned to different landscape layers. The concept of climate change and urban microclimate belong to the first layer. The second layer represents the local environment in which we live. The third layer consists of people and their activities. The fourth layer represents the concept of phenomenology and multi-sensory experience. This layer is fluent as it penetrates all the three layers and describes interactions between the layers' objects (fig. 8).

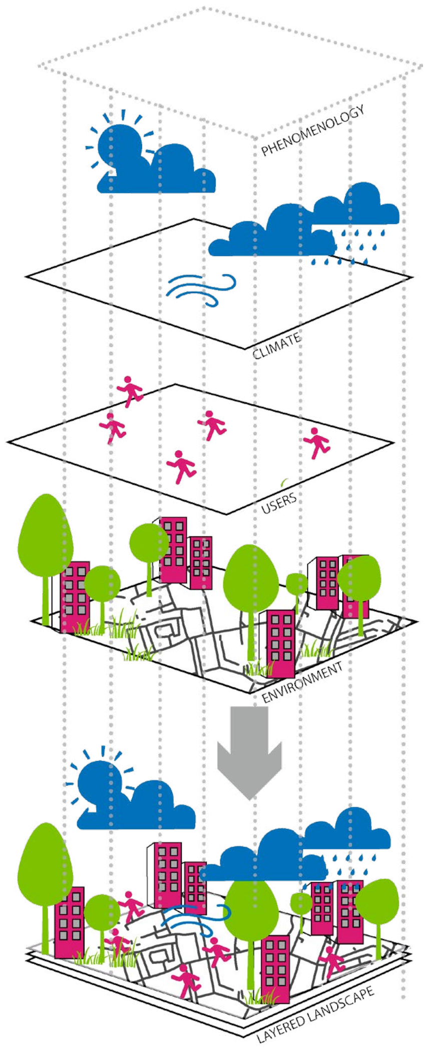


Fig. 8 Landscape layers

2.2.2 Worldview

This study is problem-focused and uses different methods, approaches and techniques. Both quantitative and qualitative methods are used to understand the problem, integrate existing knowledge and generate applicable solutions that work (Creswell, 2014). By pursuing a pragmatic approach, this research aims to find solutions to reduce heat stress in the urban environment, improve thermal comfort and sensory experience of runners on the running routes.

2.3 KNOWLEDGE GAP

2.3.1 Available knowledge

Many studies have been already done on urban microclimate (Brown & Gillespie, 1995; Klemm et al., 2015; Lenzholzer, 2015; Oke, 1978; Oke & Stewart, 2012; Steeneveld et al., 2011), UHI effects and heat stress in cities as one of the most severe consequences of climate change observed in the urban environment (van Hove et al., 2011; van Hove et al., 2015; van der Hoeven & Wandl, 2015; Steeneveld et al., 2011; Watkins et al., 2007).

The dependencies between weather conditions, including heat stress and open-air transport mode (Böcker, Dijst, & Prillwitz, 2013a; Böcker, Dijst, & Prillwitz, 2013b; Dolders & Reiling, 2015), human behaviour, athletes' performance (Martin & Buoncristiani, 1999; Maughan, Shirreffs, & Watson, 2007; Trapasso & Cooper, 1989; Vihma, 2010) and their health (Brotherhood, 2007; EPA, 2008; Rahola, van Oppen, & Mulder, 2009; Shendell et al., 2010; van der Hoeven & Wandl, 2015) have also been presented.

The gap between climate knowledge and urban design had been identified (Eliasson, 2000; Lenzholzer, 2010). In order to bridge the gap several studies were already conducted to challenge these disciplines. As a result of these studies, design tools, design principles, and design strategies for implementation climate-responsive solutions to mitigate the effects of climate change and improve thermal comfort in urban areas are provided (Brown & Gillespie, 1995; Brown & Lenzholzer, 2013; Lenzholzer, 2015; Kleerekoper, van Esch, & Salcedo, 2012; Klemm et al., 2015; Lenzholzer, 2010; Nikolopoulou & Steemers, 2003; Shendell et al., 2010).

Nevertheless, 'suitable tools' such as design recommendations or design guidelines to communicate knowledge and practice are still not developed well (Klemm, Lezholzer, & van den Brink, 2015).

2.3.2 Knowledge gap

There is a lot of knowledge about climate change, impacts of the UHI effect and heat stress on the urban environment, human behaviour and health, and startegies on how to mitigate heat stress. However, there is no knowledge on how to improve thermal comfort of runners in the urban areas by implementing climate-responsive design guidelines. Therefore, this thesis is a step to bridge climate knowledge and urban design and fill this knowledge gap by using climate-responsive solutions (fig. 9).

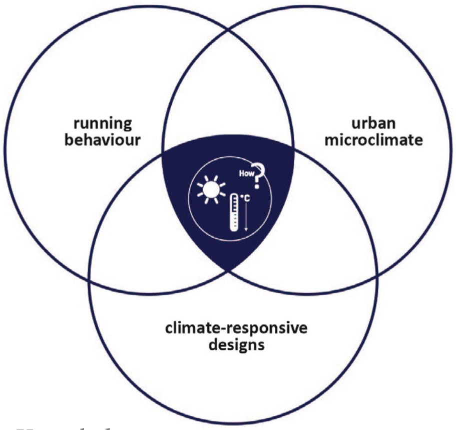


Fig. 9 Knowledge gap

More specifically, it is about finding possible climate-responsive design guidelines that improve thermal comfort of runners on running routes in warm summer days in the urban areas. The main focus on improving the urban microclimate on running routes will be to reduce heat stress locally.

2.4 RESEARCH OBJECTIVE AND QUESTIONS

This research explores possible spatial interventions to improve thermal comfort of runners in Amsterdam by providing climate-responsive design guidelines and how to implement these interventions in the urban space.

The main research question in this study is:

MRQ: ***What spatial interventions could improve thermal comfort and sensory experience of runners on running routes?***

To answer the main research question, there are three sub-research questions addressed:

SQ1. ***What are the characteristics of less used running routes in Amsterdam?***

SQ2. ***What kind of spatial configuration should running routes have to improve thermal comfort and sensory experience of runners?***

SQ3. ***In what way can the spatial configurations, which improve thermal comfort and sensory experience of runners, be implemented into design guidelines?***

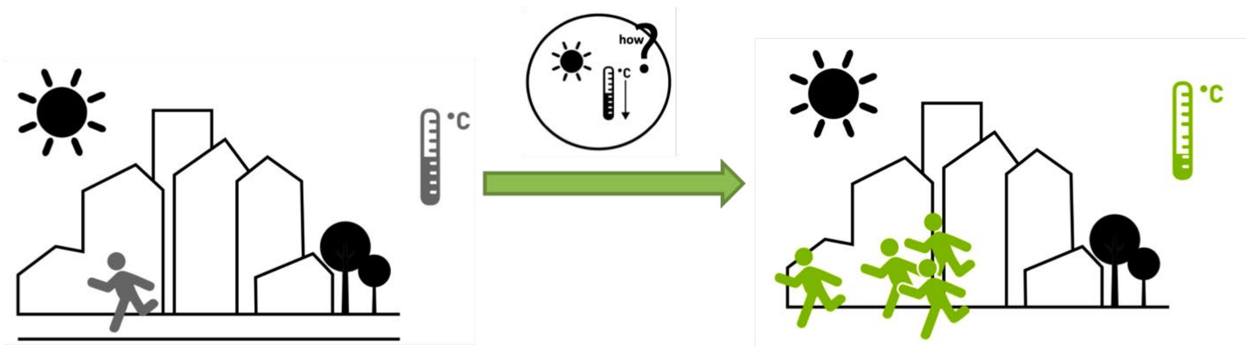


Fig. 10 Research objective

THEORETICAL FRAMEWORK

3 THEORETICAL FRAMEWORK

This chapter presents main concepts that concern and frame the research topic and questions based on existing literature. The terms discussed revolve around two main issues concerning running in the city: thermal and other sensory perception.

3.1 RUNNING

Running is an interaction between the body and environment (Cook, Shaw, & Simpson, 2016). Recreational running is evidently a popular pursuit that occurs very often in the urban environment, and running participation has significantly increased in recent years worldwide (Ettema, 2015; Shipway & Holloway, 2010). It has positive effects on both physical and mental health, and it boosts restorative capability, leads to an improved mood, health, quality of life, and assists with dealing with daily worries (Ettema, 2015; Shipway & Holloway, 2010). Running is not an evident activity of getting from point A to point B, but it is a means of moving through spaces. One of the most intense experience of the interaction between a runner and landscape is when the runner experiences a running route with all his senses and body by moving through and over different landscapes, surfaces, and slopes (Cook, Shaw, & Simpson, 2016).

3.1.1 Reasons for running

Primary reason for participating in running as a leisure activity is related to health benefits. Running is a way to counteract the ill-effects of sedentary lifestyle, improve the healthy living and physical well-being, and to maintain a slim body. Running evokes different feelings and emotions like pride, excitement, euphoria, freedom, anxiety, pain, exhilaration, etc. (Allen-Collinson, 2005; Bale, 2004; Lorimer, 2012), therefore, it has a direct impact on the well-being and psychological health. Experience-oriented runners use running as a useful method to escape from everyday life for a while. Running is a form of controlling the mood, providing a calming and relaxing activity to assist with dealing with stress and problems (Cook, Shaw, & Simpson, 2016; Shipway & Holloway, 2010). Furthermore, for some people running is a hard work rather than leisure activity in which speed and runners' own records play the main role. They run to challenge themselves and train their bodies to reach better results, performance and quicker times. Additionally, difficulties and hardships associated with running are considered as feats. Last but not least, some people decide to run as a consequence of recent high-profile campaigns, which broadly promote healthy lifestyle and encourage people to regular exercises that enhance physical and mental health (Cook, Shaw, & Simpson, 2016; Ettema, 2015; Shipway & Holloway, 2010).

3.1.2 Runninng in the urban environment

Among physical elements, which occur in the built environment and have influential impact on route's attractiveness and runners' engagement, are landscape forms, different surfaces, infrastructure, facilities, street lighting, and encounters with other types of traffic and users of the same space. An appropriate infrastructure, well-lit and well-maintained sidewalks, comfortable and smooth surfaces, greenery, and extra facilities along the running routes like water fountains, toilets, parking areas, or emergency telephones positively influence the running activities.

In contrary, poor street lighting, uneven or muddy surfaces, slopes, encounters with other types of traffic, dog owners, or parents with kids increase the probability of injury and harassment, and thereby negatively influence the running performance.

The running activities can also be influenced by social environment. Because public spaces are available for different groups of people, issues that come from the social environment are mostly considered with verbal or non-verbal harassments that are addressed to runners (Allen-Collinson & Hockey, 2013; Bull et al., 2003; Ettema, 2015; Synovate, 2008). On the other hand, some runners enjoy running in public spaces as they are attracted by lively environments that are created by tourists, residents or other runners, who are also involved in active leisure (Ettema, 2015).

Generally, it is observed that running in densely built environment is less attractive than running outside a town or in parks. However, providing special physical elements in the urban landscape, which refer to non-urban landscapes, may improve the attractiveness of a running route and positively enhance the running experience. For instance, providing an unpaved route that refers to a forest or a park may improve restorativeness of the place, and bring positive memories and experience to a runner (Ettema, 2015).

3.1.3 Running experience

According to many studies on running, there are many environmental and non-environmental factors that influence running performance and runners' experience (Cook, Shaw, & Simpson, 2016; Dolders & Reiling, 2015; Ettema, 2015; Hockey & Allen-Collinson, 2007; Qvistrom, 2016). It is concerned with an experience of the urban microclimate, thermal perception and other sensory experience of a runner (fig. 11).

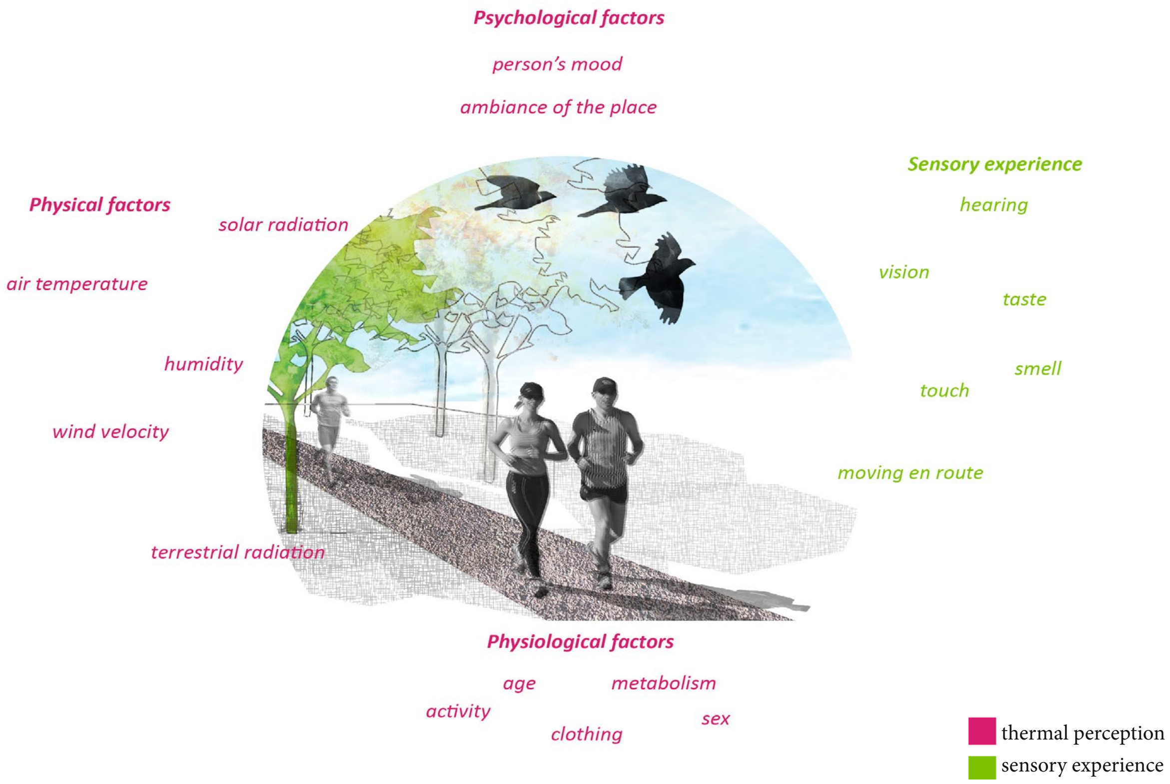


Fig. 11 Factors influencing thermal and sensory perception of runners

3.1.3.1 Experience of microclimate

People experience microclimate differently. Their experience is determined by many factors, which can be related to an individual person and his individual perception, but also by some external factors. The factors can be classified into three groups:

1.Individual physical and physiological factors. People of different gender, age, metabolism, way of clothing, habituation and during different physical activities experience the microclimate in different and individual ways. These factors can neither be modified nor influenced by landscape or urban design.

2. External physical factors like air temperature, solar radiation, terrestrial radiation, humidity, and wind velocity influence the experience of the urban microclimate a lot. Combinations of different factors result in different experiences (Lenzholzer, 2015). For example, high air temperature together with solar and terrestrial radiation bring a sense of warmth; high air temperature together with high humidity brings a sense of stuffiness; wind together with high humidity gives a sense of coldness. In contrary to the individual factors, the external physical factors can be influenced by urban designs and thus urban microclimate can be improved by specific spatial interventions.

3. Psychological factors. The ambiance of a place as well as people's mood and their company belong to psychological factors. They influence the experience of urban microclimate and can be influenced by designers. The ambiance of a place that is determined by colours, materials, spatial configuration and size can be easily improved, however, people's mood and their company cannot be modified (Lenzholzer, 2015; Nikolopoulou & Steemers, 2003).

3.1.3.2 Thermal perception

Human thermal comfort is a psychological interpretation of the physiological state of the body (Herrington & Vittum, 1977), which can be affected by many microclimatic and personal elements. According to this definition, thermal comfort is a subjective sensation.

Thermal comfort is controlled by the energy exchange between the body and its surroundings (an energy budget). Among the environmental elements that determine the heat exchange are: solar and terrestrial radiation, air temperature, relative humidity, and wind velocity. Additionally, an activity of a person plays an important role in thermal comfort as it influences metabolic heat production (Arens & Bosselman, 1989; Brown, 2010; Herrington & Vittum, 1977; Taleghani et al., 2013). Moreover, other factors like clothing worn by a person, a posture of the person, the amount and temperature of food recently eaten, or an activity that had been done before arriving to the landscape have also an impact on the human thermal comfort (Brown & Gillespie , 1995).

When the net loss of energy of the body is not equal to the production of energy by metabolism within the body, the body is under **thermal stress** (Herrington & Vittum, 1977). The thermal stress in the urban areas is affected by the Urban Heat Island effects (Koopmans et al., 2012; Rahola, van Oppen, & Mulder, 2009).

3.1.3.3 Phenomenology and multi-sensory experience

Phenomenology is a qualitative and interpretative strategy, in which a person actively engages in 'making-sense' of a phenomenon that is encountered. Phenomenology is interested in phenomena, which focus on how things are experienced or how they are given or presented to the subject to be experienced

(Gallagher & Zahavi, 2007). Phenomenology is also about being-in-the-world, describing the world and the ways it appears. The phenomenological approach introduces a subject of matter to be investigated and examined from the first-person perspective (Creswell, 2009; Deming & Swaffield, 2011; van Etteger, 2013).

Multi-sensory experiences refer to two processes: sensation and perception. Sensation is evoked by external stimuli and it is recognized through our sensory organs. Perception is concerned with processing and understanding these stimuli (Carmona et al., 2003). To experience the world, people use five senses such as vision, hearing, smell, touch, and taste. The sense of 'moving', which is concerned with kinesthetic aspect of runners, is additionally considered.

1. Vision is the dominant sense that provides more information than the others. Vision is active, highly complex, relying on distance, speed, colour, shape, texture, and contrast. Visual space concerns about objects in space (Carmona et al., 2003; Porteous, 1996).

2. Hearing is a sense that allows us to experience the 'acoustic' space around us. Hearing is poor information, but emotionally rich (Carmona et al., 2003; Porteous, 1996).

3. Smell as well as hearing is a human sense that is not very well developed. It allows us to identify odours and aromas from the surrounding. Smell is poor information but emotionally richer than any other, and often the most persistent memory of any experience (Carmona et al., 2003; Porteous, 1996).

4. Touch is the sense that actively selects and refines tactile sensations. Touch can be divided into active and passive touch. Active touch is the sense that let us actively explore surface of an object. It is mostly experienced through our feet when we walk or through our bottoms when we sit. The passive touch, however, is used to register temperature, humidity, pain, etc. (Carmona et al., 2003; Porteous, 1996).

5. Taste is less common to be used in experience of landscape than other senses. In the past, the sense of taste was used to distinguish edible food from poisonous food (Porteous, 1996). Nowadays, this sense can be considered as a 'social taste' which we mostly use for pleasure when eating or drinking.

6. Sense of 'moving' is developed for a sport body that is moving through a landscape with a greater speed than 5km/hour. This sense is concerned with locomotion and perception that is not from a static position, but a moving vantage point (Allen-Collinson & Hockey, 2013; Ingold, 2000; Stefánsdóttir, 2014;).

3.2 URBAN MICROCLIMATE

"*Microclimate is the condition of solar and terrestrial radiation, wind, air temperature, humidity and precipitation in a small outdoor space*" (Brown & Gillespie, 1995, p. 14). Therefore, an urban microclimate refers to microclimate that occurs in a small outdoor space in the urban environment. The built environment strongly influences the cities' climate, and every intervention that is taken in the urban tissue has a great impact on its microclimate (Lenzholzer, 2015).

Despite the fact that there is a scientific proof about ongoing changes in the urban microclimates and it is important to respond to this issue, many cities' designers, urban planners, landscape architects and policy-makers ignore this fact. Lack of attention, awareness and action about climatic conditions in the urban environments negatively affect conditions in the urban microclimate and its quality (Brown & Gillespie, 1995; Lenzholzer, 2015).

3.2.1 Impact of climate change on urban microclimate

Global climate change affects urban microclimates with its temperature regimes. Generally, the air temperature is regularly rising and it is expected to rise about 1-2°C worldwide by 2050 (KNMI'14, 2015). The number of summer days will significantly increase and there will be more and longer-lasting heat waves (IPCC, 2014). Therefore, the temperatures within the cities will rise, the UHI effect will be enhanced and thus heat stress enforced (KNMI'2014, 2015; Lenzholzer, 2015; Li & Bou-Zeid, 2013). Extreme heat conditions negatively affect people's comfort, their concentration, productivity and health conditions (Lenzholzer, 2015).

3.2.2 Impact of Urbanization on urban microclimate

Increasing urbanization has deteriorated the urban environment. Urban climates are distinctive and different in the properties of air, such as air temperature, terrestrial radiation, humidity and wind, between urban and surrounding non-urban environments. This is a consequence of a city form that refers to a material composition and geometry of the city, and a function that refers to all activities that are concentrated in the urban areas (Mills, 2011). It is observed that in the urban areas, naturally vegetated surfaces are being replaced with impervious surfaces. Surfaces such as concrete, asphalt and bricks trap heat and warm up local microclimates. Natural benefits of vegetation like shade for buildings, the interception of solar radiation, cooling of the surrounding air by evapotranspiration are no longer present. Therefore, the process of urbanization radically changes the surface and atmospheric properties of the areas. As a consequence, the air temperature increases, especially in the night; the relative humidity decreases, and the wind velocity lowers or drastically increases at specific spots (Brown & Gillespie, 1995; Cox, 2011; Lenzholzer, 2015; Mills, 2011; Oke & Stewart, 2012).

When air temperatures in densely built environment are higher than the temperatures of the surrounding rural environment, this phenomenon is called **Urban Heat Island** (fig. 12). The maximal temperature difference between urban and rural environments occurs during the nights and among the densest urban areas (Erell et al., 2011). The issue of the UHI effect, which many cities deal with, has been observed long time ago, however, the effects of this phenomenon have been recently increased significantly. It has serious implication for the comfort and health of citizens and energy use of buildings during heat waves. It affects human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, heat strokes, and heat-related mortality (EPA; 2008; van der Hoeven & Wandl, 2015).

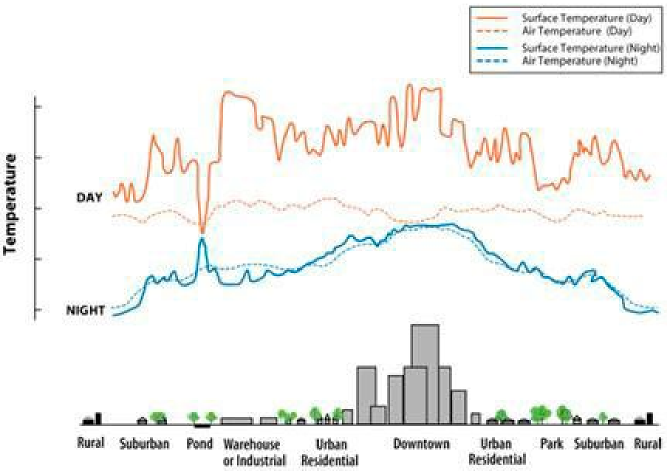


Fig. 12 UHI effect in the urban areas (U.S. Environmental Protection Agency, 2008)

3.2.3 Strategies to reduce heat stress

Because thermal stress became a serious problem in the urban environment, many studies try to find and discuss various design strategies for improving the thermal conditions in outdoor urban spaces. Different seasons require different approaches, however, this research focuses on thermal conditions during summertime, and therefore focuses on how to design with microclimate in order to reduce heat stress.

According to Nikolopoulou and Steemers (2003), greening an area, adding vegetation and landscape views, improving microclimatic parameters and redesigning urban spaces will result in increasing heat adaptation, particularly the psychological adaptation, as well as in improving short-term thermal experience. Many researches on urban microclimate claim that air temperature and relative humidity affect thermal comfort a lot, but cannot be much modified through landscape design. On the contrary, solar and terrestrial radiation and wind can be greatly affected by landscape designs (Brown, 2010; Lenzholzer, 2015; Nikolopoulou & Steemers, 2003; Oke, 1987). Brown (2010) and Lenzholzer (2015) suggest design solutions that improve thermal conditions of places in summertime by minimizing solar and terrestrial radiation, and improving local ventilation. The solutions are presented in the following section.

3.2.4 Urban heat mitigation strategies concerning running routes

Air temperature and humidity, in contrary to solar and terrestrial radiation and wind, cannot be locally modified by landscape elements. Therefore, spatial interventions and landscape elements that reduce solar, terrestrial radiation and increase ventilation in the area should be introduced in order to change thermal conditions of the urban environment (Brown, 2010; Brown & Gillespie, 1995; Lenzholzer, 2015). Based on literature study, the existing heat mitigation strategies are presented.

How to reduce solar radiation?
1. To block or admit solar radiation.
2. To adjust the angle between the sun's beam and the object in the landscape.

How to reduce the terrestrial radiation emission?
1. Intercepting the radiation along the way as to reduce the amount of the radiation arriving to the surface by providing shading devices like trees or overhead canopies (Brown, 2010).
2. To change the surface into 'low-density' surface that conduct less heat as to reduce longwave radiation emission, changing materials, de-paving, increasing vegetation layer (Brown, 2010; Lenzholzer, 2015).
3. To moisture the air to allow energy to go into evaporation. More water can lower the surface temperature reaching the air temperature or even lower (Brown, 2010). For examples waterfalls, fountains, water mist installations, de-paved areas.
4. To sprinkle the hot surface. The water will evaporate and carry the heat away (Brown, 2010).

How to increase ventilation?
1. To provide fans that introduce some air movement in the area (Lenzholzer, 2015).
2. To channel cool airflows by using volumes such as trees, hedges, buildings, walls (Lenzholzer, 2015).

3.3 MULTI-SENSORY EXPERIENCE OF RUNNERS

Because the body is at the core of runners' experience, and the experiences of the running body are mostly lived through senses (Cook, Shaw, & Simposon, 2016), a (multi-) sensory approach is introduced in order to understand the world experienced by a runner and his needs.

3.3.1 Sensory experience of runners

In this research, four out of five traditional senses are taken into consideration when analysing the sensory experience of runners on running routes. The sense of taste is not common to be used in experience of landscape (Porteous, 1996), therefore it is omitted. Our sensory apparatus and systems are adjusted to walking speed that is about 5km/hour in a linear movement. Running is in greater speed than 5km/hour, therefore, a sense of 'moving' is additionally considered. (Allen-Collinson & Hockey, 2013; Cook, Shaw, & Simposon, 2016; Fleming, 2012; Stefánsdóttir, 2014).

Moving en route

Because runners and their sensory dimensions are objects of my investigation, the first key element of that experience has to be introduced: movement. Ingold (2000, p. 166) points out that *'Locomotion, not cognition must be the starting point for the study of perceptual activity'*. Movement is linked to a feeling, which does not have to be only physical but also psychological and psychosocial. A sporting movement has two interrelated components: timing and rhythm. Rhythm organizes the flow of action, is a part of action, and can change according to individual feelings, terrain and weather conditions. Timing determines the order of occurrences of an action or events in order to achieve desired results (Allen-Collinson & Hockey, 2013; Hockey, 2006).

Soundscape of the route

Runners pay careful attention to the sounds of a landscape as it can give a precise indication of what is happening around the runners. One of the most attractive sounds that can be heard in the landscape are sounds of nature such as singing birds, rustling leaves, flowing water, etc., which are considered 'auditive delights'. However, because one of the primary concerns of runners is safety, runners also 'listen' for vehicles, kids, cyclists, another runners, or dogs as they are constituted as problematic features on training tracks in the urban areas. Additionally, runners pay attention to 'monitoring sounds' like breath and respiration as an indicator of safety, physical performance and healthy state. Another auditory resource is concerned with sounds of footfall on different kinds of surfaces. This provides information on type of surface they run on,` and inform the runner how to navigate the optimal path for traversing the route safely and effectively (Cook, Shaw, & Simposon, 2016; Ettema, 2015; Hockey, 2006).

Smellscape of the route

Runners produce and engage with immediate smellscapes that are particular for themselves and their routes. Odours or aromas can be easily referred to a special activity, space, place, or atmospheric and seasonal conditions. Therefore, smellscape helps a runner to identify his athletic identity, location, and personal experience. Furthermore, special odours can bring memories of past elements or events experienced by runners in the past, or help runners to locate themselves in space, mark where they are, and how far they run or need to go (Allen-Collinson & Hockey, 2007; Hockey, 2006). Smellscapes are emotionally rich and play important role in experiencing the runs.

Seeing the route

There are different ways of seeing, depending on an observer and a spatial context. People see when they move, and they collect their 'visual memories' as informative field notes. These memories, which have been collected during previous performances, and the active looking is necessary to accomplish a training in an effective way. Runners are concerned with safety and performance issues when seeing. They focus on ways of dealing with harassments and rare occasions assault while training in public spaces. Therefore, runners become attentive to locations, where the risks of physical attack may occur. They also pay special attention to physical features of the terrain and other type of traffic like vehicle drivers, cyclists, dogs, and all other users of the route (Hockey, 2006).

Feeling the route

Feeling the route is concerned with a haptic relationship between runners and a running route. Touch provides information about the character of the objects, surfaces, and the whole environment as well as about the running body. It is about feeling the world and understanding it. The feet can feel the ground, and perceive its shape, size, texture and temperature. The ground and its 'feeling' can give different sensual experience of the landscape, and it can influence runner's performance and his health state. For example, grass offers a gentle and elastic surface that is pleasant to joints and tendons of a runner, while stiffer surfaces are not (Cook, Shaw, & Simposon, 2016; Hockey, 2006). Moreover, skin of a runner is exposed to varying weather conditions that form the experience of the route. Therefore, the runner can be passively touched by heat, wet, cold and air part, depending on season and daytime.

3.3.2 Strategies to improve sensory experience of runners

According to the literature and my own running experience, the sensory experience of a runner can be improved by applying interventions that positively influence soundscape, smellscape, vision quality and touch, and serve safe environment to run without encounters with other traffic. For each intervention there are several tools that can be used to improve the sensory experience.

The **soundscape** can be improved by introducing landscape elements that increase the existing sounds, emanate new sounds or reduce existing ones that are not pleasant for runners. The vegetation is a very optimal and multi-functional tool. It provides habitats for animals that create natural, pleasant sounds, can give sounds of humming wind, and can block unpleasant sounds. Introducing the water objects can provide the landscape with different sounds like sounds of running water, drops of water on the surface, water-falls, sounds of different bodies in the water, etc. Materials like gravel, sand, soil, or grass that are used on running routes give different sounds when running or walking on them. Moreover, the spatial configuration defined by rows of trees, hedges, architectural objects, lowering or elevating the area can reduce the sounds and bring more calmness to the area.

The **smellscape** can be improved by an individual runner who can influence his own odour, and by a landscape designer who can modify the landscape and thus introduce new odours to the area. Modifying the landscape is mostly concerned with the vegetation around the running route. Bark, leaves, flowers and fruit of different plants can smell differently. Water can also influence the smellscape, however, depending if it is stagnant or flowing water. A spatial configuration, meaning a location of the running route, can also influence the smellscape by leading runners to the places, where there are objects like restaurants, pubs, bars that engage the runner with the smells (Allen-Collinson & Hockey, 2007; Porteous, 1985).

The **vision quality** concerns not only with the visual attractiveness of the route but also with the physical features of the terrain, position and visibility of different objects and presence of harassments on the route (Allen-Collinson & Hockey, 2006). The visual attractiveness of the route can be modified by tools such as trees and low vegetation, water objects, spatial configuration of the objects, architectural objects (overhead canopies, roofs, pavilions, buildings), materials and colours. Moreover, it is important that the horizontal clearance is kept as to provide a safe environment to run.

As described in chapter 3.1.3.3, **touch** experience can be active or passive, and several tools can be used to increase this experience. To influence the passive touch it is recommended to use objects that introduce sprayed water, mist or movement of the air. The active touch is more relevant in experiencing the running route, and it can be improved by reorganizing the space of a running route, using different materials, textures, size of the running pavement, or introducing planting next to the running route so it can be passively touched while running.

Sense of 'moving' is related to kinaesthetic experience of runners, their rhythm, timing, and experience of the route. It is related to the flow of action, and thus with nuisance with other traffic on the route (cars, cyclists, other runners, pedestrians, dogs, parents with kids). Preventing the runners from the encounters with other traffic positively influences the experience of 'moving'. It can be improved by modifying the spatial configuration in such a way that the users of the space are separated and they do not disturb each other. A spatial division can be introduced by using vegetation barrier (trees, hedges), poles, architectural objects, or different materials and colours that indicate different use of space.

3.4 DESIGN CRITERIA

Based upon the theoretical context of this thesis and existing knowledge about the thermal comfort, the urban heat mitigation strategies and multi-sensory experience of runners, this section introduces design criteria regarding thermal and non-thermal perception features. Additionally, the design criteria include practical assessment of design feasibility. The design criteria has been set in order to conduct the RTD method (chapter 4.1), and to provide a valuable research product for the university and professionals in the field of landscape architecture. The criteria are used to assess and evaluate design models.

3.4.1 Thermal perception features

Thermal perception features refer to the physical climatic factors that influence the thermal comfort. The most effective interventions to improve thermal comfort are to modify solar radiation, terrestrial radiation and wind. Air temperature and humidity cannot be directly modified by local landscape designs (Brown, 2010; Lenzholzer, 2015; Nikolopoulou & Steemers, 2003; Oke, 1987), however, they can be indirectly influenced by modifying climatic properties like shade, evaporation and evapotranspiration. Therefore, the main principles of improving thermal condition of runners is to provide shade, reduce heat conductivity of the running surface, increase evaporation and evapotranspiration, and introduce ventilation to the area.

3.4.2 Non-thermal perception features

Running behaviour is related to the landscape setting (natural, urban), nuisance (cars, cyclists, pedestrians, dogs, parents with kids), surface, traffic safety, presence of lighting, encounters with social groups, and facilities along the route. From the sensory aspects, evaluation of the running route is not just a visual process but also a haptic one. Runners see, hear, smell, touch and move. Feeling the ground, listening to the sounds of footfall, smelling the odours provide athletes with information that categorizes type of route, location, memories, previous experiences and influence their safety, performance and pleasure (Hockey, 2006). Because runners move with greater speed than walking, the senses of vision and touch are diminished. Thus designs should emphasize elements of landscape, which positively influence the sense of sight and touch, and provide safe environments to run. Therefore, the non –thermal perception features, which represent the sensory experience of the runners consist of sound, touch, smell, vision, and encounters with other types of the traffic, which is concerned with safety.

3.4.3 Feasibility

Feasibility is an assessment of how successfully a project can be completed and it tests the viability of a design idea. It is to put an emphasis on construction challenges, maintenance and practicality, and installation cost of a proposed project. Because the research is conducted by using the RTD strategy, the feasibility criteria are important assessment factors for design models. The feasibility criteria can check the project's viability and help in selecting the most appropriate design ideas, which can serve as design guidelines.

3.4.4 Grading scheme

All generated design models are evaluated according to the criteria. Using the scale from -1 to 2, the subcategories of thermal perception and non-thermal perception features are assessed.

The subcategory of feasibility has been developed as extra criteria that consider construction, maintenance and installation cost of the design. The features of this category are scored in scale from 1 to 3, where * means easy and low-cost intervention, ** means medium-difficult and medium-cost intervention, and *** means difficult and high-cost intervention.

Because different features have different relevance in influencing the urban microclimate and sensory experience of the runners in the urban environment, points of relevance are added to every feature. All the thermal perception features gain 3 points of relevance as it is the main focus of this thesis, and it refers to the urban microclimate. Among the non-thermal perception features, touch and vision gain 2 points of relevance, as these are the most important features in terms of sensory experience of a runner in the landscape. The rest of the non-thermal perception features gain 1 point of relevance.

The figure 13 presents the criteria and points of relevance. The process of evaluation the design models by using the criteria are explained in chapter 4.2.3.

1. Thermal perception features	
Shade	*3
Heat conductivity of running surface	*3
Evaporation	*3
Evapotranspiration	*3
Ventilation	*3
2. Non-thermal perception features	
Sound	*2
Touch	*3
Smell	*2
Vision	*3
Encounters with other types of traffic	*2
3. Feasibility	
Construction	* _ ***
Maintenance	* _ ***
Installation cost	* _ ***

Fig. 13 Design criteria and points of relevance for every feature

METHODS

4 METHODS

This chapter describes the research strategy and the methods used in this thesis in order to answer the research questions. Following Lenzholzer, Duchhart and van den Brink (2017), the choice of appropriate research strategy and subsequent research methods should be made regarding the research questions and the worldview. This study is problem-focused thus the research is conducted from the pragmatic perspective (Creswell, 2014) by using different methods, approaches and techniques. Both quantitative and qualitative methods are used to understand the stated problem, integrate existing knowledge and generate applicable design solutions.

4.1 RESEARCH STRATEGY

To conduct the research and answer the research questions, research for design (RFD) and research-through-designing (RTD) were used as the main research strategies.

Research for design is a category of all types of research that support generation of a design product or design process. *"Here, both the product and the process benefit from research activities in the sense that the research outcomes inform the design process"* (Lenzholzer, Duchhart, & van den Brink, 2017, p. 2). In this thesis, RFD is used to gather available knowledge and data in order to understand the problem, select the case study and translate the knowledge into a design (van den Brink & Bruns, 2014). RFD involves the acquisition and assessment of knowledge to produce general rules and the design process to split the problem into elements in order to conduct the analysis and evaluation (Milburn & Brown, 2003).

As mentioned before, thermal perception is a psychological interpretation of the physical state of body (chapter 3.1.2), and there are many factors that have an impact on this sensation. This thesis addresses an issue of heat stress that refers to thermal and sensory perception of runners. Therefore, in the context of this thesis, the model of Milburn and Brown is used to break down the problem into discrete elements for the purpose of the analysis and evaluation. As recommended, the investigated discrete problems are synthetized, and the evaluation process is conducted at the final stage to assess the design result for the purpose of improving future projects (Milburn & Brown, 2003).

Research-through-designing is a category of research processes in which designing is actively used as a research method. It is an explorative and experimental method in which designing is used as a tool to generate new knowledge and test it, so it can be applicable in design practice or further research. The new knowledge can be presented in the form of design recommendations, guidelines or principles, patterns or prototypes (Lenzholzer et al., 2013; Lenzholzer, Duchhart, & van den Brink, 2017).

Following the worldview (chapter 2.2.2) and the research questions (chapter 2.4), I used pragmatic research-through-designing. Such research includes a series of different studies that are carried out parallel, and each of them needs evaluation criteria that go along with the worldview. The combination of different evaluation criteria as well as different knowledge claims can complement each other, and can strengthen the value and relevance of the research outcomes (Lenzholzer et al., 2013).

The figure 14 presents the research outline and related methods. Multiple methods were used to get the sub-goals for specific sub-research question. Along with the sub-research questions, the outputs and their dependencies are shown.

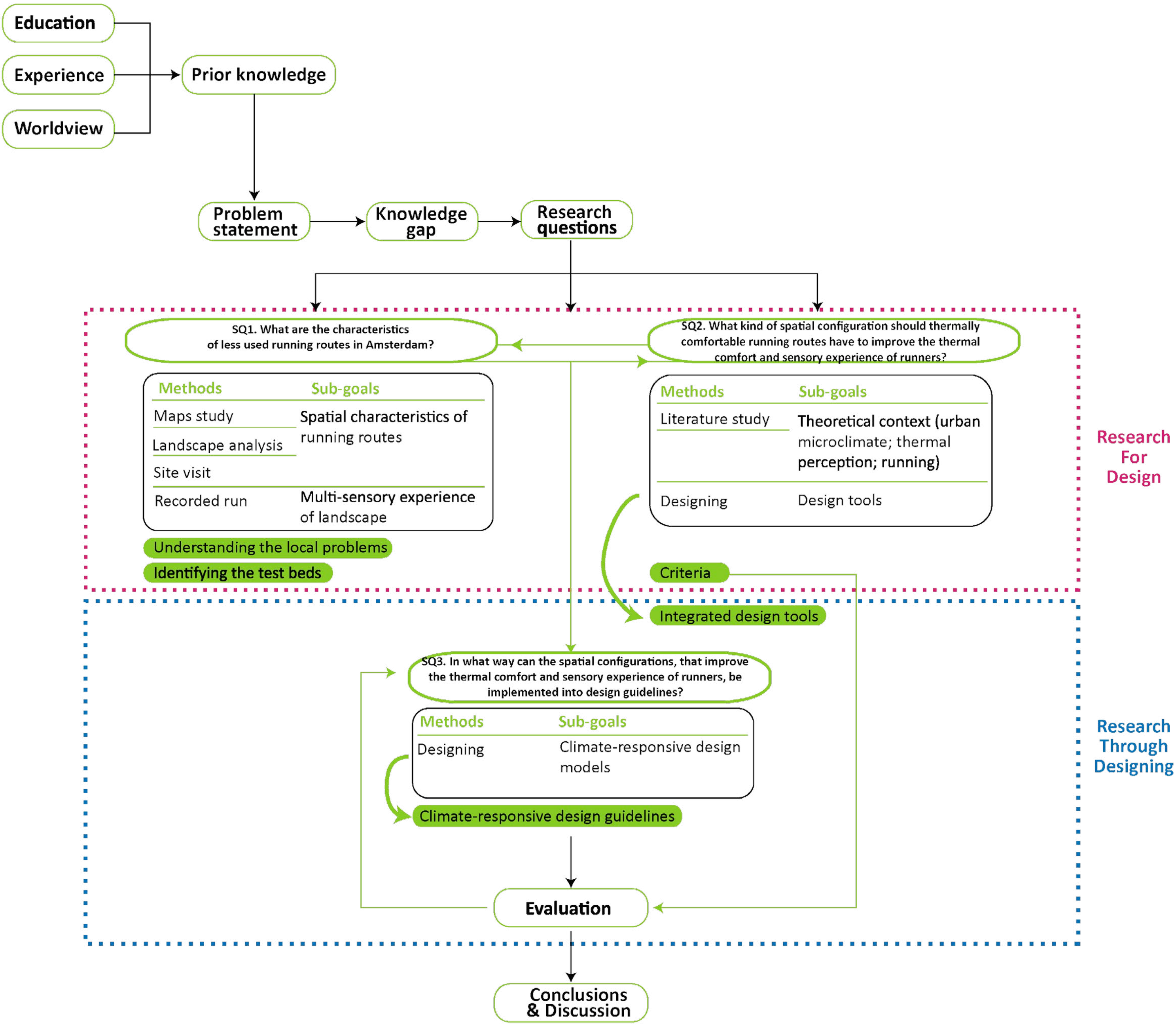


Fig. 14 Flowchart presenting the research process, strategy and used methods

4.2 RESEARCH METHODS

This section presents the use of methods used to answer the separate research questions.

To answer the main research question ***What spatial interventions could improve thermal conditions and sensory experience of runners on running routes?***, climate-responsive solutions were to be formed. These should improve thermal comfort and sensory experience of runners on running routes during warm days in the urban areas. A case of Amsterdam provided areas, where runners experience heat stress. The sub-research questions were defined to bring forward the final answer to the main research question. To answer the sub-research questions, different methods were used as described below.

4.2.1 Methods to answer the SQ1

SQ1: What are the characteristics of less used running routes in Amsterdam?

To answer the first sub-research question, the RFD was used as a mixed method research. Following the study of Dolders and Reiling (2015), there are many factors that determine the running patterns and runner's behaviour. Dolders and Reiling (2015) observed that there is less running activities in Amsterdam and the spatial division of the runners is different when air temperature is above 20°C. Therefore, the first step to answer SQ1 was to investigate which running routes are less used in Amsterdam and what characteristics these running routes have when air temperature is above 20°C. Taking into consideration the research problem (chapter 2.1) and all important aspects of thermal and sensory perception (chapter 3), the study area was analysed from the perspective of microclimate, ambiance, multi-sensory experience and spatial configuration. The analyses of the physical factors (microclimate) at the study site, the routes' ambiance and sensory experience were conducted by using both quantitative and qualitative methods.

1 In order to find out which running routes are less used when air temperature exceeds 20°C, the **map study** was conducted. The maps with the running activities when air temperature is above and below 20°C (fig. 15-16) were overlapped. The patterns of the running activities and number of the runners were compared.

Even though air temperature is one of the essential factors influencing thermal comfort, radiant exchange is the dominant meteorological factor affecting thermal comfort (Lenzholzer, 2013) and "*during daytime solar radiation is always a heat source for the runner*" (Vihma, 2010, p. 304). Therefore, the microclimate analyses, concerning solar radiation and terrestrial radiation (shadow analysis and UHI analysis), were conducted in order to find out if there is any correlation between solar radiation, UHI and the avoidance of the running routes.

2 To investigate the sun exposure and shadow patterns along the most avoided running routes, a shadow analysis was conducted. For this purpose, a 3D model was built in SketchUp (see Appendix I). The height of the buildings, trees and the street levels were indicated by using AHN (2016) or assessed from images in Google Street View. Google Maps were used to update the maps or to simulate the buildings or trees that were not indicated on the AutoCAD base map (accessible online from Grootschalige Basiskaart van Amsterdam: www.amsterdam.nl/bestuurorganisatie/organisatie/dienstverlening/basisinformatie/basisinformatie/producten-diensten/kaarten-luchtfoto/grootschalige/). The time and geo-localization in the 3D SketchUp model was adjusted thus the shadows could be presented as

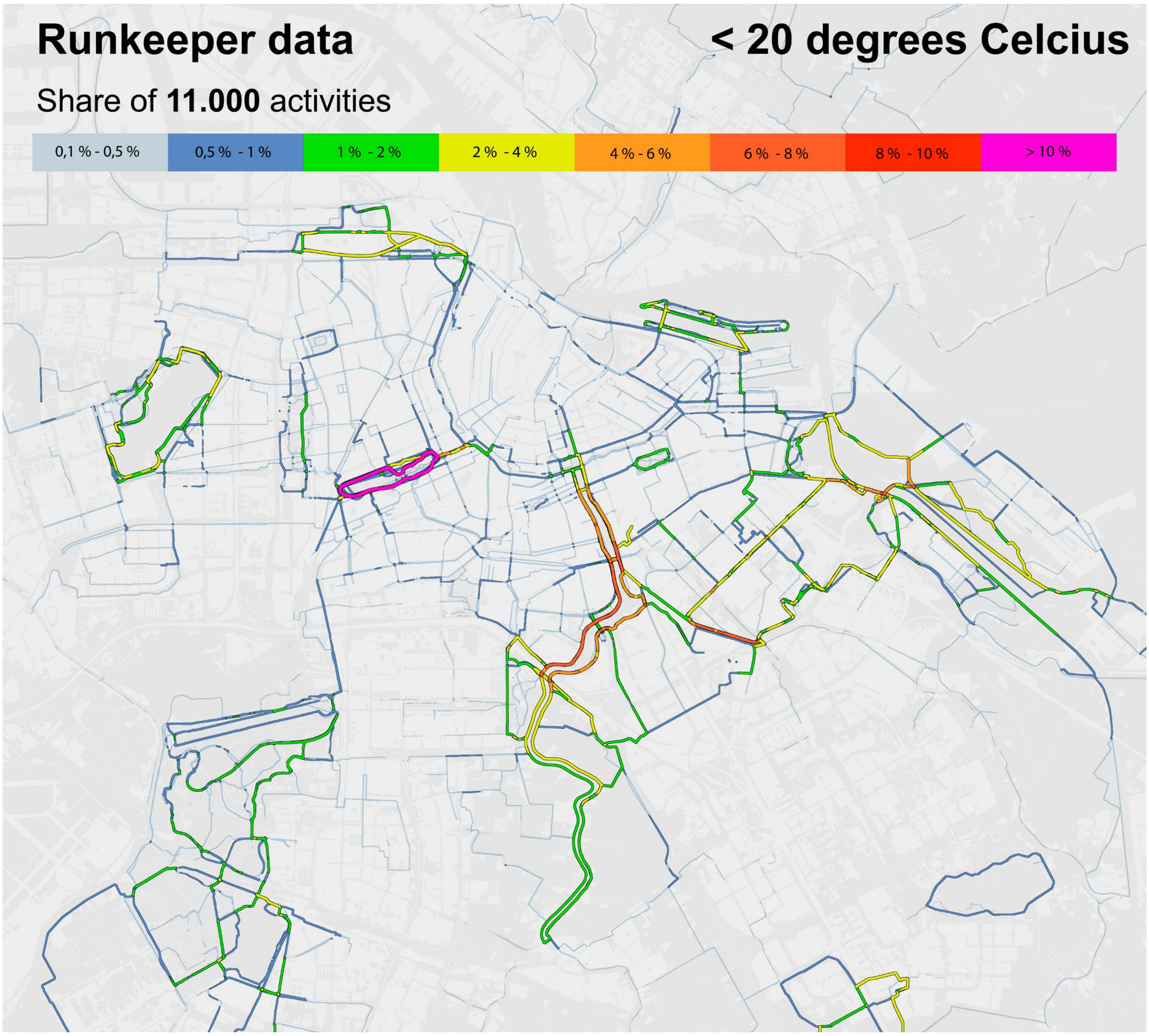


Fig. 15 Running activities in Amsterdam when air temperature is higher than 20°C (Dolders & Reiling, 2015)

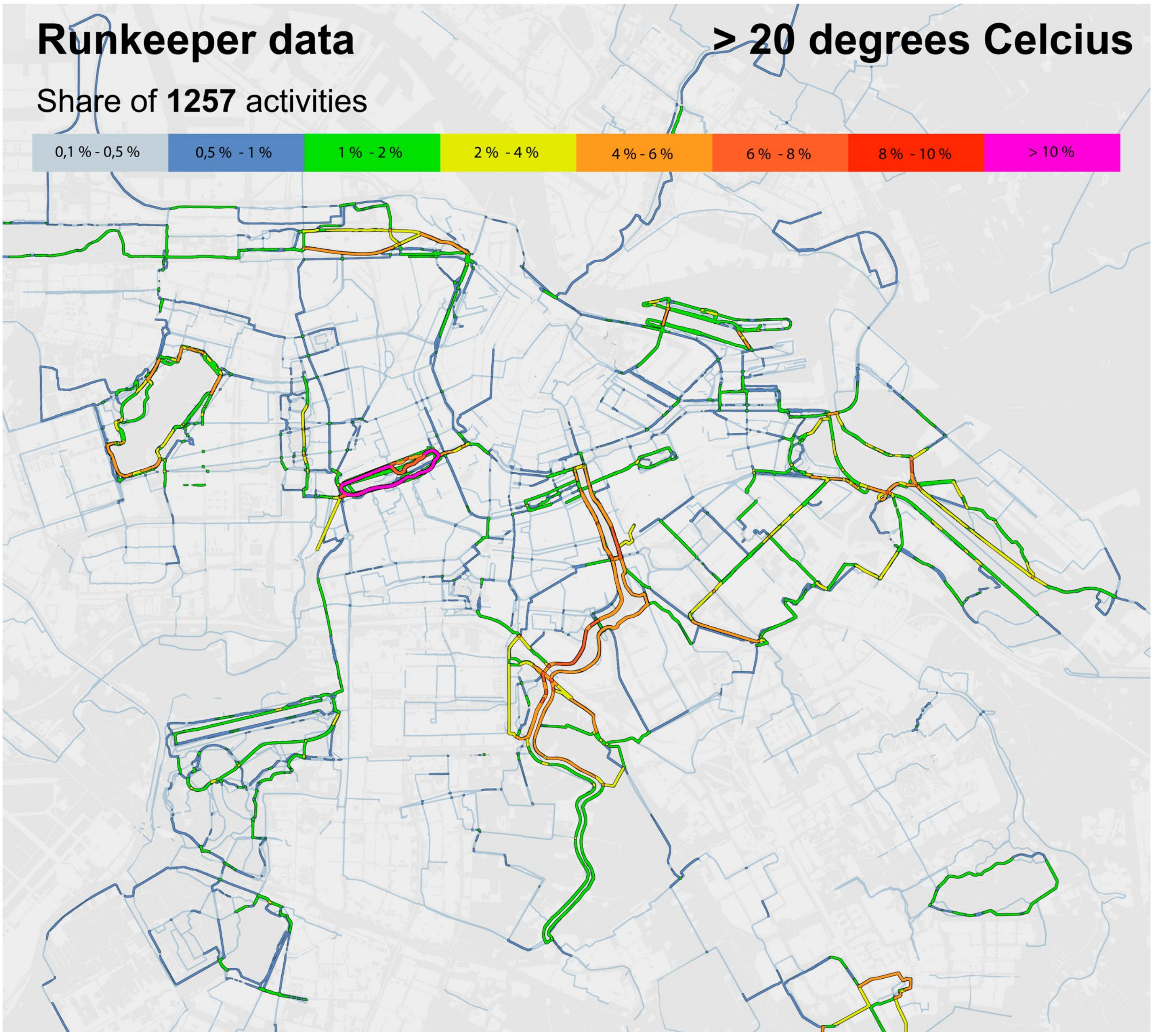


Fig. 16 Running activities in Amsterdam when air temperature is higher than 20°C (Dolders & Reiling, 2015)

they occur in the real landscape. The shadow simulations were taken for the 1st of July (a summer day) at different time points: 17:00, 18:00, 19:00, 20:00 and 21:00, representing times when the runners are the most active (chapter 1.3.2). The images with the shadow patterns for every hour were projected (see Appendix II), merged and compared by using Adobe Photoshop and Adobe Illustrator. This research method is reliable because it considers the spatial configuration in 3 dimensions, geo-location, specific day and time. This method was used in previous studies on urban microclimate (Lenzholzer, 2010; Lenzholzer, 2013).

It resulted in shadow projections (fig. 17), therefore the impact of solar radiation on running routes can be assessed. Terrestrial radiation, albedos and heat conductivity cannot be stimulated in SketchUp.

Fig. 17 Shadow projections on the running route in Amsterdam Oost

3 To investigate the correlation between the UHI effect and the avoidance of the running routes by runners, the UHI analysis was conducted. The map study served as a research method. The running network was overlapped with the UHI day- and night maps (van der Hoeven & Wandl, 2015) (fig. 18-19).

This method is simple and easy to conduct. By overlapping the maps, the correlation be tween both aspects can be easily observed.

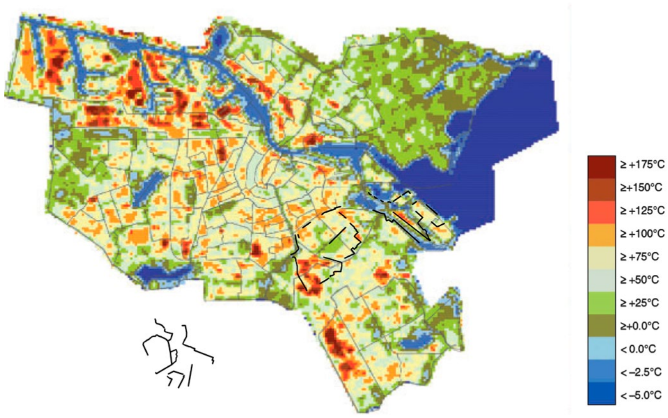


Fig. 18 UHI day map overlapped with the running routes

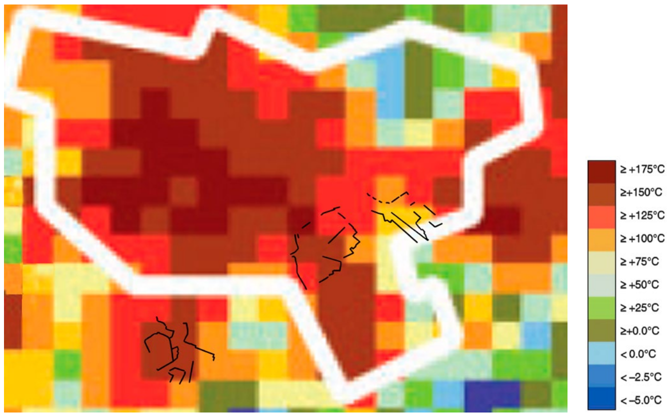


Fig. 19 UHI night map overlapped with the running routes

4 To find the spatial characteristics that influence human experience and negatively influence the running activities, qualitative methods were used. Based on the theories (chapter 3), **site visits** and **recorded runs** were conducted in order to be in direct dialogue with the environment, address all the senses and understand the landscape with its full multi-sensory appearance. These methods helped in investigating the ambiance, sensory experience and spatial configuration of the running routes.

The site visits and recorded runs were divided into three parts regarding the locations of the most avoided running routes in Amsterdam: Amsterdam Oost, Amsteelveen, and Islands of Amsterdam (chapter 5.1). Each part of the route was run individually in one day during spring 2016 (13-04-2016; 16-04-2016; 21-04-2016). The run was recorded by using a GoPro Hero camera that captures the image and sound. The camera recorded my verbal observations about the urban microclimate, ambiance of the routes, spatial characteristics (spatial configurations of different elements, colours, materials, etc) and experience of the run. The camera recorded my observations of what I saw, heard, smelled, touched, and experienced. The recorded videos are uploaded on YouTube (see Appendix III) and they were later used to sketch and map my observations (see Appendix IV).

According to Stevenson (2010), the ambiance is understood as an atmosphere, special quality, mood or a setting of the place created by particular elements of the environment. The studies of Böcker et al. (2015), Böhme (1995), Lenzholzer (2010), Lynch (1960), Lenzholzer (2013), Nikolopoulou and Steemers (2003) mention elements such colours, materials, vegetation, width and openness of the place, visual attractiveness, liveability and intensity of space usage as important features, which influence the ambiance of places. Therefore, when analysing the ambiance of the routes, I considered all these elements. To map them and analyse the ambiance of the running routes, I used the observations from the site visit and recorded videos of the runs.

The analysis of the sensory experience was related to the phenomenological concept on sensory perception and it described the running routes from the multi-sensory perspective of a runner (chapter 3.3). From the sensory aspect, the evaluation of the route is not just a visual process but also a haptic one (Hockey, 2006). The running behaviour is influenced and related to landscape setting, nuisance, surface, traffic safety, presence of lighting, encounters with social groups, facilities along the route, sounds and smells (Allen-Collinson, 2005; Cook, Shaw, & Simpson, 2016; Hockey, 2006). Based on the literature study, sense of 'moving' (chapter 3.3.1) and four out of five traditional senses (vision, smell, hearing, touch) were addressed in this study as the most valuable senses in interpreting and sensing the environment (Allen-Collinson & Hockey, 2013; Cook et al., 2015). By using sketched observations from the site visit and recorded videos, the running routes were analysed. All non-thermal features presented in the criteria (chapter 3.4) were taken into account.

5 The running routes were also analysed in the context of spatial configurations in order to generate 'testbeds' and identify the problems. Following steps were taken:

Step 1: The spatial configurations of the most avoided running routes were analysed. First, all the running routes were divided into segments, which represent similar spatial configurations and ambiance. The observations from the site visit and recorded videos were used to recognize and map the segments. Secondly, for every segment, the spatial elements such as pedestrian path, bicycle path, road, parking lot, buildings, green area (trees, group of trees, shrubs, grass verge, lawn), water (canal, ditch, marsh) were identified, mapped and represented graphically in the form of route profiles. The route profiles are 20m long and describe the spatial elements within 10 m on both sides of a runner.

Step 2: The route profiles were compared and categorized according to the same sequence of the spatial elements in the profiles. As a result, route typologies were defined and mapped.

Step 3: The length of every route's typology was calculated and presented in meters (distance) and in seconds (running time). The running time was calculated by using an average speed of a runner (7-8 km/h). The five longest routes' typologies were selected to serve as 'testbeds' as they dominate the avoided running routes and represent the majority of the researched routes.

Because some of the selected route typologies from step 3 consist of different route profiles (see Appendix V), the step 4 was taken.

Step 4: The route profiles were abstracted and generalized. The width and spatial elements of the abstracted route are an average of all spatial characteristics of the route profiles belonging to the same route typology; the direction of the route was selected according to the dominant one. The abstracted route served as 'testbeds' for design models.

The 'testbeds' were mapped and represented graphically in the form of 3D profiles. Because there are many ways of graphic representations, I conducted a questionnaire among the fellow-students (see Appendix VI) to find out the best method to represent the 'testbeds' and design models. The highest scored graphic method was used to represent the 'testbeds' and the design models in this research.

4.2.2 Methods to answer the SQ2

SQ2. What kind of spatial configuration should running routes have to improve thermal comfort and sensory experience of runners?

This question was answered by using both RFD and RTD methods. The RFD part included **literature study** as a research method to accumulate knowledge on existing strategies and design tools on how to mitigate heat stress, improve thermal comfort and enhance sensory experiences of runners in the urban environment. Firstly, the existing design strategies, which improve thermal comfort and sensory experience of runners, were listed and analysed separately in order to find what design tools are common in use. Secondly, the use of the design tools was compared. The last step towards the answer to SQ2 was to integrate the design tools.

1 **Designing** was used as the RTD method to explore new design solutions by integrating the existing ones and generating new design tools, which improve both thermal perception and sensory experience of runners.

4.2.3 Methods to answer the SQ3

SQ3. In what way can the spatial configurations, which improve thermal comfort and sensory experience of runners, be implemented into design guidelines?

To answer this sub-research question, a new contextual knowledge that revolves around the 'how' and about integration the knowledge must be generated. It deals with applying design solutions to the problems within a specific context (Lenzholzer, Duchhart, & Koh, 2013). To answer SQ3, the RTD was used as the main research method. Both quantitative and qualitative methods were used.

1 **Designing** was used as a research method to find the most optimal way to implement the spatial configuration into climate-responsive design guidelines. Firstly, the integrated design tools, which were identified when answering SQ2 were used to explore several design models for each of the 'testbeds' identified when answering SQ1. The design models had to meet the criteria (chapter 3.4) as good as possible. From many generated design models, four the most complex models, which consisted of minimum two of the integrated design tools, were selected for each of the 'testbeds', assessed and evaluated.

2 Following Lenzholzer, Duchhart and Koh (2013), it is important to test and assess the strength, value and relevance of the design

models. Therefore, I conducted the evaluation process of the design models by using the design criteria (chapter 3.4) and the assessment matrix (fig. 20). To set an optimal and equal base for assessment for the design models, the assessment matrix and grading scheme are presented.

Round 1

Criteria	Test bed			
	1	2	3	4
1. Thermal perception features				
Shade *³				
Heat conductivity of running surface *³				
Evaporation *³				
Evapotranspiration *³				
Ventilation *³				
SUM OF POINTS (1)				
2. Non-thermal perception features				
Sound				
Touch *²				
Smell				
Vision *²				
Encounters with other types of traffic				
SUM OF POINTS (2)				
TOTAL SUM				
3. Feasibility				
Construction				
Maintenance				
Installation cost				
BEST SCORE				

Round 2

Key:		Key:	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 20 Assessment matrix

The design models were assessed regarding the urban microclimate, sensory experience and feasibility features by using a grading scheme of -1, 0, 1, 2 and *, **, *** (chapter 3.4.4). The evaluation of the design models consisted of two assessment rounds (fig. 21).

The first assessment round was to assess the design models according to the thermal and non-thermal perception features (chapter 3.4.1 & 3.4.2). The design models with the highest score in the first round were selected to the second round, and evaluated by the feasibility criteria (3.4.3). Points to the solutions were given on the basis of gathered knowledge during the literature study, educated guesses and opinion of thesis supervisors. The design models with the highest scores were chosen as optimal design solutions, which do not only improve thermal comfort and sensory experience of the runners but they are also viable and feasible. These design models were selected to serve as climate-responsive design guidelines.

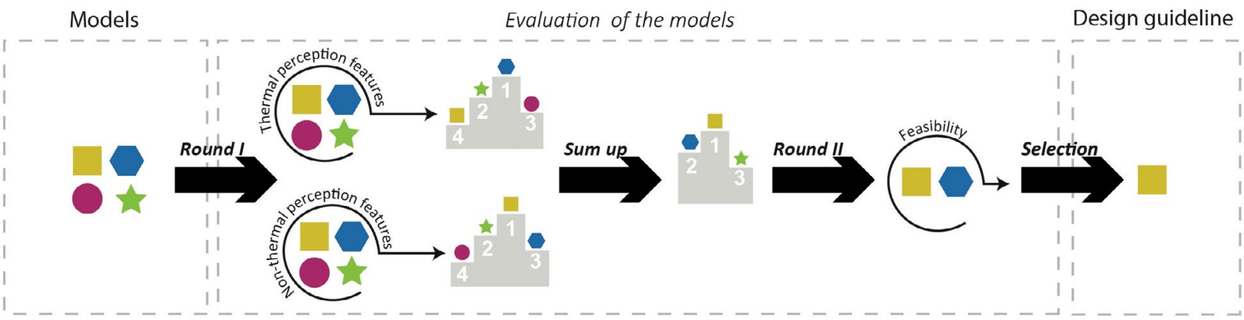


Fig. 21 The evaluation process of the design models

3 The last step to answer this sub-research question was to project the design guidelines into a real context in order to exemplify in what way the design guidelines could be implemented to the specific site, and to visualize how the multi-sensory experience of the runners could be improved.

Designing was used as a main research method. To represent the implementation of the design guidelines, Adobe Photoshop, Audacity and Adobe Illustrator were used to produce graphics and soundtracks.

RESULTS AND DISCUSSION

5 RESULTS AND DISCUSSION

This chapter presents the results of RFD and RTD process concerning the three sub-research questions, and discusses them in relation to the aspects presented in the theoretical framework (chapter 3).

5.1 RESULTS FOR SQ1

SQ1: What are the characteristics of less used running routes in Amsterdam?

1 To find the answer to this sub-search question, first, a map with a network of avoided running routes when, air temperature exceeds 20°C, was generated. The map showed that the running routes that are avoided by runners when the air temperature exceeds 20°C occur in different areas in Amsterdam. In some areas of the city, a number of avoided routes occurs more frequent than in others, and number of running activities is not constant. This research focused on the routes which are avoided by the largest number of runners. The most avoided running routes in Amsterdam were grouped into three running networks and named according to their locations: Amstelveen, Amsterdam Oost, and Islands of Amsterdam (fig. 22).

The result might be considered as limited due to the data limitations. According to Dolders and Reiling (2015), the data provided by Runkeeper presents a big difference in running activities when air temperature is lower and higher than 20°C. Therefore, it is unknown how representative these results are. It is recommended to validate the data and verify it with Strava or other run-

Fig. 22 The most avoided running routes in Amsterdam

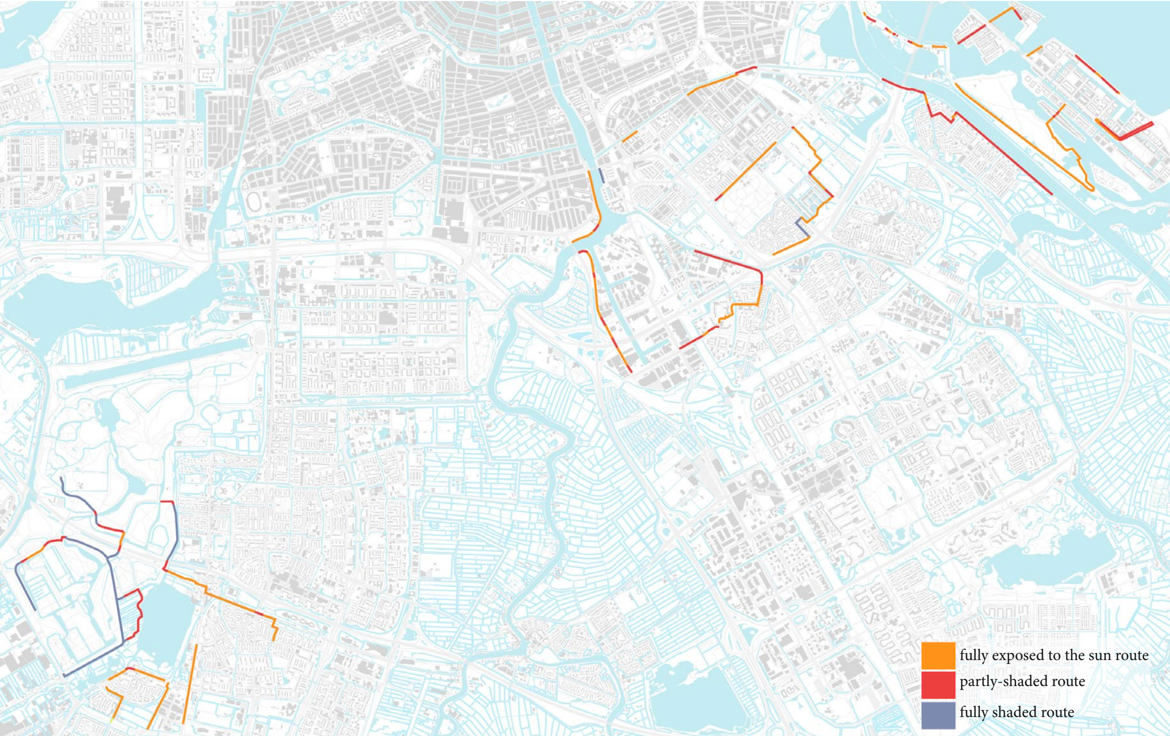


Fig. 23 Distribution of running routes according to the sun exposure during 5pm - 9pm

ning App data in further research (Dolders & Reiling, 2015).

2 Secondly, shadow analysis resulted in a map showing which running routes are fully exposed to the sun, partly shaded and fully shaded (fig. 23). It showed that 41,5% of all the avoided running routes are in the sun, 42,6% of the routes are partly-shaded and 16% of the routes are fully shaded. This result leads to a conclusion that solar radiation is a significant factor that influences the avoidance of the running routes. From another point of view, only 41,5 % of the routes are fully exposed to the sun, therefore, there must be other reasons, which influence thermal discomfort of runners on partly-shaded and fully shaded routes.

3 By overlapping the UHI daytime and night-time maps with the map of the most avoided running routes, it was observed that most of the most avoided running routes are under the influence of the UHI effect during the daytime and night-time.

This analysis presented that terrestrial radiation could be another reason for thermal discomfort of the runners. However, the UHI maps do not provide detailed information on a local scale. Thus it is quite difficult to assess how big the UHI effect is on the particular routes. Therefore, the additional analyses of the ambiance, sensory experience and spatial configurations of the running routes were conducted.

4

The results of the analysis on the ambiance of the running routes are summarised and presented graphically (fig. 24-26).

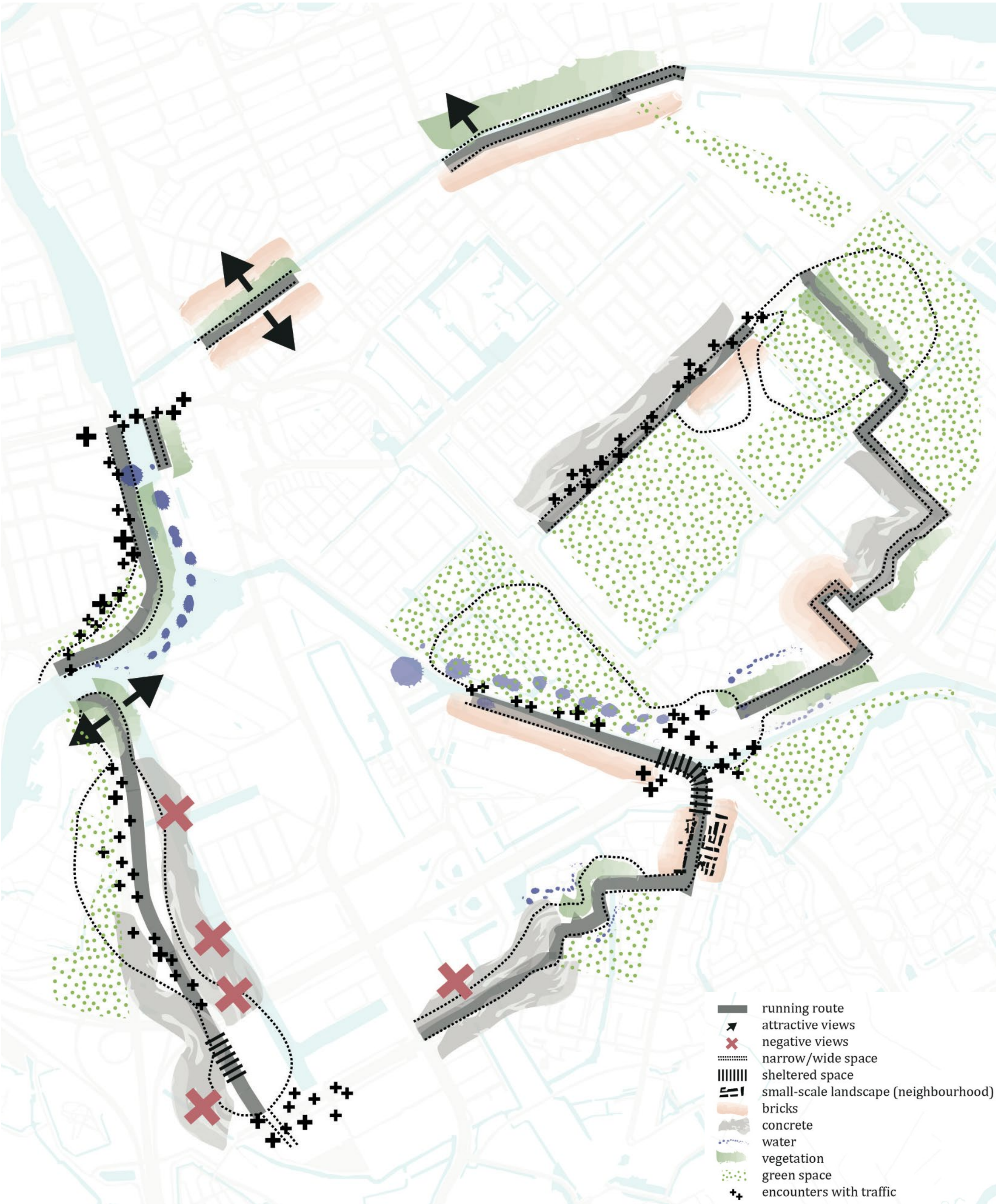


Fig. 24 Ambiance of Amsterdam Oost route

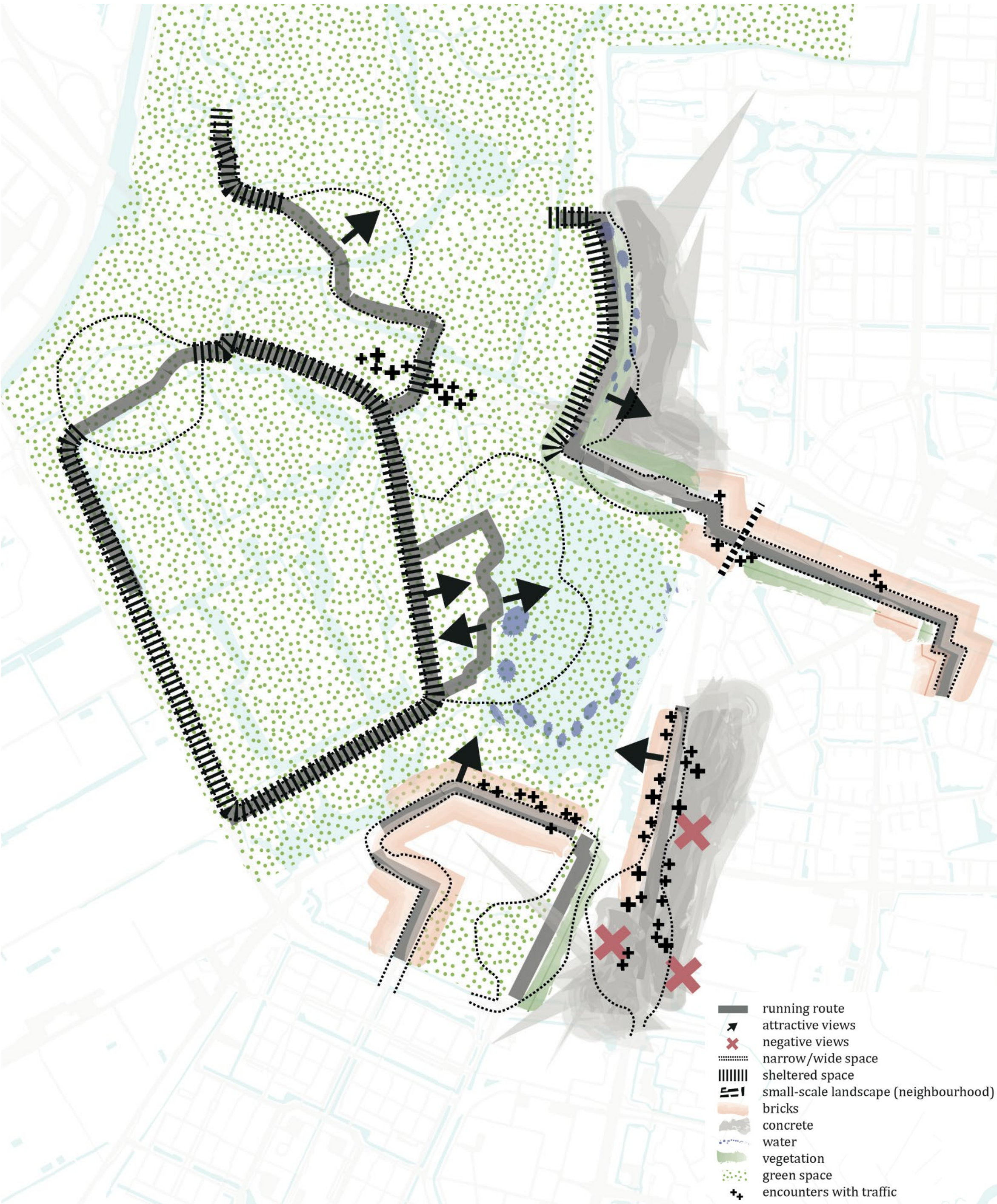


Fig. 25 Ambiance of Amstelveen route

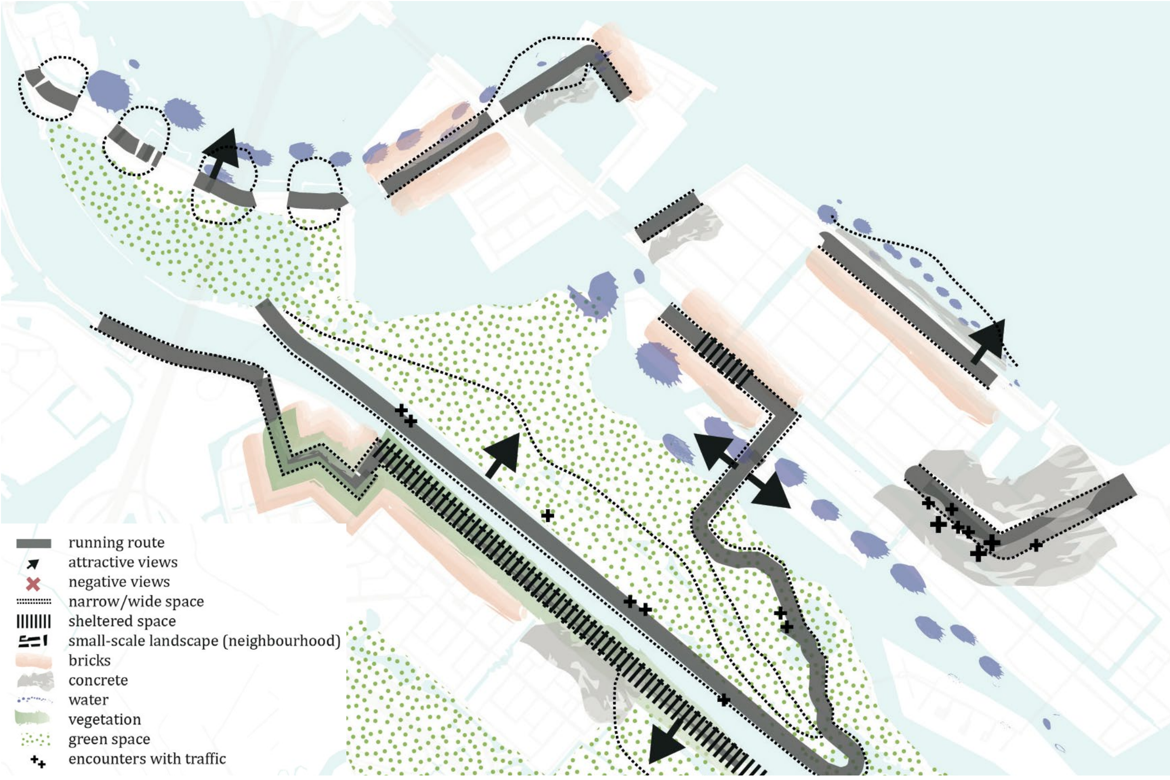


Fig. 26 Ambiance of Island of Amsterdam route

It can be concluded that each of three running routes has different spatial configuration and characteristics, however, there are many repetitive elements, which occur in the space and have a similar impact on the ambiance of the routes.

As expected, grey concrete, red bricks and asphalt are dominant materials along the running routes. They are used for both buildings and pavement. Concrete dominates among pavement material, bricks as a building material, and asphalt for car roads and parking lots along the road. These materials have high thermal conductivity and high emissivity (Lenzholzer, 2013), and thus have a great impact on thermal perception in this area. The running routes are dominated by grey, red and black colours, which have low albedo of shortwave radiation and perceived as warm colours. Narrow spaces dominate the area and they give an impression of being warmer and less ventilated than the wide spaces. Thus they also negatively influence the ambiance of the place. Sheltered spaces, which are created by a tunnel or canopy of trees above the route, are experienced as dark, humid and thermally more comfortable, however, there are only few and short in distance so they are not considered as significant factor influencing the ambiance. On the other hand, small neighbourhoods that have quite narrow streets, buildings in human scale, small front gardens, playgrounds and trees along the route makes the space more attractive for runners. Green spaces and attractive views are considered as pleasurable and more thermally comfortable. There are many green spaces along the route, but the most attractive ones are marked on the map. Grass fields, sport fields and green in between the roads or buildings represent the rest.

As expected, the urban environment is characterized by many elements that influence thermal perception from the psychological point of view. The graphic representation of the ambiance helped to recognize the areas, which are experienced as thermally uncomfortable.

5 The results of my sensory analysis are presented in the form of **sensory collages** (fig. 27-29). The collages represent characteristic elements that occur in the area, and express their influence on sensory experience of runners on the running routes.

I observed that there are many repetitive spatial elements that bring similar experiences for a runner. For instance, a busy road next to the running routes brings a lot of noise, unpleasant sounds and smell of car exhaust. Open spaces, wide roads or bridges are experienced as windy and fully exposed to the sun places, while tunnels and underground corridors as dark, cool, humid and noisy. Moving water in the canals have similar sound and have particular smell that is recognizable in many places. Water and green spaces are often experienced as attractive places, where sounds of nature (rustling trees, grasses, sounds of birds) can be heard and nice smells experienced. Green areas offer comfortable and soft surface to run on, however, these places are usually not indicated as a running route. Densely built areas are common for encounters with different types of traffic, unattractive sounds and feeling of not being safe. Attractive views, green vistas, aesthetic buildings or boats along the route positively influence the visual experience of the route.

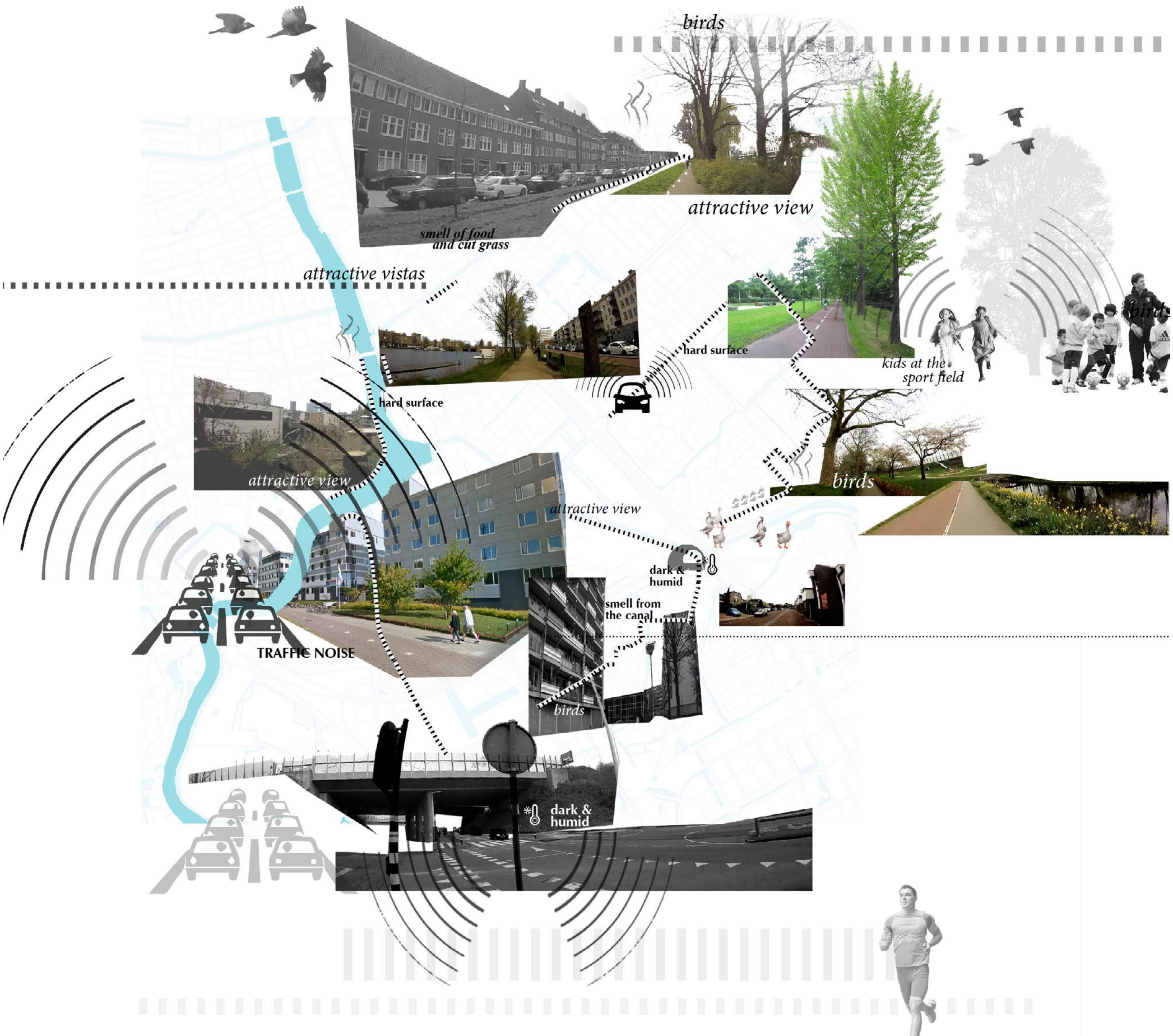


Fig. 27 Collage presenting sensory experience of a runner on Amsterdam Oost route

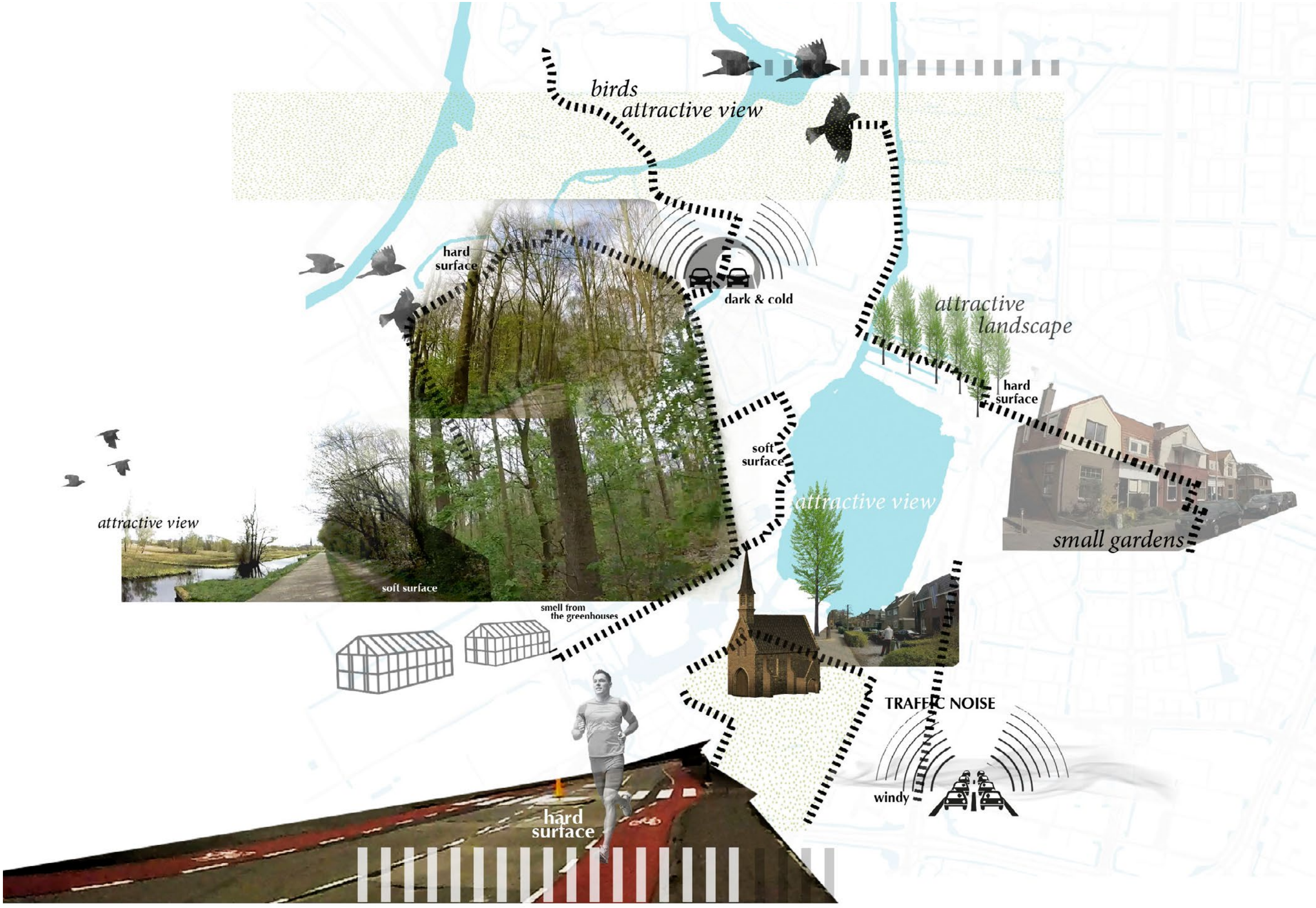


Fig. 28 Collage presenting sensory experience of a runner on Amstelveen route

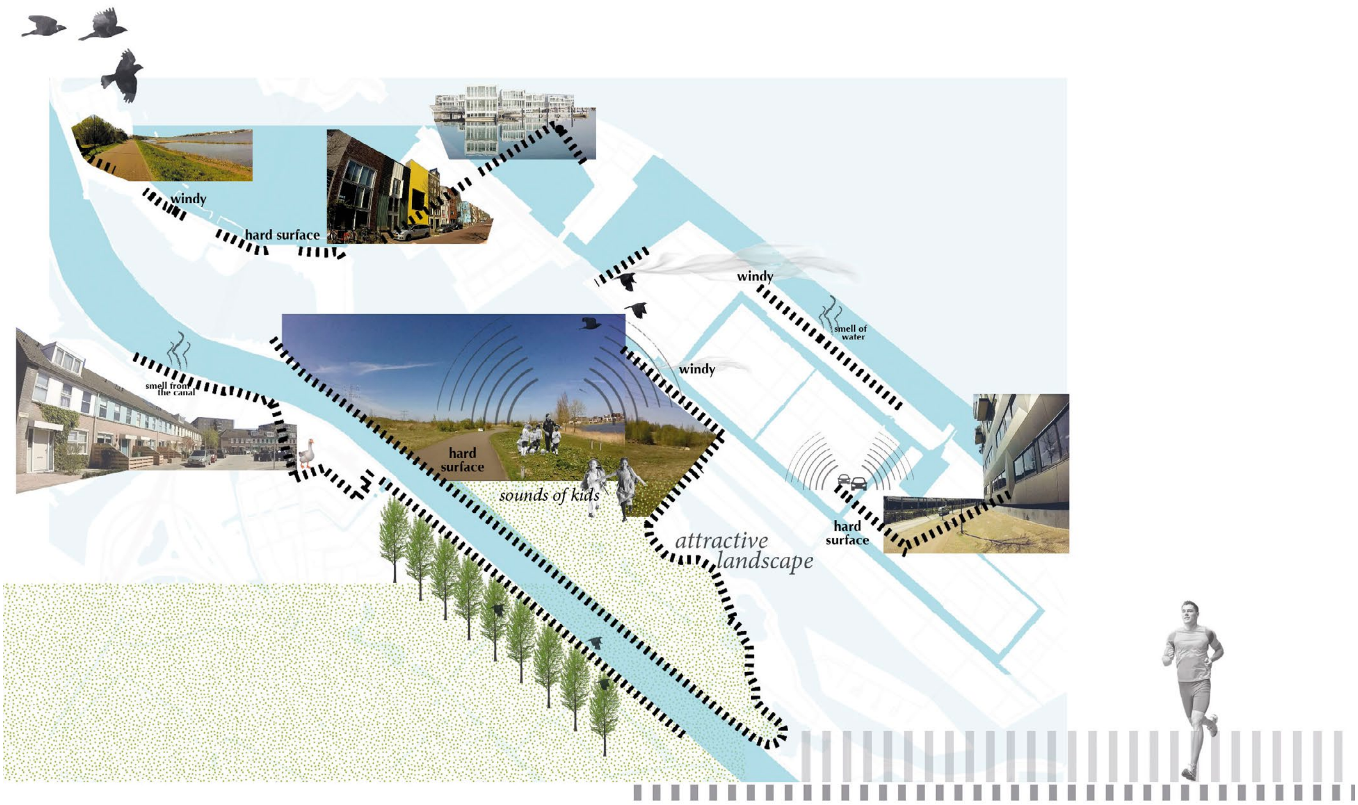


Fig. 29 Collage presenting sensory experience of a runner on Amsterdam Island route

I characterized most of the running routes are as weak in sensory experience as they have many elements that bring negative sensory experience. The artistic form of collages helped to give an impression of what can be experienced in the area and how is it related to the spatial configuration.

Step 1 of the spatial analyses of the running routes resulted in a map with 34 route profiles (fig. 30-31). The profiles represent configurations of existing spatial elements and their function. **Step 2** resulted in 16 characteristic route typologies that occur along the most avoided running routes (Appendix VIII).

Fig. 30 Map with the running route profiles

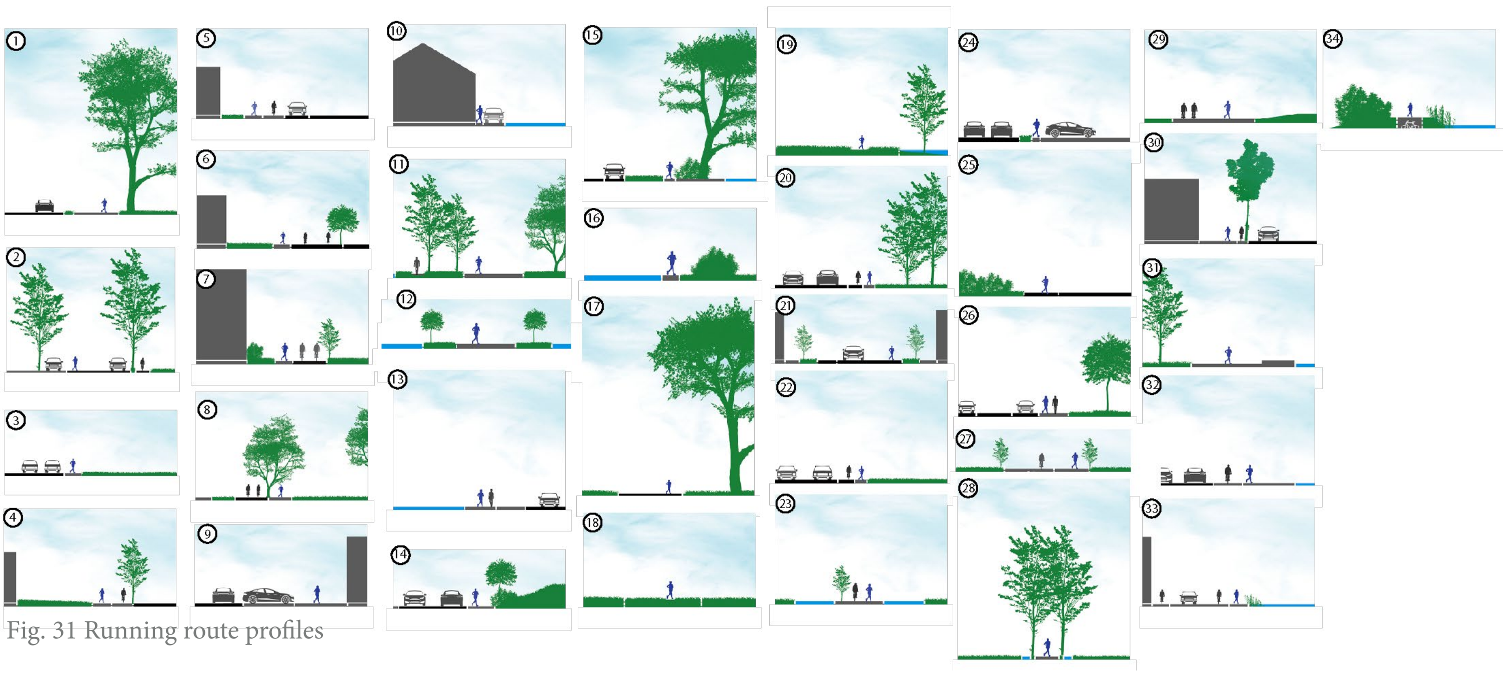


Fig. 31 Running route profiles

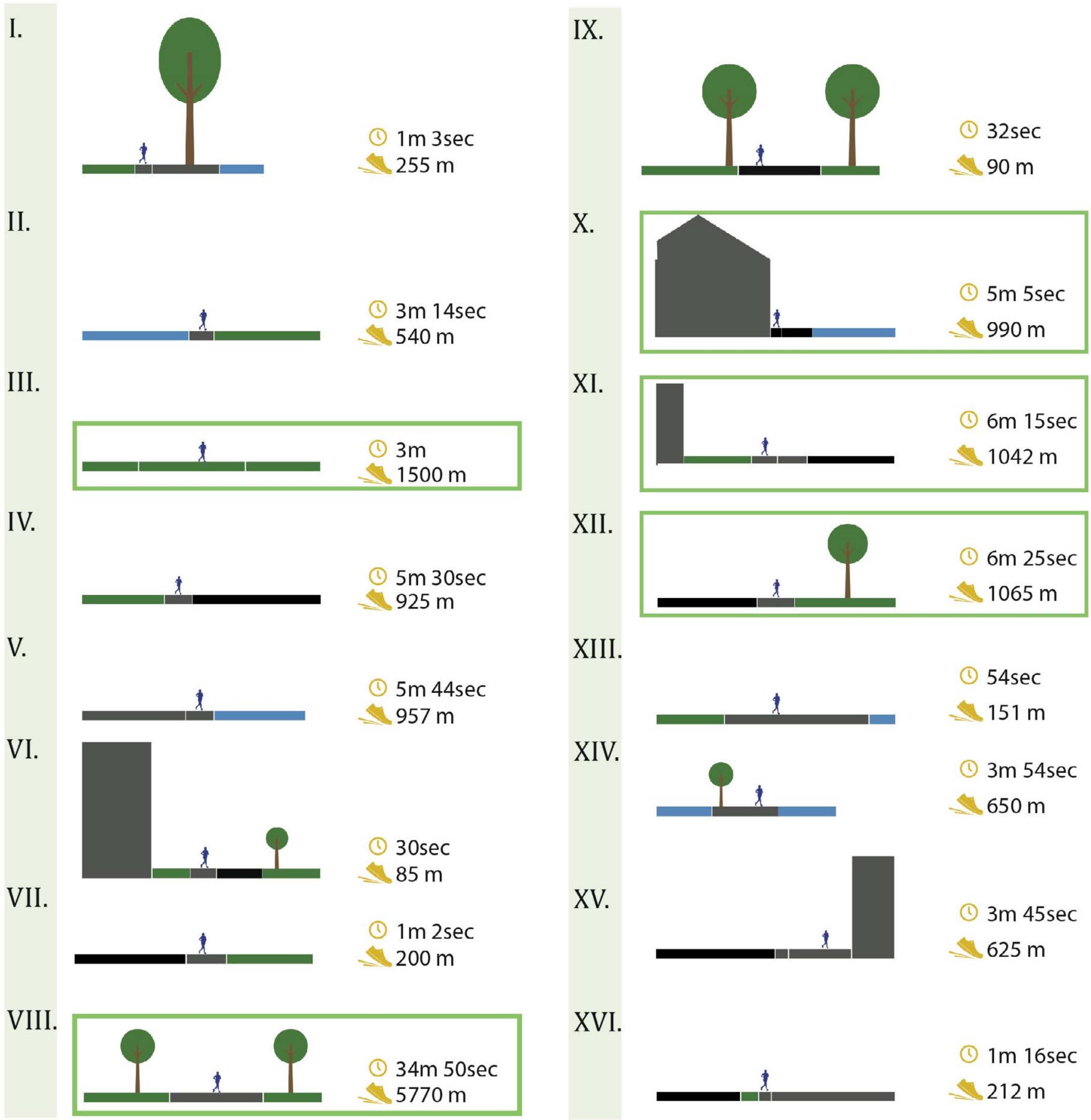


Fig. 32 Route typologies and their total length in distance and time

In **step 3** the five longest route profiles were selected (fig. 32) to be abstracted (**step 4)** and served as 'testbeds'. **Step 5** resulted in 5 'testbeds', which represent the most problematic, repetitive and dominant spatial configurations that occur in the study area (fig. 33).

The 'testbeds' were to serve as experimental setting that represent site specific spatial configuration and problems. They were used as a base for design.

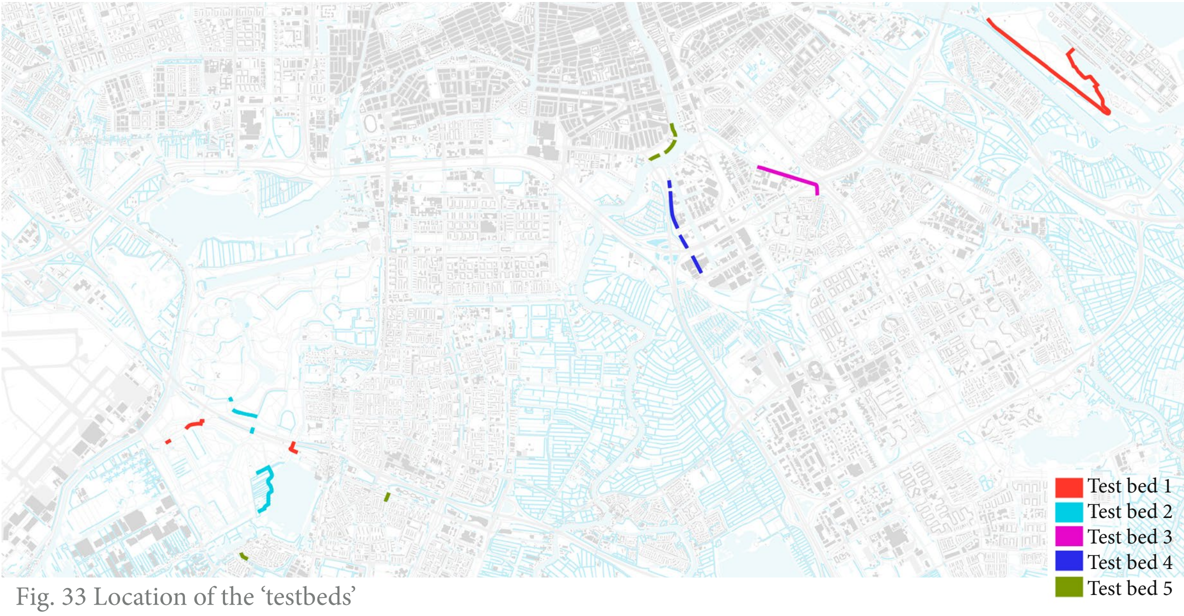


Fig. 33 Location of the ‘testbeds’

‘Testbed’ 1

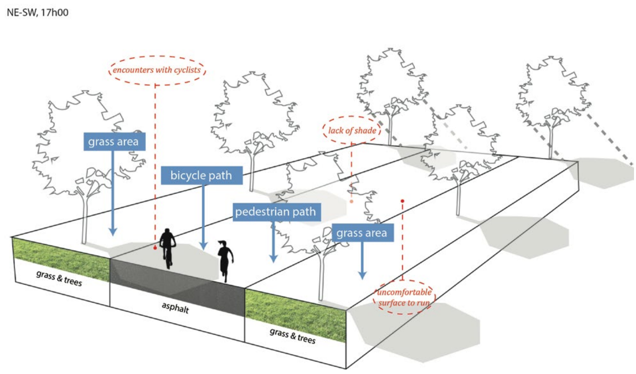


Fig. 34 Spatial configuration of test bed 1

‘Testbed’ 1 is a generalization of routes that are located both in Amstelveen and Island of Amsterdam (Diemen). The route faces NE-SW direction and represents 5200 m long asphalt route. It is located in nature area. Along the route there are single trees planted. The main problem that a runner faces on the route is lack of shade, encounters with cyclists, skaters and pedestrians, and uncomfortable surface to run. There are some trees along the route but they are small-sized and sparsely planted at random without a design. The route is fully exposed to the sun.

‘Testbed’ 2

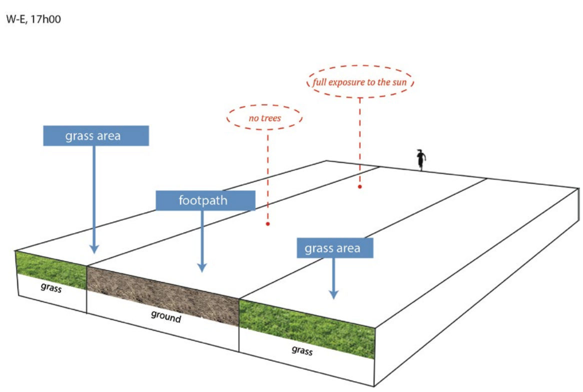


Fig. 35 Spatial configuration of test bed 2

‘Testbed’ 2 is a generalization of few running routes located in Amstelveen. The dominant direction that the route faces is at W-E direction. The ‘testbed’ represents 1500 m of the running routes which go through an open green area that is fully exposed to the sun. The main problem that a runner faces on this route is full exposure to the sun and lack of trees.

‘Testbed’ 3

NE-SW, 17h00

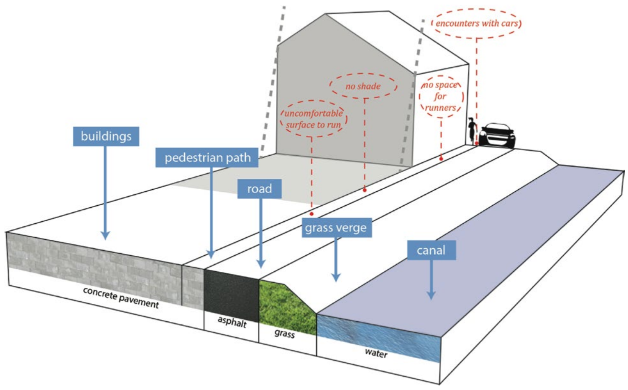


Fig. 36 Spatial configuration of test bed 3

‘Testbed’ 3 represents a route that is located in Amsterdam Oost and faces NE-SW direction. The running route is located on the pedestrian path between the row of buildings and a car road. The problems for a runner are considered with lack of shade, very narrow space and uncomfortable surface to run, encounters with pedestrians and cars, and visually unattractive neighbourhood.

‘Testbed’ 4

N-S, 17h00

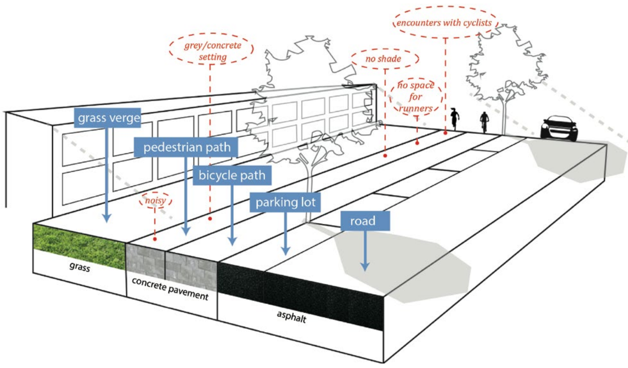


Fig. 37 Spatial configuration of test bed 4

‘Testbed’ 4 is a generalization of several running routes along Joan Muyskenweg in Amsterdam Oost. The route faces N-S direction and represents 1047 m of the running routes. The running route leads through a shared pathway with cyclists and pedestrians along the buildings with a grass verge in front, and on-road parking lot on the other side. The main problem that a runner faces is lack of shade, encounters with cyclists and parked cars on the side of the pavement, noise from the traffic, not enough space for runners, and grey concrete setting of the area.

‘Testbed’ 5

NW-SE, 17h00

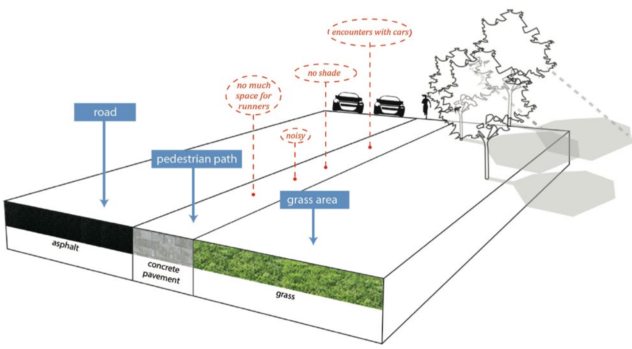


Fig. 38 Spatial configuration of test bed 5

‘Testbed’ 5 is a generalization of several running routes in Amsterdam Oost and Amstelveen. The route has NW-SE direction and is 975 m long. The runners share the space with pedestrians. The running route is located between a road and a green open area with some trees and shrubs randomly planted. The main problem that a runner faces when running along this route is lack of space, no shade, encounters with pedestrians and cars, and noise from the traffic.

Comparing all 'testbeds', it is concluded that the running routes are avoided because of thermal discomfort and insufficient sensory experience of the landscape. The most avoided running routes are characterized by following characteristics:

Regarding the microclimatic features

- High air temperature,
- High exposure to solar radiation,
- Lack of shadow,

Regarding the ambiance

- Grey colours,
- Concrete and asphalt as dominant materials,
- Not attractive landscape,
- Lack of vegetation,
- Narrow space,

Regarding the sensory experience

- Traffic noise,
- Uncomfortable surface to run (concrete or asphalt pavement),
- Unattractive views/ landscape,

Regarding the spatial configuration

- Lack or very narrow space for runners,
- Open and wide space without trees,
- No trees,
- Encounters with pedestrians, cyclists and cars,
- Traffic noise.

A 'testbed' is an abstracted form of several route profiles that belong to the same route's typology. It serves as generalized and controlled settings which represent the most problematic, repetitive and dominant spatial configurations that occur in the study area. As expected, the 'testbeds' were effective results represented in the form of 3D profiles, which pictured not only the spatial configuration but also problems of the specific running routes. It is an effective method to create a generalized setting for a design research, however, it does not present the exisiting spatial configuration. Therefore, the 'testbeds' are recommended to use for the academic purpose, but not in practice.

5.2 RESULTS FOR SQ2

SQ2: What kind of spatial configuration should running routes have to improve thermal comfort and sensory experience of runners?

1 Based on the literature study, I compared the existing strategies, which improve thermal perception of runners and sensory experience, and the design tools that are used within these strategies. This comparison resulted in figure 39, which presents the use of different tools in different interventions.

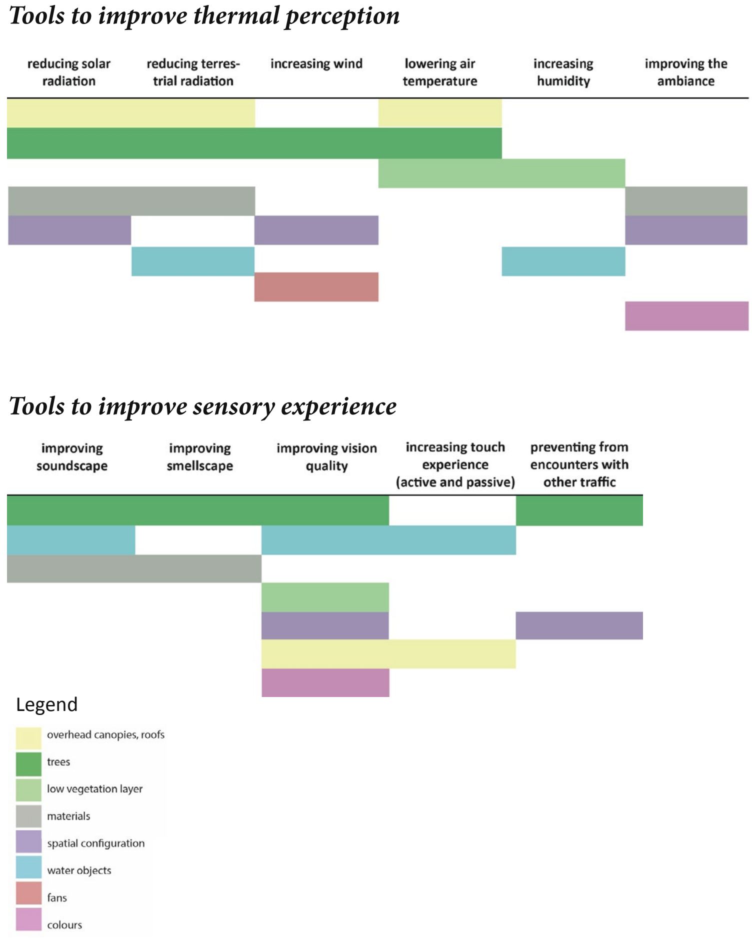


Fig. 39 Design tools which improve thermal perception and sensory experience of runners in the urban environment.

I observed that the existing design strategies, which improve thermal comfort and sensory experience, can be developed by using different design tools. It was also shown that the design strategies that improve thermal comfort use similar tools that are used in the strategies to improve sensory experience. Therefore, some of the tools have complex function, and a process of integration them bring a new set of integrated design tools that improve not only thermal comfort but also sensory experience of runners.

As a result, the integrated design toolbox was generated which consists of new, different, integrated, multifunctional and optimal design tools to be used when dealing with thermal discomfort and weak sensory experience on running routes. Several integrated design tools from the toolbox are presented and described below (fig. 40).

The integrated design toolbox offers a range of different design solutions (spatial configurations) that can be used to improve both thermal comfort and sensory experience. The toolbox provides practical tools to design with, and it is recommended to be used by professionals in the field of landscape and urban architecture to deal with heat stress on running routes. As expected, the integrated design tools are easy to use and flexible to be adjusted to different spatial settings. Combining different integrated tools can bring solutions to different and complex problems.

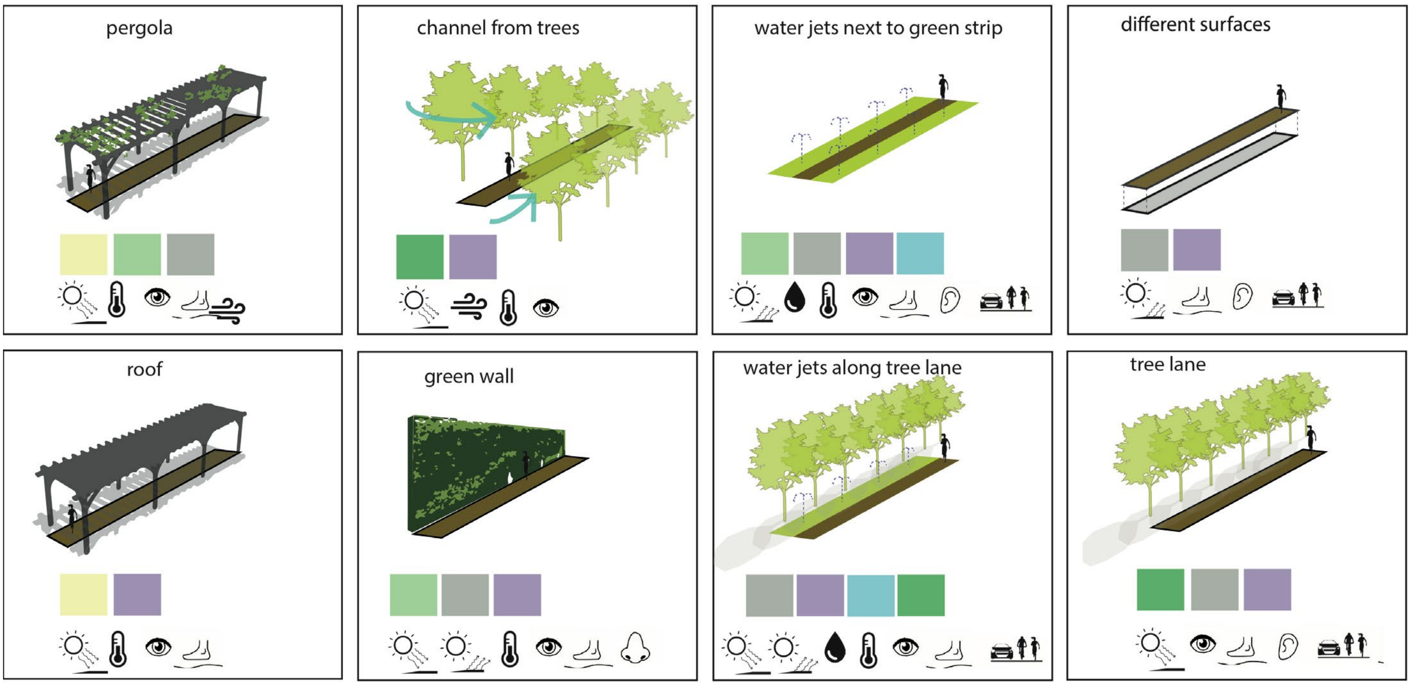
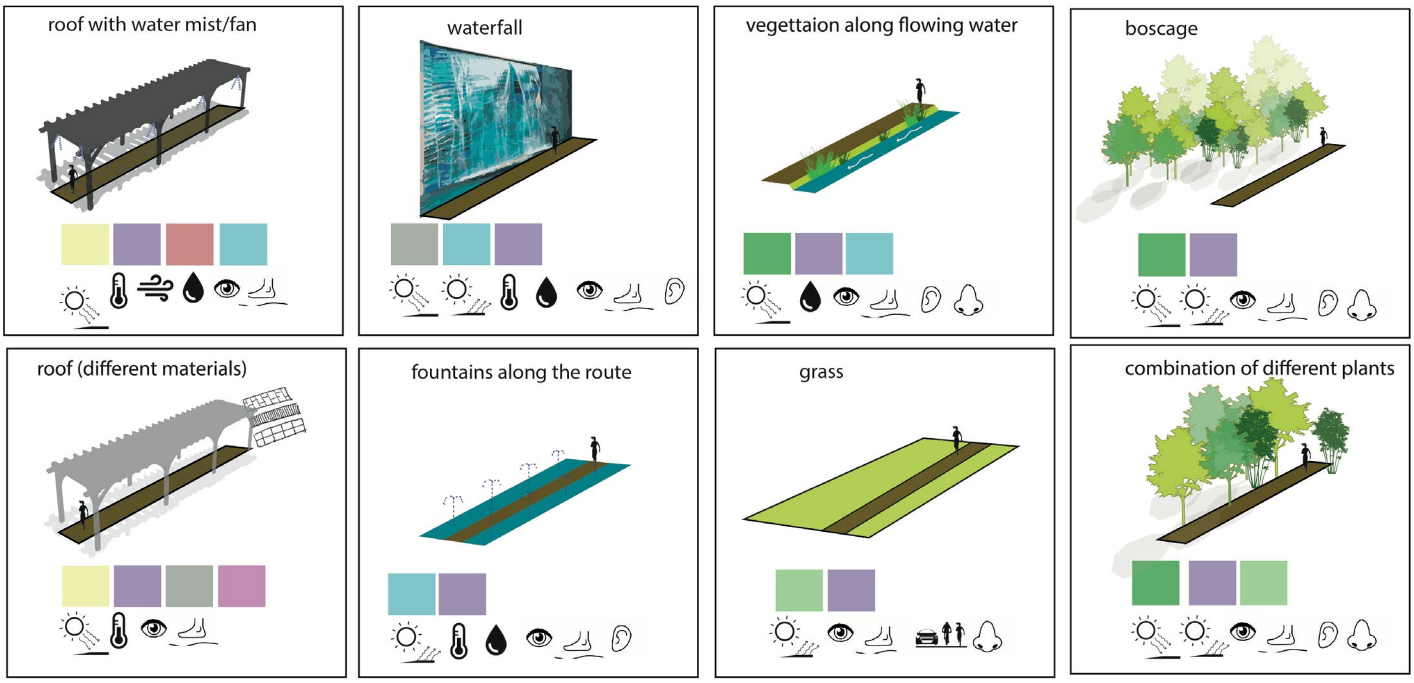


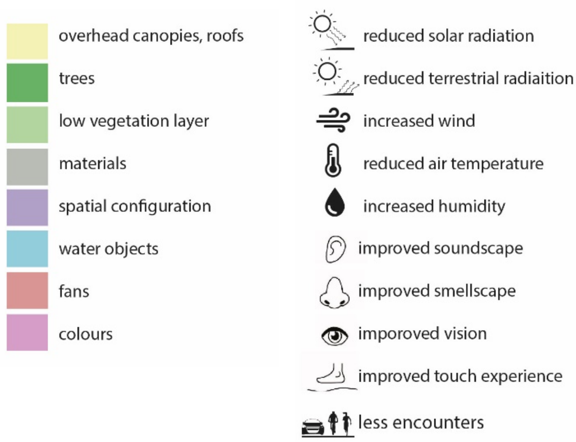
Fig. 40 Integrated design tools

5.3 RESULTS FOR SQ3

SQ3: ***In what way can the spatial configurations, which improve thermal comfort and sensory experience of runners, be implemented into design guidelines?***

1&2 The design models were explored. As described in chapter 4.2.3, the highest scored design models became the design guidelines. Every design model integrated minimum two of the integrated design tools. The design models were described, evaluated and presented graphically (p. 54-63).





'Testbed' 1

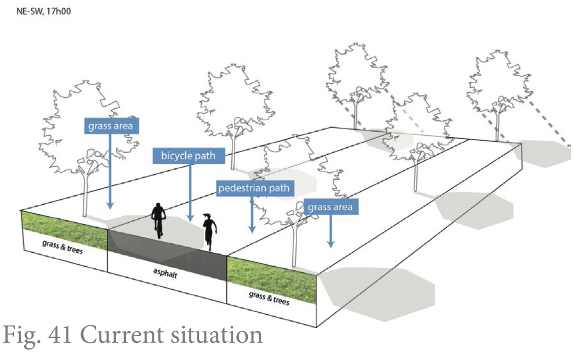


Fig. 41 Current situation

Direction: NE-SW

Qualities of the area:
- park (recreational area)
- wide and open space
- wide route for different types of traffic

Limitations for a design:
- natural area

Design models for 'testbed' 1

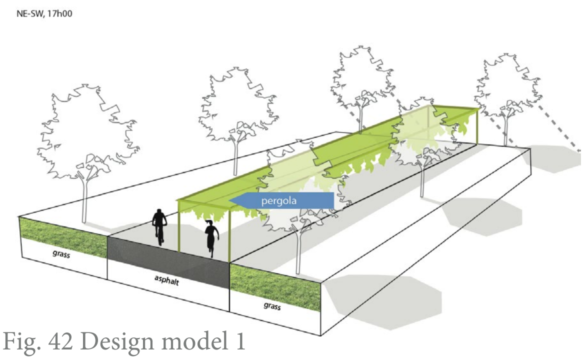


Fig. 42 Design model 1

The first solution (fig. 42) introduces a pergola over the running route. It protects runners from the solar radiation and shades the route. The vegetation on the pergola increases evapotranspiration, visual quality and smell-scape of the route. Flowers or leaves of a consciously selected climbers can provide an attractive smell.

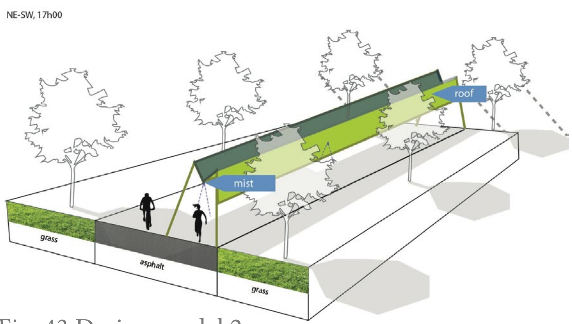


Fig. 43 Design model 2

The second solution (fig. 43) presents a roof, that spreads the mist, over the route. The roof provides shade. The mist increases evaporation and influences the passive touch. This new spatial element improves visual quality of the route.

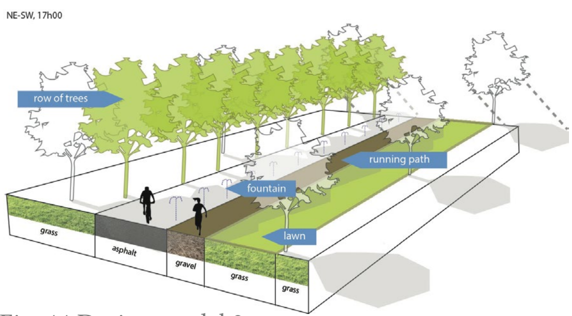


Fig. 44 Design model 3

The third solution (fig. 44) offers a row of trees to provide shade and to increase evapotranspiration. The running route is separated from the bicycle route by a row of water fountains and use of different surfaces. The fountains improve evaporation, passive touch, soundscape and visual quality of the route. The asphalt surface is reduced. Gravel is used as a running surface, so it lowers the heat-conductivity of the running surface, improves the soundscape and comfort of running. A lawn on the side of the route increases evapotranspiration and improves the visual quality.

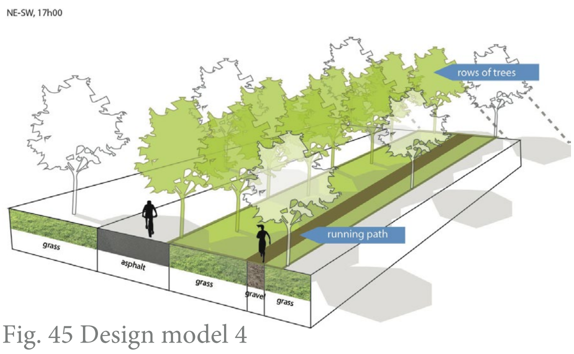


Fig. 45 Design model 4

The fourth solution suggests moving the running route to the side of the grass area (fig. 45). The surface of the running path is soft and comfortable to run. Additionally, the surface of the bicycle path is reduced and replaced with the grass so evaporation increases. The bicycle route is separated from the running path by rows of trees. Newly planted trees bring shade, evapotranspiration and reduce the traffic encounters. Additionally, clusters of trees can improve the habitats for birds and small animals so the soundscape could be also improved, however, the ventilation reduced.

Round 1

Criteria	Test bed 1			
	1	2	3	4
1. Thermal perception features				
Shade *3	1	1	1	2
Heat conductivity of running surface *3	0	0	1	1
Evaporation *3	0	1	1	0
Evapotranspiration *3	1	0	1	2
Ventilation *3	0	0	0	-1
SUM OF POINTS (1)	6	6	12	12
2. Non-thermal perception features				
Sound	0	0	2	1
Touch *2	0	1	1	1
Smell	1	0	0	0
Vision *2	1	1	1	1
Encounters with other types of traffic	0	0	1	1
SUM OF POINTS (2)	3	4	7	6
TOTAL SUM	**9**	**10**	**19**	**18**
3. Feasibility				
Construction	**	***	**	*
Maintenance	*	**	**	*
Installation cost	**	***	**	**
BEST SCORE				

Round 2

Key:		Key:	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 46 Assessment of the design models for 'testbed' 1

Design model 3 and 4 received the highest score during the first round of the evaluation. According to the criteria from the second evaluation round, the design model 4 was selected as the best solution. This model provides good thermal conditions and improves sensory experience of the runners.

‘Testbed’ 2

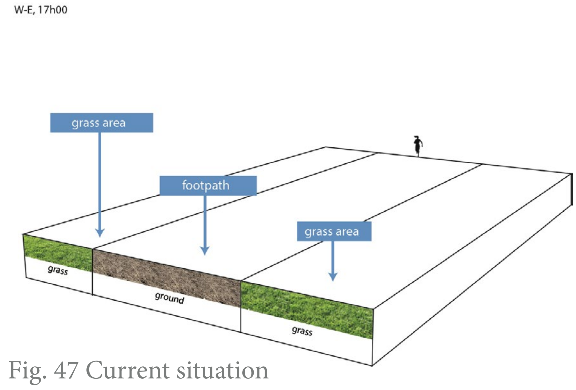


Fig. 47 Current situation

Direction: W-E

Qualities of the area:
- nature area
- wide, open space
- comfortable surface to run
- no traffic encounters

Limitations for a design:
- nature area as a limitation for introducing architectural objects that could invasive for the landscape

Design models for ‘testbed’ 2

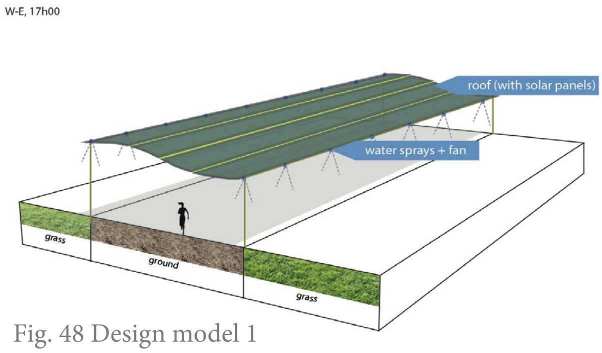


Fig. 48 Design model 1

The first solution (fig. 48) introduces a roof with water sprays and fan devices over the running route. It shades the route, improves evaporation and brings some ventilation to the area. The mist improves the touchscape. The roof can be covered with few solar panels to generate energy for water sprays and fans.

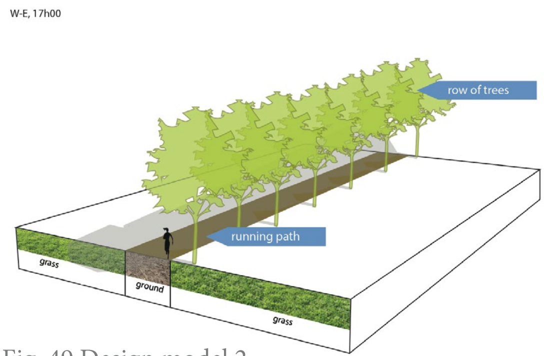


Fig. 49 Design model 2

In the second solution (fig. 49) the running route is narrowed and a row of trees planted along the route. The trees cast shadow on the route, increase evapotranspiration and improve the visual quality of this landscape. The trees may also improve soundscape by attracting some birds to the area. The comfort of running on the ground surface stays the same.

Fig. 50 Design model 3

The third solution (fig. 50) introduces many trees and shrubs that create a boscage around the running route. It enhances evapotranspiration and cast the shadow on the route. The visual quality of the landscape, soundscape and smell-scape are improved. Because of densely planted vegetation, the ventilation can be negatively affected.

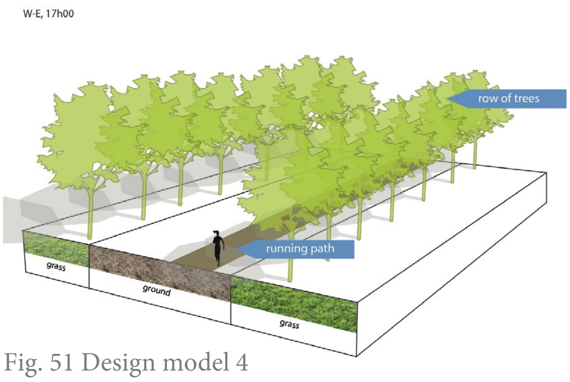


Fig. 51 Design model 4

The fourth solution (fig. 51) narrows the running route and introduces 2 rows of trees on both sides of the route. The trees increase evapotranspiration and shade the route. They improve soundscape and visual aspect of the route. The ventilation may be reduced.

Round 1

Round 2

Criteria	Test bed 2			
	1	2	3	4
1. Thermal perception features				
Shade *³	1	1	2	1
Heat conductivity of running surface *³	0	1	1	1
Evaporation *³	1	0	0	0
Evapotranspiration *³	0	1	1	2
Ventilation *³	1	0	-1	-1
SUM OF POINTS (1)	9	9	9	9
2. Non-thermal perception features				
Sound	0	1	1	1
Touch *²	1	0	0	0
Smell	0	0	1	0
Vision *²	1	1	1	1
Encounters with other types of traffic	0	0	0	0
SUM OF POINTS (2)	4	3	4	3
TOTAL SUM	**13**	**12**	**13**	**12**
3. Feasibility				
Construction	***	*	*	***
Maintenance	**	*	*	**
Installation cost	***	*	**	**
BEST SCORE				

Key:		Key:	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 52 Assessment of the design models for 'testbed' 2

After the first round of the evaluation process of the design models, all the models were taken into consideration during the second evaluation round. According to the feasibility criteria, the second design model was the lowest-demanding model considering construction, maintenance and installation cost. Therefore, this model was selected to serve as a design guidelines.

'Testbed' 3

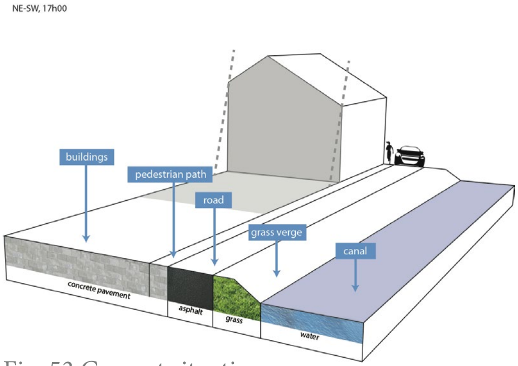


Fig. 53 Current situation

Direction: NE-SW

Qualities of the area:
- the edge of the neighbourhood and nature area
- attractive landscape on the side of the canal

Limitations for a design:
- narrow space between the buildings and the canal
- industrial area so not very visually appealing

Design models for 'testbed' 3

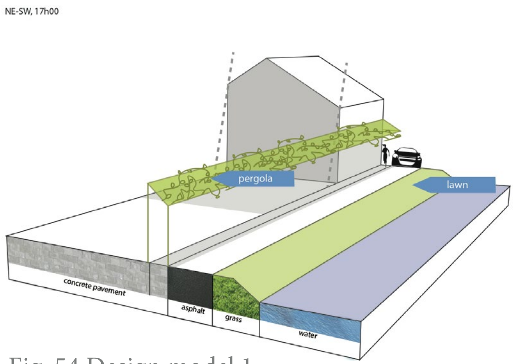


Fig. 54 Design model 1

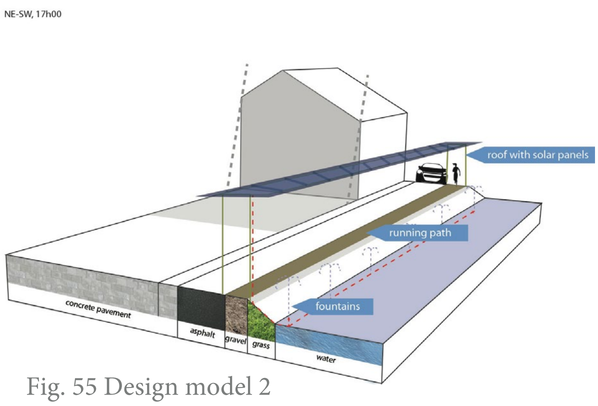


Fig. 55 Design model 2

The first solution (fig. 54) introduces a pergola above the running route. It blocks the solar radiation coming to the ground, provides shade, and enhances evapotranspiration by introducing vegetation on the pergola. A lawn on the slope along the canal provides an additional evapotranspiration surface. The pergola and the lawn improve the visual quality of the route. The smell-scape is improved by choosing special climbers that produce nice smell.

The second solution (Fig. 55) suggests moving the running route to the grass verge on the other side of the road and to install a roof over the route. The roof provides shade. The running route is located closer to the canal so the evaporated water from the canal can positively influence the thermal perception of a runner. Additionally, to enhance the evaporation from the canal, the water must be in a constant move, and therefore a set of water fountains are installed. Gravel surface of the route lowers heat conductivity, and improve sound-scape and active touch. The new location of the route reduces the grass surface so evapotranspiration is also reduced. The solar panels do not influence the urban microclimate or thermal perception of a runner, but add a sustainable value to the neighbourhood. A part of the energy generated from the sun can be used to power the fountains. Relocating the path along the water and installing the water fountains improve the visual and sound experience of the route. The encounters with pedestrians and cars are reduced.

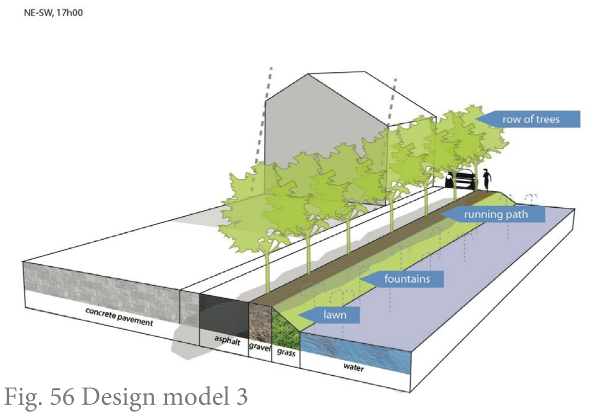


Fig. 56 Design model 3

The third solution (fig. 56) introduces the running route closer to the canal, a row of trees along the route, gravel as running surface, lawn on the slope to the water and set of fountains in the canal. The trees provide shade, improve evapotranspiration and create a barrier from the traffic encounters. The gravel surface lowers heat conductivity of the running surface and improves the soundscape when running. As mentioned in the previous design model, water fountains improve evaporation, soundscape and passive touch. This model also improves the visually quality of the route.

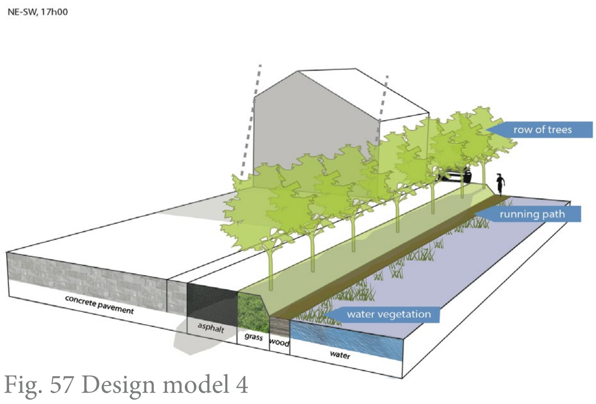


Fig. 57 Design model 4

The fourth solution (fig. 57) provides a row of trees and a new location for the running route. The trees provide shade and increase evapotranspiration. The new location of the running route brings runners closer to the water so the soundscape and visual quality is improved. The wooden surface decreases heat conductivity, improves soundscape and active touch. The runners are well separated from the traffic encounters.

Round 1

Criteria	Test bed 3			
	1	2	3	4
1. Thermal perception features				
Shade *3	1	1	1	1
Heat conductivity of running surface *3	0	1	1	1
Evaporation *3	0	1	1	0
Evapotranspiration *3	0	-1	1	1
Ventilation *3	0	0	0	0
SUM OF POINTS (1)	3	6	12	9
2. Non-thermal perception features				
Sound	0	1	1	1
Touch *2	0	1	1	1
Smell	0	0	0	0
Vision *2	1	1	1	1
Encounters with other types of traffic	0	1	2	2
SUM OF POINTS (2)	2	6	7	7
TOTAL SUM	**5**	**12**	**19**	**16**
3. Feasibility				
Construction	**	***	**	***
Maintenance	*	**	*	*
Installation cost	**	***	**	**
BEST SCORE				

Round 2

Key:		Key:	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 58 Assessment of the design models for 'testbed' 3

During the first evaluation round, the third design model got the highest score. According to the second evaluation round, this model was also the most optimal, and thus it was selected for a design gudeline.

'Testbed' 4

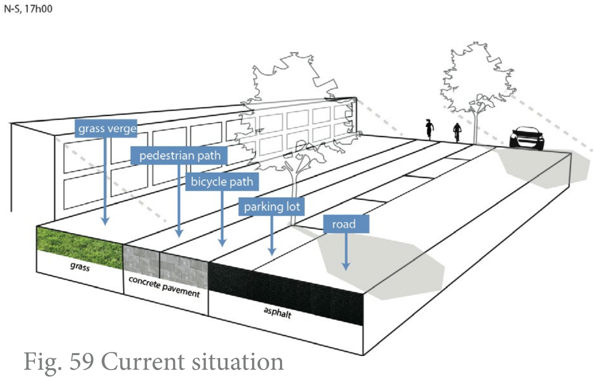


Fig. 59 Current situation

Direction: N-S

Qualities of the area:
- open and wide space

Limitations for a design:
- streetscape
- parking lots cannot be removed

Desing models for 'testbed' 4

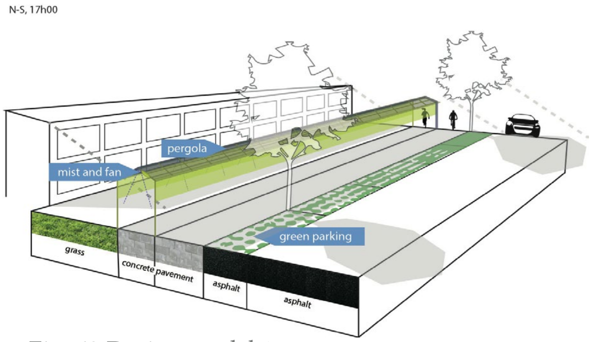


Fig. 60 Design model 1

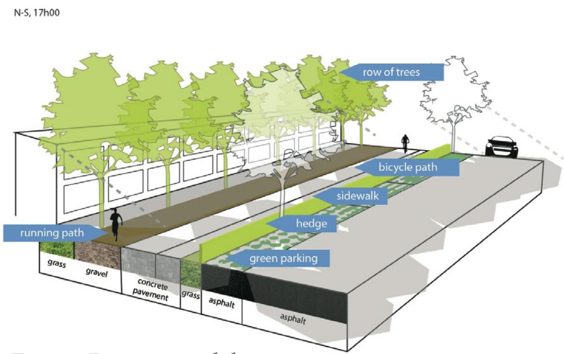


Fig. 61 Design model 2

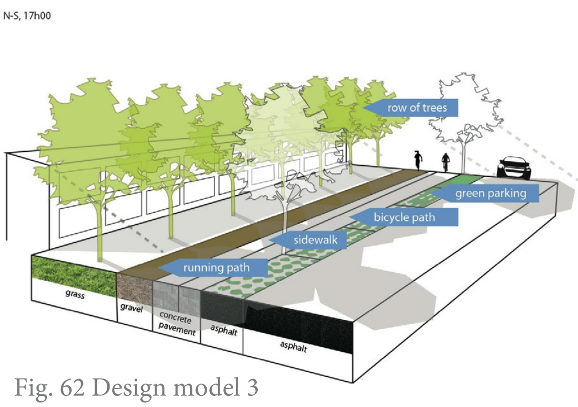


Fig. 62 Design model 3

The first solution (fig. 60) is a fusion of a pergola and a roof with mist and fan devices. It is located over the running route and it provides shade on the route, increases evaporation and ventilation in the area. The vegetation on the pergola increases evapotranspiration. Additionally, the parking lot is green and permeable, which increases evapotranspiration and lowers the heat conductivtiy.

The second solution (fig. 61) introduces more trees into the area and relocates the running route to the side of the buildings. The space for cyclists is kept and reduced for pedestrians. In this way there is an extra space created for a hedge between the cycle path and the road. A row of trees is planted along the running route so they cast shade on the route, increase evapotranspiration and have positive impact on visual quality of the route. The soundscape is improved by introducing vegetation that attract more birds to the site. Running on gravel surface gives extra sound and improves the sense of touch. A green parking lot is introduced.

The third solution (fig. 62) suggests changing the spatial distribution of the traffic. The road and a parking lot stay in the same location. The bicycle path is moved next to the road; the pedestrian path in between, and the running route to the side of the buildings. The problem of traffic encounters is solved. There is a row of trees planted along the running route. The trees cast the shadows and increase evapotranspiration. The running route is surfaced with gravel. It reduces the heat conductivity of the running surface, improves soundscape and active touch. Green parking lots are introduced.

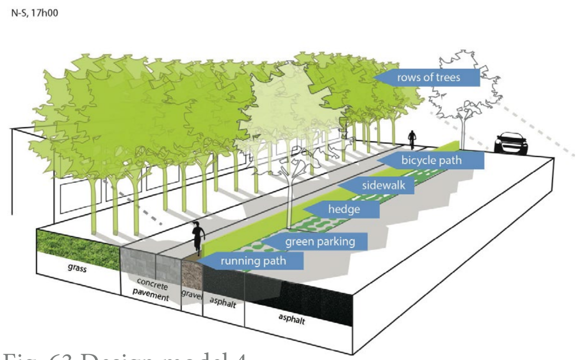


Fig. 63 Design model 4

The fourth solution (fig. 63) suggests moving the running route between pedestrian path and on-road parking lot. The route is surfaced with gravel. On the side of the buildings there are few rows of big trees planted, so the running route is in shade. The trees provide shade, evapotranspiration and improve soundscape by improving habitats for birds. Due to densely planted trees, the ventilation might be reduced. The surface of the route is comfortable to run on. The hedge improves the traffic enounters, and a green parking lot increases evapotranspiration.

Round 1

Round 2

Criteria	Test bed 4			
	1	2	3	4
1. Thermal perception features				
Shade *³	1	1	1	1
Heat conductivity of running surface *³	0	1	1	1
Evaporation *³	1	0	0	0
Evapotranspiration *³	1	2	1	2
Ventilation *³	1	0	0	-1
SUM OF POINTS (1)	12	12	9	9
2. Non-thermal perception features				
Sound	0	1	1	1
Touch *²	1	1	1	1
Smell	1	0	0	0
Vision *²	0	1	1	1
Encounters with other types of traffic	0	1	1	1
SUM OF POINTS (2)	3	6	6	6
TOTAL SUM	**15**	**18**	**15**	**15**
3. Feasibility				
Construction	***	**	**	**
Maintenance	**	*	*	*
Installation cost	***	***	**	**
BEST SCORE				

Key:		Key:	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 64 Assessment of the design models for 'testbed' 4

Design model 2 was scored highest solution during the first evaluation round. It was also an optimal design solution regarding construction, maintenance, and installation costs in the second round. This model was selected to be a design guideline.

‘Testbed’ 5

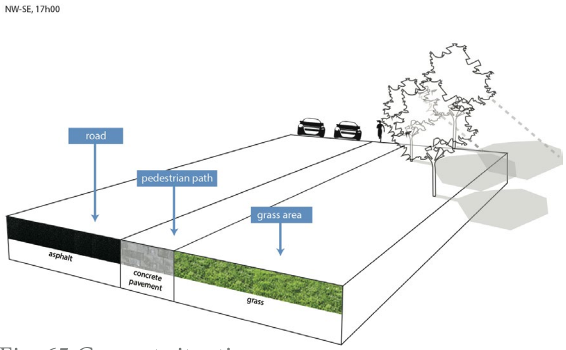


Fig. 65 Current situation

Direction: NW-SE

Qualities of the area:
- open green space with some trees

Limitations for a design:
- streetscape

Design models for ‘testbed’ 5

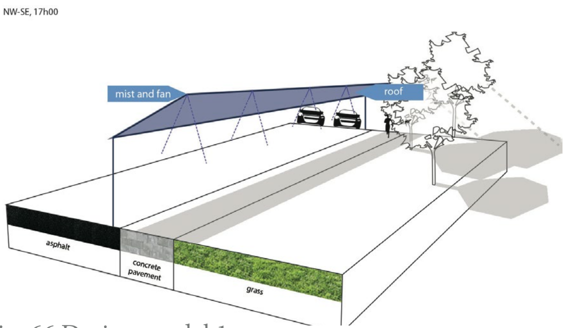


Fig. 66 Design model 1

The first solution (fig. 66) introduces a roof with integrated mist and fan device. The roof shades the route. An installed mist device increases evaporation, and a fan device improves ventilation in the area. Both devices influence the passive touch.

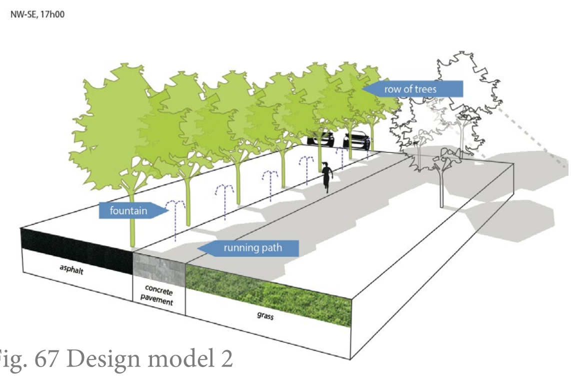


Fig. 67 Design model 2

The second solution (fig. 67) suggests changing the concrete pavement into a permeable one. Therefore, a row of trees and a line of water fountain can be installed along the running route. The trees cast shadow, increase evapotranspiration and can function as a noise-barrier. The runners’ encounters with cars are reduced, however, the route is still shared with pedestrians. The water fountains improve evaporation and the soundscape. The general visual quality of the route is diversified.

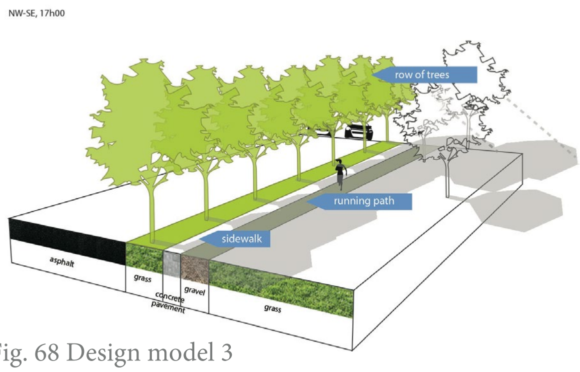


Fig. 68 Design model 3

The third solution (fig. 68) increases vegetation along the running route. A row of trees shades the running route and increases evapotranspiration. The running route is surfaced with gravel so the design provides comfortable surface to run on. Heat conduc-

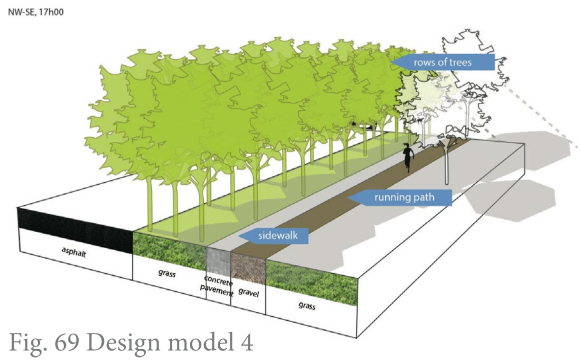


Fig. 69 Design model 4

tivity of the running surface is reduced. The fourth solution (fig. 69) suggests moving the pedestrian and running paths to the grass area. The created space between the sidewalk and the car road can be filled with trees. The trees cast shadows on the running route and provide evapotranspiration. The running route is surfaced with gravel and located on the grass next to the sidewalk. The dense structure of the trees separates runners from the traffic. Additionally, it blocks the noise from the car road and provides sounds of birds that live in the tree crowns.

Round 1

Round 2

Criteria	Test bed 5			
	1	2	3	4
1. Thermal perception features				
Shade *³	1	1	1	2
Heat conductivity of running surface *³	0	0	1	1
Evaporation *³	1	1	0	0
Evapotranspiration *³	0	1	1	2
Ventilation *³	1	0	0	-1
SUM OF POINTS (1)	9	9	9	12
2. Non-thermal perception features				
Sound	-1	1	1	2
Touch *²	1	0	1	1
Smell	0	0	0	0
Vision *²	1	1	1	1
Encounters with other types of traffic	0	1	2	2
SUM OF POINTS (2)	3	4	7	8
TOTAL SUM	**12**	**13**	**16**	**20**
3. Feasibility				
Construction	***	**	*	*
Maintenance	**	**	**	*
Installation cost	***	**	*	***
BEST SCORE				

Key:		**Key:**	
Negative	-1	Low value	*
Neutral	0	Medium value	**
Positive	1	High value	***
Very positive	2		

Fig. 70 Assessment of the design models for 'testbed' 5

After the first evaluation round, design model 4 was the highest scored design solution. According to the feasibility criteria, the installation cost is high due to the underground installation that might need to be replaced and the pedestrian pavement moved. However, the construction and maintenance is easy and low cost. Model 4 was thus selected as a design guideline.

3 Every design guideline was projected in a real context. The implementation of the design guidelines respected the current situation, location of the running route, and existing problems. The projections of the design guidelines resulted in the form of **artistic impressions** (fig. 71- 75), which exemplified the visual effect and multi-sensory experience of runners. The artistic impression consist of a visualization, soundtrack and description added to the picture. A combination of a visualization, soundtrack and added text to the pictures is a useful way to give a grasp of what runners can experience when running.

A visualisation presents how the specific running route could be improved by a design and what can be seen when running. A soundtrack gives an impression of what can be heard when running, and an added text is to describe other sensory experience such as smell, feel and touch, which cannot be presented visually or acoustically. The artistic impressions are presented below. The sound records are accessible (with internet connection) by clicking on the play button, otherwise they are also listed in Appendix XVIII.

Fig. 71 Artistic impression of the running route in the open space of Amsterdamsebos

Fig. 72 Artistic impression of the running route in Diemen Park

Fig. 73 Artistic impression of the running route along Duivendrechtsekad street

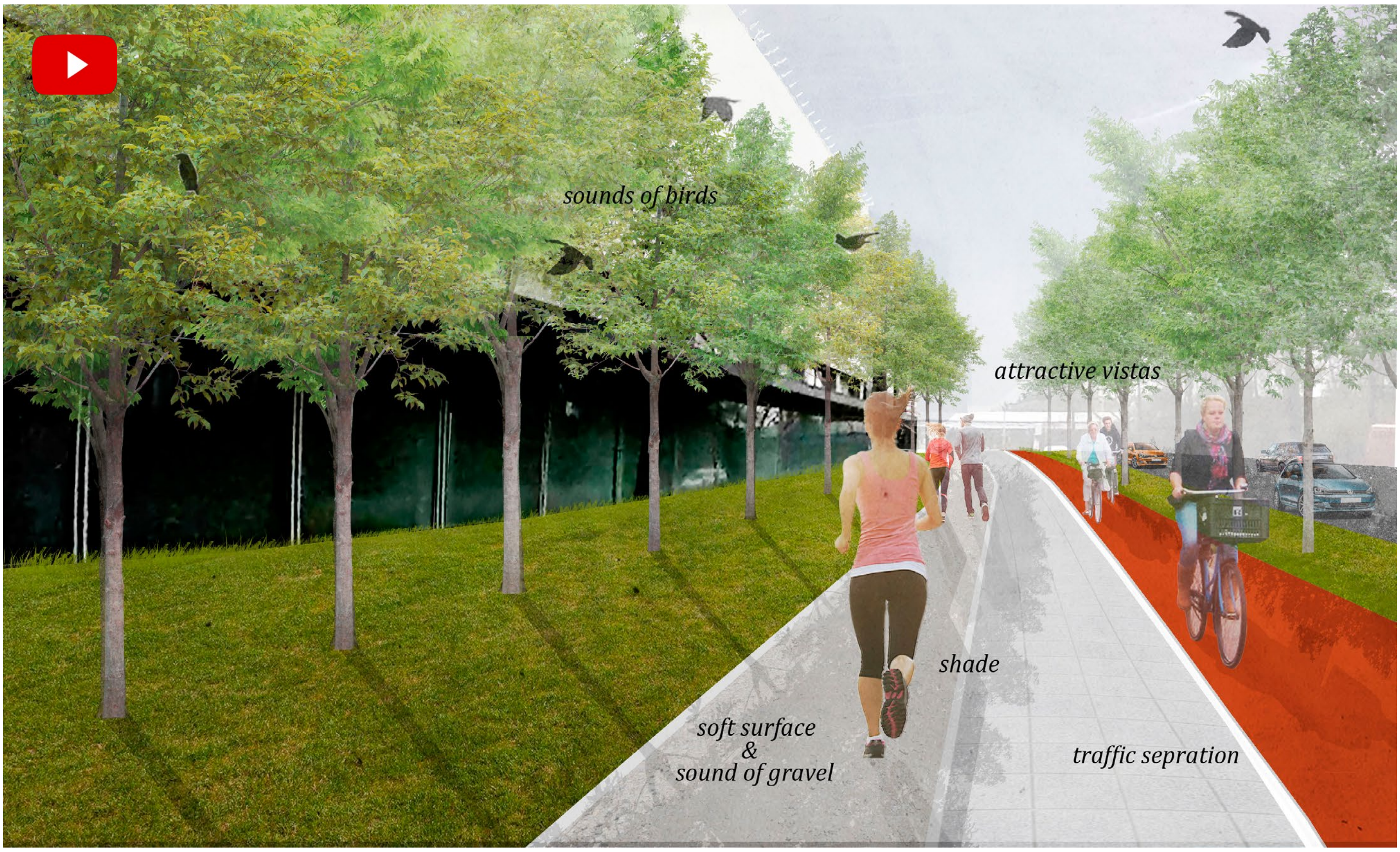


Fig. 74 Artistic impression of the running route along Amsetldijk street

Fig. 75 Artistic impression of the running route along Joan Muyskenweg street

Projecting the climate-responsive design guidelines into a real context brought additional reflections on what other design requirements should be taken into further consideration when detailing the design of the route. These observations serve as additional 'operational principles' to the guidelines.

Additional 'operational principles'

1. Safety

It is important to reduce the encounters with other traffic to its minimum and reduce any nuisance that may occur on the route. For this purpose, it is recommended to provide spatial barriers (hedges, verge of grass), or use different colours or surface materials to indicate a division in use of the space. Furthermore, visibility is particularly important at intersections with roads and other routes.

2. Connectivity

Routes should have convenient access points from the surrounding system of other running routes, sidewalks and bicycle paths in order to provide a network of connected running routes to make loops and runs at different distances.

3. Response to location

The design of the running route should respond to opportunities, constraints and character of the surroundings. The historical context, character of the place, technical requirements and site-specific problem should be considered when detailing the design.

4. Diversity of runners

The design guidelines consider frequent and informal runners of different age, sex and ability. When detailing a design, it is also important to consider competitive runners who may use the routes for running events. Therefore, it is important to design places which could be scheduled for running competitions, field events and gathering places other participants of the event could stay.

5. Design construction

Running route should be precisely engineered to be virtually flat with enough slope to shed rainfall. The drainage system should be carefully designed with consideration of soil, site hydrology and surface water movement. Even though the minimum width of the route should be 60 cm, it is recommended to build the route wider assuming that the designed running routes become more popular among runners. To compare, the optimal athlete running lane is 122 cm wide.

6. Materials

It is recommended to use low heat-conductive surface that is smooth and comfortable to run on. For the thermal and sensory purpose, I suggested to use graveled surface on the running paths. However, other materials could also be used. Ground, sand, grass, or synthetic rubber, which is commonly used for running tracks worldwide, could serve as comfortable surface to run, however, they have many negative side effects for the experience of run. When designing a long-distance running route, the use of different materials for the surface could be an idea to bring diverse and rich sensory-experience as well as to avoid running injuries related to running on the same surface for a long time.

7. Planting

Generally, it is important to use species which fit to existing environment, habitats, and are climate-resilient. In this way, the cost of maintenance is lowered to its minimum and the ecological value is kept. To positively influence thermal conditions during warm days by using vegetation, it is recommended to use deciduous trees that have low radiation transmissivity. Lenzholzer (2013) presents a list of trees which are recommended for the urban environment. Furthermore, the design should provide enough space for plant growth. If necessary, the vegetation should be regularly trimmed in order to keep horizontal clearance on the route.

8. Programming
To enhance running activities and enrich a program of the running routes, it is recommended to design places where a runner can stop, drink some water, do some fitness exercise, take rest and relax.

It is important to mention that additional analysis of the location, which were chosen for the guidelines' implementation, was omitted. It means that the implementation of the guidelines gave only an impression of how the guideline could be implemented in the landscape. Nevertheless, this process was sufficient to draw conclusions about the aspects that should be considered when implementing a design guideline into a real context and detailing the design.

CONCLUSIONS

6

6 CONCLUSIONS

In this chapter, the conclusions of this thesis are formulated and elaborated by answering the research questions. In order to answer the main research questions, first the sub-research questions are addressed and answered in the following paragraphs.

SQ1: What are the characteristics of less used running routes in Amsterdam?

This study demonstrated that less used running routes are characterized by thermal discomfort and weak sensory experience of runners on the running routes. As the results showed, there are many physical and psychological factors that influence the running activities during warm summer days. The characteristics of less used running routes were found and helped to identify the problems of the most avoided running routes, which were generalized into 'testbeds'.

SQ2: What kind of spatial configuration should running routes have to improve thermal comfort and sensory experience of runners?

Based on the existing design strategies and tools, the study provided a set of new integrated design tools, which deal with thermal discomfort and improve sensory experience of runners on running routes. The integrated design toolbox offers a big range of different spatial configurations that improve different thermal and non-thermal features. In this thesis, the integrated design tools were used to explore design models and to provide optimal and effective solutions to the complex problems of each of the 'testbeds'.

SQ 3. In what way can these spatial configurations (SQ2) be implemented into design guidelines?

The study explored a set of design guidelines. Based on the generated 'testbeds' and design criteria, the design guidelines are not only climate-responsive but also enhance sensory experience of runners, and provide applicable and feasible solutions. By implementing these design guidelines into a real context, the study demonstrated how these climate-responsive design guidelines could contribute to further research on processes of exploring design guidelines and application of design guidelines into practice.

MRQ: What spatial interventions could improve thermal comfort and sensory experience of runners on running routes?

The findings of this thesis presented new insights to ameliorate the thermal conditions on the running routes in the urban environment by introducing climate-responsive design guidelines. With the proposed design guidelines from this research, heat on the running routes is mitigated, and the level of thermal comfort and sensory experience of runners is improved. According to the design criteria and evaluation process, the most optimal and effective design interventions were proposed.

A comparison of the design models and assessment of their impacts on thermal conditions and sensory experience of runners helped to generate the guidelines for thermally comfortable running routes.

By comparing all five design guidelines, it can be concluded that the most effective and viable design interventions integrate several design tools that provide shade, reduce solar and terrestrial radiation, increase evapotranspiration, introduce new smells and sounds, improve the comfort of running by using gravel, prevent from the traffic encounters, are feasible, and at low-cost and maintenance.

Among the spatial interventions used for the design guidelines, there are repetitive elements such as:

- One or more rows of trees,
- Increased surface of low vegetation,
- Soft and comfortable surface on the running route,
- Re-location of the running route,
- New surface of the running route.

Conclusions in summary: This thesis contributes to an understanding of how climate-responsive design interventions could be implemented in the urban space to improve thermal condition and sensory experience of runners in cities. The results from this research conducted on running routes in Amsterdam confirm the importance of bridging the gap between the urban microclimate and urban design. This study showed that modifiying the urban environment by using climate-responsive design guidelines brings positive impacts on thermal conditions and sensory experience of runners.

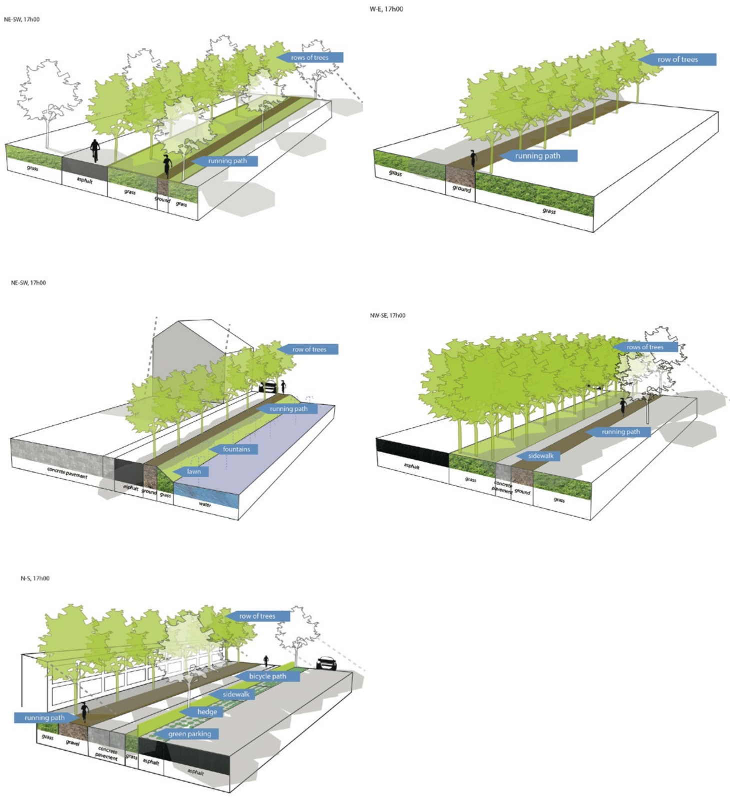


Fig. 76 Five design guidelines - final result of this research

GENERAL OBSERVATIONS AND FURTHER RESEARCH

7

7 GENERAL OBSERVATIONS AND FURTHER RESEARCH

This chapter aims to critically reflect and discuss the research strategy, methods and findings of this study, and provides recommendations for further research. The six aspects are discussed as follows: 1) research strategy and methods, 2) similarities and differences between the result of this and similar studies, 3) reflection on research and design results from academic and professional perspective, 4) further research, 5) significance of this research, and 6) recommendations.

7.1 RESEARCH STRATEGY AND METHODS

7.1.1 Research strategy

Research for design supported generation of the design product and the design process by collecting and combining existing knowledge. RFD involved maps study, literature study, site visit and recorded run as research methods. By using these methods I gathered sufficient information and existing knowledge, which formed a solid scientific base to frame the research topic and form the design criteria. The research outcomes of this process informed the design, and enabled me to find and collect the knowledge that was necessary to conduct RTD process.

Because this thesis focuses on climate knowledge and sensory experience of runners, I used the ***pragmatic 'research-through-designing'*** (Lenzholzer, Duchhart, & Koh, 2013) as the main strategy. It merged the post (positivistic) worldview on how to reduce heat stress in the urban environment with the constructivist worldview on how to improve the experience and complex interactions of runners with the environment. This integration resulted in unique knowledge.

In this thesis, RTD was an iterative and experimental process of designing, testing and assessing generated design experiments. As a result, RTD bridged climate knowledge and urban design, resulting in credible and precise research product. Because RTD is an explorative and iterative process, it is important to be aware that RTD process may take a lot of time to provide the final research product. However, due to many tests and assessment loops, the final research and design products are credible, feasible and out-of-the-box. Additionally, these products (design guidelines) are flexible and easy to modify if necessary, therefore, RTD is recommended as a research method in similar studies.

7.1.2 Reflection on selected research methods

The ***run (site visit)*** gave me a good insight and understanding of the multi-sensory experience of the most avoided-running routes of Amsterdam. Because of limited time, I used the main principles of phenomenological method by van Etteger (2013) and simplified it into a one continuous run. This method may be criticised as being subjective and not very representative as the run was conducted only once and during spring time, when the air temperature was lower than 20°C. Therefore, it is recommended for further research to conduct interviews with representative groups of runners in this area, or ask them to write running-diaries in which they would describe their thermal and sensory experience during every run. In this way the study could gather explicit data about runner's experience and verify the reasons why the specific running routes are avoided. As a result, the design solutions in further research could respond more specifically to defined problems.

Recording the runs appeared as practical method to gather data, record my visual and acoustic experience and to record my verbal observations. These records were useful in conducting analysis on landscape, ambiance and sensory experience in later phase of the research. The recorded runs allowed me to have a better insight and understanding of the landscape from its multi-sensory perspective.

Designing was a creative and explorative research method to integrate existing knowledge, generate integrated design tools and explore possible design solutions to the problems. It was a useful research method to find the form and explore a way to integrate design tools in different spatial settings in a creative way. Designing process helped to understand the challenges of the 'testbeds', solve the problems, and find the most optimal design solutions (design guidelines). Designing is recommended as useful research method to explore and find creative design solutions. The process to find the most optimal solution may be quite long thus the evaluation and assessment process is needed to evaluate the design ideas and steer the designing process.

Assessment and evaluation process

The assessment matrix was simple in use and served as an optimal base. This matrix can be used by other designers to evaluate and assess their designs. Despite the fact that this thesis focuses on improving thermal conditions and sensory experience of runners, this assessment matrix could also be used to evaluate designs concerning thermal comfort of pedestrians or cyclists. The criteria for thermal features and feasibility factors can stay the same, however, the criteria for sensory experience should be reconsidered and adjusted with regard to the object of investigation (users). Further research could implement quantitative methods in the design evaluation. Even though the criteria and matrix assessment of this thesis were generated on the basis of the literature, educated guesses and opinion of the thesis supervisors, quantitative methods could compare and measure improvements of thermal conditions for each of the design model. Therefore, the research would result in more precise and viable product. For instance, numerical simulations and physical modelling could be used as additional methods.

The method of ***projecting the design guidelines*** appeared as a useful and quick to apply alternative to check how the design guidelines could function and be implemented into a real context. By using designing as the research method, the form, scale and spatial configuration of the design guidelines were found. It is recommended to use this method in studies, which develop design guidelines but do not provide final detailed designs. Projecting the design guidelines occurred as a practical way to validate design guidelines and formulate additional 'operational principles' to the guidelines (chapter 5.3, p. 67).

7.2 COMPARISON OF THE RESULTS OF THIS AND SIMILAR STUDIES

By comparing the findings of my research with the results of the studies of my fellow-students from the Climatelier group (Cangosz, 2017; Gao, 2017; Huijben, 2017), I observed that our final research results (design guidelines) varied even though the research strategy, methods, and evaluation process were similar. The research results of my fellow-students Gao (2017) and Huijben

(2017) seemed to be more innovative, architectural, and out-of-the-box than the findings of this research.

Even though the final research products of all mentioned studies (Cangosz, 2017; Gao, 2017; Huijben, 2017) were integrated design guidelines, the process of generating them was different. Some of the fellow-students, first, searched for several different preliminary design solutions to solve mainly microclimatic problems, and later they combined them into integrated preliminary design guidelines, which were assessed according to the criteria. As a result, final integrated design guidelines, which solve a complex problem, were generated. In my research, first, I analysed the exisiting preliminary design solutions (provided by literature) and I translated them into integrated design tools, which I used to explore different design models that responded to both microclimatic and non-microclimatic features.

My research resulted in nature-based, more realistic and less-out-of-the-box design interventions than the results of Gao (2017) or Huijben (2017). In my opinion, it is concerned not only with slightly different focus of our theses but also different process of generating the integrated design guidelines. From the beginning of this thesis I focused on providing improvements to both urban microclimate and multi-sensory experience. Therefore, the aspects of aesthetics, soundscape, smellscape and touchscape were equally important as the aspects that improve thermal conditions of runners when integrating the design tools. As a consequence, the nature-based design models were dominant and better scored in the evaluation process.

7.3 RESEARCH AND DESIGN RESULT

This thesis does not only provide design criteria for thermally comfortable and multi-sensory running routes, but also provides several design models and design guidelines for representative running routes ('testbeds'). In this section I reflect upon the research and design results from academic and practical perspective.

7.3.1 Academic reflection on the relation theory-practice

Professionals may criticize the design and research results of this thesis as too theoretical and not really practical. An explanation for such results is that the academic research must be theoretically framed and argued, and therefore, it influences significantly the research strategy and its results. Moreover, *"generating a wide range of alternative solution concepts is an aspect of design behaviour which is recommended by theorists and educationists but appears not to be normal practice for expert designers"* (Cross, 2004, p. 439). The other explanation for this may be concerned with an expertise and experience of a designer. Following Cross (2004), novice designers are problem-focused and tend to develop many models to solve a problem. However, expert designers are solution-focused and they rapidly attach to a single, early solution that continuously develops into a satisfactory result.

7.3.2 Practical perspective on the research and design result

The developed design guidelines can be applied on running routes in North and Western European cities with similar climate as the Netherlands.

It is necessary that the design guidelines are introduced to running routes with similar spatial configurations as the 'testbeds' at the beginning of design process. It will be easier to implement the recommended design guidelines into a design, and adjust the later design phase. The developed guidelines can be helpful for many designers when tackling heat stress and insufficient sensory experience on running routes in cities. The design guidelines are relatively flexible and can be easily compromised with design requirements such as form, aesthetics, feasibility, function, etc. However, there may be also other design requirements and aspects, which may make the application of the design guidelines impossible, or the guidelines have to be so compromised that they lose their prescriptive effect.

Even though this thesis focuses on exploring design solution in the context of running, it is important to mention that the developed design guidelines may also be applied to public spaces dedicated to pedestrians and cyclists. Design solutions that improve thermal comfort for runners can have similar quality and effect for pedestrians or cyclists. Among the features proposed in the design guidelines that should be reconsidered and adjusted in the context of different users is a width of a path and type of material used for the surface. A sidewalk for pedestrians should be wider and with smoother and more comfortable surface to walk on. When applying the guideline into a space for cyclist, it is important to remember that cyclists demand safer and better surface to cycle on. Furthermore, cyclists move with a higher speed, therefore, the aspects of safety, traffic encounters, and kinaesthetic and sensuous experience should gain more attention (Fleming, 2012; Stefánsdóttir, 2014). All in all, when designing the space for cyclists or pedestrians with the proposed guidelines, the guidelines should be slightly modified and adjusted with regard to requirements of different users.

This research focuses on thermal condition of runners during warm days with the air temperature above 20°C, therefore the design guidelines provide improvements only for summer time. Because the design guidelines do not provide temporary solutions, it is important to discuss the function of the design guidelines in the urban space during other seasons. Regarding seasonal changes and different weather conditions, nature-based solutions may not only positively influence the aesthetic values of the route over the year but also indicate seasonal changes and offers good protection against the rain and wind. It is preferable to plant deciduous trees in order to allow the sunshine to penetrate the area during winter (Lenzholzer, 2015), and thus improve thermal conditions for a runner. Increased amount of vegetation enhance the biodiversity, so it provides different experiences of nature along with seasonal changes. The gravel or grassed surface may provide new feelings (touch experience) and sounds, however, it may be uncomfortable and unsafe to run during rainy or snowy days.

Due to the fact that the 'testbeds' represent controlled and generalized settings of different running route profiles, the explored design guidelines may occur as unsuitable solutions for a real site even if the site has similar spatial configuration as the 'testbed'. This may be concerned with site-specific problems, local requirements, historical context, character of the place, or technical issues, which I did not consider when generating the 'testbeds'. From the perspective of a practitioner, these aspects are crucial when designing, and therefore, in this section I would like to discuss two ways of how the process of exploring design guidelines could be improved from the perspective of a professional practice.

1) Before an implementation of a design guideline into a site-specific design, it is recommended to explicitly analyse the site

(local requirements, historical context, character of the place, technical issues, etc.) and check if the design guideline positively responds to these requirements. It may occur that the design guideline does not meet the criteria and requirements of the real site, and it cannot be applied. In this case, it is recommended to test and consider applying other design models, which were already explored for the 'testbeds' during RTD process but were rejected due to insufficient evaluation score. Some of these explored design models may respond to the requirements of a real assignment more effectively, and provide more suitable solution to the specific site than the design guideline. Thus this should be implemented in the real design. Even though the other design models do not present as high thermal and sensory qualities as the design guidelines, it is recommended to use them as they improve thermal condition and sensory experience of runners.

2) From the practical point of view, it is recommended to avoid generating design guidelines that are inapplicable in a real context. Therefore, I suggest that the process of exploring design guidelines and implementing them into a real context should go hand in hand. Before the phase of developing design models, design criteria, 'testbeds' and requirements of a specific location should be defined. Design models should be created with relation to the 'testbeds', but also with respect to the design criteria and local requirements. Every design idea should be evaluated during the process of generating design models from a theoretical and practical point of view. The 'theoretical' evaluation should consider the design criteria (thermal, sensory and feasibility criteria), and 'practical' evaluation should consider the local requirements. As a result, the generated design models would not only be climate-responsive and multi-sensory but also they would fit to the local context. Additionally, final design models for the same 'testbeds', but different locations could be analysed and compared. As a result, generalized final design guidelines could be defined.

7.4 FURTHER RESEARCH

Based on the observations about the differences between novice and expert designers (chapter 7.3), it could be interesting for further research to explore how an expert designer would conduct similar research and design task. It could be interesting to see how the results of such research would differ from the result of this study.

It could be also interesting for further research to test if the developed design guidelines are understood by different group of practitioners such as designers, landscape architects, urban planners, policy-makers, and how these guidelines could be applied into real design assignments. Additionally, the design guidelines could also be tested in a design excercise by a group of landscape architecture students. This experiment could be useful to test and validate the use of design guidelines in practice.

Furthermore, it is recommended for further research to test the credibility and applicability of the design guidelines in a real context. It could be an interesting exercise to explore if the design guidelines positively interact with each other in a local setting, with its surroundings, and if they offer a sufficiently attractive program to the area. Additionally, regarding the fact that running routes are linear and considered as long pieces of an area to be designed, implementing one proposed design guideline along a route may be insufficient to provide interesting program for the users. Therefore, further research could explore an impact of climate-responsive design guidelines on attractiveness of the space and find possible improvements to the guidelines that would make the route more attractive.

The generated design guidelines provide design solutions only for small-scaled designs. It could be interesting to develop a set of climate-responsive design guidelines for running routes in the scale of a neighbourhood or a city. Therefore, the toolbox could serve not only for designers, who design locally, but also for municipalities and urban planners who design and develop strategies of how to reduce heat stress and improve sensory experience of runners in a bigger scale.

7.5 SIGNIFICANCE OF THIS STUDY

The **academic relevance** of this study is concerned with an improved knowledge on climate-responsive solutions to the previously stated problem (chapter 2.1). By providing climate-responsive design guidelines, this research bridges the gap between theory and practice, and the gap between climate knowledge, urban design and multi-sensory experience of runners (chapter 2.3). Additionally, this thesis explores methods of the RTD process, and provides conclusions and observations that may have a significant impact on further development of academic methods in the field of landscape architecture.

The **landscape architectural relevance** of this study is shown through an improved understanding of climate-responsive design as a practical way of facing challenges to rebuild or retrofit cities and its landscape for the effects of climate change (Lenzholzer and Brown, 2013). By combining climate-responsive solutions with running infrastructure, the use of the urban space may be positively influenced and outdoor activities during warm future summer days may be enhanced. Introducing a set of new climate-responsive design guidelines may inspire other landscape architects and urban planners to implement them when designing the urban environment. Moreover, by providing design guidelines, which are credible and flexible, urban designers and policymakers have an opportunity to use and apply them in a creative way in new designs (Kleerekoper, van Esch, & Salcedo, 2012).

The **social and health relevance** of this study is concerned with an improvement of outdoor thermal comfort and running space. The explored design guidelines may positively influence the running patterns and the use of outdoor space throughout the year (Nikolopoulou & Steemers, 2003). By lowering heat stress in the urban areas, the use of running routes during future warm days may increase, and not only runners but also other oudoor users may be less affected by heat-stress. The general health condition of runners may be improved and the running 'trend' in the urban environment during warm days will be catered for. The proposed design interventions could be additionally presented to a broader audience (citizens), so the social awareness about importance of physical activities, positive impacts of outdoor sports on quality of life and people's health, the issue of heat stress in cities, and possible solutions to mitigate heat stress may be raised. Additionally, running may be promoted as an effective and safe urban outdoor sport.

The **study relevance for Amsterdam and the project itself** is concerned with a significant knowledge about possible design solutions to improve local microclimates and enhance runners to run during warm future summer days. It is important that through this study, policy makers and decision-makers become aware of the relevance of the heat issue in Amsterdam and its negative effects on running activities and health conditions of runners, and give priority to these matters (Kleerekoper, van Esch, & Salcedo, 2012). This thesis suggests credible design solutions that respond to this problem. By translating the results of this thesis and implementing them into a real context, the city of Amsterdam could not only improve thermal and multi-sensory conditions on running routes, but also extra benefit. First of all, greening the city may bring environmental and social benefits. With an increased green surface in the city, a green infrastructure of the city, quality of air and soil and habitats for wildlife may be improved. Additionally, green surface is permeable so water can be infiltrated and kept in the ground. Moreover, more green, aesthetically pleasing and attractive landscapes as well as an improved microclimatic conditions in the urban areas may improve human well-being, health and quality of life. Secondly, redesigned running routes may positively influence property values and attract new inhabitants to the area. Thus, it may bring economic benefits for Amsterdam. Thirdly, an improved running infrastructure in the city may also influence the land use, increase local economy and result in changing transport mode from public transport to running. Therefore, it could have a positive impact on traffic and infrastructure policies in the city. Moreover, the design guidelines could be considered in the future city development and could give an advice how to improve locations for specific sport events in the future, for instance for marathons (Shendell et al., 2010). Last but not least, a city that is green, climate-proof, healthy and environmentally friendly could be promoted worldwide and Amsterdam could become a prestigious example for other cities.

7.6 RECOMMENDATIONS

This section suggests several recommendations for the municipality of Amsterdam or other cities, which aim to be healthy and climate-proof.

It is needed that decision-makers consider the urban heat stress as an important issue to be solved in the urban environment, and respond to this problem by local-scale designs and strategic planning of the city. Local design interventions can be very effective in improving local thermal conditions by reducing solar and terrestrial radiation, increasing evaporation, evapotranspiration and ventilation, and improving spatial features that influence the ambiance of a place and sensory experience of runners.

In addition, it is recommended for urban planners and designers to use the developed climate-responsive design guidelines as an effective tool to tackle heat stress and to improve sensory experience of runners in the urban areas. If the spatial configuration of the problematic areas in other cities differs from the spatial configuration of the explored ‘testbeds’ in this study, it is recommended to use the integrated design toolbox and assessment matrix to find suitable design interventions. Additionally, it is recommended to consider the reflection given in chapter 7.3.2 on the design guidelines from the perspective of a professional practice. Therefore, the final design product could be even more effective, valid, feasible and realistic to be applied.

Last but not least, figure 78 gives an example of six steps, which could be taken by the municipality in order to implement the climate-responsive design guidelines into a real project.

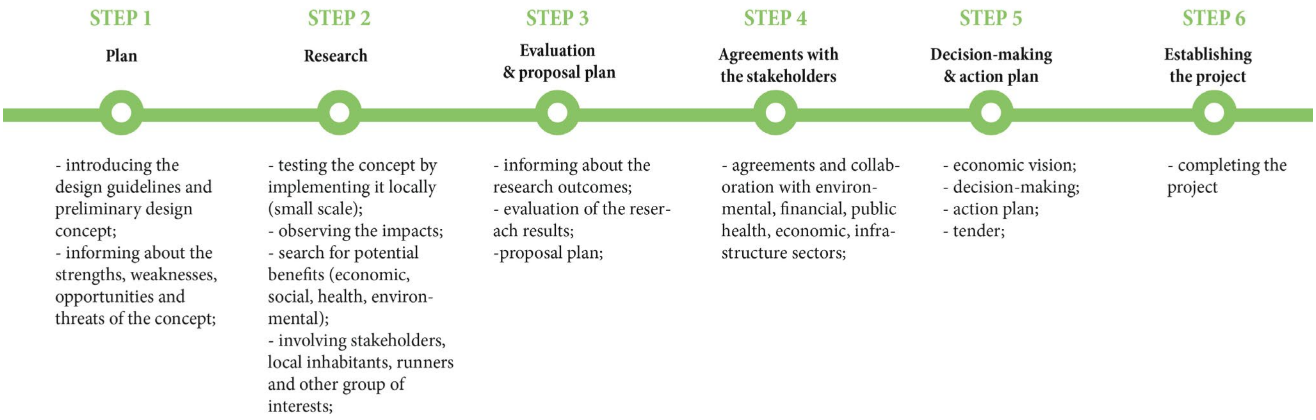


Fig. 78 Measures and key actions

GLOSSARY

This glossary is intended to assist you in understanding commonly used terms and concepts in this research.

Charactersitic - a feature, an attribute or a quality belonging typically to a place or an object and serving to identify it;

Design guideline - the most optimal, viable and feasible design solution that can be applied to the similar spatial settings in different areas; it provides a solution in the local scale;

Design model - a design solution;

Design tool - a tool, which is considered as a concept, an idea or a strategy, that is used in designing to solve defined problem;

Design toolbox - a collection of different design ideas, concepts or strategies which solve different problems;

Integrated design tool - a concept or an idea that integrates existing ideas;

Route profile - geometric design of a running route;

Route typology - a classification of running routes according to general type of route profiles;

Running route - a way, trail or track that is used for running;

Spatial characteristic - a quality or a typical feature occurring in space;

Spatial configuration (distribution) - a configuration or distribution of different spatial elements or features of the landscape;

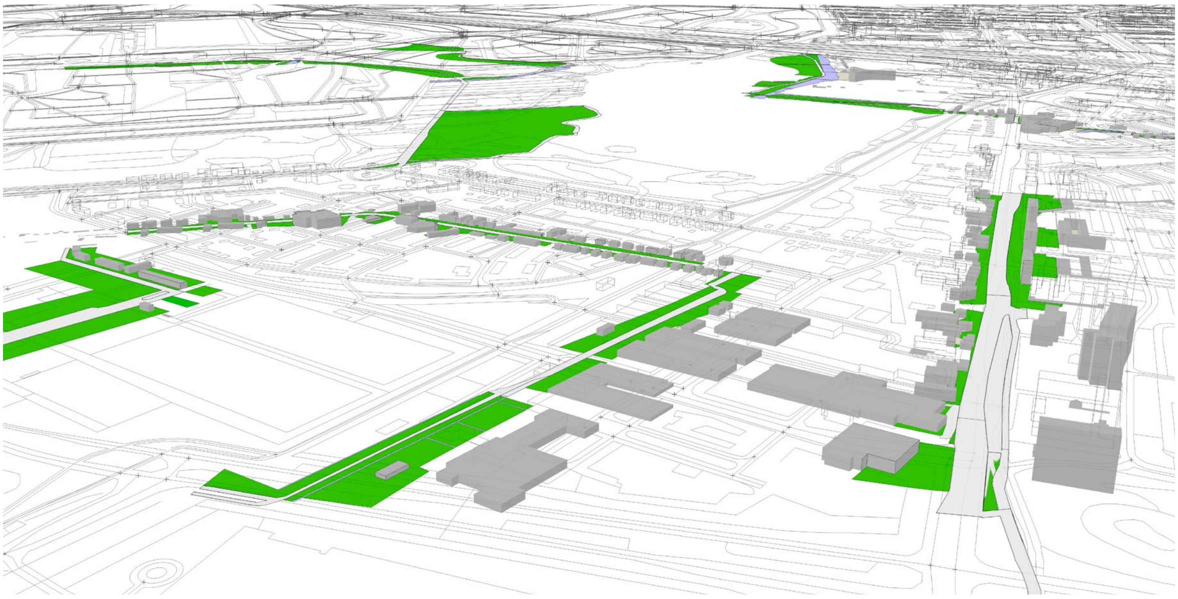
Spatial element - a landscape component including water, infrastructure, vegetation, and objects occurring in space;

Testbed - a generalized and controlled setting which represents the most problematic, repetitive and dominant spatial configurations occurring in the real context. The testbed is to serve as an experimental area for which different design solutions can be generated;

APPENDICES

I. 3D SketchUp models
II. Shadow projections
III. Videos of the recorded runs
IV. Notes from the site visit
V. Questionnaire to select a graphic representation for design models
VI. Abstraction of the route profiles
VII. Route typologies
VIII. Sounds to the visualisations

APPENDIX I. 3D SketchUp models



3D SketchUp model of Amsterdam Oost route

Top view of 3D modelled trees and buidlings of Amstelveen route

APPENDIX II. Shadow projections

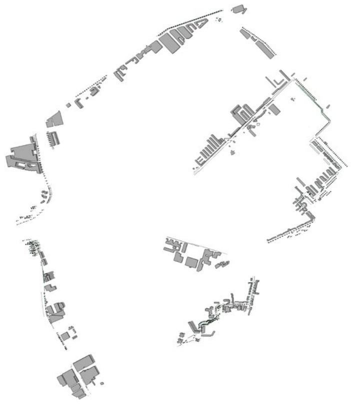


Fig. A-1 Shadow projections at 17:00 in Amsterdam Oost

Fig. A-4 Shadow projections at 20:00 in Amsterdam Oost

Fig. A-7 Overlapped shadow projections: Amsterdam Oost route (17:00-21:00)

Fig. A-2 Shadow projections at 18:00 in Amsterdam Oost

Fig. A-5 Shadow projections at 21:00 in Amsterdam Oost

Fig. A-8 Overlapped shadow projections: Amstelveen route (17:00-21:00)

Fig. A-3 Shadow projections at 19:00 in Amsterdam Oost

Fig. A-6 Overlapped shadow projections in Amsterdam Oost (17:00-21:00)

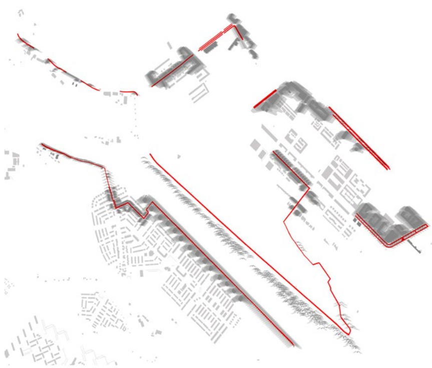


Fig. A-9 Overlapped shadow projections: Islands of Amsterdam route (17:00-21:00)

APPENDIX III. Videos of the recorded runs

The videos are accessible (with internet connection) by clicking on the link. Otherwise, all recorded runs can be found at:

1. Running route: Amsterdam Oost, Spring 2016

https://youtu.be/HlYGMufle7E
https://youtu.be/b4h9VXBYXhM
https://youtu.be/wsVNNn2Sgt8
https://youtu.be/al9cIz_tL40
https://youtu.be/bBf84pRFkTQ

2. Running route: Amstelveen, Spring 2016
https://youtu.be/PLjiggIhd00
https://youtu.be/GVBUHJFaSms
https://youtu.be/cp_EvlVmJys
https://youtu.be/5SlehbvvUEs
https://youtu.be/bltPPIeSs_c
https://youtu.be/KRw82cgmDX4
https://youtu.be/gZKKGMLDTOs
https://youtu.be/s9txdmSAmLI

3. Running route: Islands of Amsterdam, Spring 2016
https://youtu.be/CGIpQ4onOBU
https://youtu.be/L1nKPbP7XEo
https://youtu.be/WOj7tQJFS0s
https://youtu.be/J3z-2Lz4sRE
https://youtu.be/9RYSRMwj2nA
https://youtu.be/vnRSF-wG_Ic
https://youtu.be/RwHI-ngOiuQ
https://youtu.be/GPga6XiEAQc

APPENDIX IV. Notes from the site visit

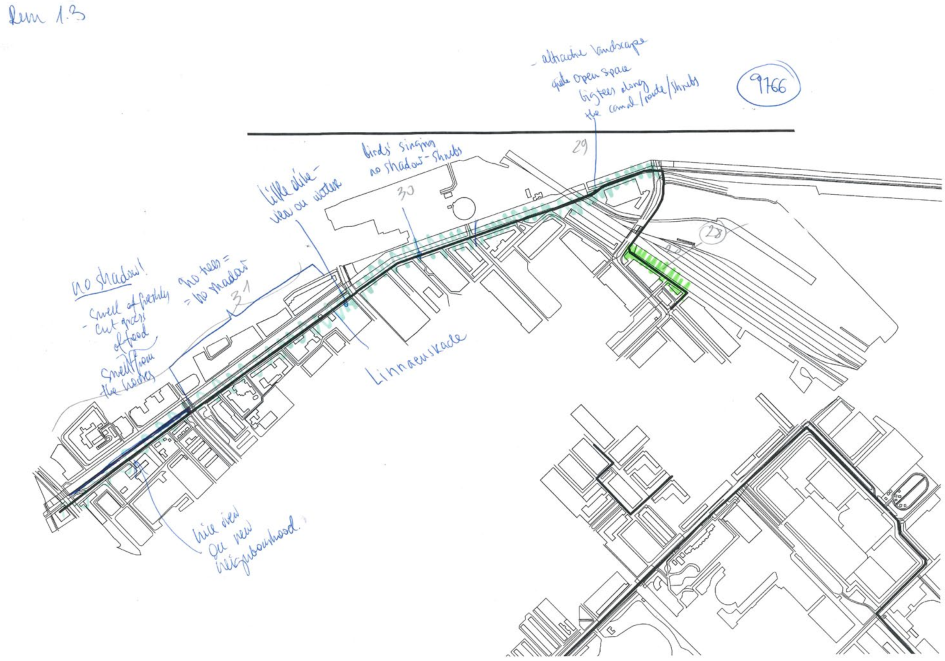


Fig. A-10 Notes from the site visit (run) in Amsterdam Oost part I

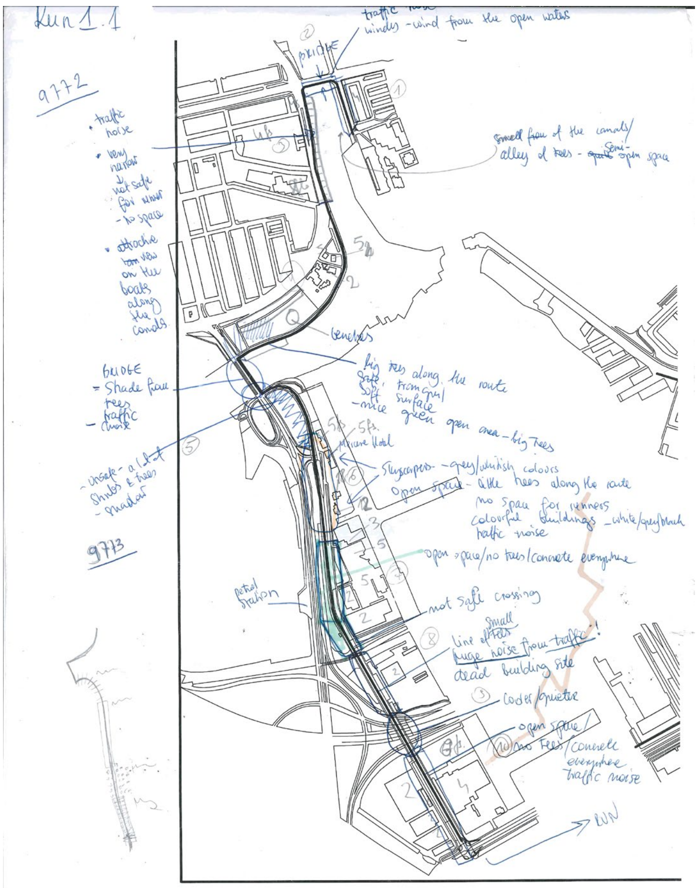


Fig. A-11 Notes from the site visit (run) in Amsterdam Oost part II

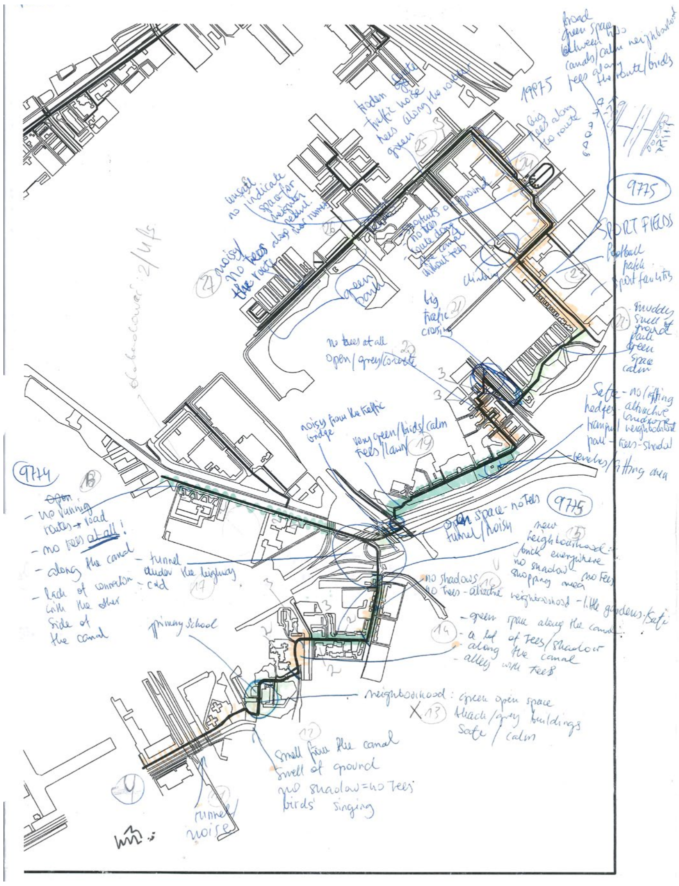


Fig. A-12 Notes from the site visit (run) in Amsterdam Oost part III

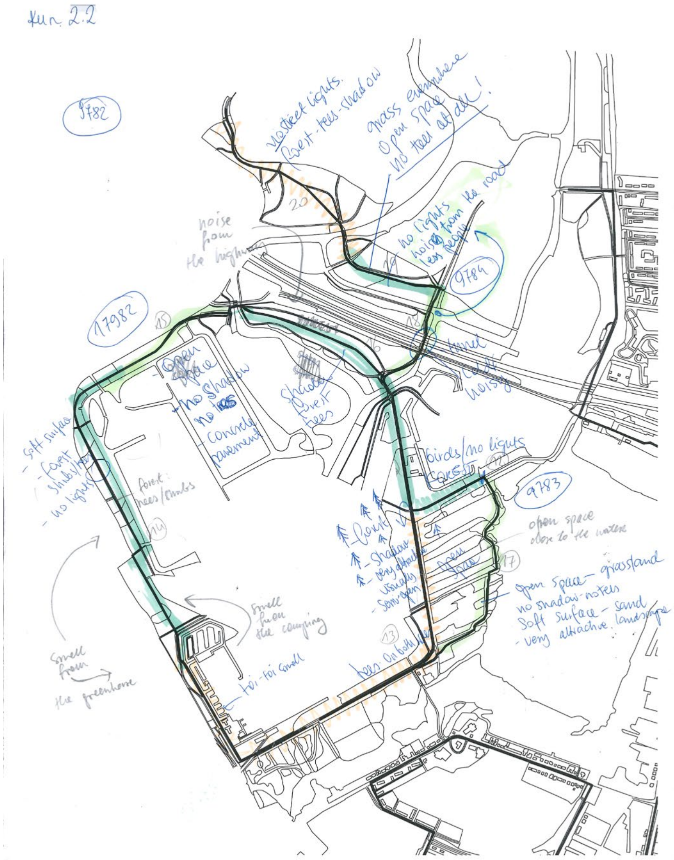


Fig. A-13 Notes from the site visit (run) in Amsterveen part I

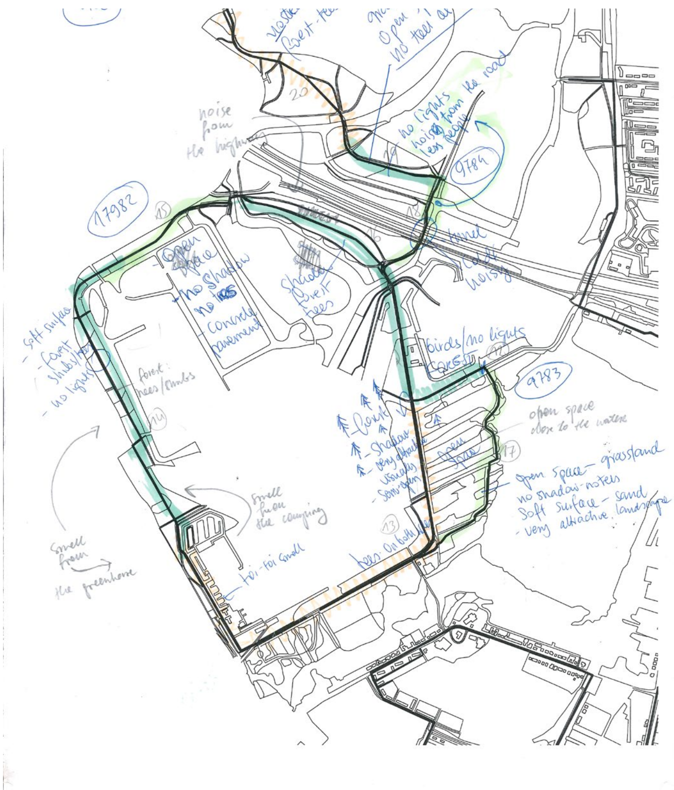


Fig. A-14 Notes from the site visit (run) in Amsterveen part II

Fig. A-15 Notes from the site visit (run) in Islands of Amsterdam part I

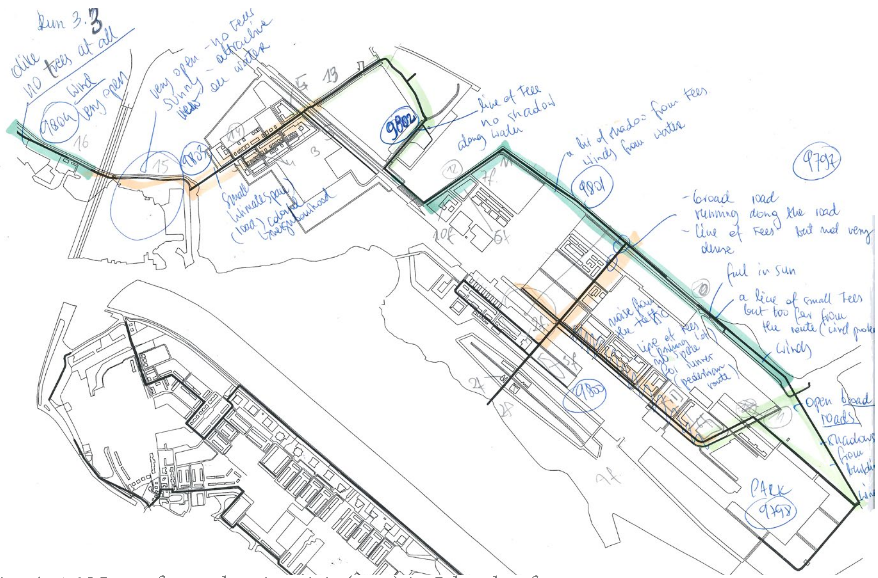


Fig. A-16 Notes from the site visit (run) in Islands of Amsterdam part II

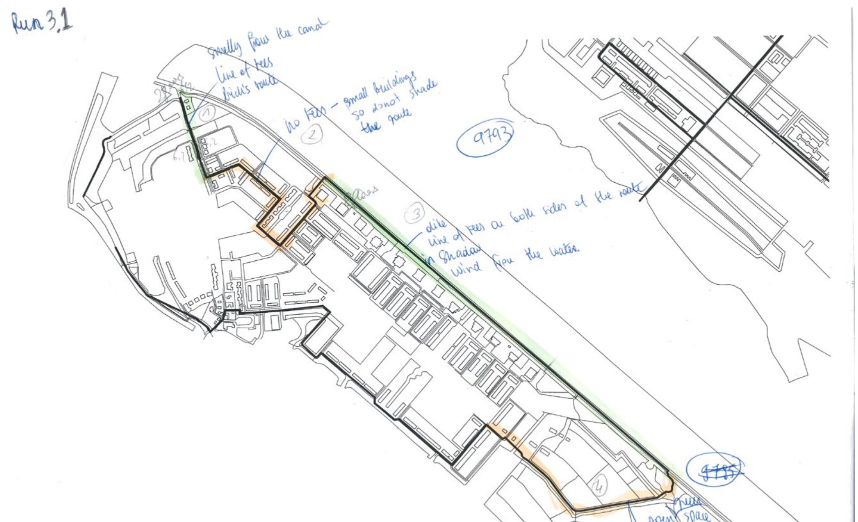


Fig. A-17 Notes from the site visit (run) in Islands of Amsterdam part III

APPENDIX V. Questionnaire to select a graphic representation for design models

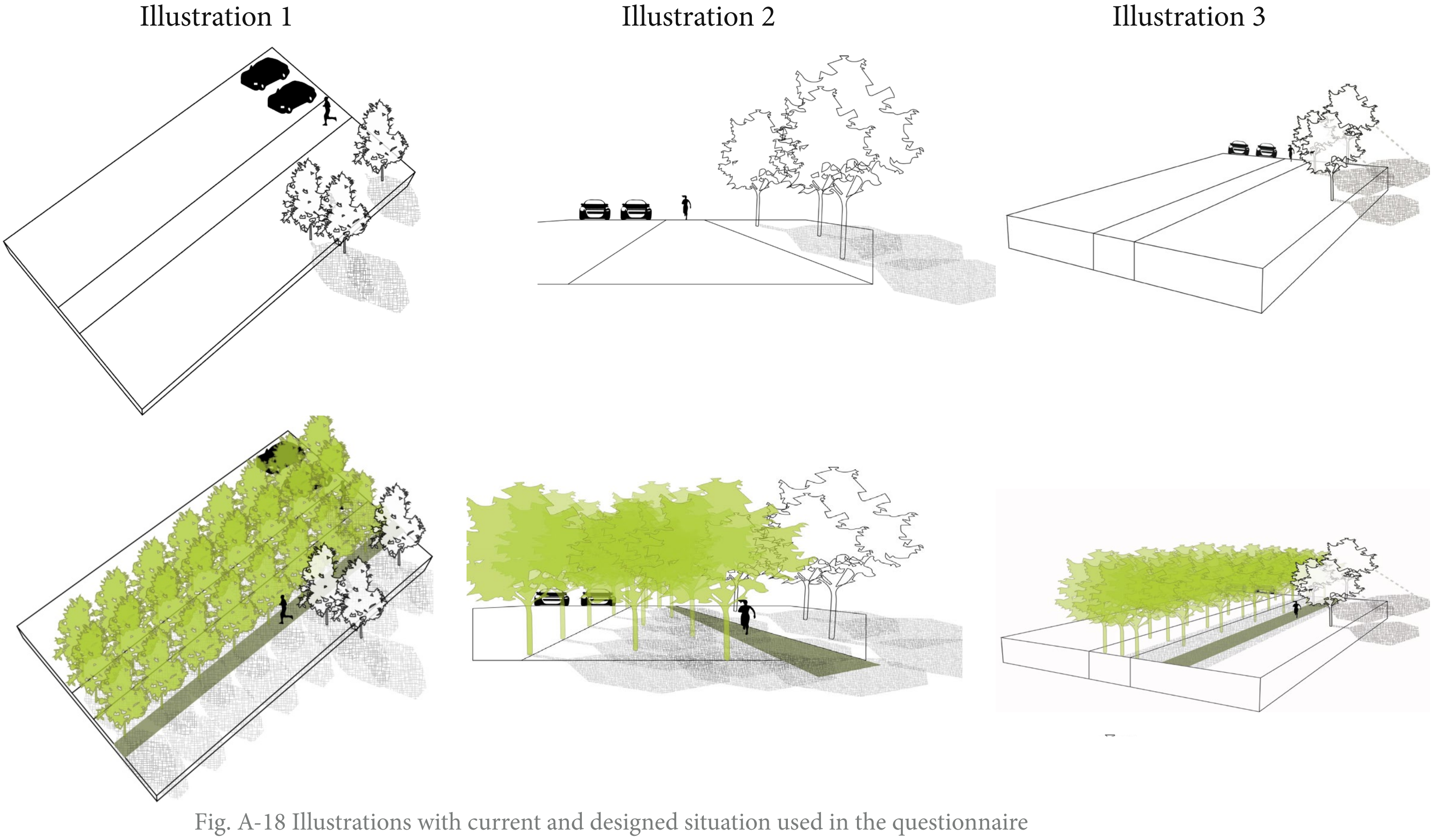


Fig. A-18 Illustrations with current and designed situation used in the questionnaire

The questionnaire was conducted among 5 students of landscape architecture. The questions and results are presented below:

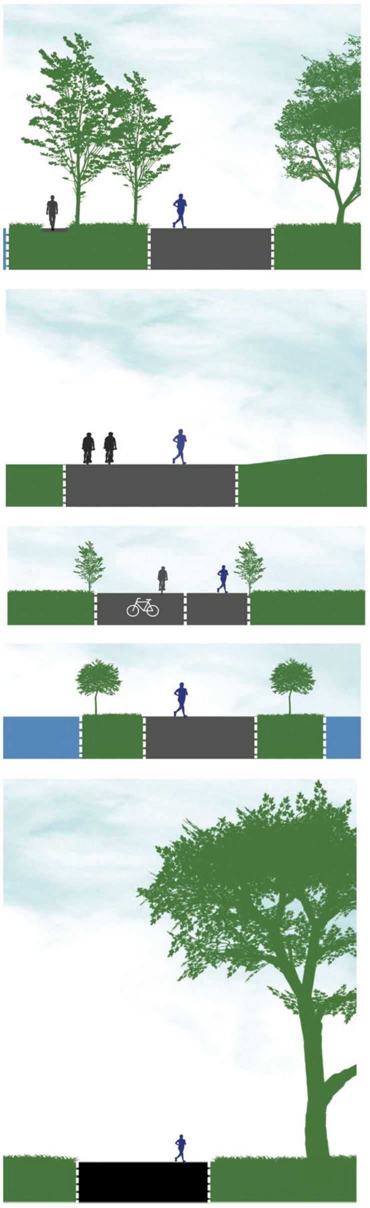
Question 1. Which graphic representation is the best to represent a running route and its surroundings?
Results: 3 votes for illustration 3; 1 vote for illustration 2; 1 vote for illustration 1;

Question 2. Which graphic representation does illustrate the current situation in the easiest way to understand?
Results: 3 votes for illustration 3; 2 votes for illustration 2

Question 3. Which graphic representation does illustrate a design idea in a clear and understandable way?
Results: 4 votes for illustration 3; 1 vote for illustration 2

APPENDIX VI. Abstraction of the route profiles

Example: Route typology VIII



1. The route profiles of the same route typology were compared (fig. A-19)
2. The average width of the route profile was caluclated
3. The dominative elements occuring in the landscapes were selected
4. The dominant geo-location was selected
5. The dominant characterisitcs of these landscape were chosen
6. The abstracted profile serves as a design model (fig. A-20).

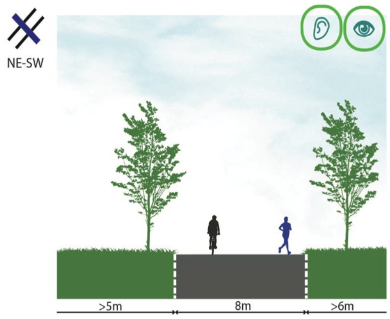
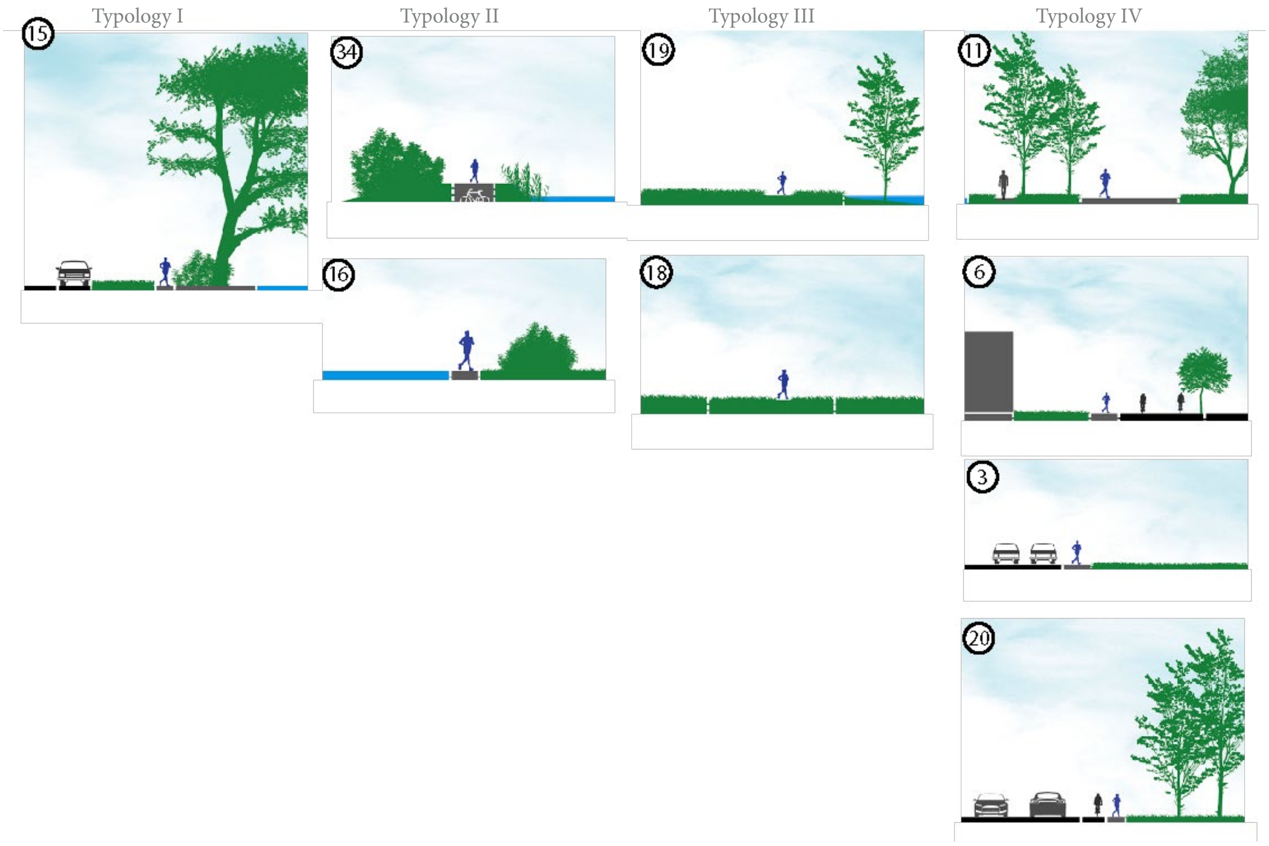
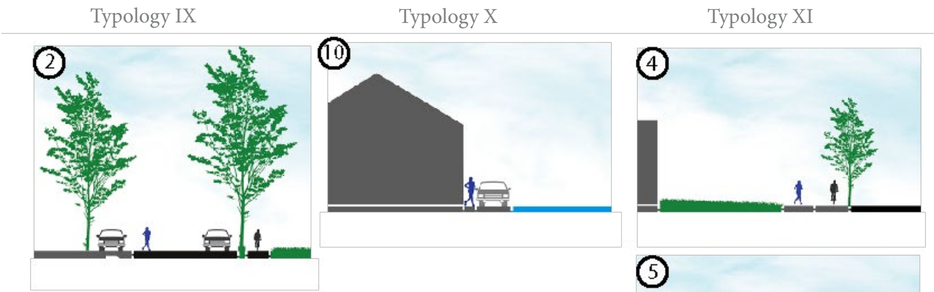


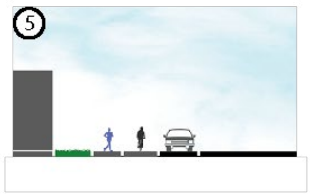
Fig. A-19 Route profiles of similar spatial configuration

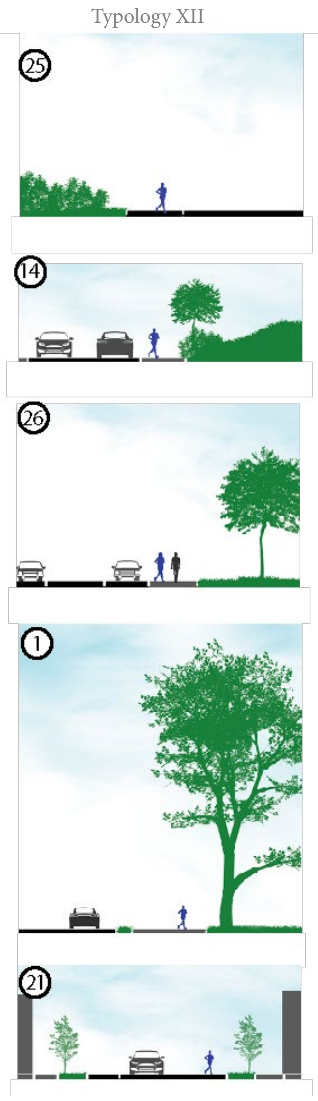
Fig. A-20 The abstracted route profile and generalized that serve for a 'testbed 1'

APPENDIX VII. Route typologies



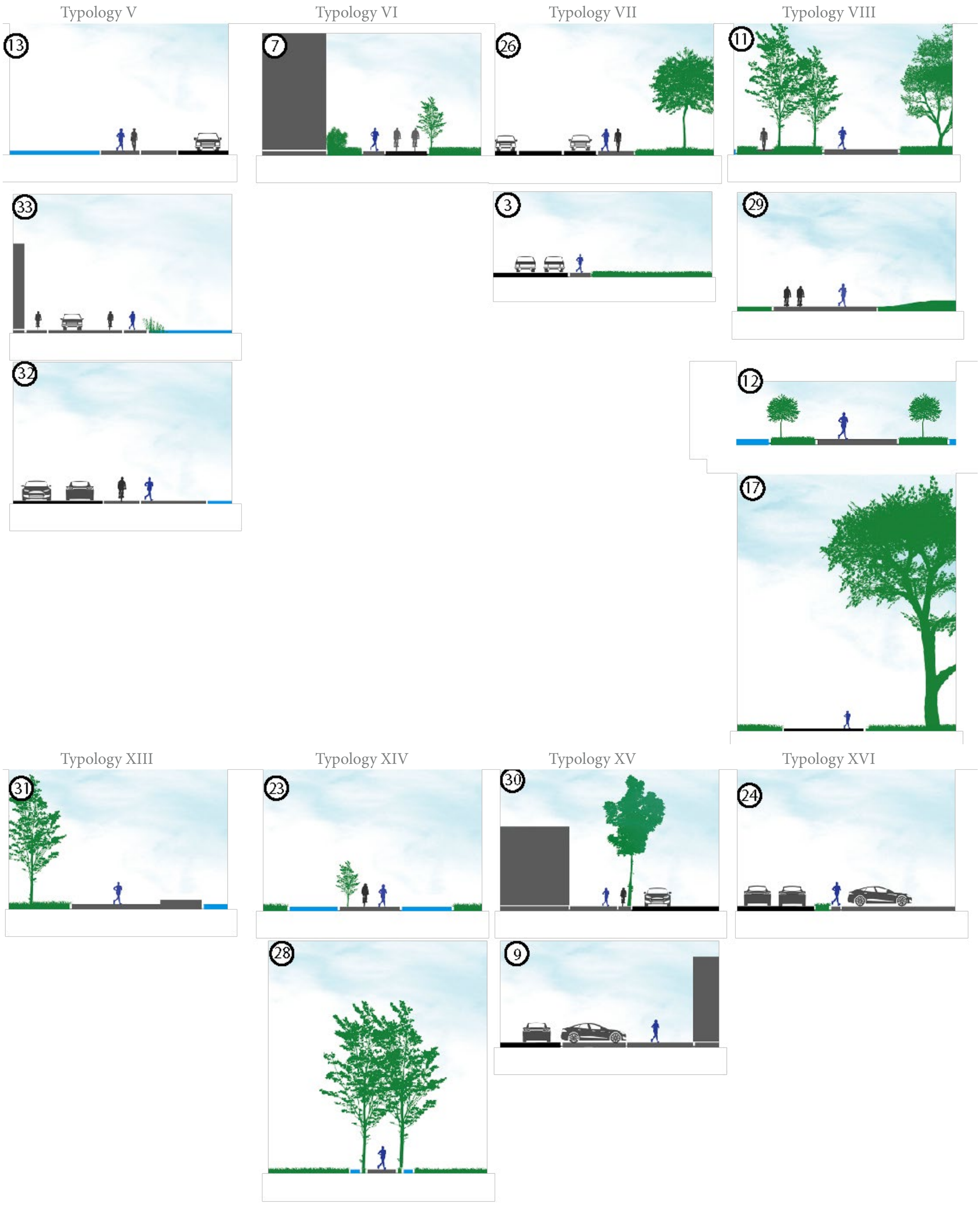






Route typologies
I. Route between grass verges along a road and a waterfront
II. Route between an open waterfront and green area with shrubs
III. Field route in the open nature area
IV. Route between a waterfront and on-road bicycle path
V. Route between a canal and bicycle path in the urban setting
VI. Route between green verge along the buildings and bicycle path
VII. Route between open green area and a road
VIII. Broad asphalt route in green surroundings
IX. Route along an on-road parking lot
X. Route in a narrow space between buildings and a road
XI. Route in an open space between industrial buildings and a road
XII. Route between green space and car road
XIII. Route along the waterfront in the urban setting
XIV. Narrow route in between ditches
XV. Route along the housing and on-road parking lots
XVI. Narrow route between a parking lot and car road

A-21 Route's profiles categorized in sixteen route typologies


Typology V
Typology VI
Typology VII
Typology VIII
13
7
26
11
33
3
29
32
12
17
Typology XIII
Typology XIV
Typology XV
Typology XVI
31
23
30
24
28
9

APPENDIX VIII. Sounds to the visualisations

The soundtracks recorded for all visualisation (chapter 5.3, p. 64-66) can be found at:

1. https://youtu.be/Ai6HtjySEKo
2: https://youtu.be/7iXIwDDgeNY
3: https://youtu.be/G0Z0zg66FtU
4: https://youtu.be/UDKNzpBhDRY
5: https://youtu.be/oWsUWyXBvuU

REFERENCES

AHN. (2016) Actueel Hoogtebestand Nederland. [online] Retrieved from http://www.ahn.nl/index.html

Allen-Collinson, J., & Hockey, J. (2007). Grasping the Phenomenology of Sporting Bodies. International Review for the Sociology of Sport, 42(2), 115-131.

Allen-Collinson, J., & Hockey, J. (2007). ‘Working Out’ Identity: Distance Runners and the Management of Disrupted Identity. Leisure Studies, 26(4), 381-398.

Allen-Collinson, J., & Hockey, J. (2013). From a Certain Point of View. Journal of Contemporary Ethnography, 44(1), 63-83.

Arens, E., & Bosselmann, P. (1989). Wind, sun and temperature—Predicting the thermal comforf of people in outdoor spaces. Building and Environment, 24(4), 315-320.

Bale, J. (2003). Running Cultures: Racing in Time and Space.

Barrow, M. W., & Clark, K. A. (1998). Heat-related illnesses. American Family Physician, 58(3), 749-756.

Blair, S. N., Y., C., & Holder, J. S. (2001). Is physical activity or physical fitness more important in defining health benefits? Medicine and Science in Sports and Exercise, 33(6), 379-399.

Böcker, L., Dijst, M., Faber, J., & Helbich, M. (2015). En-route weather and place valuations for different transport mode users. Journal of Transport Geography, 47, 128-138.

Böcker, L., Prillwitz, J., & Dijst, M. (2013). Climate change impacts on mode choices and travelled distances: a comparison of present with 2050 weather conditions for the Randstad Holland. Journal of Transport Geography, 28, 176-185.

Böcker, L., Prillwitz, J., & Dijst, M. (2013). Impact of Everyday Weather on Individual Daily Travel Behaviours in Perspective: A Literature Review. Transport Reviews, 33(1), 71-91.

Böhme, G. (1995). Atmosphären. Frankfurt/Main: Suhrkamp.

Branca, F., Nikogosian, H., & Lobstein, T. (2007) The challenge of obesity in the WHO European Region and the strategies for response. WHO Regional Office for Europe: Denmark.

Brotherhood, J. R. (2007). Heat stress and strain in exercise and sport. Journal of Science and Medicine in Sport, 11(1), 6-19.

Brown, R. D. (2010). Design with microclimate: the secret to comfortable outdoor spaces. Washington, DC: Island Press.

Brown, R. D., & Gillespie, T. J. (1995). Microclimatic landscape design: creating thermal comfort and energy efficiency. New York: Wiley.

Cangosz, A. (2017). Heat strike on tourism: a thermally comfortable tourist route in Thessaloniki. Wageningen University, [Netherlands].

Carmona, M. (2003). Public places, urban spaces: the dimensions of urban design. Oxford: Architectural Press.

CBS (2013). Overgewicht. Retrieved from https://www.volksgezondheidenzorg.info/onderwerp/overgewicht

Cook, S. (2015). Mobility, space and culture. Area, 47(2), 214-215.

Cook, S., Shaw, J., & Simpson, P. (2016). Jography: Exploring Meanings, Experiences and Spatialities of Recreational Road-running. Mobilities, 11(5), 744-769.

Cox, J. (2011) Cool Neighborhoods within the New York Metro Heat Island. In: Hebbert, M., Jankovic, V. and Webb, B. (2011) City Weathers: meteorology and urban design 1950-2010. Manchester Architecture Research Centre, University of Manchester, 133-146.

Creswell, J. W. (2014). Research design : qualitative, quantitative, and mixed methods approaches. Los Angeles: Sage.

Cross, N. (2004). Expertise in design: an overview. Design Studies, 25(5), 427-441.

Deming, M. E., & Swaffield, S. (2011). Landscape Architectural Research: Wiley.

Dolders, T., & Reiling, M. (2015). Running Amsterdam : designing a runner friendly city. Wageningen University, [Netherlands]. Retrieved from http://edepot.wur.nl/368414

Eliasson, I. (2000). The use of climate knowledge in urban planning. Landscape and Urban Planning, 48(1), 31-44.

Erell, E., Pearlmutter, D., & Williamson, T. J. (2011). Urban microclimate: designing the spaces between buildings. London: Earthscan.

Ettema, D. (2015). Runnable Cities. Environment and Behavior, 48(9), 1127-1147.

Fleming, S. (2012). Cycle space: Architecture & urban design in the age of the bicycle. Rotterdam: nai010 publishers.

Gallagher, S., & Zahavi, D. (2007). The Phenomenological Mind: An Introduction to Philosophy of Mind and Cognitive Science: Routledge.

Gao, Z. (2017). Truly cooling water bodies: lowering urban heat-stress. Wageningen University, [Netherlands]. Retrieved from http://edepot.wur.nl/414192

Gemeente Amsterdam. (2015). Sportaccomodatieplan 2015-2020. [online] Retrieved from: http://www.sportengemeenten.nl/images/Visie_beleid/Accommodatiebeleid/Amsterdam%202015.%20Plan%20Amsterdam%20sport%20de%20stad%20in.pdf [Accessed on: 20th January 2016]

Hebbert, M., & Jankovic, V. (2011). City weathers : meteorology and urban design 1950-2010. Manchester: Manchester Architecture Research Centre, University of Manchester.

Herrington, L. P., & Vittum, J. S. (1977). Human thermal comfort in urban outdoor spaces. In: Heisler, Gordon M.; Herrington, Lee P., eds. Proceedings of the conference on metropolitan physical environment; Gen. Tech. Rep. NE-25. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 130-138.

Hockey, J. (2006). Sensing the Run: The Senses and Distance Running. The Senses and Society, 1(2), 183-201.

van Howe, A. S., & Boden, B. P. (2007). Heat-Related Illness in Athletes. The American Journal of Sports Medicine, 35(8), 1384-1395.

Huijben, D. F. M. (2017). Transform weather for cycling: solutions for thermally comfortable cycling. Wageningen University, [Netherlands]. Retrieved from http://edepot.wur.nl/406581

Ingold, T. (2000). The perception of the environment: essays on Livelihood, dwelling and skill. London: Routledge.

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].IPCC, Geneva, Switzerland, p. 155.

Kleerekoper, L., van Esch, M., & Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. Resources, Conservation and Recycling, 64, 30-38.

Klemm, W., Heusinkveld, B. G., Lenzholzer, S., Jacobs, M. H., & van Hove, B. (2015). Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands. Building and Environment, 83, 120-128.

Klemm, W., Heusinkveld, B. G., Lenzholzer, S., & van Hove, B. (2015). Street greenery and its physical and psychological impact on outdoor thermal comfort. Landscape and Urban Planning, 138, 87-98.

Klemm, W., Lenzholzer, S., & van den Brink, A. (2015). Developing design guidelines for climate-responsive green infrastructure.

Klok, L., Zwart, S., Verhagen, H., & Mauri, E. (2012). The surface heat island of Rotterdam and its relationship with urban surface characteristics. Resources, Conservation and Recycling, 64, 23-29.

KNMI (2014). KNMI'14: Climate Change scenarios for the 21st Century – A Netherlands perspective. Retrieved from http://www.klimaatscenarios.nl/scenarios_samengevat/index.html

Koopmans, S., Theeuwes, N. E., Steeneveld, G. J., & Holtslag, A. A. M. (2012). Quantifying the urbanization induced temperature effect of weather station De Bilt (Netherlands) between 1900–2000. In Proceedings of the 8th International Conference on Urban Climates in Dublin: Wageningen University.

Lenzholzer, S. (2015). Weather in the city. Rotterdam: nai010 publishers.

Lenzhölzer, S. (2010). Designing atmospheres : research and design for thermal comfort in Dutch urban squares. (Proefschrift Wageningen), s.n.], [S.l. Retrieved from http://edepot.wur.nl/139053

Lenzholzer, S., & Brown, R. D. (2013). Climate-responsive landscape architecture design education. Journal of Cleaner Production, 61, 89-99.

Lenzholzer, S., Duchhart, I., & Koh, J. (2013). 'Research through designing' in landscape architecture. Landscape and Urban Planning, 113, 120-127.

Lenzholzer, S., van den Brink, A., & Duchhart, I. (2017). The relationship between research and design. In A. van den Brink, D. Bruns, H. Tobi, & S. Bell (Eds.), Research in Landscape Architecture (pp. 45-64): Routledge.

Li, D., & Bou-Zeid, E. (2013). Synergistic Interactions between Urban Heat Islands and Heat Waves: The Impact in Cities Is Larger than the Sum of Its Parts. Journal of Applied Meteorology and Climatology, 52(9), 2051-2064.

Lorimer, H. (2012). Surfaces and Slopes. Performance Research, 17(2), 83-86.

Lynch, K. (1960). The image of the city (Vol. 11). Cambridge: MIT press.

Martin, D. E., & Buoncristiani, J. F. (1999). The Effects of Temperature on Marathon Runners' Performance. CHANCE, 12(4), 20-24.

Maughan, R. J., Shirreffs, S. F., & Watson, P. (2007). Exercise, heat, hydration and the brain.

Merriman, P. (2012). Mobility, Space and Culture: Routledge.

Milburn, L., & Brown, R. D. (2003). The relationship between research and design in landscape architecture. Landscape and Urban Planning, 64(1), 47-66.

Mills, G. (2011) Cubes and canyons: Different perspectives on the urban climate. In: Hebbert, M., Jankovic, V. and Webb, B. (2011). City Weathers: meteorology and urban design 1950-2010. Manchester Architecture Research Centre, University of Manchester, 21-24.

Nikolopoulou, M., & Lykoudis, S. (2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. Building and Environment, 41(11), 1455-1470.

Nikolopoulou, M., & Steemers, K. (2003). Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy and Buildings, 35(1), 95-101.

Oke, T. R. (1987). Boundary layer climates. London: Methuen.

Penedo, F. J., & Dahn, J. R. (2015). Exercise and well-being: a review of mental and physical health benefits associated with physical activity.

Penninx, N., Reith, E., Marcé, S., Hilgers, H. (2015) Sport de stad in Plan amsterdam. Amsterdam: Gemeente Amsterdam. Retrieved from https://www.amsterdam.nl/publish/pages/727557/plan_amsterdam_-_sport_de_stad_in.pdf

Porteous, J. D. (1996). Environmental aesthetics: ideas, politics and planning. London: Routledge.

Porter, A. M. W. (1984). How do marathon runners fare? British Journal of Sports Medicine, 18(1), 46.

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. International Journal of Environmental Health Research, 15(5), 319-337.

Qviström, M. (2016). The nature of running: On embedded landscape ideals in leisure planning. Urban Forestry & Urban Greening, 17, 202-210.

Raaphorst, A. T., van den Dool, R., & Vogels, R. (2014). Uitstappers en doorzetters. De persoonlijke en sociale context van sportdeelname en tijdsbested ing aan sport. Den Haag: Sociaal en cultureel planbureau.

RIVM. (2014, April 28). Overweight and Obesity. Retrieved from http://www.rivm.nl/en/Topics/W/WHO_Collaborating_Centre_for_Nutrition/Fields_of_expertise/Overweight_and_Obesity

Salcedo Rahola, T. B., Van Oppen, P., & Mulder, K. (2009). Heat in the city : an inventory of knowledge and knowledge deficiencies regarding heat stress in Dutch cities and options for its mitigation. Delft: TU Delft.

Scheerder, J., & Breedveld, K. (2015). Running across Europe : the rise and size of one of the largest sport markets. New York: Palgrave Macmillan.

Selten R, Greven J, Bosveld W. (2013) Sportmonitor 2013: inzicht in het sportgedrag van Amsterdammers. Gemeente Amsterdam, Bureau Onderzoek en Statistiek. Retrived from: http://www.ois.amsterdam.nl/pdf/2013_sportmonitor2013.pdf

Shendell, D. G, Alexander, M. S., Lorentzson, L. and McCarty, F. A (2010). Knowledge and awareness of heat-related morbidity among adult recreational endurance athletes. International Journal of Biometeorology 54(4), 441–448.

Shipway, R., & Holloway, I. (2010). Running free: Embracing a healthy lifestyle through distance running. Perspectives in Public Health, 130(6), 270-276.

Steeneveld, G. J., Koopmans, S., Heusinkveld, B. G., van Hove, L. W. A., & Holtslag, A. A. M. (2011). Quantifying urban heat island effects and human comfort for cities of variable size and urban morphology in the Netherlands. Journal of Geophysical Research: Atmospheres, 116.

Stefansdottir, H. (2014). A Theoretical Perspective on How Bicycle Commuters Might Experience Aesthetic Features of Urban Space. Journal of Urban Design, 19(4), 496-510.

Stevenson, A. (Ed.) (2017) Oxford Dictionary of English (3 ed.). Oxford: Oxford University Press.

Stewart, I. D., & Oke, T. R. (2012). Local Climate Zones for Urban Temperature Studies. Bulletin of the American Meteorological Society, 93(12), 1879-1900.

Synovate. (2008). Reasons to run survey. Retrieved from www.everythingaboutrunning.asics.eu

Taleghani, M., Kleerekoper, L., Tenpierik, M., & van den Dobbelsteen, A. (2015). Outdoor thermal comfort within five different urban forms in the Netherlands. Building and Environment, 83, 65-78.

Taleghani, M., Tenpierik, M., Kurvers, S., & van den Dobbelsteen, A. (2013). A review into thermal comfort in buildings. Renewable and Sustainable Energy Reviews, 26, 201-215.

Trapasso, L. M., & Cooper, J. D. (1989). Record performances at the Boston Marathon: biometeorological factors. International Journal of Biometeorology, 33(4), 233-237.

U.S. Environmental Protection Agency. (2008). Urban Heat Island Basics. In: Reducing Urban Heat Islands: Compendium of Strategies. Retrieved from https://www.epa.gov/heat-islands/heat-island-compendium.

van Etteger, R. (2013). Wish you were Here Walking With Me: Walking as a o Tool for the Asethetic Evaluation of Designed Landcsapes. In: Heather, H. And Collier, M. Selected Essays from the: On Walking Conference. Suderland: Art Editions North, 326-337.

van der Hoeven, F., & Wandl, A. (2014). Amsterwarm: Mapping the landuse, health and energy-efficiency implications of the Amsterdam urban heat island. Building Services Engineering Research and Technology, 36(1), 67-88.

van der Hoeven, F., & Wandl, A. (2014). Amsterwarm: Mapping the landuse, health and energy-efficiency implications of the Amsterdam urban heat island. Building Services Engineering Research and Technology, 36(1), 67-88.

van Hove, L. W. A., Jacobs, C. M. J., Heusinkveld, B. G., Elbers, J. A., Steeneveld, G. J., Koopmans, S., & Holtslag, A. A. M. (2011). Exploring The Urban Heat Island Intensity Of Dutch Cities. Paper presented at the City Weathers meteorology and urban design 1950 - 2010, Manchester Architecture Research Centre.

van Hove, L. W. W., Jacobs, C. M. J., Heusinkveld, B. G., Elbers, J. A., van Driel, B. L., & Holtslag, A. A. M. (2015). Temporal and spatial variability of urban heat island and thermal comfort within the Rotterdam agglomeration. Building and Environment, 83(1), 91-103.

Vihma, T. (2010). Effects of weather on the performance of marathon runners. International Journal of Biometeorol, 54:297–306.

Watkins, R., Palmer, J., & Kolokotroni, M. (2007). Increased Temperature and Intensification of the Urban Heat Island: Implications for Human Comfort and Urban Design. Built Environment (1978-), 33(1), 85-96.

World Health Organization (2010). Global Recommendations on Physical Activity for Health. Geneva: WHO Press. Retrieved from http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_eng.pdf

World Health Organization. (2013). Nutrition, Physical Activity and Obesity, Netherlands. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0018/243315/Netherlands-WHO-Country-Profile.pdf

World Health Organization. (2016) Physical activity. Retrieved from http://www.who.int/mediacentre/factsheets/fs385/en/