Sandra Lenzhölzer

Research and Design
for Thermal Comfort
in Dutch Urban Squares

# Designing Atmospheres

Sandra Lenzhölzer

Research and Design
for Thermal Comfort
in Dutch Urban Squares

# Designing Atmospheres

## Thesis committee

### Thesis supervisors

Prof. dr. Jusuck Koh, Wageningen University
Professor of Landscape Architecture

Prof. dr. Lutz Katzschner
Professor of Environmental Meteorology, University of Kassel, Germany

### Other members

Prof. dr. B. Holtslag, Wageningen University
Prof. dr. ir. Martin de Wit, Eindhoven University of Technology
S. Thorsson, PhD, University of Gothenborg, Sweden
Prof. dr. Robert D. Brown, University of Guelph, Canada

This research was conducted under the auspices of the Netherlands Research School for the Socio- Economic and Natural Sciences of the Environment (SENSE)

# Designing Atmospheres

## Research and Design for Thermal Comfort in Dutch Urban Squares

**Sandra Lenzhölzer**

## Thesis

Submittted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. dr. M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Friday 18th of June 2010
at 1.30 p.m. in the Aula.

Sandra Lenzhölzer
Designing Atmospheres, Research and Design for Thermal Comfort
in Dutch Urban Squares
196 pages.

Thesis, Wageningen University, Wageningen, NL (2010)
With references, with summaries in Dutch and English
ISBN 978-90-8585-660-3

# Table of contents

# Preface and acknowledgements

This was the most difficult chapter to be written because so many things can be said... Shall I speak about the thousands of hours of spare time I spent on this dissertation, secluding myself from family, friends and colleagues? Or about the great pressure I had to finish this thesis in 5.5 years next to my busy schedule as an assistant professor? Or about the pains one has to go through growing from a ‘reflective designer’ becoming an ‘academic designer?

No. After this project is finished, much of this becomes irrelevant, just like the pains of labor after birth are forgotten so quickly. I would like to speak about all the things I have experienced, learnt, that have shaped me and made me grow and I want to thank all the people that have helped me and accompanied me in this process.

First of all I want to thank my dear friends Dr. Dipl.- Ing. Daniela Karow- Kluge, Ir. Caroline Voet and Dr. Dipl.- Ing. Heide Schuster for motivating me to conduct a PhD research and also their support as ‘sisters in arms’.

As one of the triggers for my research on “atmosphere”, microclimate and perception my study of phenomenological thought was very inspirational and I want to thank my colleague Rudi van Etteger for the fruitful discussions on this topic.

One of the major phases in this PhD project was my fieldwork. I spent 40 days in Dutch squares and I spoke to more than a thousand people. It was a special experience, just being on a square for whole days in all kinds of weather, having to cope with averse and comfortable microclimates. This has sharpened my microclimate awareness even more. All the interviewees and other people I talked to were an enormous source of knowledge and it was a great joy to learn form them. I was surprised that almost every person I spoke to was interested in my research and considered the issue of microclimate in public spaces very important. It was then that my research got the most general attention up to now. The local and regional media (radio, television, newspapers) repeatedly reported about my research. In this context I want to thank all the people I was able to interview and all the people who helped me to make this fieldwork possible: Prof. dr. Lutz Katzschner and Martin Rösler who lend me the measuring equipment from Kassel (the famous ‘Willi Wortel -wagentje’), the people from the municipalities in Groningen, Den Haag and Eindhoven who provided me with all kinds of maps and information: Tjerk Ruimschotel, Jan van de Bospoort, Arjan Schipper, Almut Röwekamp and Cees Donker. I am also indebted to dr. Sjerp de Vries who advised me on the contents of the questionnaires. I would like to thank Michel Simons and Wim van den Bosse for the tutoring on GIS and Eric Bovekerk who helped me with the production of hundreds of GIS- maps depicting the research data.

The next phase in my project was ‘data evaluation’. Very supportive for evaluating my first fieldwork results were the discussions on conferences and visits that I paid to specialists abroad. I want to thank all these colleagues:

prof. dr. Simos Yannas, prof. dr. Koeen Steemers, dr. Marialena Nikolopoulou, dr. Sofia Thorsson, prof. Ulla Westerberg, prof. dr. Helmut Mayer, prof. dr. Martin de Wit and prof. Mark Francis. A very important person for my data evaluation was Nickie van der Wulp who helped me with the statistics and was a co-author of chapter 6.

The phase of 'research by design' brought along new challenges because the method of research by design was ill- defined in our field. I went on an intellectual 'expedition' with the Academic Master Cluster students in 2008 and continued this with our MSc student Jeroen Matthijssen to figure out what 'research by design' might be. Eventually this helped us to define what 'research by design' is not… But I did not give up and later my discussions with the colleagues from my chair group and especially dr. Ingrid Duchhart were very fruitful. The 'research by design' itself would not have been possible without the support of the people who developed the simulation software I used: Envi-met®. Prof. dr. Michael Bruse, Sebastian Huttner and their former thesis student Anne Ihde were always ready to help and advise me.

For the final stretch of this project, I would like to thank Adrie van't Veer, Monique Jansen and Audrey Raijmann-Schut for their help on all sorts of tasks, Jean Tee for her language check and Joseé Langen for the graphic design of the book.

The process of my PhD research and the academic environment in the university has shaped me during the last years. Coming from a practical environment in design offices where I worked before I came to WUR, I was then able to share thoughts that would never have been discussed in the practical context. I had fruitful intellectual exchange with my colleagues from the landscape architecture chair group: prof. dr. Adri van den Brink, prof. dr. Erik de Jong, dr. Ingrid Duchhart, dr. Marlies Brinkhuijsen, Adriaan van Haaften, Paul Roncken, Rudi van Etteger and Sven Stremke, but also my colleagues from the chair group Social- Spatial Analysis: dr. Henk de Haan, dr. Martijn Duineveld and dr. Maarten Jacobs.

The persons that enabled all this research were my supervisors prof. dr. Jusuck Koh, and prof dr. Lutz Katzschner. Having two different approaches, they supplemented each other in the process of coaching me. Jusuck Koh liked to tutor me on theoretical terms and Lutz Katzschner helped me in many practical ways to 'make things happen'. I want to thank Jusuck Koh for all the time he took to revise my written work very conscientiously, his continuous intellectual challenge and criticism. He has broadened my intellectual scope and wakened my interest in design theory. He has evoked the process of growth I went through from being a 'reflective designer' becoming an 'academic designer'. I want to thank Lutz Katzschner, who coached me on all the measurement techniques and on acquiring more understanding of urban climate. He always encouraged me to 'learn the language of climatologists'. He has succeeded in that and also introduced me in his network of urban climatologists, an asset that is of great value for my future.

And last but not least I am also grateful for everybody else who supported me- all my friends, Ma, Pa and my sister Anja who were always convinced that I would make it. Thanks to all of you, I love you!

# 1

# Introduction

“To she [air, nature, woman] who, immediate omnipresence, surrounds the whole in her imperceptible embrace… soft light breath that inspires every living being, that every living being breathes.”

*(Irigaray 1999, p. 106)*

## 1.1 Motivations for this research

There is an infinite amount of unanswered questions that could be tackled in a research project. They are, metaphorically speaking, as innumerable as air molecules and every new breeze reconfiguring these molecules brings about new questions that deserve further enquiries.

So why did this one specific ‘breeze’ concerning human experience of space, ‘atmosphere’ and microclimate evoke a ‘storm’ in me and make me set off for a research project that explores the issue of thermal comfort and microclimate in a new way? The motives for dealing with this topic of thermal perception are threefold and I will briefly elucidate them.

The first motive to look into the topic of outdoor thermal comfort was an experience I had during my practice in landscape architecture and urban design. In the year 2000 the refurbishment plan of the Canadaplein-square in Alkmaar, to which I contributed in a substantial way, was implemented. The result was a contemporary design that was received with enthusiasm by both public and commissioners. Shortly after the newly built square was taken into use, however, people started to complain about wind nuisance in certain parts of the square. Eventually the layout of the square was adjusted, but this lead to a complete deviation from the initial design intentions. All this was due to the fact that none of the people involved in making the design – me, my colleagues and the commissioners – were aware of the influence of urban microclimate.

This got me thinking about this practical problem with outdoor microclimate and many questions arose: Why did we never learn about microclimate in our studies? Why is microclimate a forgotten factor in the design of public spaces when it is of such great importance for the sojourn quality of a place? Why is there not more focus on the perceptions of the users of public places? More personal questions then followed: Is my attitude towards the design of public places appropriate? Am I, as a designer, sufficiently aware of all sensory perceptions?

Phenomenological thought was the basis for my second motive to study this subject of thermal perception. For me, phenomenology was specifically inspiring because it addresses some of the aforementioned questions about perception and the human senses. One basic notion in phenomenology is that concepts formed in a person’s mind about what is perceived are inextricably entangled with sensory perceptions (Woodruff Smith 2008). Phenomenological thought can be relevant for a designer because many aspects of the physically perceptible environment can be altered through designs, but the mental constructs can be addressed in design as well. The German philosopher Böhme (1995) defined this embodied interaction between the physical designed environment and mental constructs as ‘Atmosphäre’ (‘atmosphere’). He consequently describes designers as ‘ästhetische Arbeiter’, as makers of these atmospheres (pp. 14-16, 97-98). Accordingly, phenomenological thought was an inspiration for this research. Moreover, I was interested in addressing a sense that has hitherto been underrepresented both in phenomenological discourse and in urban design: thermal perception.

The first two incentives gave rise to a third: a scientific motivation to contribute to the development of new design knowledge that seemed to be missing. It appeared that there are not many climate-responsive design recommendations for the design of public spaces that can be easily applied and that also take the psychological influence of 'atmosphere' into account. An extensive literature review yielded a rather meagre outcome. In the next subchapter I will give a brief overview of this general literature research and the knowledge gaps that I identified.

## 1.2 Overview: urban thermal comfort studies and identification of knowledge gaps

I will keep this overview concise because in the coming chapters, which mainly consist of published or submitted articles, I will expound on the existing literature and specific knowledge gaps. This overview consists of different parts as research that became relevant for urban outdoor thermal comfort studies evolved from two sides. On the one hand it evolved from the thermal comfort and climate control research within the building sciences and on the other hand from the larger scale research on urban mesoclimate. Urban microclimate research that forms the 'middle ground' between the scale levels of the two fields was actually not taken into scientific consideration for a long time. Fortunately, the research on this scale level eventually gained increasing attention. Hence, I will first sketch the developments of research in the two neighbouring fields and then arrive at the 'middle ground' of urban microclimate research.

### 1.2.1 Thermal comfort research originating from the building sciences

Much research on thermal comfort originates from the architecture and building sciences, because bio-climate control in human shelters was one of the main 'raisons d'être' for architecture itself (Givoni 1998; Olgyay 1963). Research on this issue is very broad, and the large number of research institutes (such as the Martin Centre, Cambridge, UK, Fraunhofer Institute, Germany and many others) and scientific journals (such as Environment and Building, Solar Energy, Energy and Buildings and Built Environment) devoted to this field manifest this. Influential outcomes of building science research in relation to urban outdoor climate research are the definitions and standards of 'thermal comfort' that were initially set for indoor thermal comfort.

The concept of thermal comfort has been described as "that condition of mind which expresses satisfaction with the thermal environment" (American Society for Heating, Ventilating and Air-conditioning Engineers, 1989). Although this description suggests psychological influences, thermal comfort was approached from a purely physical perspective for a long time. In order to assess thermal comfort, a broad range of indices was developed. These indices changed over time and became more complex. This evolution was influenced by the increasing sophistication of measuring techniques and progresses in neuroscience that successively revealed the system of human thermal sensation. We now know that thermal sensation happens through heat and cold receptors in the human skin. These are mainly susceptible to radiation and air movement. Their sensations are also influenced by the regulating vasoconstriction and sweating mechanisms of the skin. The interactions of the thermo-sensory system are mainly controlled by the hypothalamus (Parsons 2003, pp. 34-39).

The thermal indices first consisted of the simply measurable physical variables like air (dry-bulb) temperature (Parsons 2003, p. 197). Later thermal indices included wet-bulb temperature and air velocity, like the indices based on 'Effective Temperature' (Parsons 2003, pp. 198-199; Gagge et al. 1986). A range of other indices for thermal comfort that included (amongst others) more personal parameters like clothing degree and metabolic rate were developed later with the 'Predicted Mean Vote' (PMV) by Fanger (1970, pp. 19-43), which is still one of the most commonly used indices. This standard is also often used in outdoor comfort research and it was later supplemented with more specific standards for outdoor thermal comfort such as the 'Physiological Equivalent Temperature' (PET) (Höppe and Mayer 1987; Mayer 1993; Matzarakis et al. 1999; Höppe 2002) and the COMFA index (Brown and Gillespie, 1995). All these indices, however, focused on physiological and physical circumstances and this was increasingly criticized because – as was expressed by ASHRAE: thermal comfort is a state of mind. This idea later had its repercussions within the research on thermal comfort. Researchers within the field have identified the psychological factors of comfort experience to be of equal importance as the technically measurable comfort indices (Auliciems 1981). Nikolopoulou and colleagues revealed that human perception of actual, momentary outdoor thermal comfort (Actual Sensation Vote) is more flexible than the PMV indices derived from measurement series would suggest (Nikolopoulou et al 2001; Nikolopoulou and Steemers 2003; Nikoloupoulou and Lykoudis 2006). However, long-term perception of thermal comfort in urban space and the psychological schemata that people develop on the microclimate of places has not been addressed to balance peoples' momentary impressions, although this is an important issue in avoidance and preference behaviour. Various researchers have already shown that avoidance or acceptance behaviour is influenced by the momentary thermal comfort impressions (Whyte 1980; Gehl 1987; Givoni et al. 2003; Eliasson et al. 2007; Katzschner et al. 2002, Thorsson et al., 2004; Walton et al. 2007), especially when outdoor spaces are used for sojourn purposes (Zacharias et al. 2001; Thorsson et al. 2007a). Momentary thermal comfort thus influences the success of places and whether or not they are used. Similarly, it can be expected that long-term perceptions and schemata also influence the acceptance or avoidance of an outdoor public place. This is why I devoted a large part of my research to long-term perceptions and schemata in outdoor thermal experience.

### 1.2.2 Research in urban mesoclimate

Climate systems can be studied on different scale levels and nested hierarchies can be found in these systems. Since the urban microclimate is nested in the urban mesoclimate, research on urban mesoclimate has a great impact on urban microclimate research.

Meso-scale research on climate of urban agglomerations became a topic in the industrialized countries, especially in Germany, since the beginning of the 20th century. Meso-scale research on climate was based on a quest for knowledge on air pollution and urban heat islands. There was also a demand for tools to adapt to the negative effects of air pollution and urban heat islands (Kratzer 1956; Geiger 1965; Landsberg 1981; Schmalz 1984; Grimmond and Oke 1999, 2002; Santamouris 2001). Results of this research on adaptation were applied in urban planning schemes in several European agglomerations with strong air pollution and/or urban heat island problems (Ruhr-area, Stuttgart, Athens, London). These problems were less prominent in the Netherlands because this country has never been heavily industrialized. It is probably due to this lack of urgency that there was very little urban meso-climate research in the Netherlands. Research in this field was therefore rather incidental. However, two Dutch PhD projects should mentioned here because they laid important foundations for further Dutch research: a study on the case of the urban heat island of Utrecht (Conrads 1975) and a research on differences between wind-regimes close to and outside of the cities (Verkaik 2006). Very recently, the shortage of research in urban climate issues has been acknowledged in the Netherlands, and an accelerated process of catching up is now in full swing through nationwide research projects such as ‘Klimaat voor Ruimte’ and ‘Kennis voor Klimaat’.

### 1.2.3 Urban microclimate research

The need for urban miroclimate research has been identified in many countries over the last decades. Within urban microclimate research, different major fields of research have evolved, starting with the study and description of microclimate processes. The research relevant to this study focuses on microclimate research in relation to outdoor thermal comfort. Amongst these studies, contributions such as those of Oke (1987), Bosselmann et al. (1995), Katzschner (2004), Matzarakis (2001), Moriwaki and Kanda (2004) and Stathopoulos (2006) were interesting for urban design because they addressed factors that can be changed through urban design interventions. Also some research from the agricultural studies (Nägeli 1946; Dierickx et al. 2001; Dierickx et al. 2002) is of potential interest. Another field of study is the prediction of microclimate processes: the development of models or simulations. This field is also important for design because models or simulations can be used to test design interventions. Here, the work of Matzarakis on radiation simulation (2001) and that of Bruse on simulations for various factors influencing thermal comfort (2005) are influential.

This overview indicates that there is actually not that much microclimate knowledge that addresses urban design interventions for thermal comfort. The design guidelines mainly have to be derived from results and conclusions in scientific articles in urban meteorology. Here, another important problem lies in the ‘comprehensability’ of some microclimate knowledge. Much of this possibly useful knowledge is expressed in very abstract climate-physics terms or formulae that are not understandable for designers. Eliasson (2000) earlier identified this ‘translation-gap’ or problem that designers and climatologists do not ‘speak the same language’.

Still, fortunately, some useful design guidelines on the physical aspects of urban microclimate adaptation are available in a Building Research Establishment (BRE) report (Littlefair, 2000) and guidelines with a focus on rural circumstances (Brown and Gillespie 1995; Robinette 1983). Yet accessible, usable guidelines for urban design and especially public space design are still scarce.

It would have been useful to have such research for the Dutch situation as well. In the Netherlands, though, hardly any research on microclimate and outdoor thermal comfort was done. In the Netherlands, the focus was on studying wind dangers for pedestrians around tall buildings and wind-hazard effects on building constructions (Alberts 1981, 1983; Beranek, 1982) where especially researchers within TU Eindhoven made important contributions (Bottema 1993; Blocken and Carmeliet 2004; Willemsen and Wisse 2007).

Most of the microclimate research in relation to thermal comfort had a focus on physical issues, similar to the development of thermal comfort indices discussed under 1.2.1. In that context, researchers like Nikoloupoulou and Steemers (2001) asked for further research on psychological issues in thermal comfort experience. Recent research addresses this aspect and focuses on the connection between perception of thermal comfort and other influences that might have an effect on people’s perception, such as their personal memories and origin (Knez 2005; Knez and Thorsson 2006). However, issues concerning the perception of the ‘atmosphere’ of outdoor built environments in relation to thermal perception have not been addressed yet. This ‘atmosphere’, as Böhme (1995) described it, is influenced by factors that can be manipulated by urban design, such as size and materialization of spaces. Clearly, research is needed to identify these psycho-physical factors of urban spaces in relation to thermal experience of the urban environment.

In summary, three main knowledge gaps can be identified:

1. No research on long-term thermal comfort assessment was done in the field of outdoor thermal comfort research.
2. Very little urban climate and outdoor thermal comfort research was conducted for the Netherlands and its specific climate.
3. No research exists on spatial ‘atmosphere’ perception influencing outdoor thermal comfort.

## 1.3 Research questions and research methods

### 1.3.1 The research questions in general

Within these knowledge gaps, a large number of questions can be identified that need further research. It would go beyond the scope of one dissertation to tackle all of these questions. I decided to focus on a cluster of questions that could have useful implications for urban design and landscape architecture: the relation of people's thermal experience, perception of urban space and the design modifiers like spatial layout and materiality that influence 'atmosphere'. Apart from the empirical interest in the influence of these modifiers (which is addressed in chapters 4 to 6), this decision was also inspired by phenomenological thought. I offer a more detailed discussion on how phenomenology influenced my research questions and methods in chapter 2.

The main research issue I addressed concerns the relation between microclimate and thermal perception and spatial aspects of 'atmosphere'. I assumed that thermal comfort relates with synaesthetic (involving more than one sense) experiences that are induced by the experience of the designed urban environment and microclimate. The overview in figure 1.1 shows how sensory perceptions, the built and climatic-atmospheric environment are related, and on which of these synaesthetic experiences I focused in my research.

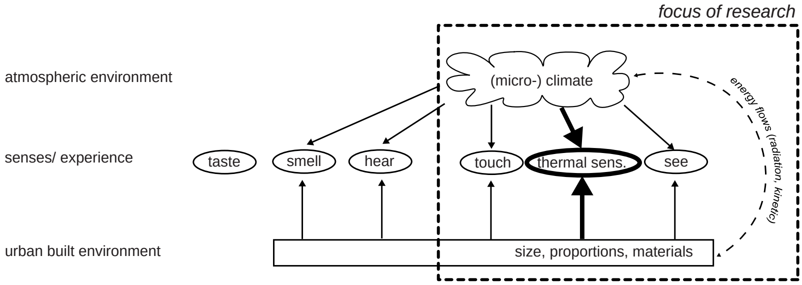


*Fig. 1.1 General focus of the research on thermal perception in relation to other senses, microclimate and the built environment*

I concentrate most of my inquiries on the interpretation of 'environmental cues' in the built environment, specifically the urban design modifiers like size, proportion and materialization. The cues that I studied are mainly perceived through touch (like materials), vision (like spatial configurations of the environment) and thermal reception (see fig. 1.1).

Apart from this multi-sensory perception of environment and microclimate, I considered another issue: the physical relations between the built environment and microclimate. It is well-known that urban microclimate strongly depends on the urban built environment (depicted by the dashed line in fig. 1.1) and thus it can also be influenced through urban design. Consequently, I was interested in generating new design guidelines for this physical aspect.

As I indicated in the overview of my general research questions, all the research questions concerned parameters that can be affected by urban design measures and thus were expected to bring about usable urban design guidelines. In the following I discuss the specific research questions in connection with the different methods used. These methods have different relations between 'research' and 'design'.

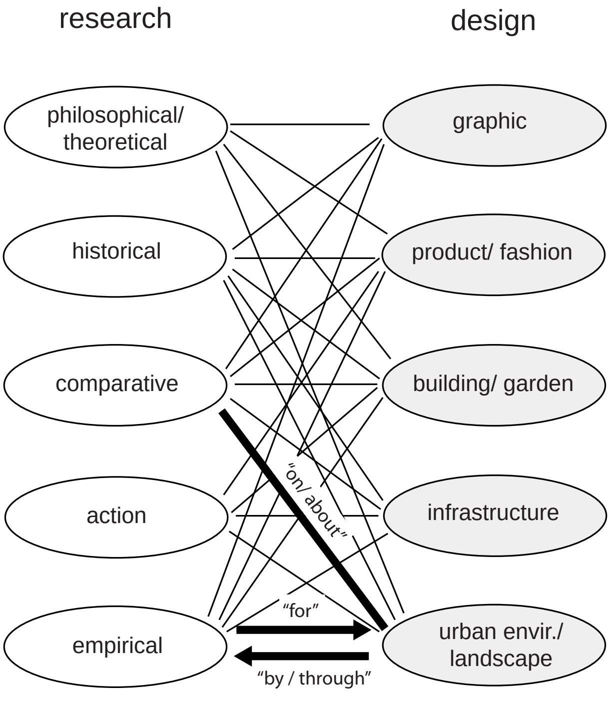
### 1.3.2 Specific research questions and research methods

Before I specify the different research questions and the methods used, I would like to discuss how the terms 'research' and 'design' could relate to each other. This leads to three methods used in my study: 'research on, for and by design'.

Different types of research methods can be identified. They are often used by specific academic disciplines. For instance, there are different research types such as theoretical, historical and empirical research. Similarly, there are different types of design (where the term 'design' is used in the classical sense of 'giving form'). In design, different scale levels and degrees of complexity can influence design types in different disciplines.

Within the different fields of design, design can be studied through various types of research (see fig. 1.2). For instance, in the field of urban design and landscape architecture, design is often studied with the use of historical methods (e.g. in Garden History), comparative methods (e.g. 'case-studies', Francis 2001) and empirical methods as used in the natural and social sciences (e.g. Post Occupancy Evaluation).

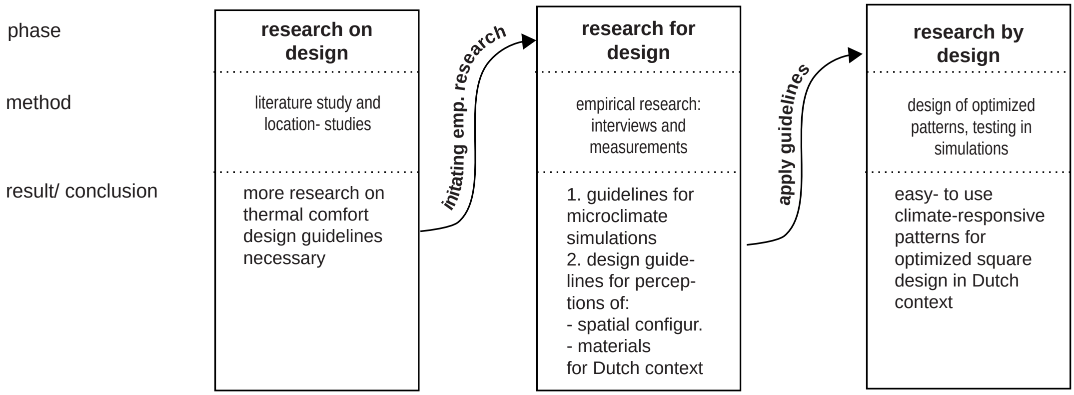
*Fig. 1.2 Relations between types of research and types of design and the focus of this research*



The relations between the different research methods and design can be described with different prepositions: ‘on/ about’, ‘for’ and ‘by/ through’. When designs are reflected upon and compared with each other, this could be called ‘research on or about design’. When the environment is studied with empirical methods of social sciences or environmental psychology to develop design guidelines, it could be called ‘research for design’. When design itself is conducted with empirical scientific methods, we could call this ‘research by or through design’. Since ‘research by or through design’ has hardly been discussed in urban design and landscape architecture, I explore ‘research by design’ in more depth in chapter 7.

The research questions I formulated required different types of research, which were conducted through ‘research on, for and by design’ within three distinct phases of the project (see fig. 1.3).

*Fig. 1.3 Interactions of the three phases of the research project*



I started my research with the question about the main issues in microclimate perception in Dutch urban squares. I first tried to find answers to these questions through literature and Internet reviews on public opinions about Dutch squares and by carefully studying various Dutch squares with respect to their design intentions and the way they were eventually built. In this ‘research on design’ it became clear that more useful design guidelines were necessary.

In the second phase I tried to generate new design guidelines. These were based on the answers of the main question: how is microclimate perception of a place related to the constituents of ‘atmosphere’ that can be influenced by urban design interventions. All questions were studied using empirical research methods. The perceptions of people were investigated with methods from the social sciences and environmental psychology and the ‘real’ microclimate was investigated with measurements as used in urban climatology. Since the outcomes of this empirical research served as design guidelines, this phase was a ‘research for design’.

The outcomes of this empirical ‘research for design’ consisted of more ‘don’ts’ than ‘do’s’. So more research was needed to generate more ‘positive’ design guidelines for climate responsive Dutch squares. Also I tried to apply some of the new design guidelines derived from the second phase on the design of a Dutch square. I developed models for a climate responsive Dutch square and tested them with microclimate simulations to find an optimized model. This method actively involved design and followed the criteria of empirical scientific research. Therefore I call this phase 'research by design'. This 'research by design' was conducted for two places that were identified to be quite problematic with respect to microclimate in the empirical research phase.

## 1.4 Brief overview of contents of chapters

*Chapter 2 - Phenomenology and related thought - inspirations for the project*

This chapter reflects one of my main inspirations for this project – the ideas of phenomenology being the philosophical study of human experience. In phenomenology, the relation between the 'life-world', human body and mind are explored. One important notion is 'embodiment' and the role of multi-sensory perceptions. I explain how this idea has influenced my research on a neglected sense, being thermal perception and how this relates to other sensory experiences. Another important inspiration from phenomenology concerns the idea of 'phenomenological reduction': the relation between perception and 'reality'. This dialectic was one of the major aspects that I studied for thermal perception in the empirical 'research for design'.

### Research on design

*Chapter 3 - A city is not a building - architectural concepts for public square design in Dutch urban climate contexts*

This chapter is a critical review of recent design approaches for urban public spaces. A prominent approach in urban design uses the metaphor 'city as a building'. This metaphor often brings about an architectural, minimalist design of plazas. The problems arising from this approach with respect to urban microclimate, human bioclimatic needs and perceptions are identified. Here I also go deeper into the problems that occurred around the redesign of the Canadaplein in Alkmaar. I criticize the lack of interest in microclimate issues and speculate on the possible reasons for that ignorance.

### Research for design

*Chapter 4 – Engrained experience – a comparison of microclimate perception schemata and microclimate measurements in Dutch urban squares*

This chapter describes the study of people's microclimate perception schemata. The assumption was that people's long-term perception of urban microclimate is based on the common situations (with rather agreeable micro-weather) that they experience when they use the urban outdoors. This was studied through a comparison of people's long-term microclimate perceptions with measurements taken in different micro-weather situations.

*Chapter 5- Immersed in Microclimatic Space-Microclimate Experience and Perception of Spatial Configurations in Dutch Squares*

This chapter documents the way people 'read' spatial configurations in relation to microclimate implications. As the preceding chapter had shown, people have developed psychological schemata on microclimate situations. In this chapter now volumetric properties of the spaces are addressed and how people read these visual cues in relation to microclimate. Data were acquired through interviews on spatial microclimate and gathered in 'collective cognitive microclimate maps'. These maps were analyzed on reoccurring patterns and some spatial properties such as dimensions and enclosure.

*Chapter 6 - Thermal experience and perception of the built environment in Dutch urban squares*

This chapter deals with the influence of some more spatial properties that influence the 'atmosphere' of a place and people's thermal comfort or discomfort. It explicitly addresses parameters that can be influenced by urban design: proportions of squares, their degree of openness and their materials. In this case results of interviews taken on the squares were statistically analyzed to identify the relationship between experience of thermal comfort/discomfort and the factors proportions, degree of openness of the square and materialization.

### Research by design

*Chapter 7 - 'Research by design' in academic landscape architecture: generating design guidelines*

Supplementary to the actual 'research by design' part of this dissertation, I give a methodological account of 'research by design', because this term was not yet defined within landscape architecture and urban design. This account firstly entails a clarification of the relation between scientific research and design and to what extent 'design' can be called 'research'. Secondly, it concerns procedural issues: what kind of design process can bring about generalizable results or design guidelines? The framework developed guides the practical 'research by design' process that is described in the next chapter.

*Chapter 8 - Designing for thermal comfort in Dutch urban squares - towards an optimized model*

This chapter illustrates 'research by design' by giving an account of the process of generating a thermal comfort-responsive design model for Dutch squares of a medium size. It reflects the iterative phases that consist of generating spatial models that are assumed to have an optimal microclimate performance and that are then tested through microclimate simulations until a 'satisficing' model is generated. The result is an easily applicable, thermal comfort-responsive design pattern for Dutch squares that improves microclimatic conditions in different seasons.

*Chapter 9 - General conclusions*

A reflection on the entire research considers the main research questions within 'research on, for and by design' and the answers found. Apart from those considerations that are rather specific design guidelines for landscape architecture and urban design, more general considerations round up this chapter. In these I return to the inspirations from phenomenology and reflect how my research has related to the ideas of embodiment and 'phenomenological reduction'.

# 2

# Phenomenology and related thought

– inspirations for the project

## 2.1 Overview

This chapter relates inspirations I gained from phenomenological thought and how these inspirations influenced this research. First I give a brief sketch of this philosophy as a general reference for my argumentation. From phenomenological thought on sensory perceptions and the related criticism on the dominance of vision in philosophy and design theory, I arrive at the main object of this research: thermal perception, a non-visual sense that has been ignored, especially in architecture, urban and landscape design. Building upon the important concept of 'embodiment', which is based on multisensory perception, I argue the necessity to consider thermal perception in relation to other senses and the interactions of different senses with thermal perception. I then address another major concept within phenomenology: 'phenomenological reduction' - the relation of 'real' experience and mental constructs of the experienced, because this is important for the type of design interventions designers can choose from: the ones relating to reality or experience.

## 2.2 Brief sketch of major concepts in phenomenology

Phenomenology is defined as 'the study of structures of experience, or consciousness. Literally, phenomenology is the study of 'phenomena': "appearances of things or things as they appear in our experience, thus the meanings things have in our experience. Phenomenology studies conscious experience as experiences from the subjective or first person point of view" (Woodruff Smith 2008).

Edmund Husserl, considered to be the founder of phenomenology, has dedicated a large part of his work to the development of phenomenology (Woodruff Smith 2008; Sokolowski 2000, pp. 2-3). He criticized the Cartesian mind-body split – the differentiation of an intra-mental and an extra-mental world and the consequence that philosophy got increasingly detached from the 'Lebenswelt' or 'life–world'. He argued that human beings spontaneously and unreflectively perceive the phenomena of their environment, their life-world, and generate their mental world based on these perceptions. Sokolowski calls this the 'natural attitude' (2000, pp. 42-51). This way of perceiving was described by Husserl through the notion of 'intentionality': the directedness of perception towards objects or situations or the consciousness of these. For Husserl, the study of this intentionality (which can take many forms) was the core of phenomenology (Woodruff Smith 2008). Another important notion within Husserl's phenomenology is how the intentionality of experience should be studied. His term of 'phenomenological reduction' emphasized that the target of study should be the experience itself. Husserl introduced this new approach of phenomenology both in philosophy and psychology (Husserl, 1962; Ashworth and Cheung Chung 2006).

Later, Husserl's original work that was a rather logical account of the idea of phenomenology, was supplemented with more poetic, hermeneutical approaches. Most influential thinkers in this respect were Bachelard, Heidegger and Merleau-Ponty. The former, with his 'Poetics of Space' certainly gave the most characteristic account of this poetic stream (Bachelard 1958). But also Heidegger made ample use of poetic inspirations. His interpretations of 'Dasein' in his book *Being and Time,* or the idea of 'dwelling' in his text *Poetry, Language, Thought,* stand for the many ways in which the 'Lebenswelt' can unconsciously be experienced with the mind and senses. These two thinkers, unlike Husserl, did not address the issues of phenomenological reduction – the differentiation of what is 'real' or 'experienced' (Woodruff Smith 2008).

Merleau-Ponty, on the other hand, was more rigorous in his thought about the connection between perception and mental constructs. In *The Phenomenology of Perception,* he elaborated on the notion of the human being as a bodily multi-sensory being whose conceptions of the world are based on sensory, aesthetic experiences (Woodruff Smith 2008). Merleau-Ponty pointed to the interchange of information derived from the different senses and how they enhance each other into a total 'embodied' experience that constitutes a conception of the human world (Merleau-Ponty 1964; Gutting 2001).

Following these influential founding theorists, more recent thinkers elaborated on phenomenology. Amongst these, Luce Irigaray was very inspirational for me. Developing phenomenological thought from a gender-related perspective she stated that women and men have different sensory perceptions and consequently they have different concepts of the world (Irigaray 1993). Other contemporary thinkers further developed phenomenological studies about the sensory perceptions and philosophical concepts, resulting in a critique on the 'hegemony of vision' (Levin 1993). Another contemporary thinker, Gernot Böhme, came up with a very inclusive model of embodied experience. He sees body, mind and environment as a continuum and describes this with the term 'atmosphere' (1995). He emphasized the influence of 'aesthetic workers' like designers, architects and others on the creation of 'atmospheres'.

As one of the leading movements in modern thought, phenomenology has recently gained increasing attention in architecture and other spatial design disciplines (Leach 1997, pp. 83-84), mostly because it deals with the relation of environments (that are often shaped by design) and human beings. Specifically, the experience of physical, material environments, their sensory properties as well as the mental concepts about these physical environments are of great concern for the design of environments.

These aspects of the appearance, physical properties and the related mental concepts have also inspired my own research.

## 2.3 Critique of ocularcentrism and attention for proximal senses

Human senses as the main mediators for intentionality play a crucial role in perception and Merleau-Ponty has most explicitly discussed the importance of sensory perception (1962, pp. 207-242). Although the phenomenologists were major thinkers on the subject of human multi-sensory perception, some of them were accused of ocularcentrism – an overemphasis of the sense of vision. Since different sensory experiences were also related to different philosophical concepts of the world, this focus on vision was considered problematic (Levin 1993; Pallasmaa 2005). Descartes considered vision as the most 'clear' sense that has closest relations to a rational view of the world. It was thus not surprising that Descartes posed vision as the most distinguished of all senses (Pallasmaa 2005; Jay 1993). This focus on vision evoked a one-sided perception of the world and thus one-sided concepts of the world. This was, for instance, discussed in the *Hegemony of Vision* by various authors (Levin and Cheung 1993). According to Arnold Berleant, the overemphasis on the visual and audible is derived from old Greek ideas of aesthetics where sight and hearing were praised as the 'higher senses'. Berleant calls for invigoration of these 'other senses' from their neglect and to embed them in a transactional system of the body and its surroundings (Berleant 2004, pp. 75-77, 86-88). Criticisms on the dominance of vision came from other fields as well. The geographer Yi-Fu Tuan states that "in the modern world vision tends to be emphasized at the expense of the other senses..." (Tuan 1974, p. 245).

Jay (1993) and Levin (1993) argue that there is an apparent visual focus in the works of Husserl, Heidegger and Merleau-Ponty. Thinkers like Heidegger and Merleau-Ponty had a significant influence on architectural theory building (for example on Norberg-Schulz, 1979). Even so, since their views remained quite focused on the visual it does not come as a surprise that the visual senses were still overemphasized in architectural theory and practice. The architect Juhani Pallasmaa has criticized the dominance of vision in the architectural professions. He attributes this, in addition to the reasons mentioned above, to the use of visual simulation technologies as design tools. He makes a plea for the reintroduction of the other senses in architectural paradigms (Pallasmaa 2005). Richard Sennett, an urban sociologist and thinker, likewise criticizes this sensual detachment of the designers through their use of virtual simulation techniques and also urges the designers to be more sensitive to tactile experiences (2008).

The invigoration of other senses besides the visual has also received much attention in the work of the contemporary philosopher Luce Irigaray. In her criticism of Merleau-Ponty she states that he omits the idea of the tactile sense as the most 'basic' human sense, and that his thought keeps revolving around 'sight' as the central sense and as the focal point of multi-sensory experience (Irigaray 1993, pp. 174-175). As an alternative, Irigaray brings the proximal senses into focus. These proximal senses, as opposed to the 'distal senses' of sight and hearing, include smell, taste, touch and thermal perception. She posits that men and women perceive the world differently. Irigaray bases her idea of sexual difference and specific female perception on the different physiology of the female body (Irigaray 1993, pp. 12-18). Departing from this idea, she emphasizes the importance of the 'proximal senses'. She discusses the proximal senses and the more intense sensory engagement with the environment (Irigaray 1999, p. 96), especially through touch (Irigaray 1999, pp. 185-217). Moreover, Irigaray accentuates the higher sensory sensitivity of women in general (Irigaray 1993, p. 63).

It is not only Irigaray who devoted thought to the issue of proximal senses. Other women in the field of environmental design professions and female scientists seem to show an explicit concern for this issue as well. This possibly originates from the higher sensibility of women to the proximal senses. It is, for instance, widely known that the female sense of smell is more developed than that of the male (Havlicek et al. 2008). It is also proved that women are more sensitive to thermal influences and microclimate than men. Parsons (2003, pp. 223-225) reports about several researches on indoor climate that showed these differences, and Oliviera and Andrade (2007) showed that gender-related differences also exist in outdoor thermal comfort. So it is perhaps only logical that it was a woman devoting a book to thermal comfort. In *thermal delight in architecture* the architect Lisa Heschong extensively elaborates on the issue of thermal experience, emphasizing multisensory perception and making cross-relations to phenomenologist thought (Heschong 1979, pp. vii, 24, 29).

Yet, although some attention is given to the thermal sense being one of the primal vital senses, it still has not been recognized as a sense that extends the classical 'five senses'. This is surprising, because thermal perception is clearly different from other senses. Thermal perception has its own receptors in the human skin that react to radiation and that are differentiated into heat and cold receptors (Parsons 2003, pp. 34-39). It is significantly different from the sense of touch, which also has receptors in the skin, but these react to kinetic stimuli and not radiation. I think that thermal perception, as a very vital sense, needs more consideration. Certainly, it needs more attention in the design of our environments. This is why I chose the thermal sense and how it can be influenced by design interventions as the main focus of my research.

## 2.4 Embodied experience and synaesthetic perception

The concept of ‘embodiment’ plays a central role in phenomenological philosophy. Embodiment refers to the body and its surrounding world as one entity, where the body is the main agent for perceiving and conceiving the world. Husserl describes it as “the sphere that is primordial in our specific sense, my animate organism is the central member of ‘Nature’ the ‘world’ that becomes constituted by means of governance of my organism. In like manner, my psychophysical organism is primordial for the constitution of the Objective world of mutual externalities, and, with the oriented mode of givenness of this world, enters it as a central member” (1960, p.134). Lefebvre uses a similar expression when stating that ”the body serves both as point of departure and as destination” (1974, p. 194). Based on this notion he elaborates on the role of the body in perceiving and conceiving the world (1974, pp. 196-218).

So, fluxes of matter and information are exchanged between body and environment and the senses have a crucial function in this exchange, as Merleau-Ponty has broadly elaborated upon in his work. He describes the central role of the body, and its exchange with the environment through fluxes with the metaphor of the heart: “Our own body is in the world as the heart is in the organism” (1962, p. 203). In this system, the senses with their mutual interaction shape perceptions. Merleau-Ponty describes this as “natural perception, which we achieve with our whole body all at once and which opens a world of interacting senses...” (1962, p. 225). Pallasmaa beautifully illustrates this mutual enhancement of different senses when he speaks of ‘the eyes of the skin’ or ‘the taste of stone’. He thinks that “every touching experience of architecture is multi-sensory; qualities of space, matter and scale are equally measured by the eyes, nose, skin, tongue, skeleton and muscle” (2005, p. 41). Lefebvre also discusses the interaction of body and environment through the different senses of the ‘lived body’ and how it produces its own space (1974, pp. 196-218). The German philosopher Böhme is most clear about the influence of space (‘räumliche Träger von Stimmungen’, p. 29) and qualities of the environment (‘Umgebungsqualitäten’, p. 23) on the synaesthetic perception and the psychological influences (‘Stimmung, Befindlichkeit’, pp. 177, 190) and calls this interaction of embodied experience ‘Atmosphäre’: atmosphere. He emphasizes that these atmospheres can be ‘designed’ to a great extent by carefully alluding to the different senses in order to generate certain feelings (pp. 34-39). His elaborations on ‘designability’ make his work specifically inspiring for environmental design professionals. Böhme also explicitly mentions the atmospheres that can be governed with respect to ‘warm’ or ‘cold’ materials and colours (p. 55). Before him, Merleau-Ponty had already indirectly related colour and ‘atmosphere’ (‘Raumfarbe’) (1992, p. 226), but he never directly addressed ‘atmosphere’ as a general inclusive concept the way that Böhme did.

This focus on multi-sensory perception was inspiring for my research. I decided to combine research about thermal comfort with other perceptions of the environment and 'atmospheres'. Much of these 'atmospheres' can be influenced by design – through materials, and the proportions and shapes of spaces. They can allude to different senses through their thermal, visual, haptic and other sensory qualities. Accordingly, I studied some sensory perceptions of the environment such as visual and haptic properties in relation to the thermal perceptions (see fig. 1.1). In the empirical research phase, I studied these interactions mainly with methods from the social sciences and environmental psychology. This is based on Gutting who states that phenomenological thought has "revealed its own need to be complemented by social-scientific knowledge" (2005, pp. 10-11) and Ashworth et al. (2006) who demonstrated that phenomenology has been a great inspiration for psychological research.

## 2.5 Relation of experience and reality

Husserl has argued against the alleged opposition and clear distinction between the 'experienced appearances' and 'outer reality' by Descartes (Sokolowksi 2000; Husserl 1960). Alternatively, Husserl developed the central idea of his phenomenology: intentionality. As indicated earlier, this notion deals with the 'directedness' of human perceptions on objects or situation in the environment, the 'life-world'. Within phenomenology, he tried to study the processes of perception and consciousness, the exchange between the mental world and the 'life-world'. He differentiated between two types of consciousness: the 'natural attitude', a non-reflecting, primordial consciousness of things or beliefs, and a more philosophical, transcendental attitude. The latter attitude tries to contemplate the natural attitude and does so by transcending it. Husserl also defined this transcendental view on human experience as the 'phenomenological reduction' (Sokolowksi 2000). Husserl proposes to achieve this view by the 'époché' or 'bracketing out' the objective world: "This universal depriving of acceptance, this 'inhibiting' or 'putting out of play' of all positions taken toward the already given Objective world and, in the first place, all existential positions ... – or as it is also called, this phenomenological époché and 'parenthesizing' of the Objective world – therefore does not leave us confronting nothing" (1960, p. 20).

This fundamental question is also relevant for my research and for designers in general: do designers address physical reality or people's experience? Also, illusions in physical design of places can influence people's perception. Classical examples are the painted illusions of depth in Baroque buildings or the spatial illusions of long perspectives in Baroque gardens. I found a similar example concerning design for indoor thermal perception. Rohles (1980) revealed that the appearance of the environment has an effect on thermal perception of people. He tested the thermal experience of people in indoor environments with different decoration and finishing. The results showed that people who were surrounded with ‘warm’ materials, such as wood and textiles, perceived temperatures to be warmer than people who were surrounded by ‘cold’ materials – despite of the fact that the ‘real’ air temperature was the same in all settings.

Designers can use design interventions to govern both the ‘factual’, measurable and the ‘perceived’, maybe illusionary. I considered this an important question to investigate: the relation between the ‘perceived’ and the ‘real’.

# 3

# A city is not a building

## Architectural concepts for public square design in Dutch urban climate contexts

# Abstract

This article elaborates on an architectural approach to urban design – to the idea of 'city as a building' in relation to user's perceptions and urban microclimate based on Dutch examples. A brief analysis of urban square design approaches in The Netherlands since WW II reveals a prominent tendency to use the metaphor 'city as a building'. The architectural, often minimalist design of plazas frequently features a 'void' spatial layout, hard materialization, cool, bright colours and furniture that has its origin in interior design.

The problems arising from this approach with respect to human bioclimatic needs and perceptions as well as urban microclimate will be elucidated and practical solutions proposed. As a general conclusion, a different approach to urban design that conceives the 'city as landscape' is suggested.

*Published in Journal of Landscape Architecture 5, 2008, pp. 44-55*

## 3.1 Introduction

The Dutch public is dissatisfied with the quality of its urban public spaces. This was clearly shown in the results of a sizable inquiry launched by an influential Dutch newspaper in 2007 [1]. The opinions aired in internet fora and the newspapers show similar concerns about the quality of many Dutch public squares, and they reflect the generally more negative than positive perceptions about these places. The ‘hits’ for positive search terms such as “beautiful/comfortable/cozy/appealing square” show that only a few Dutch squares are mentioned in a positive way, and these will be discussed later. The ‘hits’ for negative terms such as “ugly/uncomfortable/draughty/uninviting square” far outnumber them. A range of typical worries occurs: next to social nuisances (drug and alcohol addicts, loitering youngsters, vandalism, etc.) a number of problems in the physical urban surroundings are often mentioned. One of the most important seems to be the neglect of public spaces with indicators such as broken or rotten street furniture [2,3,4]. But the spatial setup of many Dutch urban squares is also criticized when squares have a too open and empty character. Another problem often mentioned is that squares appear too “hard and smooth” and “cold and grey”. This criticism of the spatial set-up and materialization is in almost all cases related to specific places and it is striking that the ones mentioned often are recently (re)designed squares in Dutch cities, and that they feature combinations of the above points of criticism. These squares are:

1. Spuiplein, Den Haag (fig. 3.1), designed by architect Joan Busquets in cooperation with Den Haag municipality and artist Peter Struycken, completed in 1996;
2. Schouwburgplein, Rotterdam, designed by West 8 urban design and landscape architecture, completed in 1996
3. Zaailand, Leeuwarden (fig. 3.2), designed by Leeuwarden municipality, completed in 1990
4. Grote Markt, Groningen (fig. 3.3), part of the ‘ruimte voor ruimte’ inner city refurbishment masterplan by Mecanoo architects, implementation plans by Groningen municipality, completed in 1997
5. Heuvelplein, Tilburg (fig. 3.4), designed by diederendirrix architects, completed in 1996
6. Stadhuisplein, Zoetermeer, designed by Zoetermeer municipality, completed in 2004
7. Marie Heinekenplein, Amsterdam, designed by D.C. Apon, completed in 1995,
8. Brinkplein, Hengelo (fig. 3.5), designed by Juurlink en Geluk landscape architects and Bolles Wilson architects, completed in 1999
9. Binnenrotte, Rotterdam (fig. 3.6), designed by West 8 urban design and landscape architecture, completed in 1996
10. Bus station square, Enschede (fig. 3.7), OKRA landscape architects in cooperation with Enschede municipality, completed in 1997
11. Stationsplein, designed by Leiden municipality, completed in 2003.

*Fig. 3.1 Spuiplein, Den Haag ,*

*Fig. 3.2 Zaailand/ Wilhelminaplein, Leeuwarden*

*Fig. 3.3 Grote Markt, Groningen*

*Fig. 3.4 Heuvelplein, Tilburg*

*Fig. 3.5 Brinkplein, Hengelo*

*Fig. 3.6 Binnenrotte, Rotterdam*

*Fig. 3.7 Bus station square, Enschede*

Questions arise about the evolution of design paradigms leading to the type of Dutch square design that features the ‘empty’, ‘hard’ and ‘cool’ characteristics so strongly criticized by the public. A brief overview of the developments in Dutch public space design over the last 50 years might help to explain this phenomenon.

## 3.2 A brief overview of developments in the design of Dutch public spaces since WW II

Present Dutch public design is in many ways related to design movements after WW II with the ‘coming and going’ of different design concepts, fashions and hypes that in the Dutch context represent strongly contrasting approaches. After WW II the design of public spaces such as squares and parks was a minor priority for municipalities in The Netherlands because rebuilding the cities was more important. In the old city centres the squares were more and more used for mobility – rising car ownership after the war quickly generated a need for parking space. At that time many of the old squares were simply serving as open air car parks (Dordregter 2003, p. 16) (fig. 3.8) and sometimes for commercial purposes such as street markets and funfairs. Because of these functional demands the squares were not used for resting, meeting and amusement and did not invite people to linger.

Furthermore, Dutch society at that time was generally not accustomed to meeting and socializing outdoors in central urban squares (Wagenaar 1999, p. 43; Lemstra 1991, pp. 6-7). Along with this, Dutch town planners in the early 1960s did not actually consider that public spaces could be used for both commercial and recreational purposes. During the late 1960s, with the student movement in The Netherlands in the ascendant, many things

*Fig. 3.8 Market square in Arnhem used as a car park (Gelders Archief)*

changed abruptly. Young Dutch people developed a hedonistic way of life and accordingly made active use of public spaces with 'sit-ins' and 'love-ins'. This new zeitgeist brought a different way of looking at the city and its public spaces.

Public places were considered to be the meeting places in a "recreational city" (Dufour 1979; Reijndorp and Nio 1996, p. 151). The layout of the modernist city that was considered too functionalistic, large, sterile and inhuman was rejected, and design for the small, human, scale was the answer (Reijndorp 1996, p. 14), also inspired by the writings of Jane Jacobs and many others. Human beings and their behaviour in urban space became a major field of study and led to a strong inclusion of the 'people in the street' in design approaches. This attitude was reflected in new planning processes with a strong inclination to advocacy and participatory planning (Reijndorp 1996, p. 23).

Public spaces were increasingly shaped to meet the recreational needs of the city, also with the help of 'the people in the street' in manifold participative design procedures. To offer a 'cozy' atmosphere the cities' outdoor spaces were equipped with all sorts of colourful elements such as kiosks, pavilions, sitting corners, bicycle racks, playgrounds, sculptures and a lot of other urban furniture. Along with that, the streets and squares still had a strong commercial function, and gaudy advertising and displays of goods in the streets in showcases and on stalls was everyday practice (fig. 3.9). These eventually led to unpleasant overcrowding, culminating in a decline of the central public places (Krop 1989, p. 11). The time arrived to rethink the role of urban designers whose design competences had been radically eroded by participatory planning practices.

From the late 1980s, Dutch city centres, like many European cities, went through a process of urban revitalization (Van Duren 1992; Oosterman 1992). Dutch inner cities however, with their 1970s designs denigrated as crammed and outdated, were not fitted for this new liveliness – and a problem had arisen within the design professions: the artistic, creative aspect in

*Fig. 3.9 A 1970s shopping street in Emmeloord (Goudappel Coffeng bv)*

design of public space had drawn little attention in the 1970s and 1980s. Through the years of participatory planning, many urban and landscape designers had abandoned their design practice for the role of facilitators, and landscape architects had a utilitarian rather than a creative role (Louwerse 1995, pp. 13, 86). When landscape and urban planners still had ambitions in urban design, their 'reference albums' and artistic expressiveness needed new inspiration. This inspiration was often found in Paris, Lyon and especially in Barcelona (de Josselin de Jong 2003, p. 142).

In France at that time, artistic, architectural approaches for public spaces were fashionable. New public spaces such as the Place de Terreaux in Lyon were designed by architect Christian Drevet together with artist Daniel Buren, in Paris the Place de Stalingrad was designed by architect Bernard Huet, and last but not least, the Parc de la Villette by architect Bernard Tschumi. The French tradition of urban furniture design fed this development and Lyon became famous for its elegant and consistent urban furniture (Dordregter 2003, p. 15). The French influence on Dutch public space design, however, was limited. A much stronger influence can be traced to Barcelona's architects.

Barcelona had developed a specific urban revival strategy under its city architect Oriol Bohigas. Design of public spaces showed some typical design features of the period. Bohigas interpreted urban public spaces in an architectural way – as urban 'rooms', the façades being their 'walls' (Dordregter 2003, p. 15), with ample use of hard materials and refined street furniture and little attention to the natural environment and its materials (de Josselin de Jong 2004, pp. 150-151). Furthermore, public spaces were often designed in a minimalist manner: empty, dominated by the façades of surrounding architecture or containing few built elements or sculptures (Broadbent 1990, pp. 286-290).

The new designs from Barcelona were highly influential abroad, and especially in The Netherlands, for several reasons. The minimalist designs from Barcelona coincided with the austere Dutch design tradition (Knuijt et al. 1995, p. 51; van Dijk 1999, p. 144). At the same time it answered the need for a strong aesthetic counter-movement to the 1970s mediocrity of participatory and ecological design, an outgrowth of what Adriaan Geuze calls the 'hippies' approach (Geuze 2001).

The fact that the architectural places were 'built' created an instant aesthetic result and visual quality on completion (as opposed to 'planted'and hence slowly growing spaces). As a consequence some Dutch municipalities commissioned French and Barcelona-based architects to design their public spaces (Wiegersma 2007), but Dutch design professionals also quickly adopted the minimalist, architecturally inspired design mode that offered the quick success of instant spatial and visual results from their project work (Dettingmeyer 1991, p. 21).

## 3.3 The idea of a public square as a 'building'

A closer look at squares redesigned or built in the 1990s that were inspired by the new architectural and minimalist trend reveals four main design characteristics: the idea of public space as an urban 'room' or 'void', the use of hard and smooth materials cool, and bright colours, and elegant, refined street furniture. These characteristics all relate to the idea of public spaces as 'buildings' or – as Kevin Lynch calls them – "large scale architecture" (Lynch 1990, p. 254). The concept of the 'urban room/void' as a subunit of 'the city as a house' speaks for itself. The other characteristics actually follow from this idea of the urban 'interior'. An architectural interior consists essentially of hard walls and flooring, generally stone, and the walls of the outdoor urban places – the 'placas duras' in Barcelona or 'hard places' elsewhere – correspond to this. Interiors are often decorated with bright colours for better daylight reflection and smooth materials for hygienic reasons, and this treatment was applied to outdoor space. Last but not least, a building's interior allows the use of elegant and refined furniture – similarly, this kind of furniture was used to furnish outdoor space appealingly.

Further examination of design jargon reveals that the concept of urban places as 'buildings' was widely used in the profession, starting with Camillo Sitte (Sitte 1889, p. 146). Later, many more urban designers looked at urban open spaces as "unroofed buildings" (Louwerse 1995, p. 15) or even as buildings with a roof by the Barcelonan architect Andreu Arriola (Knuijt et al. 1995, p. 29). In the Netherlands, too, this idea was often applied – architect Aldo van Eyck was already speaking of the “stad als huis” (‘city as house’) in the 1960s, and the term reoccurs in many concepts for public space development [5]. The idea of public space as the interior of the ‘city as a building’ perhaps becomes most manifest in the title of the Dutch professional education in urban public design: the ‘Urban Interior’ Master’s course taught at the Hogeschool voor de Kunsten Utrecht.

Interestingly, these characteristics of architecturally inspired outdoor spaces are often criticized by the Dutch public. There seems to be a striking congruence between criticism of the ‘emptiness’ of the squares, choice of materials and colours and neglected appearance of furnishing and the four aspects of the ‘city as building’ concept with its ‘voids’, ‘hard places’, cool colours and elegant furniture. These discrepancies between the four architectural concepts and public opinion merit further investigation, and will be discussed in the following, casting a critical eye on the validity of public perceptions.

## 3.4 Urban squares as ‘voids’

The notion of the city as a building with ‘rooms’ and the related concept of the ‘urban void’ is chiefly based on figure-ground theory (Trancik, 1986, p. 103), describing the spaces without buildings in the volume of the city, and has been widely used. According to the ‘city as house’ analogy, many Dutch public spaces were labelled ‘living rooms’ (Koerse 2003, p. 85), ‘foyers’ and ‘theatres or stages’.

The term ‘urban stage’ was coined more than forty years ago by the social sciences to describe a setting for human behaviour and interactions in urban public places (Goffman 1959; Messinger et al. 1962) and was later increasingly applied to describe the physical open space of the city. For example, the notion of the ‘square as a theatre’ was frequently used in Barcelona’s urban revitalization programme (Dettingmeyer 1991, p. 22). Following this notion, many examples of ‘urban stages’ were developed from the 1980s. The seminal Schouwburgplein by Adriaan Geuze is one (Geuze 1995, p. 42), as is Spuiplein, which was conceived as a podium in front of the new town hall in Den Haag (Rodermond 1996, p. 80).

Many squares and streets have thus been conceived as a setting for the ‘theatre of urban life’, and emptiness is their main shared characteristic. In Barcelona several public spaces were designed with the ‘theatre idea’ in mind, while concurrently expressing the ‘poetry of emptiness’ (Esefeld 1994, p. 115) to epitomise urban life. These notions of offering empty space or ‘voids’ for individual expression and ‘the urban stage’ have often been mentioned in the same breath. The idea of ‘the void’ became a buzzword in the 1990s, initially in architecture, promulgated by Rem Koolhaas’ book S,M,L,XL where the term often occurs and a whole chapter is dedicated to

the ‘strategy of the void’ (Koolhaas 1995, pp. 603-661). It was also used by architect Bernard Huet, celebrating emptiness in the urban ‘volume’, exemplified by his design for Place de Stalingrad in Paris (Huet 1995, pp. 23-24). Gradually, creating a ‘void’, an empty surface, became a design imperative for urban squares (Rodermond 1996, p. 81). Adriaan Geuze used the same language in his
publication for the Venice Biennale ‘colonizing the void’, an urban design manifesto which proposes:
“- excavating urban voids in contrast to urban congestion,
- creating large-scale voids that challenge colonization,
- providing individual voids for urban expression” (Geuze 1996, p. 24)
These ideas were – amongst others – based on Geuze’s earlier thoughts on the design of Schouwburgplein, which he calls a “void” that allows the urban inhabitant to use the free open surface for their ultimate personal expression (Geuze 1995, p. 42, 47). He is well aware that he created a space to provoke agoraphobia here, and considers it an appeal to the citizens to “colonize” this empty void (Geuze 2000, p. 256). It can be questioned if this arose from an honest personal conviction about the ‘emancipated citizen’ or was just design rhetoric to attract attention with challenging exclamations.

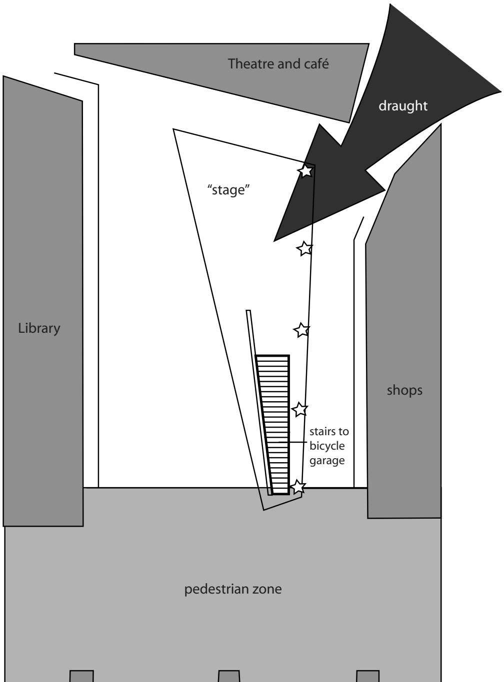
The idea of emptiness in the city has become a more general theme in Dutch urban design for two main reasons. Repudiation of the earlier ‘cluttered’ public space in the 1970s Netherlands is one. Many of the recent urban refurbishment projects were primarily implemented to make urban places more “empty and tidy” (Reijndorp and Nio 1996, pp.152, 159). Streets and squares were freed not only from traffic, but also from furniture, advertising, commercial showcases, sculptures, old street furniture and other “white noise” (Blok 1998, p. 106) to create visual rest. The other, closely related reason for the celebration of ‘emptiness’ is the strong minimalist tradition in Dutch visual culture. This revaluation of minimalism occurred along with a re-appraisal of modernism. In the early 1990s a movement in architecture appeared in the Netherlands, often called ‘supermodernism’ which in many respects was a re-editing of old modernist ideas.

These ‘voids’ as a specific type of very open urban squares cause some typical problems. To start with, Adriaan Geuze’s prediction that the citizens’ reaction to Schouwburgplein would be agoraphobia was absolutely right. People reportedly feel uneasy in these wide open spaces. General public opinion on many Dutch squares is that they are too big and empty (Spuiplein, Den Haag [13,14,15] Schouwburgplein, Rotterdam [6]; Zaailand, Leeuwaarden [7,8,36 ]; Grote Markt, Groningen [18,19,20]; Stadhuisplein, Zoetermeer [22,23,24]; Binnenrotte, Rotterdam [21]; Brinkplein, Hengelo [11,12,37], Bus station square Enschede [16,17]; Marie Heinekenplein, Amsterdam [9], Station Square, Leiden [10]).

Even the profession criticizes these ‘void’ squares: Hans Stevens remarks upon the emptiness and deadness of most Dutch squares (Stevens 1989) or Frank de Josseling de Jong ponders the distinction between “spacious” and “empty” squares (de Josselin de Jong 2004, p. 153). It is surprising that designers had not taken these predictable agoraphobic responses into account, when many classical writings on urban open space had touched upon this issue, starting with Sitte (Sitte 1889, pp. 183-184). They were developed further after WWII with the prospect-refuge theory of environmental psychologists (Appleton 1975) and thorough behavioural research on public urban spaces by W. Whyte, A. Rapoport, J. Gehl and many others. Design approaches based on behavioural research that encouraged design for small human scale and behaviour resonated strongly in 1970s and 1980s urban design practice. These findings and resultant design approaches were then later either ignored or – in the case of Geuze and others – consciously rejected as an answer to the previously-discussed 'hippie' urban design.

The other main problem in 'void' squares is thermal discomfort. They offer no shade or shelter, and thus no microclimate variation; users are left with no choice between microclimate zones (Nikolopoulou 2004; Steemers et al. 2004). Some squares are also considered windy or draughty by the general public (Zaailand, Leeuwarden; Schouwburgplein, Rotterdam, Station square, Leiden; Spuiplein, Den Haag; Bus Square, Enschede; Binnenrotte, Rotterdam). This perception is generally true – there are problems with wind discomfort, for different reasons. Firstly, the combination of square width and rather low surrounding buildings often makes open squares effective wind catchment areas, because the lee sides of lower buildings do not offer enough wind- protected depth (Boutet 1987, pp. 57-63; Bottema 1993, pp. 141-144; Alberts 1984, pp. 26-32).

*Fig. 3.10 Layout of Canadaplein, Alkmaar*



When a square is surrounded by taller objects, more problems with downwash and turbulence occur (Alberts 1984, p. 31). This is the case in many Dutch squares with a high church spire on their margins. The oft-criticised Grote Markt in Groningen is a typical example, as is Spuiplein in Den Haag, where the wide, open square is flanked by the tall new town hall building causing hazardous wind situations at the foot of the building and on the square (Peutz associates 2000). Another typical wind problem on a square is the draughtiness of street canyons entering the squares due to corner streams (Bottema 1993, pp. 84-88) or funnel effects (Bottema 1993, pp. 97-101).

A representative example is Canadaplein in Alkmaar. This square was designed by the author in 2000 while working for Sant en Co landscape architects. The square, laid out in front of the city's theatre, was conceived as an 'urban stage' for the citizens to enact their own urban 'theatre of life'. The square was consequently designed as an open void with a low 'stage platform', which was appropriated by an outdoor café. After one summer season there were complaints about thermal discomfort, especially draughts in the outdoor café (fig. 3.10).

*Fig. 3.11 a-c Canadaplein, Alkmaar – from 'open stage' square towards a 'cage' square.*

Eventually the local authority asked the author to design a special wind screen to protect the outdoor café. This screen covered one third of the outdoor café area. This was still considered insufficient protection, so two years later the entire outdoor café was enclosed in a kind of 'cage' of wind screens. All these additions to create thermal comfort have entirely disrupted the initial 'open stage' design concept (fig. 3.11 a-c).

Places that were supposed to be open are now completely enclosed by the wind screens. If microclimatic data had been available during the design process this type of 'open void/stage' design concept would have been considered unsuitable, and the square would have been designed very differently.

To recap the issue of 'voids': in general, public perception of these squares as wide and windy correlates with scientific knowledge of environmental psychology and the microclimatic reality on Dutch squares.

## 3.5 Dutch squares as 'hard places'

The concept of 'hard places' with hard, stony and also often artificial materials that are not 'grown' but 'built' has various origins. One is the influence of inspirational French and especially Catalan squares with such typical architectural materials as stone, tiles, enamel, glass and metal (fig. 3.12), and elegant, smooth surfaces. Plants and natural contexts played a minor role. Barcelona's inhabitants coined the term 'placas duras' ('hard places') for the numerous squares of this type being built in their city. It is interesting to note that even in Barcelona, where the tradition of architectural public spaces has always been strong, severe criticism was voiced by users of these 'placas duras'. Many Barcelonans described the 'placas duras' as "uncomfortable, too grey, having too little green and no shadow" (Kesser, 1984, pp. 24-25; Schneider 2002, p. 222).

*Fig. 3.12 'placa dura': Placa dels Angels, Barcelona*

On the other hand it was not only foreign inspiration that led to the design of 'hard places'; the strong Dutch modernist design tradition also influenced their evolution. The typical characteristics of modernist architectural materialization have been widely discussed, and it is known that many of the typical hard, smooth and man-made materials are not highly regarded by the public. Critical voices about Dutch squares often mention their hardness (Spuiplein, Den Haag [30,31]; Schouwburgplein, Rotterdam [26,27]; Marie Heinekenplein, Amsterdam [28]; Stationsplein, Leiden [29]; Heuvelplein, Tilburg [25]; Brinkplein, Hengelo [11,12,37]; Stadhuisplein Zoetermeer [23,24]).
Problems with this 'hard' type of square in the Netherlands are strongly related to thermal discomfort and climate. The 'hard places' have a typically harsh microclimate that aggravates peak air temperatures because stony surfaces store heat and emit them via long-wave radiation (Santamouris 2001, pp. 160-165). Also the 'touch' of the hard materials with their heat conductivity properties plays a role. Stony materials, steel and glass are generally very dense, with comparatively high conductivity (Givoni 1998, p. 119-122). These materials feel quite cold in cooler climatic circumstances, but in warm circumstances can become very hot. These thermohaptic properties of the materials and the accentuated peaks in air temperatures do not serve the human need for thermal comfort.

Next to their appearance, these widely used hard, smooth materials have functional deficiencies in the wet and rather cool Dutch climate. Smooth surfaces become dangerously slippery for pedestrians and cyclists, as seen in the 'ruimte voor ruimte' scheme in Groningen, where many people complain about hazardous situations caused by the pavement's smoothness, as well as in Den Haag's Spuiplein (fig. 3.13). Schouwburgplein in Rotterdam is also described as very slippery [26].

Generally speaking, the negative impressions that many people have about the hardness and smoothness of many squares is easily verifiable.

*Fig. 3.13 Slippery tiles on Spuiplein, Den Haag*

## 3.6 Cool, bright colours

'Cool' or bright colours are often used in the newer squares. This can partly be attributed to inspirations from the Modern Movement, but also to the Mediterranean influence, where bright colours are ubiquitous in outdoor space and façades.

In the Dutch context, however, the public often sees these squares as too "cool and grey" (Heuvelplein, Tilburg [32]; Spuiplein, Den Haag [30,34]; Schouwburgplein, Rotterdam [38]; Zaailand, Leeuwaarden [33]; Binnenrotte, Rotterdam [35], Grote Markt, Groningen [18], Bus Station Square, Enschede [17]; Brinkplein, Hengelo [11,12], Marie Heinekenplein, Amsterdam [28]). These perceptions are deeply rooted in Northern European colour perception schemata, attuned to the cold element of water and ice (Rijgersberg 1967, pp. 56-57), and bright colours thus have rather negative connotations in the cool Dutch climate with its frequent grey skies. For many people, thermal perception is thus not only influenced by the physical facts but also by the colour schemata they have in mind. A place with a cool ambiance will generally not be preferred in Dutch circumstances and is thus avoided more quickly than 'warmer' places.

But the bright colours also create typical problems in the Dutch climate – a classic example is the previously mentioned urban refurbishment project, 'ruimte voor ruimte', for the inner city of Groningen, where Barcelonan influence is seen in its bright, cheerful colours (Houben/ Mecanoo 2001, pp. 65, 67; de Josselin de Jong 2006, p. 213). These colours often do not suit the dampness of the Dutch climate, where algae develop quickly and dust particles and water leave traces, making the places or objects look neglected (fig. 3.14). Along with this, bright colours are quite reflective, so additional discomfort from glare can often arise, making a place even less attractive.

*Fig. 3.14 Brightly coloured bricks à la Barcelona in Groningen's inner city, subjected to Dutch weather*

## 3.7 Refined urban furniture

Site-specific or, as in Lyon, city-specific design lines of street furniture have often been developed. Great attention was devoted to very refined design and fancy materials such as soft wood, special ceramic tiles, light metal and others. These materials, bright colours and delicate construction were often derived from design principles for interior space. Street furniture of this type gave the public places an instant appeal, tactile quality and elegance (ten Cate 1990, p. 11). Unfortunately the Dutch climate was not taken into account when light and elegant street furniture was installed in outdoor space. Many materials proved to be unsuitable because they rot much quicker in the wet, cool Dutch climate. This particularly applies to materials such as light wood, certain types of concrete, terracotta, ceramic tiles, etc. As a result of weathering by wind and rain, much urban furniture quickly becomes unusable. The effects show quickly, often after less than five years: wooden seats are splintered, filigree steel starts to corrode, tiles crack etc. (fig. 3.15). These deficiencies considerably detract from the appearance and amenity value of a public space, and eventually lead to depreciation and under-use.

*Fig. 3.15 Barcelona-inspired street furniture rotting away in Groningen*

## 3.8 Specific conclusions and design recommendations

### Voids

Obviously the choice of the 'open void' concept is wrong in the Dutch context. Public criticism of the emptiness of squares is based not only on the users' personal impressions but also on the findings of behavioural science, environmental psychology and microclimatology.

People's preferences for places that offer sufficient prospects as well as refuge calls for a square design that offers both – an open space combined with points or lines of refuge elements. Refuges can be built or planted elements, as long as they are high enough to provide shelter. These elements can help make an empty square less agoraphobic, but they can also – ifintelligently designed – fulfil microclimatic functions. When the refuge elements are high enough they create shade in a square that might otherwise be uncomfortable to cross, or they can offer protection from rain. These elements can also provide wind protection, although the typical wind problems of squares can only be partially solved with refuge elements. Trees or hedges are most beneficial in this case, as more effective windbreaks than solid built elements (Boutet 1987, pp. 47-50). Of course, the large wind catchment of a wide square area can also be minimized by changing the surrounding building configuration to reduce the proportions of the square. This, however, is often difficult because many squares also need a critical size to accommodate markets, festivals, circuses etc. The problems close to large buildings with downwash winds can best be solved with changes in the architecture of the respective buildings such as lean-to roofs, canopies or protrusions to deflect the downwash at the foot of the buildings (Bottema 1993, pp. 110-118). The last typical wind problem is of wind from street canyons, and here, too, efforts should be made to deflect the wind – if necessary– from areas of intensive use or where people gather.

Seeing these measures cumulatively, to provide protection from unpleasant microclimates on a typical 'void' square, it might appear that making a large open square bioclimatically comfortable will always result in breaking the emptiness. Even so, the squares also do not have to be cluttered with elements and vegetation, as happened in the times of 'hippie design'. A good balance of prospect, open areas and 'refuge' – protective elements – is necessary to create a comfortable place.

### Hard places

The hard places cause problems with their heat and cold storage and conductivity of their materials, but the smoothness of many materials is also a problem in outdoor climates.

The simplest way to mitigate the temperature problems in hard places is to introduce vegetation that casts shade and buffers temperature peaks with extra evaporation (Olgyay 1963, pp. 74). But other softer materials should also be introduced because they have lower conductivity and their 'touch' is warm. This influence of soft materials on temperature perception has been proven in experiments where people were exposed to 'hard' rooms and 'softer' ones clad with wood and textiles. Although the temperatures were exactly the same in both environments, people estimated temperatures in the 'soft' environment to be higher than in the 'hard' one (Rohles 1980).

But the wetness of the Dutch climate should also be taken into account with respect to the slipperiness of hard and smooth materials. If hard materials cannot be avoided, such as in pavements and other heavily used elements, they should be rougher or coarser to reduce the risk of skidding.

### Cool and bright colours

The choice of colour in Dutch squares should focus less on cold and neutral colours, because the vault of the sky as an important part of the visual field in outdoor space often contains these cold grey tones. A 'warming' contrast of colours will make outdoor spaces visually more diverse, and thus more appealing to a larger group of people, because colour preferences differ strongly (Rijgersberg 1967, pp. 63-69).

The use of bright colours on the squares should be very carefully considered. On ground surfaces it should be avoided because the generally wet Dutch climate means that surfaces quickly become stained, and in the summer months glare can be annoying for users, especially when the surfaces are smooth. On the other hand, bright and warmer tones can substantially 'cheer up' an atmosphere and should hence be part of the total colour scheme. But the bright colours should rather be used as accentuations in facades or special elements that are not heavily used or exposed to strong weathering.

### Refined urban furniture

The elegant street furniture that was inspired by indoor furniture should be replaced by suitable outdoor furniture. Sturdy weatherproof outdoor furniture, however, need not be inelegant; it is more a question of smart design becoming aware of climatic circumstances and material durability. Furniture that lasts longer has a very strong impact on the liveability of public spaces.

A closer examination of the few public squares that are in fact cherished by the Dutch public, such as Onze Lieve Vrouwenplein in Maastricht [39,40], Brink in Deventer (fig. 3.16) [41,42] and Oude Markt in Enschede (fig. 3.17) [43,11] shows that these squares could actually be called built versions of the above-mentioned design recommendations. They are either rather small (Onze Lieve Vrouwenplein, Maastricht) or the space is deflected in shape (Brink, Deventer) or subdivided by a building such as an old-scale building or church (Brink, Deventer; Oude Markt, Enschede). Next to that, all the examples have a substantial number of trees along their margins, and some in the middle of the space which also break the emptiness and balance the hardness of the stone surfaces. The colours used in all these places are classic Dutch: mainly brick in warm tones with a few brighter accentuations in special elements.

*Fig. 3.16 Brink Square, Deventer*

*Fig. 3.17 Oude Markt, Enschede*

For better examples of climate-responsive outdoor places it is also valuable to 'backtrack' the setup of historical Dutch squares. This reveals that old squares were often well suited to climatic circumstances and offered sufficient elements for human comfort. The markets were either enclosed by buildings that offered protection by arcades in the ground floor or featured a town hall in the middle of the square that had an open market hall underneath (fig. 3.18), or they had protective elements for the perishable goods, which at the same time offered protection to the stallholders and visitors (Abrahamse 2007, p. 39). Typically, for example, the old fish stalls were made of stone (fig. 3.19) or there were groups or lines of trees shading the market square (fig. 3.20).

*Fig. 3.18 Dam square with town hall arcades, Amsterdam, around 1611 (Rijksmuseum Amsterdam)*

*Fig. 3.19 Fish stalls on the market in Brugues*

*Fig. 3.20 Grote Markt, Arnhem, 1838 (Gelders Archief)*

## 3.9 General conclusions

As argued in the previous pages, the general public's perception is closely related to their experience 'in situ' on public squares. Human "perceptual acuity" (Tuan 1974, pp. 77-79) or intuitive understanding of physical environments is generally a reliable indicator of environmental quality, in this case spatial properties in relation to microclimate.

From the examples of the four typologies of architectural minimalist public space discussed here, clearly a lack of understanding of the physical natural circumstances and especially of climate can be discerned among designers using the 'city as building' approach. The architectural approach to urban space especially has created problems through a supposed 'interiorness' which has proven deceptive. In a building, various technological devices (air conditioning etc.) can regulate the environment to create stable, homogenous conditions. But in public squares the urban climate with its very specific mechanisms is omnipresent. People in outdoor space experience this climate, and are unfortunately more often exposed to the unpleasant effects than to the beneficial ones. So it comes as no surprise that the architectural, minimalist square is heavily criticized by the general public.

However, what is surprising is that it is precisely this type of public space that is often valued by architecture, urban design and landscape architecture professionals. Many examples have been celebrated in professional organs as 'cutting edge', 'epoch-making' works – Schouwburgplein (Ibelings 2000, pp. 224-225) and Brinkplein in Hengelo (Van Dooren 1999, pp. 22-25) – or made it into the yearbooks of Dutch urban design like Spuiplein (Jaarboek landschapsarchitectuur en stedebouw 1998: 138-141), the bus station square in Enschede (Harsema et al.1998, pp. 142-143) as well as the 'ruimte voor ruimte' project in Groningen (Harsema et al. 1998, pp. 146-149) and won awards as did the Enschede square [44]. So there seems to be a wide gap between the perceptions of the general public and the design league at their desks.

This could be due to the fact that designers are too detached (Girot 2006, p. 95) from the places they design and from the climatic reality 'out there' in the public spaces they design. Another reason may be that they are still too preoccupied with design for visual effect alone and neglect basic physiological needs such as thermal comfort and the other senses (Pallasmaa 2005).

It may also be that the complex nature of urban microclimate processes is considered incomprehensible by designers, although some literature on the issues of microclimate and urban form is available (Brown and Gillespie 1995; RUROS project 2004; Givoni 1998; Boutet 1987, etc.). Yet there is a lack of simple design guidelines taking urban climate into account, and these guidelines will have to vary regionally. Within the temperate zone for example, it makes a great difference if a place is situated close to windy coastlines or lies more inland [45].

Most existing public design for urban climate is climate-responsive, mitigating the problematic effects of climate. What has not been investigated further or experimented with is an approach that actively includes the climate-an approach that could be coined ‘climate-revelatory’ (in line with the existing term ‘eco-revelatory’, see Landscape Journal special issue 1998). It has to be understood that the urban ‘voids’ are actually not empty, but full of climatic forces such as radiation patterns, airstreams and water/humidity. These climatic forces can be used – the sun to warm special places, shade to generate patterns, wind to move furniture or elements into or out of the wind, rainwater to induce the opening of rain protection elements etc. Another starting point for designing with climate could be the interaction of people and climatic forces where movable elements can be shifted to change microclimate. It could be fascinating to see the occurring ever-changing dynamic spatial patterns and what they reveal about the interplay of climatic forces and people. This can provide a special poetic experience, but also enforce the experience of nature in the city. In inner cities, climate is often the only perceivable ‘reminder’ of natural landscape when the soil and water have disappeared under pavements and into canal systems. And people actually appreciate these climate experiences and actively look for them, as has been proven by Swedish research (Eliasson et al. 2007, p 11-12).

The perceptions of people and the facts on Dutch squares discussed in this article clearly indicate that the ‘city as a building’ approach for public design needs revising. The landscape’s forces, and especially climate, still play an important role in the urban physical reality and people’s perception of places. Hence an alternative approach, ‘city as landscape’, seems more appropriate for urban design when the term ‘landscape’ is interpreted according to Alexander van Humboldt’s idea of landscape being “the total character of a region on earth” with all its natural and cultural processes (Humboldt 1845). The strength of Humboldt’s notion of ‘landscape’ lies in its inclusion of the natural and the human environment. An urban design paradigm of ‘city as landscape’ suggests a stronger respect for natural forces in the city, but also for the corresponding human perceptions. The ‘city as landscape’ idea suggests that designers should be made more aware of the natural forces within the city and the human habitat. ‘City as landscape’ also accentuates the characteristic of the city as something that changes and grows, and this aspect should also be reintroduced to the design of public spaces. Public places do not all have to be built ready to use; they can grow, along with the vegetation that structures them. As argued earlier, the general public appreciates the experience of nature in the form of vegetation, of water and climatic influence.

Within the ‘city as landscape’ approach, designing for the urban climate can take a prominent role – on the one hand to improve existing situations and adapt to future challenges by climate change, and on the other hand to create ‘climate-revelatory’ designs making ‘nature’ experienceable and legible in the urban human habitat. This, however, still requires more research: first, more fundamental empirical research on the relationships between human perception and microclimate, and second, research by design to supply the urban design community with comprehensible and easily applicable microclimate knowledge on the most dynamic and fascinating parameter of ‘landscape in the city’.

# 4

# Engrained experience

## – a comparison of microclimate perception schemata and microclimate measurements in Dutch urban squares

# Abstract

Acceptance of public spaces is often guided by perceptual schemata. Such schemata also seem to play a role in thermal comfort and microclimate experience. For climate-responsive design with a focus on thermal comfort it is important to acquire knowledge about these schemata. For this purpose, perceived and 'real' microclimate situations were compared for three Dutch urban squares. People were asked about their long-term microclimate perceptions, which resulted in 'cognitive microclimate maps'. These were compared with mapped microclimate data from measurements representing the common microclimate when people stay outdoors. The comparison revealed some unexpected low matches; people clearly overestimated the influence of the wind. Therefore, a second assumption was developed: that it is the more salient wind situations that become engrained in people's memory. A comparison using measurement data from windy days shows better matches. This suggests that these more salient situations play a role in the microclimate schemata that people develop about urban places. The consequences from this study for urban design are twofold. Firstly, urban design should address not only the 'real' problems, but, more prominently, the 'perceived' problems. Secondly, microclimate simulations addressing thermal comfort issues in urban spaces should focus on these perceived, salient situations.

*Published in International Journal of Biometeorology, 54(2), 2010, pp. 141-151*

# 4.1 Introduction

The sojourn quality of public spaces is very important for cities because these places influence the image and attractiveness of cities to a great extent (Hajer and Reijndorp 2001, p. 7-10; Schäfer 2002, p. 5). Often, the acceptance of public spaces depends on the mental 'images' or 'schemata' that people have developed about such places (Lang 1987, pp. 135- 144). In addition, the use of public spaces is also influenced by other factors, one of which is microclimate (Gehl 1987; Eliasson et al. 2007).

It seems that people are often comfortable with the microclimate that they encounter when they use outdoor spaces. This is due mostly to the fact that people use these spaces under rather mild micro-weather circumstances for sojourn, whereas in more extreme situations they try to avoid outdoor environments (Nikolopoulou et al. 2001; Eliasson et al. 2007). More clement weather circumstances are thus the most common situations that people experience in outdoor spaces, especially when they use it for sojourn.

However, there are hints that people are not always that comfortable with the microclimate situation. Public opinion of Dutch urban outdoor spaces indicates that people can be rather critical about microclimate in public spaces. They consider urban squares to be 'too windy', 'too sunny', etc., and it seems that these ideas often become rather manifest through their long-term experience (Lenzholzer 2008a; Coeterier 2000, p. 156). Indeed, also authors dealing with urban design seem to share similar impressions (Moughtin 1992, p. 87). This raises questions about the underlying mechanisms of long-term microclimate perception in space and how this relates to microclimate 'reality'- questions that have not yet been researched in a systematic way.

Actually, it is important to acquire deeper knowledge about these long-term perceptions or 'schemata' because they dominate behavioural responses and the acceptance or avoidance of places (Rapoport 1977, pp. 178-191; Lang 1987, pp. 135- 144). For urban designers, landscape architects and other professionals who deal with climate-responsive design, for instance, it is very important to know more about the fixed ideas that people have developed about the microclimate of a place since these can be taken into account in a better design of that place.

Furthermore, for microclimate simulations that are supposed to predict outdoor thermal comfort, it is also relevant to have a better informational basis on the microclimate situations that really count from the public's perspective. This can bring about results that are better fitted to people's experience.

The central aim of the study presented here is thus to gather more knowledge about the perceptual microclimate schemata that people develop, and how this relates to the common microclimate circumstances they encounter in urban public spaces.

The concept of perceptual schemata was developed in psychology and is often used in the behavioural sciences and environmental psychology. Schemata can be circumscribed as 'images' or 'models' of the environment that are strongly shaped by expectations (Neisser 1976, pp. 22, 43–46; Brewer and Treyens 1981; Pezdek et al. 1989). Extensive research into schemata has proven that human behaviour, including the avoidance or preference of places, events, etc., is guided by these schemata and, to a lesser degree, by the actual situation (Kaplan 1973; Lee 1973; Mark et al. 1999). However, there is a strong relationship between schemata and 'reality', because schemata depend on learning (Neisser 1976, p. 54). The learning processes that shape schemata about places also rely on interpretation of environmental 'cues', which are physical objects, events or circumstances in the real environment. Brunswick explains his concept of cues through his 'lens-model', where the cues are basically 'lenses' through which the environment is read or interpreted (Brunswik 1956; Ittelson et al. 1974).

Perceptual schemata, although being subject to change through learning, can linger for a long time—even when the 'real' situation has changed for a long time already. This can result in distorted perceptions and misinterpretations (Gould 1973; Bechtel 1997, pp. 67-70).

The approach of this study is essentially different from earlier approaches used to get to grips with outdoor thermal comfort. Most previous studies have focussed on the physical and physiological aspects of thermal comfort. Thermal comfort models have developed from simple models like 'vapour pressure' or 'equivalent temperature' towards models including human physiological processes and clothing degree, such as the Predicted Mean Vote (PMV) developed by Fanger (1970, pp. 19-43), which is commonly used for the prediction of indoor climate. For outdoor climate, other specific indices, such as the Physiologically Equivalent Temperature (Mayer and Höppe 1987; Mayer 1993) and COMFA (Brown and Gillespie 1995), have been developed. Most models have been designed to assess steady state energy balance conditions but more recent research tries to generate more dynamic models (Höppe 2002; Bruse 2005).

In addition, the experiential aspects of thermal comfort have gained more interest recently. Physiological models were compared to the actual thermal experience 'Actual Sensation Vote' (ASV), in a study by Nikolopoulou and colleagues (Nikolopoulou et al. 2001; Nikolopoulou and Steemers 2003) and later also by others within the European RUROS project (RUROS 2004; Nikolopoulou and Lykoudis 2006). The research on ASV focussed on the instantaneous experience of thermal comfort, and how this can influence the use of outdoor spaces. However, as mentioned earlier, research on schemata has shown that it is often the long-term experience of a place that influences people's use or avoidance of a place. Therefore it was considered necessary to study people's long-term microclimate experience.

The main question addressed in this study is thus: what kind of long-term schemata have people developed about microclimate and how do these relate to microclimatic 'reality'?

This issue will be researched according to the main assumption that people's microclimate schemata match with measurement data that represent the common microclimate situations that people experience in urban outdoor places.

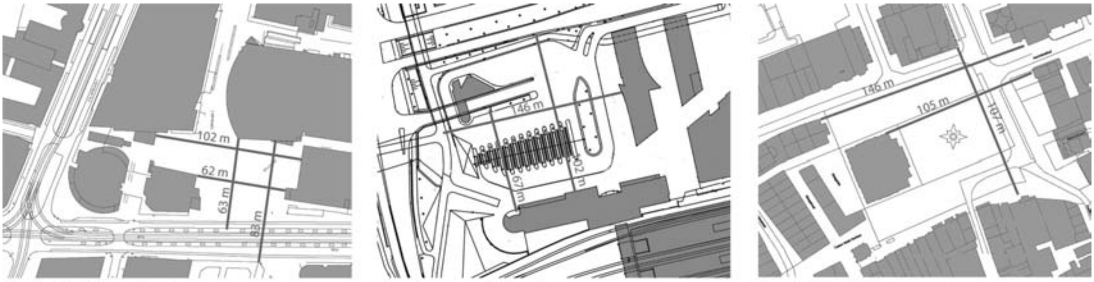
## 4.2 Methods

As a method a comparison of microclimate experience maps (belonging to the family of ‘cognitive maps’) and mapped results from microclimate measurements are used. The data for this study were derived from fieldwork in three Dutch urban squares, specifically the Spuiplein in Den Haag (the Hague), the Neckerspoel in Eindhoven and the Grote Markt in Groningen; the squares will be described in detail in the following sections. The method of generating cognitive maps and the methods used for measurements and mapping will then be explained.

### 4.2.1 Study squares

The squares chosen for the project share some characteristics, such as their size (around 100 m diameter; Fig. 4.1). However, in terms of surrounding building structure and function, the squares differ substantially (maps with further information on each square can be found in the Electronic Supplementary Material (ESM, see CD).

*Fig. 4.1 Case-study squares and their sizes*



Spuiplein, Den Haag

Neckerspoel, Eindhoven

Grote Markt, Groningen

*Spuiplein, the Hague*

The Hague (475,580 inhabitants) is the administrative centre of the country. Spuiplein Square (52°04’ N and 4° 19’ E, see Fig. 4.2) is situated in the city centre at a place where several pedestrian routes converge. It is also flanked by a main traffic artery. The square is restricted to pedestrian and bicycle traffic and is well connected to public transport. The square’s central area has an eye-catching feature in the summer: a field of about a hundred little fountain jets. Occasionally used for events such as music and sport festivals, most of the time throughout the year it is an open surface without significant activities.

*Fig. 4.2 Spuiplein, Den Haag (the Hague)*

*Neckerspoel, Eindhoven*

Eindhoven (210,860 inhabitants) is known as a centre of technological expertise, with the headquarters of Philips and the Technical University of Eindhoven. Neckerspoel Square (51°25'N and 5°28' E, see Fig. 4.3), which serves as the main bus terminus of the city, lies on the northern flank of the central railway station building. The main waiting area for passengers lies on the northern side of the station building, where some snack- and flower-shops can also be found. The square allows limited automobile traffic to serve for 'kiss and ride' and taxis on the eastern side; the rest of the square is reserved for buses. It should be noted that, just at the time when field-work started, a broad canopy was built to cover large parts of the waiting area, which is very relevant to the thermal comfort of passengers.

*Fig. 4.3 Neckerspoel, Eindhoven*

*Grote Markt, Groningen*

Groningen (180,908 inhabitants, of which 42,000 are students) is the administrative and cultural centre of the north-east of The Netherlands. The Grote Markt (53°13' N and 6°34' E, see Fig. 4.4) is the historical main market square of the city and lies in city centre as a part of a sequence of squares.
The square features two city landmarks: the Martini church tower, on the north eastern corner, and, on the opposite side, the old town hall. Motor traffic (buses and taxis only) is limited to the eastern side. The rest of the square is open to pedestrian and bicycle traffic and loading activities related to the market. The market is held on two mornings per week and fun-fairs or events take place a few times per year. But for the majority of the time the square is an open, rather unused place.

*Fig. 4.4 Grote Markt, Groningen*

### 4.2.2 Generation of cognitive microclimate maps

The method of cognitive mapping was identified as a main means to depict primary knowledge about space-related experience (McDonald and Pellegrino 1993; Kitchin 1994). Many cognitive map studies have been conducted on orientation and wayfinding, and on the distortions that occur in people's mental maps (Lynch 1960; Golledge 1992; Tversky 2003). Furthermore, other perceptions of the spatial environment were also studied through cognitive maps, for example Gould's preference mappings for living places in the United States (Gould 1973).

Researchers in the field describe a cognitive map as a spatially configured collection of “schemata” (Kaplan 1973, pp. 74–76; Neisser 1976, pp. 108–127; Kitchin 1996). This makes the cognitive map method a suitable means for the present study, which tries to relate schemata about microclimate experience to places. For this project, a method similar to Gould’s preference-mapping was applied, but on a smaller spatial scale. In this case, cognitive mapping was used to depict people’s long-term microclimate experience. This was accomplished by interviews with users of the squares who were already familiar with the place for a longer time.

To gather information about spatial thermal experience patterns, the interviewees were asked to describe locations within the square to which they assign one of several possible microclimate characteristics (see Table 4.1). This knowledge was generally expressed about the zones that interviewees knew due to their routines, so the cognitive map produced by an interviewee did not normally cover all parts of the square.

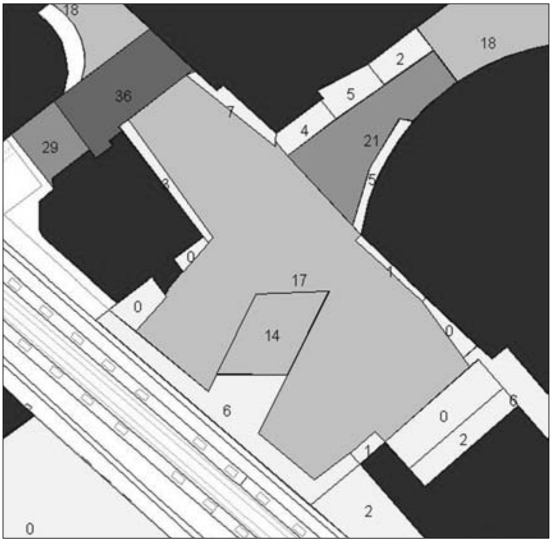
*Table 4.1 Possible reasons for interviewees’ microclimate comfort/ discomfort*

| **comfort** | **discomfort** |
|---|---|
| Wind comfortable | Too windy |
| Shade comfortable | Too shady |
| Sun comfortable | Too sunny |
| Good rain-protection | Bad rain-protection |
| Others comfortable | Others uncomfortable |

The maps from individual interviews were collated to generate collective cognitive maps on the different parameters, e.g. wind, sun, etc. (see Table 4.1), and were visualized through the GIS application ArcView. Since people did not differentiate their experiences between the different seasons, the maps show one general picture of their long-term experience. People described the zones to which they assigned the above-mentioned microclimate characteristics in a spatially distinct way (“in front of that building there”, “on that terrace”, etc.), so that the accumulated cognitive maps also show distinct zones (an example can be seen in Fig. 4.5, for a complete set of accumulated cognitive maps, see ESM on CD).

The series of interviews were conducted in parallel with a series of measurements taken during the outdoor seasons spring, summer and autumn in 2005 and 2006 on 4 days per season. Winter was left out because the research focusses on sojourn in public places and people in The Netherlands do not use public space for sojourn during winter. The interview series resulted in an average of 232 interviews and individual cognitive maps per square (Spuiplein, Den Haag: n=218, Neckerspoel, Eindhoven: n=254, Grote Markt, Groningen: n=223).

*Fig. 4.5 Example of an accumulated cognitive map: situation 'too windy' in Spuiplein, Den Haag*



### 4.2.3 Measurements and simulations

Measurements were made to gain insight into the common microclimate situations on site. A comparison of the average weather data from the measurement days taken at the nearby weather stations (www.wetteronline.de) with the long-term climate data from the Dutch Meteorological Institute KNMI (www.knmi/klimatologie/normalen1971-2000/per_station) shows that the days on which measurements took place were in general days with agreeable weather (with a few exceptions). On days when measurements took place, the averaged maximum air temperatures were higher than the maximum climate averages measured by KNMI, and the averaged wind speeds were lower than the climate averages recorded by KNMI. Specific comparisons can be seen in Table 4.2. Thus, it can be concluded that the measurement series represents common situations when people use outdoor spaces for sojourn.

A range of data was measured, but most important for the study presented here, which focusses on the parameters shown in Table 1, were wind speed and wind direction.

The instruments used were a cup-anemometer and a wind-vane. Measurements were collected on 4 days per each of the three outdoor seasons at 0900,1100,1300,1500 and 1700 hours. At these time points, measurements were taken at five spots in the square in the Hague and six spots in the squares in Eindhoven and Groningen (see maps with points in ESM under "general information"). The results were visualised using the GIS application ArcView and an example can be seen in Fig. 4.6. It was not possible to measure the other important microclimate parameter—sun and shadow patterns—in a sufficiently dense grid over the squares. As an alternative, the patterns of sun and shadow were simulated using the 3D-software SketchUp (http://sketchup.google.com/) for days in the middle of the three seasons (15 April, 15 July and 15 October). An example can be seen in Fig. 4.7.

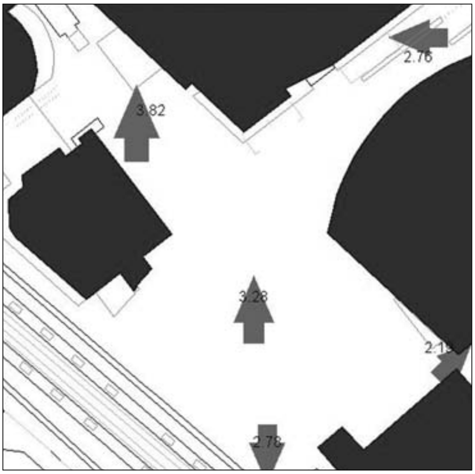


*Fig. 4.6 Example of map derived from wind measurements*

*Table 4.2 Comparison of measurement series weather data (from www.wetteronline.de) and general climate data from KNMI Dutch Meteorological Institute (www.knmi/ klimatologie/ normalen 1971–2000/per_station)*

| | **Den Haag** | | **Eindhoven** | | **Groningen** | |
|---|---|---|---|---|---|---|
| **air temperatures** | | | | | | |
| **season** | **max. airtemp. per meas. day wetteronline** | **average max. air temp. KNMI** | **max. airtemp. per meas. day wetteronline** | **average max. air temp. KNMI** | **max. airtemp. per meas. day wetteronline** | **average max. air temp. KNMI** |
| spring average | 19,68 | 12,40 | 16,38 | 13,80 | 12,80 | 12,60 |
| diff.meas. days/ KNMI | 7,28 | | 2,58 | | 0,20 | |
| summer average | 22,40 | 20,10 | 28,20 | 21,90 | 23,38 | 20,90 |
| diff.meas. days/ KNMI | 2,30 | | 6,30 | | 2,48 | |
| autumn average | 19,13 | 13,90 | 18,18 | 14,20 | 18,03 | 13,40 |
| diff.meas. days/ KNMI | 5,23 | | 3,98 | | 4,63 | |
| total diff. meas. days/KNMI | 4,93 | | 4,28 | | 2,43 | |

| **wind speeds** | | | | | | |
|---|---|---|---|---|---|---|
| **season** | **windsp.per meas. days wetteronline** | **average windsp. KNMI** | **windsp.per meas. days wetteronline** | **average windsp. KNMI** | **windsp.per meas. days wetteronline** | **average windsp. KNMI** |
| spring average | 3,19 | 5,20 | 3,10 | 4,30 | 4,79 | 4,60 |
| diff.meas. days/KNMI | -2,01 | | -1,20 | | 0,19 | |
| summer average | 2,08 | 4,60 | 4,03 | 3,70 | 4,38 | 3,90 |
| diff.meas. days/KNMI | -2,52 | | 0,33 | | 0,48 | |
| autumn average | 4,31 | 5,10 | 2,29 | 4,00 | 3,48 | 4,30 |
| diff.meas. days/KNMI | -0,80 | | -1,71 | | -0,83 | |
| total diff. meas. days/KNMI | -1,77 | | -0,86 | | -0,05 | |

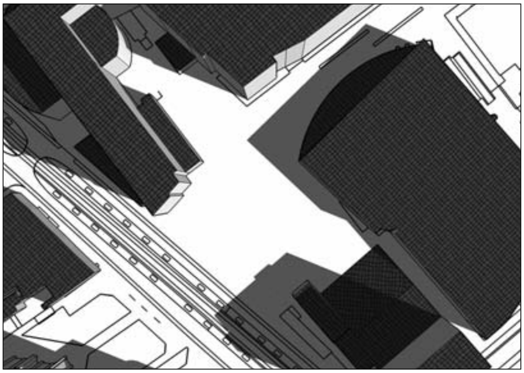


*Fig. 4.7 Example of shadow simulation map*

### 4.2.4 Comparison method

For each of the three squares, two main sets of maps were produced (also see ESM) for the comparisons:

1. maps with the user's long-term microclimate perceptions and reasons (wind, sun, shade, etc.)
2. maps showing the averages of measured wind data and the shadow simulations per season and time slot per day (0900,1100,1300,1500,1700 hours)

The accumulated cognitive maps, representing people's schemata, form the starting point of the comparisons. A value of 10% (of total votes) positive or negative evaluation on the microclimate perceptions per zone was taken as a threshold because lower values might be caused by incidences. All zones that received more than 10% of the votes were then compared to the measurement- and simulation-maps according to the criteria for matches and mismatches listed in Table 4.3.

*Table 4.3 Comparison matrix for experience data and measured/ simulated/observed data*

| Experience | Measured/ simulated/ observed |
|---|---|
| wind comfort/ discomfort | measured wind situation |
| sun and shadow comfort/discomfort | shadow simulations |
| Rain protection | assessed by observation of researcher |
| Other reasons | assessed by observation of researcher |

The wind-measurement data were assessed with the help of existing threshold values in order to define if the wind situation was comfortable or not. In the Dutch situation, other researchers have developed threshold values that range between 1.5 m/s (Tacken 1989) and 1.8 m/s for wind discomfort in stationary activities (Peutz and Associes 2000). Thus, values below 1.5 were considered to be comfortable in terms of wind, values between 1.5 and 1.8 were considered 'neutral' and above 1.8 m/s was considered to cause wind discomfort. To assess the adequacy of experiences regarding sun or shadow a comparison with the shadow simulation maps was made.

For rain protection and other reasons the evaluation had to be based on site observations by the researcher because data could not be measured for these parameters. For all parameters, counts were made of the number of matches between the cognitive maps and the measured, simulated and observed mapped data, and expressed in percentages. A value of 100% means that the experiences matched the measurement data in all cases, and 0% means that there were no matches between experienced and measured data.

## 4.3 Results and discussion

The comparison of the cognitive map zones (with votes above 10%) with the measured and simulated data is summarised in Table 4.4.

In the cognitive microclimate maps, a few microclimate parameter zones were considered to be comfortable in terms of 'sun'. The perceptions of 'sun comfortable' sometimes matched with the shadow simulations quite well, e.g. zone 12 in Groningen, which was sun-exposed for very long periods. Another point in the Groningen square, zone 20 (a popular outdoor terrace) was considered to be comfortable in terms of sun, but that was not supported well by the shadow simulations. Here, the reason for people feeling comfort was probably less related to actual sun exposition but rather to the friendly atmosphere of the place. Similar reasons seemed to go for a broad flight of sitting steps in the Hague, zone 4, which was also less sun exposed than people felt. But here also, many people get together and enjoy the atmosphere. Another reason might be the fact that the steps were used mostly during lunch breaks when the steps actually did have good sun-exposure.

In Eindhoven, two zones represented the experiences 'rain protection good' and 'rain protection bad'. From onsite observations it was possible to conclude that people's perceptions in those zones were adequate.

The most prominent parameter that got many votes in many zones was the perception 'too windy'. When the wind perceptions were compared to the averaged measurement data, remarkable discrepancies became apparent. There were several zones that got a high number of mentions in all three squares where the experience of 'too windy' and the averaged measurement data did not match. It seemed that people overestimated the influence of wind. Therefore, the initial assumption that peoples' perceptions match the common microclimate situations was not well supported. This finding raised the question: why is there such a great discrepancy? Is maybe a different mechanism influencing people's microclimate schemata with respect to wind?

To find indicative answers, an alternative assumption was developed, namely that more salient wind events influence people's microclimate schemata. To tentatively test this second assumption, the most windy days of the measurement series were chosen for a second comparison. The days selected were: Spuiplein, the Hague: 3 November 2005; Neckerspoel, Eindhoven: 14 July 2006; Grote Markt, Groningen: 24 May 2006. On these days

*Table 4.4 Results of comparisons of microclimate perception and averaged measurement/simulation/observation data*

| **Spuiplein, Den Haag** | | | **Neckerspoel, Eindhoven** | | | **Grote Markt, Groningen** | | |
|---|---|---|---|---|---|---|---|---|
| *Experienced "too windy"* | | | *Experienced "too windy"* | | | *Experienced "too windy"* | | |
| Zone nr. | votes (in %) | matching averaged measure data | Zone nr. | votes (in %) | matching averaged measure data | Zone nr. | votes (in %) | matching averaged measure data |
| 1 | 17 | 53% | 3 | 13 | 60% | 1 | 20 | 27% |
| 9 | 21 | 27% | 4 | 15 | 60% | 4 | 16 | 40% |
| 10 | 18 | 13% | 6 | 14 | 0% | 9 | 12 | 67% |
| 15 | 36 | 33% | 8 | 15 | 0% | 10 | 18 | 73% |
| 16 | 18 | 33% | 9 | 19 | 0% | 11 | 12 | 46% |
| 17 | 29 | 33% | | | | 22 | 12 | 73% |
| 18 | 14 | 47% | | | | 23 | 14 | 66% |
| | | | | | | 28 | 15 | 40% |
| | | | | | | 29 | 17 | 73% |
| *Experienced "comfortably sunny"* | | | | | | *Experienced "comfortably sunny"* | | |
| Zone nr. | votes (in %) | matching simulation data | | | | Zone nr. | votes (in %) | matching simulation data |
| 4 | 12 | 40% | | | | 12 | 13 | 67% |
| | | | | | | 20 | 11 | 30% |
| | | | *Experienced "rainprotection bad"* | | | | | |
| | | | Zone nr. | votes (in %) | matching with observations | | | |
| | | | 9 | 11 | 100% | | | |
| | | | *Experienced "rainprotection good"* | | | | | |
| | | | Zone nr. | votes (in %) | matching with observations | | | |
| | | | 8 | 15 | 100% | | | |

the wind speeds measured at the nearby weather stations were the highest amongst all the days on which the measurement series took place. The results of comparisons based on this second assumption are shown in Table 4.5.

The results indicated—and that is not surprising—that the public's cognitive maps for 'too windy' situations matched better with maps for stronger wind situations. Thus, the more salient wind situations seem to explain people's microclimate schemata better than the wind events that people encounter throughout the more common situations in public squares. The fact that these more memorable events constitute perception schemata is consistent with psychological theory (Brewer and Treyens 1981; Pezdek et al. 1989). More extreme microclimate situations are not only more memorable but, in case of wind, they are also negative experiences. This 'negativity bias' can be explained through the important physiological role of thermal comfort for survival. It is of vital importance for a human being to keep a high awareness and critical attitude towards the thermal environment because it might be life-threatening. In this context, the concept of "threat cues" (Ittelson et al. 1974,

p. 273) that give hints to a possibly threatening situation also explain this rather negative microclimate schema. Similar “negativity bias” cases have been discussed broadly in the psychological literature (Rozin and Royzman 2001; Baumeister et al. 2001).

*Table 4.5 Results of comparisons for wind perception and windy day measurement data*

| **Spuiplein, Den Haag** | | | **Neckerspoel, Eindhoven** | | | **Grote Markt, Groningen** | | |
|---|---|---|---|---|---|---|---|---|
| *Experienced “too windy”* | | | *Experienced “too windy”* | | | *Experienced “too windy”* | | |
| Zone nr. | votes (in %) | matching windy day data | Zone nr. | votes (in %) | matching windy day data | Zone nr. | votes (in %) | matching windy day data |
| 1 | 17 | 80% | 3 | 13 | 80% | 1 | 20 | 100% |
| 9 | 21 | 80% | 4 | 15 | 80% | 4 | 16 | 80% |
| 10 | 18 | 80% | 6 | 14 | 40% | 9 | 12 | 60% |
| 15 | 36 | 100% | 8 | 15 | 40% | 10 | 18 | 80% |
| 16 | 18 | 100% | 9 | 19 | 60% | 11 | 12 | 80% |
| 17 | 29 | 80% | | | | 22 | 12 | 100% |
| 18 | 14 | 80% | | | | 23 | 14 | 80% |
| | | | | | | 28 | 15 | 60% |
| | | | | | | 29 | 17 | 100% |

## 4.4 Conclusions

This study suggests that people have more salient wind situations engrained in their perception schemata on the microclimate in public outdoor places. This negativity bias in wind experience can lead to a rather negative image of a public place and can keep people from using it, which can in turn lead to general neglect of that place. Therefore, it is crucial for urban designers to take action to improve thermal comfort experience in public squares.

The implications for urban design disciplines in the improvement of the thermal comfort experience are twofold. Firstly, the negative schemata that people have often developed have to be counteracted with a strong positive stimulus. Such a kind of counter-stimulus could be, for instance, the creation of more wind-protected spots in places that are interpreted as ‘too windy’ by the public.

Secondly, when microclimate simulations are used in design projects for public spaces, a more “experience oriented” approach could be used for the choice of input data.

Currently, average climate data are often used, but according to the outcome of this study it might be advisable to simulate somewhat more extreme wind situations. Such simulations could form a better basis for design with respect to people’s comfort perception.

In addition, it might be advisable to conduct some indicative study on the public’s cognitive microclimate maps in the analysis phase preceding urban design projects. This information could be very valuable in cases where design should respond to people’s microclimate perceptions.

There are still many open questions requiring further research. Firstly, the question arises if people's microclimate schemata in The Netherlands can be transferred to other countries or climate zones. Therefore, it might be worthwhile conducting similar studies to the one described here in other climate zones. For the Dutch situation it would be specifically interesting to study microclimate perception in countries that currently have climate characteristics that can be expected for the future climate in The Netherlands due to climate change.

Although this study revealed some hints regarding people's microclimate schemata and their relationship with "reality", it is important to inquire further into the possible reasons for the remaining mismatches between experienced and measured  microclimate situations. Although salient situations explain people's experiences to some degree, still some cases could not be explained by the measured microclimatic situation in this study. Reasons for this could include the atmosphere, the spatial setup, the materialization of the square, or other parameters. Deeper inquiries into these parameters might yield more useful insights into people's microclimate experience in public spaces.

# 5

# Immersed in microclimatic space:

## Microclimate experience and perception of spatial configurations in Dutch squares

# Abstract

Thermal comfort forms an important factor for the usability and attractiveness of outdoor places. Recent research on thermal comfort indicates that next to physical parameters psychological factors are equally important. Yet, new knowledge on perceptions of microclimate in outdoor space that can serve as a basis for urban spatial design has been lacking. Therefore, this study tried to elucidate some of the essential factors influencing microclimate perceptions and how these perceptions relate to the typical microclimate of these spatial configurations. To achieve this, data on long-term spatial microclimate perception were acquired through interviews and microclimate measurements on three Dutch squares. The microclimate impressions of users were mapped and compiled in 'collective cognitive maps' for microclimate perceptions. Analysis of these maps showed that people assign certain microclimate characteristics to some spatial configurations. These spatial configurations were firstly compared to microclimate measurement results taken on the three squares. Secondly, they were analyzed according to their volumetric properties and expected microclimate properties. This revealed that people's microclimate perceptions were generally speaking quite accurate. Some useful spatial design guidelines that respond to people's microclimate perception could be concluded from this study.

*Published together with Koh, J. in Landscape and Urban Planning, 2010, 95, pp. 1-15*

## 5.1 Introduction

Public urban squares have become places of increasing importance in Dutch cities. Through the revival of urban centres many squares now accommodate leisure-oriented functions. To create urban places suitable for leisure it is vital to achieve sojourn quality for a substantial period of time throughout the outdoor seasons. This sojourn quality is affected by several parameters and microclimate and thermal comfort were identified as influential (Gehl 1987, Eliasson et al. 2007, Zacharias et al. 2001).

The concept of 'thermal comfort' was described by the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE) to be "that condition of mind which expresses satisfaction with the thermal environment" (1966). That implies that thermal perception is determined not only by physical and physiological factors, but also by psychological influences. This requires a thorough study of the 'mental' thermal comfort aspects, next to the physical and physiological aspects of human biometeorology. The latter have already gained much attention in research. For example, a broad range of sophisticated physical models for thermal comfort has been developed. This includes, for instance, the studies of Fanger (1970, pp. 19-43) on the Predicted Mean Vote, the studies of Mayer and Höppe on the Physiologically Equivalent Temperature (1987), the COMFA-formula by Brown and Gillespie (1995) or the latest research on a Universal Thermal Climate Index.

Only recently the concept of thermal comfort in outdoor space was also studied from a more psychologically oriented perspective. A broad study on thermal comfort experience was conducted by Nikolopoulou and others. The main attention on the 'actual sensation vote' (ASV) of thermal comfort where information on the momentary thermal comfort experience of people in outdoor places was obtained and compared to 'factual' measurement data that were taken parallel with the interviews. It resulted in the conclusion that classical thermal comfort indices might often be too 'strict' in their evaluation and that people in the outdoors show a greater tolerance to different thermal impacts than these indices suggest (Nikolopoulou and Steemers 2003, Nikolopoulou and Lykoudis 2006). Researchers like Knez and Thorsson investigated other psychological and cultural factors influencing outdoor thermal experience, such as the origin of people from different climate zones or their autobiography (Knez 2005, Knez and Thorsson 2006, Knez et al. 2009, Thorsson et al. 2007).

These studies, however, brought about findings that are not immediately useful for the urban designer. They focus on factors such as clothing degrees, length of outdoor stay, thermal history (the sequence of exposure to different thermal in- and outdoor conditions), personal origin, and weather conditions, that are not influenced by urban design interventions. Also, the concept of the momentary experience represented in the studies on the ASV cannot easily be translated into urban design due to its 'transient' nature and the fact that it does not relate to the spatial surroundings.

Urban design interventions are by their nature spatial, generally rather permanent and cannot easily respond to transient conditions. Therefore, our research project, of which a part is presented in this manuscript, was launched to generate more usable design guidelines for the design of urban squares for microclimate and thermal comfort. The following part deals with one of the main questions: how do people's longer term microclimate perceptions relate to the spatial configuration of urban outdoor spaces?

There is some Dutch literature pointing towards the existence of such relations (Coeterier 2000, Lenzholzer 2008a), but this was not researched systematically. Deduced from this we assume that people have microclimate 'images' or 'schemata' about urban places that relate to the spatial layout of place. Research on human environmental perception has shown that people develop these 'schemata' on a plethora of environmental circumstances. Schemata are a means to structure and quickly assess these environmental circumstances (Eysenck 2006, pp. 275-285; Lee 1973; Neisser 1976, pp. 51-78). Schemata are based on learning processes (Neisser 1976, pp. 51-78) and on the interpretation of many different stimuli. In the case of environmental perception this can be certain situations, spatial configurations, or spatial elements being "environmental cues" (Brunswik 1957; Gibson 1979). Schemata that have once been developed can have the tendency to show mismatches with the situation they are applied to because they tend to remain in people's minds for a long time even when the actual real situation has changed. This can lead to 'illusionary' misjudgments, distortions (Eysenck 2006, pp. 275-285) and sometimes behavioral maladaption (Bechtel 1997, pp. 67-70).

The fact that interpretations of environmental cues influence schemata is essential for this study, because we think that it is not only the microclimate itself that people perceive but also the spatial settings in which it happens. The phenomena of microclimate are not easily intelligible for people who are not familiar with the dynamic physics of microclimate and we assume that interpretation and schematization of visible environmental cues with respect to microclimate might therefore be a commonsense solution to get to grips with the complex invisible phenomenon of microclimate. Also, these spatial cues giving "hints" on the expected microclimate can consist of physical environments or objects which can serve as modifiers in urban design.

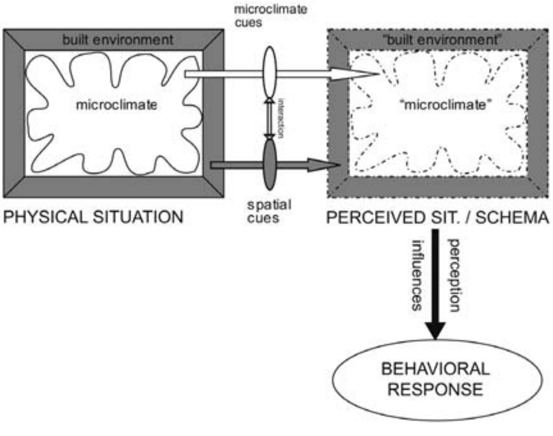


*Fig. 5.1. Conceptual model for research on microclimate perception in urban space.*

The underlying conceptual model of our research project is shown in Fig. 5.1 and is based on the theory on schemata and environmental cues that was discussed above. It differentiates the 'real' environment from the perceived environment and indicates that the 'real' urban environment influences local microclimate. It is assumed in this model that people in their perception of places also develop a schema on how certain urban configurations influence microclimate. This schema of the environment is represented in dashed lines. In the larger context of the research project the relation of real and perceived microclimate was also analyzed, indicated as "microclimate interpretation" in the diagram. The results of that corresponding analysis suggested that long-term microclimate schemata are influenced by rather salient microclimate situations (especially windy ones in the Dutch situation) that get engrained in a person's memory (Lenzholzer 2010). The analysis presented in this manuscript focuses on the spatial cues (highlighted in grey color in the conceptual model) in relation to the real microclimate.

Many potential cues exist in the urban realm that might influence microclimate perception. Especially the permanent spatial configurations of the built environment with their dimensions and proportions and objects might serve as visual cues for microclimate. These elements serving as cues are usually created or changed by urban design interventions. If it is possible to discover spatial cues that influence people's microclimate schemata for a place, then operable design guidelines can be identified to change the cues and eventually the schemata people have developed. For such design guidelines it is also important to know if people's perceptions are accurate or rather imagined because the urban design response would be different. In the first case, the true microclimate problems should be solved whereas in the second case measures that influence people's perceptions should be taken into consideration. To identify the existence of these cues (being spatial configurations) and examine their relationship with microclimate reality two questions were to be answered:

1. Are there spatial configurations that function as spatial cues for microclimate?
2. How are these spatial cues or configurations related to the real microclimate in these configurations?

## 5.2 The research

The two research questions were investigated with different methods. The first question on the spatial configurations functioning as cues was investigated through the analysis of cognitive maps based on user interviews. The second question was inquired through comparison of the spatial configurations (including the analysis of geometric properties) that were assigned certain microclimate properties with measurement results and microclimate literature.

The study was conducted on three Dutch squares (Spuiplein in Den Haag, Neckerspoel in Eindhoven and Grote Markt in Groningen). The squares share some similar characteristics such as their size in plan which ranges roughly around 100 m ×100 m (Fig. 4.1). But in terms of surrounding building structure and function the squares differ substantially.

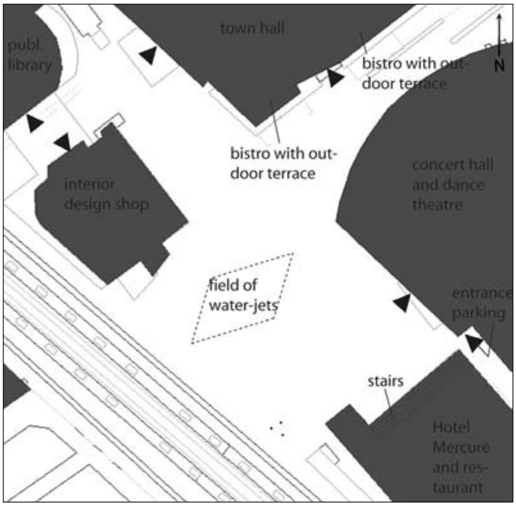


*Fig. 5.2. Map of functions and building entrances, Spuiplein.*

1. Spuiplein in Den Haag (52°04_N and 4°19_E, Figs. 4.2 and 5.2): Den Haag (475,580 inhabitants) is the administrative centre of the country. The Spuiplein square is situated in the city centre in a place where several pedestrian routes converge. It is also flanked by a main traffic artery. The square is restricted to pedestrian and bicycle traffic and well connected to public transport. The square's central area has an eye-catcher in the summer: a field of about a hundred little fountain jets. Occasionally used for events such as music and sport festivals, most of the time throughout the year it is just an open surface without significant activities.

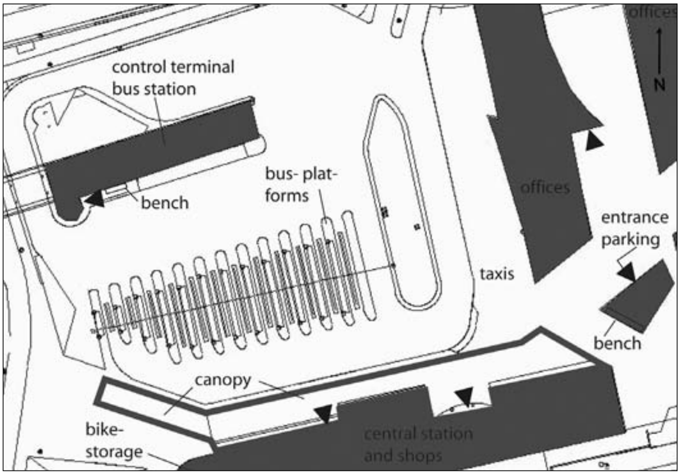


*Fig. 5.3. Map of functions and building entrances, Neckerspoel.*

2. Neckerspoel in Eindhoven (51°25_N and 5°28_E, Figs. 4.3 and 5.3): Eindhoven (210,860 inhabitants) is known as a centre of technological knowledge with the main branch of Philips and the Technical University of Eindhoven. The Neckerspoel square serves as the main bus terminal of the city and lies on the northern flank of the central railway station building. The main waiting area for the passengers lies on the northern side of the station building where also some snack- and flower shops can be found. The square allows limited automobile traffic to serve for ‘kiss and ride’ and taxis on the eastern side and the rest of the square is reserved for buses. It has to be mentioned that just when the field-work had started a broad canopy was built to cover large parts of the waiting area which is very relevant to thermal comfort of passengers.

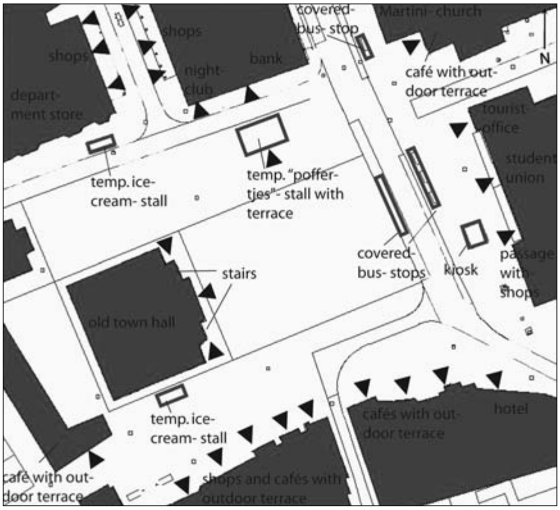


*Fig. 5.4. Map of functions and building entrances, Grote Markt.*

3. Grote Markt in Groningen (53°13_N and 6°34_E, Figs. 4.4 and 5.4): Groningen (180,908 inhabitants, of which 42,000 are students) is the administrative and cultural centre of the Northeast of The Netherlands. The Grote Markt is the historical main market square of the city and lies in the centre of the city as a part of a sequence of squares. The square features a landmark, the Martini church tower, on the North Eastern corner. Motor traffic (buses and taxis only) is limited to the eastern side. The rest of the square is open for pedestrian and bicycle traffic and loading activities related to the market. The market is held on two mornings per week and fun-fairs or events take place a few times per year. But for the majority of the time the square is an open, rather unused place.

### 5.2.1. Generation of cognitive maps and analysis

To answer the first research question, “are there spatial configurations that function as spatial cues for microclimate?”, we used cognitive maps. As discussed in Section 1, the interpretation of cues that get embedded in mental schemata, seems to be influential on microclimate experience. Neisser carried the concept of mental schemata further into the concept of cognitive maps. He describes a cognitive map as a spatially configured collection of schemata (Neisser 1976, pp. 108-127). Since then, this idea has been broadly used by researchers in the field of cognitive mapping (Golledge and Stimson 1997, pp. 225-266; Kitchin 1994, 1996; Mark et al. 1999; Tversky 2003). Because we were interested in the relation of the mental schemata that people had about a space, we considered cognitive mapping a promising research tool.

Many cognitive map researches focused on visual orientation, way-finding, mental representation of geographical maps and distance estimation, such as the landmark research of Lynch (1960) that has boosted research in the field (Kitchin 1996; Mark et al. 1999). But other, non-visual cues perceived through other senses are also described to be part of cognitive maps (Kitchin 1996, Mark et al. 1999, McDonald and Pellegrino 1993). Therefore we think that a cognitive map method is also usable to depict thermal or microclimate experience.

Probably, much of the research on visual orientation, wayfinding, mental representation of geographical maps and distance estimation was conducted because this was easily comparable with measurable reality and therefore distortions can easily be revealed. In our case, it is also possible to use more objective criteria derived from measurements and scientific knowledge to compare these cognitive maps with reality.

Several authors have identified cognitive maps as a helpful tool for planners and designers (Golledge and Stimson 1997, p. 239; Kitchin 1994; Kitchin et al. 1997) who normally have to address both with their interventions: the physical reality and people’s perceptions of it. Since we were trying to generate design recommendations for climate-responsive design we too consider the cognitive map as an aid to generate this basic design knowledge. For the reasons stated above we decided to use cognitive maps based on interviews with people in the study squares as a main tool in our research.

Given our interest in long-term experience or schemata of people we had to limit the sample group to the long-term users. Hence, the interviewees were asked if they know the square for a longer time already and come there on a regular basis. This way, groups such as tourists that visit the place only occasionally could be excluded from the sample group.

The series of interviews were taken during the outdoor seasons (spring, summer and autumn in 2005 and 2006) on 4 days per season. Winter was left out because people in The Netherlands generally do not use public space for sojourn during winter. There was an average amount of 232 interviews per square (Spuiplein, Den Haag: 218, Neckerspoel Eindhoven: 254, Grote Markt, Groningen: 223).

The method to generate the cognitive maps was a combination of two methods described in Golledge and Stimson (1997): a “base map with overlays” with a “word list”. We wanted to inquire people’s fine-grained microclimate experience of sub-zones in the squares rather than their impressions of the entire squares. This was done because we knew that within the squares different microclimates existed and we were interested in how far people perceive these differences. Therefore we asked people to identify the zones within the respective square that they perceived microclimatically comfortable or uncomfortable for sojourn from their long-term experience. This was recorded on a base map. Sometimes people marked the areas on the maps on the questionnaire sheet themselves. But the majority of people preferred to point out the areas on the squares and have the researcher draw them into the map. The fact that a square is rather easy to overlook was of great advantage for this. The place-related microclimate knowledge was only aired about the places which interviewees knew and about which they had an opinion. So the cognitive map generated from one interview was normally not covering all parts of the square. Additionally, people were asked to specify their comfort or discomfort experiences in the respective areas: were these experiences caused by wind speed, shadow, sun, rain protection or others (Table 5.1)? A combined application of the two methods can be seen in an example derived from an individual interview in Fig. 5.5.

*Table 5.1 Reasons for microclimate long-term experience.*

| **comfort** | **discomfort** |
|---|---|
| Wind comfortable | Too windy |
| Shade comfortable | Too shady |
| Sun comfortable | Too sunny |
| Good rain-protection | Bad rain-protection |
| Others comfortable | Others uncomfortable |

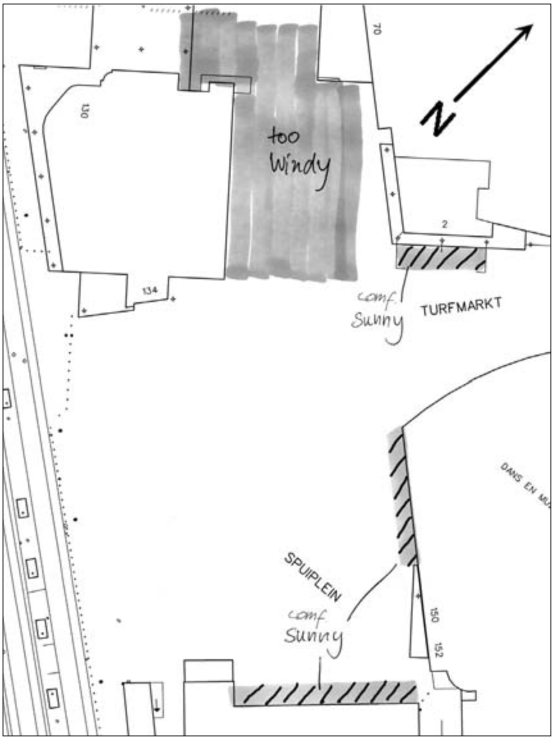


*Fig. 5.5. Example of an individual cognitive map derived from an interview.*

The individual cognitive maps showing the different zones and microclimate experiences were accumulated and overlaid in GIS. Generally, this was not problematic because borders of these zones mentioned were mostly quite distinct. This is because the areas that people pointed out had clear limitations due to spatial markers such as vertical delineations, height differences, roads or changes in the pavement. All the assessments by the users were subdivided according to the different reasons for the experiences (Table 5.1). They were added up in a database per zone per square and depicted in GIS (Appendices 1–3, upper two rows, see CD).

Since some areas showed zones that were perceived both comfortable and uncomfortable for certain reasons we needed to get a more generalized picture for further analyses. Therefore, we balanced all positive ('comfort') and negative ('discomfort') votes of the different microclimate experiences (wind, shade, sun, rain protection and 'other reasons') per sub-zone. This was done by assigning the sum of experiences causing discomfort (subdivided according to the reasons wind, shade, sun, rain protection and 'other reasons') with negative values and experiences causing comfort with positive values. After this balancing, the sub-zones that were perceived predominantly comfortable showed positive values and the ones perceived predominantly uncomfortable showed negative values (see examples Figs. 5.6 and 5.7, complete set of maps in Appendices 1–3, lower row, see CD).

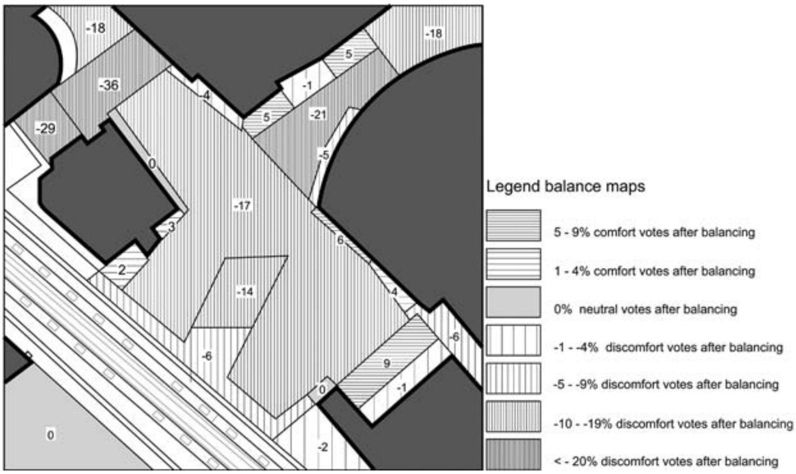


*Fig. 5.6. General cognitive map after balancing comfort and discomfort perceptions on 'wind' for Spuiplein, Den Haag.*

For further investigation we excluded sub-zones that got votes due to sub-zone specific incidental reasons. Hence, we selected only the sub-zones that got values >5% or <−5% of the balanced votes for the different microclimate parameters (wind, shade, sun, rain protection and 'other reasons').

During the interviews certain spatial configurations were mentioned quite often (e.g. "here in the central area of the square", "there in that street entrance", "here under the canopy") in relation to certain microclimate properties. Further visual assessment of the balance maps revealed that indeed certain types of areas, sometimes consisting of only one sub-zone, sometimes consisting of a cluster of them, were assigned rather similar microclimate

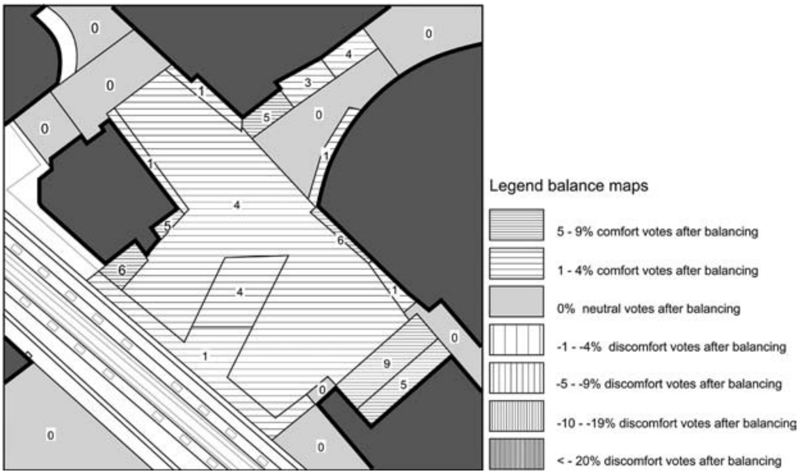


*Fig. 5.7. General cognitive map after balancing comfort and discomfort perceptions for 'sun' for Spuiplein, Den Haag.*

characteristics. Since this might reveal regularities in the ways how people interpret these spatial patterns in relation to microclimate, we analyzed these patterns further and identified a range of spatial types. These spatial types were identified for all the squares (overview in Appendix 4, see CD).

For a subsequent analysis of the spatial configuration types and their role as cues for microclimate the selection of spatial types was narrowed further because we believed that singular occurrence of a spatial configuration type of one square might be caused by local incidences. So the spatial configuration types that were selected for further analysis were the types reoccurring in the spatial type overview, either within one and the same square or in different squares (see Appendix 4 on CD).

From results of this selection we found answers to the first research question. There was indeed a range of spatial configuration types that were often assigned certain microclimate conditions in different places. The types were:

1. Places perceived to be 'too windy'
   (a) Central open square area;
   (b) foot of a tall building;
   (c) entrance of street canyon;
   (d) passage.
2. Places perceived to be 'comfortable in terms of wind'
   (a) Semi-enclosed area;
   (b) foot of a low building.
3. Places perceived to be 'comfortably sunny'
   (a) Semi-enclosed areas;
   (b) foot of a low building.

This list indicates that there were certain spatial configurations that serve as cues with respect to microclimate. It was interesting to notice that the question of scale was influential here and that the spatial types with some sense of enclosure were rated more positive than the spatial types like large open squares. The 'semi-enclosed places' for example scored with only positive balances. This preference for spatial enclosure, smaller scale places and avoidance of large open space is consistent with findings from other studies

(Carr et al. 1992; Gehl 1987). Reasons for such preference were predominantly sought in 'proxemics'—the body of knowledge on spatial patterns based on people's social interaction and the minimum distances related to those interactions (Gehl 1987; Hall 1966). Those studies, however, did not focus on the microclimate aspect.

### 5.2.2. Microclimate measurements

To acquire comparison data for validation of people's long-term experiences microclimate measurements were conducted parallel with the interview series. For each square we selected a range of points to depict different microclimate situations. The measurements were carried out on 4 days for each of the three outdoor seasons at 9, 11, 13, 15 and 17 h. At these times measurements were taken at five spots in the square in Den Haag and six spots in the squares in Eindhoven and Groningen (Figs. 5.8–10). Spot no. 6 in Eindhoven was eventually excluded from evaluations because too many measurements were taken between waiting buses that strongly distorted the microclimate in terms of shadows cast and wind deflected.

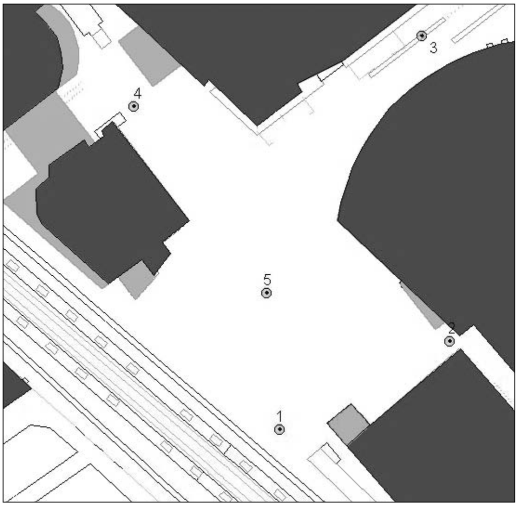


*Fig. 5.8. Map with measure point numbers, Spuiplein, Den Haag.*

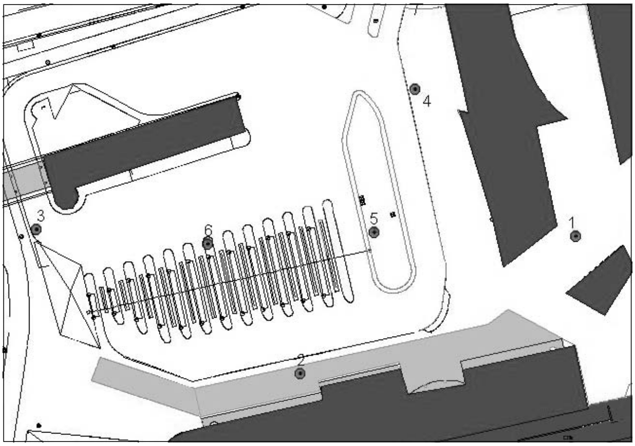


*Fig. 5.9. Map with measure point numbers, Neckerspoel, Eindhoven.*

*Fig. 5.10. Map with measure point numbers, Grote Markt, Groningen.*

The factors measured for thermal comfort were air temperature, globe temperature, short-wave radiation, wind speed and wind direction. The instruments used were a cup-anemometer with vane and a combined thermometer and hygrometer by Thies company, a globe-thermometer consisting of a black plastic ball with Pt100 and a pyranometer for short-wave radiation measurements by Kipp und Zonen company.

Not all of these measured parameters proved to be of importance to serve as a reference for microclimate experience. Wind speed was clearly the most important parameter in terms of people's experiences. For the analysis in this regard, the wind speeds of all the measurements taken were averaged per measurement point.

This average provides a picture of wind speeds over time which we consider most suitable to be compared with people's long-term wind experience.

Also the parameter 'sun' was important. Since the measurements did not show the very fine-grained and continuous changes of sun and shadow clearly enough, we decided to use shadow simulations. The patterns of sun and shadow were simulated through the 3D-software SketchUp for 3 days in the middle of the three outdoor seasons (15th of April, July and October). The evaluation of shadow patterns was based on percentages of time that shows in how many cases the places are indeed sunny. The results of these measurements and shadow simulations will be shown and discussed in the following in direct relation to people's spatial microclimate schemata.

### 5.2.3. Relating spatial cues for microclimate to microclimate reality

To address the second research question, "how are these spatial cues or configurations related to the microclimate in these configurations?", two steps were taken. Firstly, the microclimate schemata related to different configurations were compared with the results from the measurements in points that represent these configurations, respectively with the shadow simulations. The overview in Table 5.2 shows the average wind speeds in the different points that represent the spatial configuration types. In Eindhoven two measurement spots occurred to be situated either within an area that was not mentioned by people (point 3) or in a spatial type that occurred in Eindhoven only (under an overhang, point 2). Thus we decided that measurements from these points could not be considered for the comparisons.

*Table 5.2 Results of wind speed measurements*

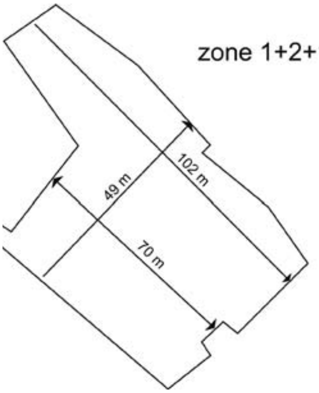
| **spatial configuration type** | **Den Haag meas. pt. numbers** | **Den Haag average wind speeds per type (m/s)** | **Eindhoven meas. pt. numbers** | **Eindhoven average wind speeds per type (m/s)** | **Groningen meas. pt. numbers** | **Groningen average wind speeds per type (m/s)** | **total average wind speeds per type (m/s)** |
|---|---|---|---|---|---|---|---|
| **too windy** | | | | | | | |
| a) central open square | 1 and 5 | 1.65 | 5 | 1.16 | 6 | 1.78 | 1.53 |
| b) foot of a tall building | \ | \ | 4 | 1.11 | 1 | 2.15 | 1.63 |
| c) entrance of street canyon | \ | \ | 1 | 2 | 4 and 5 | 1.9 | 1.95 |
| d) passage | 4 | 1.5 | \ | \ | \ | \ | 1.5 |
| **comfortable in terms of wind** | | | | | | | |
| a) semi- enclosed | 3 | 1.1 | \ | \ | 3 | 1.2 | 1.15 |
| b) foot of a lower building | 2 | 1.3 | \ | \ | 2 | 1.47 | 1.39 |

The shadow simulations (Appendix 5, see CD) were used to be compared with the impression that a place is ‘comfortably sunny’. Here we investigated if it is indeed ‘sunny’ in the places all the time, knowing that the shadow patterns change over the day. This is evaluated by counting the ‘matches’ for the different spatial types on the shadow-maps. That is, when a place lies in the sun the entire day, the match is 100% and when it is in the shade the entire day it is 0%. The results are shown in Table 5.3.

Additionally, an analysis of the geometric properties of the spatial configuration types was conducted because we consider this as crucial for the physical microclimate. The sizes of the spatial types on the ground as well as the heights of surrounding or adjacent buildings and resulting proportions (when applicable) were measured. Figs. 5.11 and 5.12, show two examples. For the complete overview of geometries, see Appendix 4 on CD. The resulting geometric properties were then analyzed on their probability to bring

*Table 5.3 Results of shadow-map analysis.*

| **spatial configuration type** | **Den Haag zone numbers** | **Den Haag match with shadow simulations** | **Eindhoven zone numbers** | **Eindhoven match with shadow simulations** | **Groningen zone numbers** | **Den Haag match with shadow simulations** | **total percentage match** |
|---|---|---|---|---|---|---|---|
| **comfortable in terms of sun** | | | | | | | |
| a) semi- enclosed | 4 | 53% | \ | \ | 12 | 80% | |
| a) semi- enclosed | 13 | 73% | \ | \ | 20 | 53% | |
| a) semi- enclosed | 21 | 53% | \ | \ | | | 62% |
| | | | | | | | |
| b) foot of a lower building | 7 | 73% | \ | \ | 25 | 40% | |
| b) foot of a lower building | | | \ | \ | 7 | 80% | |
| b) foot of a lower building | | | \ | \ | 5 | 73% | 66% |



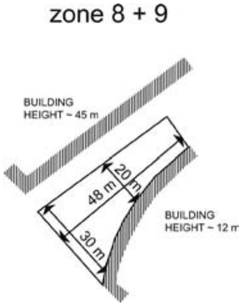


*Fig. 5.11. (left) Example of geometric analysis of 'open square surface' type.*

*Fig. 5.12. (right) Example of geometric analysis of 'street canyon entrance' type*

about the microclimate effects that people ascribe to them. This was done with help of existing literature on microclimate and microclimate modifiers.

The results of the two analyses—the local measurements and the descriptions from microclimate literature for each spatial type are discussed in the following:

**1. Places perceived to be 'too windy'**

*(a) Central open square surface (example Fig. 5.13):*

In all three squares these places are considered to be too windy. The measurement data also support for all three squares that these areas indeed show higher wind speeds than the areas considered comfortable in terms of wind (also see Table 5.2). In order to assess further if the central areas of squares are prone to be windy in general, we analyzed their spatial properties in detail. The proportions of a square are often expressed through the height/width ratio (H/W), as shown in Fig. 5.14. This ratio sets the height of the surrounding buildings in relation to the square's depth from 'wall to wall' of the square. That is, the lower the H/W ratio-value the wider are a square's proportions. We calculated this ratio for each square, also taking the different heights of surrounding boundaries into consideration. For the Spuiplein, Den Haag this results in the H/W ratio of 0.14, the Neckerspoel, Eindhoven in 0.11 and Grote Markt, Groningen in 0.10. When we compare this H/W ratio with the threshold value of H/W ratio 0.25 in other researches on urban wind dynamics (Bottema 1993, pp. 84-101; Oke 1987, pp. 266-67) we see that all three central areas of the squares are well below that threshold of 0.25. Squares that have an H/W ratio lower than 0.25 show typical wind flow patterns that bring flows of wind higher speeds ('isolated roughness flows') to the central areas of a central square area (Fig. 5.15). Considering the measurement results and the wind pattern research knowledge together we conclude that user's assessments of the open square areas to be 'windy' matched well and that people have developed a good comprehension of the wind climate in these types of places.

*Fig. 5.13. Impression of spatial cue type 'open square surface', Grote Markt, Groningen.*

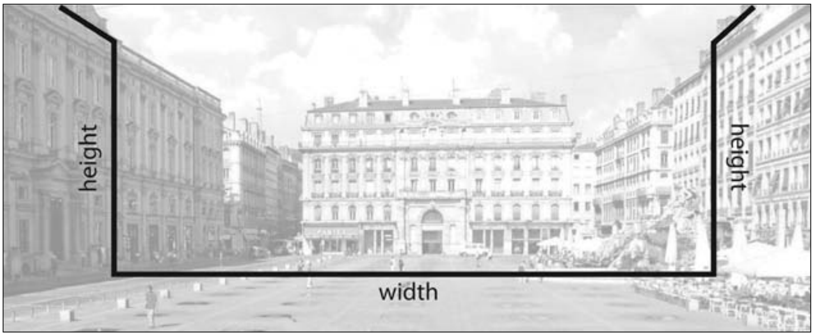


*Fig. 5.14. Diagram of height and width relation in a square.*

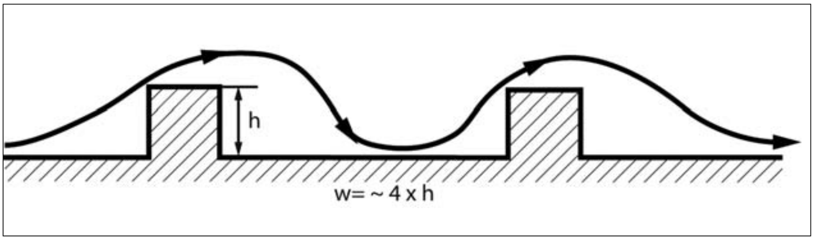


*Fig. 5.15. Typical wind pattern of 'isolated roughness flow' on squares withH/W atio smaller than 0.25, adapted from Oke, 1987, p. 267 with wind flows of higher speeds touching the square surface.*

*(b) Foot of a tall building (example Fig. 5.16):*

Here measurement data for two such places supported that these areas indeed had higher wind speeds than the areas considered comfortable in terms of wind (also see Table 5.2). The measurements in place no. 4 in Eindhoven, however, showed only marginally higher wind speeds than places that were considered comfortable in terms of wind. This might have to do with the wake of trees that suppress winds from the prevailing wind directions in that spot. But other studies give a clear support of people's impressions. The buildings described to be 'tall' in this case are at least 20 m high. The threshold of 20 m in height used here relates to the Dutch building recommendation (NEN-norm 8100, 2006), calling for a special wind-assessment procedure for building projects exceeding a total height of 20 m. Other research on wind patterns confirms that the areas around the feet of tall buildings are generally windy due to downwash effects (Bottema 1993, pp. 179-192; Littlefair et al. 2000, pp. 83-85). So we conclude that in this case the perception of people about these places being 'windy' is justified, both by the measurement results and other research. But the appropriateness of these evaluations can also be a function of the orientation of the buildings. The fact that these taller, towershaped buildings are often free-standing (due to building regulations) causes a wind exposition to many sides. So the chance that at one of their bases downwash effects occur is quite high.

*Fig. 5.16. Impression of spatial cue type 'foot of a tall building', Neckerspoel, Eindhoven.*

*(c) Entrance of street canyon (example Fig. 5. 17):*

The street entrance areas clearly show higher wind speeds in our measurements than areas that are perceived comfortable in terms of wind. These places are prone to higher wind speeds due to two causes. Firstly street canyons can work as wind funnels increasing wind speeds due to higher pressure 'venturi' effects (Bottema 1999; Johnson and Hunter 1999). Secondly, since a street canyon is normally open to two sides there is a great chance that winds are caught and channeled, especially when the street lies parallel with the predominant wind directions. Furthermore, angular building corners – as opposed to buildings with corners rounded off – are often more gusty due to corner pressure effects (see Fig. 5.18, Bottema, 1993, pp. 84-101, 1999). In this case people often correctly read the cues for wind climate in these types of spaces.

*Fig. 5.17. Impression of spatial cue type 'entrance of street canyon', Neckerspoel, Eindhoven.*

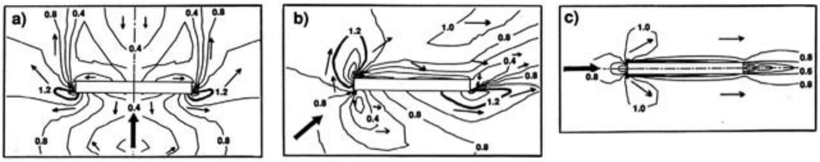


*Fig. 5.18. Plan view of corner pressure wind effects under different wind directions with indication of wind speed isolines (Bottema, 1993a,b, p. 85).*

*(d) Passage (example Fig. 5.19):*

Our measurements had only one point that is situated at the end of a passage-type of space, but the measurement results here were once more higher than the ones in the places considered comfortable in terms of wind. The geometry of this spatial type depends on the size of the overarching buildings. This configuration type's air flow physics show a clear tendency to act as strong wind funnels (Bottema 1993, pp. 84-101, Littlefair et al. 2000, pp. 83-85). Again, in this case people's interpretations are quite appropriate.

It might be worthwhile to remark that respondents often used a special term to describe the latter two kinds of configurations (entrance of street canyon and passage). They call these places "tochtgaten", literally translated: "draftholes". This word indicates that a climatic phenomenon ('draft') is associated to a spatial configuration ('hole').

*Fig. 5.19. Impression of spatial cue type 'passage', Spuiplein, Den Haag.*

### 2. Places perceived to be 'comfortable in terms of wind'

*(a) Semi-enclosed area (example Fig. 5.20):*

*Fig. 5.20. Impression of spatial cue type 'semi-enclosed area',Grote Markt, Groningen.*

All the measurements taken in these areas showed indeed lower wind speeds than the ones taken in places considered to be 'windy'. Semi-enclosed areas are usually surrounded by buildings or other vertical structures like wind-screens, walls or vegetation. A typical configuration for instance is the café terrace that is bounded by a building along one long side and laterally by wind-screens. These areas can offer wind protection from three sides.

For example, in case of the typical wind-screens of 1.5 m height that usually flank the café terraces a wake area is approximately 10–15 m (Fig. 5.21, Oke 1987, p. 243, Robinette and Mc Clennon 1983, pp. 21-39). Most café terraces do not exceed this width. Thus, there is only a small probability that the semi-enclosed areas get exposed to wind when it comes right from the front. So people's interpretation of this spatial cue 'semi-enclosed area' has a high probability to be suitable.

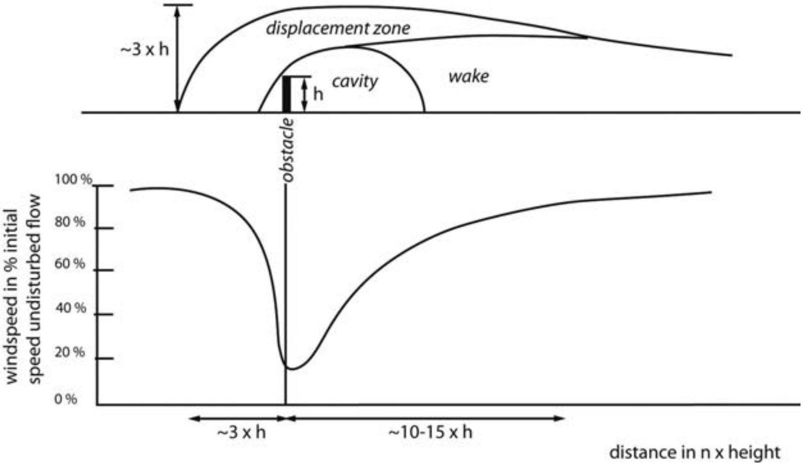


*Fig. 5.21. Dimensionless, proportional size of wake and wind speeds around a wind obstacle, adapted from Oke (1987), p. 243 and Robinette and Mc Clennon (1983), p.36*

*(b) Foot of lower buildings (example Fig. 5.22):*

The averaged measurements taken in two typical spots also show lower wind speeds than the places perceived 'windy'. However, point no. 2 in Groningen shows values that are somewhat higher than some points in areas that are perceived to be 'windy' (points 4 and 5 in Eindhoven). This type of place lies at the foot of buildings, without vertical screening elements on the side. The low buildings discussed here generally do not exceed 20 m in height. People's perception of a 'foot of a lower building' being comfortable in terms of wind can be supported by other researches, particularly for the cases where wind directions are perpendicular to the building. Generally, at the foot of lower buildings downwash effects that are associated with taller buildings do not occur.

Also the buildings provide wind protection for two directions as a part of the cavity area on the windward side or a wake area on the lee-side (also see Fig. 5.21, Oke 1987, p. 243; Robinette and Mc Clennon 1983, pp. 21-39). However, this strongly depends on the exposure of a building. Also our measurement data show that there can be bigger differences. So we assume that people's assessment might be based more on the reading of the spatial cues than the wind microclimate.

*Fig. 5.22. Impression of spatial cue type 'foot of lower building', Spuiplein, Den Haag.*

**3. Places perceived to be 'comfortably sunny'**

*(a) Semi-enclosed areas:*

The analysis of shadow simulations showed that matches of the perception 'sunny' over time varies between 50 and 80% for the different areas. The total match of 62% indicated that people's perceptions of sun tend to be only partly appropriate, with still a large percentage unexplained. Semi-enclosed areas are often surrounded by buildings or other vertical structures like wind-screens, walls or vegetation. These elements all cast shadows and it depends on the orientation of the surrounding vertical structures for this type to actually receive sun. People's perceptions do not seem to take this sufficiently into account in their judgments. It seems that in this case people's perception of 'comfort in terms of sun' is based more on the spatial setting than the real sun/shadow climate.

*(b) Foot of lower buildings:*

The analysis of shadow simulations showed that matches of the perception 'sunny' were between 40 and 80% for the different areas. The total match of 66% shows that people's perceptions of sun tend to be rather appropriate, with still quite a large percentage unexplained. This type of place is generally a longer strip along the foot of buildings that generally do not exceed 20 m in height. This type of space might sometimes have a good sun-exposure, and sometimes not, depending on the building orientations. However, the places that were pointed out by the interviewees were in most cases indeed spots with a relatively good sun-orientation. These types are often café terraces or some benches or other sittable elements are situated in these areas. In these places the perception of 'comfortable in terms of sun' might also have to do with the fact that people enjoy a friendly atmosphere and relate this to their overall feeling of comfort. Or people unconsciously choose sunny places to stay and thus base their experience on the time they spend in these sunny spots.

## 5.3 Conclusions

From this research we can conclude that there are significant correlations between people's interpretation of spatial configurations and microclimate perception and that people have developed schemata on microclimatic space.

Concerning the first research question, "are there spatial configurations that function as spatial cues for microclimate?", we can answer with yes. There are spatial configuration types that are associated with certain microclimate properties and this was in general supported by measured microclimate data. To summarize them again:

1. Places perceived to be 'too windy' are the central open square surfaces, foot areas of tall buildings, entrances of street canyons and passages.

2. Places perceived to be 'comfortable in terms of wind' and 'comfortably sunny' are semi-enclosed areas and areas at the foot of low buildings.

Concerning the second research question, "how are these spatial cues or configurations related to the microclimate in these configurations?", we conclude that many people have developed acuity for the general microclimate reality for most of the places. The cues seem to be a tool to 'quick-scan' spaces on most probable microclimate properties. However, there are exceptions. Not in all cases the interpretation of the spatial configuration on their expected microclimate was right. Especially the data on sun-exposure showed this. But these incidental misinterpretations are typical for the way that mental schemata work. They form a probabilistic approximation tool to assess the environment, risking that they do not always work appropriately. Yet, generally speaking, people's interpretations of spatial/visual cues for microclimate, most of the time, have a good relation to reality and misinterpretations of cues are more exception than rule. For design recommendations this means that design should focus on the real microclimate situations and that it would only in exceptional cases be recommendable to respond to 'imagined' microclimates.

Some practical recommendations can be derived from this study for the Dutch situation and for similar climate contexts in temperate maritime North Western Europe. We summarize them in the following by restating the conclusions for the spatial configurations and adding implications for urban design.

1. Open squares with a height/width ratio lower than 0.25 often are perceived windy and indeed tend to be windswept. Open places of this proportion should rather be avoided in urban design because higher wind speeds are likely to touch the square's floor area. When these square proportions are not avoidable, remedies should be provided: spatial objects such as screens, vegetation, larger sized furniture or pieces of art. These elements can at the same time help to mitigate wind impact and can act, for example, also as shadow devices. They break the scale of the open squares and offer the diversity of smaller scaled spots (e.g. the semi-enclosed areas) which tend to be preferred by the interviewees.
2. The foot areas of tall buildings are perceived uncomfortably windy and also often prove to be windy, indeed. Here, measures should be taken to

mitigate the downwash effects by either adding awnings or other wind deflecting devices or trying to keep the main public away from these zones.

3. Entrances of street canyons are perceived uncomfortably windy and can factually show strong wind effects. Here, measures to mitigate wind impact can be difficult, because winds come from several sides, just as the main traffic movements. This problem can better be solved by avoiding sojourn functions in these areas.
4. Passages which often are perceived uncomfortably windy, are in fact very problematic in terms of wind properties. This situation is difficult to solve. Wind is pushed in from various directions and all movements have to through the passages, too. The best remedy is to avoid sojourn functions here.
5. Semi-enclosed areas are perceived to be 'comfortable in terms of wind' and this perception is often correct. So it is advisable to create sufficient semi-enclosed places to offer wind protected spots through screens, walls, mounds, vegetation, etc.
6. The foot areas of lower buildings are also perceived 'comfortable in terms of wind' but this depends on the building orientations. In urban refurbishment or public design projects the erection of more buildings to create these kinds of zones is generally not possible. However, making better use of well-oriented areas by situating sojourn functions at the foot of existing buildings is often feasible.
7. Semi-enclosed areas are often considered to be 'comfortable in terms of sun'—even if they are factually not that sun exposed over the day. If possible, more semi-enclosed areas that have an ideal south facing sun exposition should be provided.
8. The foot area of lower buildings is seen to be comfortably sunny, but that depends on the building exposure. Here goes that public design can generally not influence the erection of more buildings to create these kinds of zones. However, making better use of these areas at the foot of existing buildings, and especially the ones with a good sun-orientation, by situating sojourn functions there is often possible.

Our study has shown that there are relations between people's spatial/visual and microclimate perceptions and based on this, we have given some hints for public space design. Our findings represent only a little fraction of the plethora of relations that are expected to exist between spatial and microclimate perceptions. It would be worthwhile, for instance, to conduct similar research as the one presented here in other places that have very different sizes or spatial setups. This might yield a refinement of our results or more spatial configuration types that are read as microclimate cues. Also, it would be interesting to study this in different climate zones because it is very likely that people develop different schemata and interpretations of spatial cues for microclimate depending on the regional climate. In general, more knowledge on people's microclimate perceptions will help to create more precise urban design guidelines for climatically comfortable urban outdoor spaces.

# 6

# Thermal experience and perception of the built environment in Dutch urban squares

# Abstract

Thermal comfort is an important issue to be considered in the design of urban squares. We hypothesized that thermal experience can be affected by the perception of spatial structures and materials, which can be influenced by urban design. We therefore conducted surveys in three Dutch squares (in Den Haag, Eindhoven and Groningen, respectively) to identify relationships between people's long-term thermal experience and three factors: width of the square, spatial openness and appearance of materials. The results reveal that all three factors have an influence: Dutch people experience thermal discomfort when spaces are 'too wide', 'too open' and consist of 'cold' materials.

*Article written together with Wulp, N.Y., accepted for publication in Journal of Urban Design*

## 6.1 Introduction

Public urban squares are vital for Dutch cities because they are gaining increasing importance as outdoor sojourn places (Dufour 1979; van Duren 1992; Reijndorp and Nio 1996; Montgomery 1997). The sojourn quality of urban open spaces can be improved through good design. Well-designed spaces contribute to the quality of life in a city by offering an alternative to indoor environments, by creating places for encounters between various groups of citizens and, in the Dutch situation, by offering space for events and entertainment (Oosterman 1992). Various parameters shape the sojourn quality of an urban open space, for instance physical and social comfort parameters (Gehl 1987; Carmona et al. 2003). However, many spaces are not designed to offer some degree of comfort, which results in their sub-optimal use or under-use.

The sojourn quality of an urban open space can be improved by taking thermal comfort issues into account in urban design. Thermal comfort is one of the aspects that have been identified as crucial factors for the use and acceptance of public spaces (Whyte 1980; Gehl 1987; Givoni 2003; Eliasson et al. 2007; Walton et al. 2007), especially when they are used for sojourn purposes (Thorsson et al. 2007a). In spite of this, the effects of thermal comfort on the quality of urban open spaces have frequently been neglected in design (Westerberg and Glaumann 1990/91; Zacharias et al. 2001; Thorsson 2004; Stathopoulos 2006). By addressing thermal comfort, urban design can enhance the sojourn quality of urban open spaces.

Thermal comfort is an important physiological state that keeps a living organism functioning well, but it is also described as “that condition of mind which expresses satisfaction with the thermal environment” by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE 1966). Thus, two aspects are involved in the concept of thermal comfort: a physiological and a psychological aspect.

Most of the early research in the field focused on purely physiological aspects of thermal comfort. A range of formulae and indices were developed to evaluate thermal comfort. In the first place they were developed to assess the climatic conditions in indoor environments. The most commonly used indices are the Standard Effective Temperature (SET) index and the Predicted Mean Vote (PMV) index; both were developed by Fanger (1970). The indices combine air temperature, air-movement conditions, relative humidity, mean radiant temperature and person-related factors, such as metabolism rates and clothing degree. Later, research was conducted on outdoor thermal comfort. Based on the indices developed for indoor climate, new, extensive indices – such as Out_SET* (Pickup and de Dear 1999) and PET (Mayer and Höppe 1987) – were developed for outdoor climate.

Although psychological issues play an important role in the concept of thermal comfort, they were long ignored, as was criticized first by Auliciems (1981) and later by others (Westerberg and Glaumann 1990/91; Nikolopoulou et al. 2001; Thorsson 2004). The psychological factors influencing thermal comfort have recently received more attention in research.

For instance, the momentary thermal ‘Actual Sensation Vote’ by those who visit public spaces has been investigated by means of interviews carried out throughout Europe and compared to the values derived from measurements. This revealed that people in different countries show a great variation in what they consider comfortable temperatures (Nikolopoulou and Steemers 2003; Nikolopoulou and Lykoudis 2006). Other studies on psychological issues that influence thermal experience have focused on the relation between thermal comfort and the personal make-up of those who visit open spaces, such as their places of origin and their cultural differences (Knez and Thorsson 2006; Thorsson et al. 2007a; Knez et al. 2009).

Unfortunately, all these studies concentrated on parameters that cannot be modulated through urban design. The results on ‘Actual Sensation Vote’ provide hints regarding an alternative thermal index and furnish no clues about the experience of the designed environment. The studies of Knez, Thorsson and colleagues focused on personal factors, which are undoubtedly important but cannot be addressed by urban design interventions. Thus, although research has shown that thermal comfort is influenced by psychological issues, there have been no clear recommendations for urban design on how to integrate psychological issues with regard to thermal comfort in order to improve the quality of urban open spaces.

Urban design offers a range of design parameters or principles that can influence the thermal perception of people in urban public spaces, such as the configuration of the spatial structure of spaces, their proportions and degrees of openness, their furnishings and the building materials used. Unfortunately, urban design moderators have thus far not been related to microclimatic properties. Knez and colleagues (2009) mentioned similar parameters in their conceptual model for outdoor place and weather assessment. They introduced a wide range of parameters for their model; some were grounded in empirical research they had conducted, while others awaited further study. The urban design moderators were amongst the latter.

Conversely, research on urban spatial perception does take such issues as the structure of spaces into account very broadly; unfortunately, however, they are not connected to microclimatic properties. For instance, the work of Herzog, Kaplan and Kaplan (1976, 1982) and Herzog (1992), and more recently that of Salingaros (2005), comprise elaborate studies of perception of urban spatial configurations. There is also a range of design guidelines that are based not on empirical research but on studies of traditions in urban design and visual approaches. The classic example is Sitte’s study on the proportions and sizes of traditional European squares (1889). This was followed by Blumenfeld’s considerations (1954), Christopher Alexander’s pattern language (1977), Ashihara’s contemplations (1981), Moughtin’s reflections (1992) and, more recently, Loidl and Bernard’s ideas on the spatial proportions of outdoor space (2003). In this literature, considerations of the microclimate effects of these proportions are also very sparse. It is not clear why this issue has received so little attention. It might be attributable to the ocularcentric tradition in urban design and the fact that the effects on other senses (such as the thermal sense) have not been considered. Another reason might be that design recommendations on microclimate issues are sparse, scattered and not easily accessible.

In the present research, we posited that there is a relation between spatial setting perceptions and thermal comfort, as Knez and colleagues recently propounded. Our conjecture was inspired by a phenomenological, multisensory approach to thermal perception. In line with Brunswik's theory of 'distal cues' (Brunswik 1956, 1957), we postulated that people interpret visual cues in the environment with respect to microclimate. Literature supports the hypothesis that several variables in the urban environment are distal cues for thermal perception, and it was in accordance with this that we formulated our research questions.

First, there seems to be a relation between the width of outdoor spaces and a perceived microclimate. Moughtin (1992) and Confurius (1997), for example, speak of 'windswept' wide squares. However, this was not based on empirical evidence. Therefore, our first research question was: 'Does the width of a square influence the thermal experience of Dutch people?'

Second, in a quick scan of people's opinions on Dutch public spaces, Lenzholzer (2008) observed that many people assign microclimate characteristics to spaces. A frequent complaint was that squares were cold, open, empty spaces. However, whether these relations between the openness of a space and thermal discomfort actually exist has not been rigorously studied. Therefore, our second research question was: 'Does the openness of a square influence the thermal experience of Dutch people?'

Finally, research by Rohles (1980) suggests that the materialization or finishing of a space is influential. Rohles revealed that the appearance of the environment has an effect on people's thermal perceptions. He tested the thermal experience of people in indoor environments with various types of decoration and finishes. The results showed that people who were surrounded with 'warm' materials – such as wood, textiles, etc. – perceived temperatures as being warmer than people who were surrounded by 'cold' materials. We therefore assumed that materials play a role in thermal experience also in outdoor spaces. The third research question was thus: 'Do the materials in the outdoor space appear cold or warm to Dutch people, and how does this relate to thermal comfort?' To this we added a sub-question that is very important for the choice of materials in urban design: 'Which materials do people actually perceive as having a warm or a cold appearance?'

The results of this study into the influence of proportions of spaces, their degree of openness and their materialization on thermal experience have led to conclusions that will be useful to landscape architects and urban designers, because design interventions can directly influence these parameters.

## 6.2 Methods

This study was mainly based on interviews with visitors to three Dutch squares about their long-term thermal comfort experience and spatial perception. Parallel with the interviews, the microclimate parameters that influence physiological thermal sensation were measured. The fieldwork was conducted on four spring days, four summer days and four autumn days, and each had the typical season-specific weather conditions in which people tend to spend time outdoors. The interviews were held in three squares, namely Spuiplein (Den Haag), Neckerspoel (Eindhoven) and Grote Markt (Groningen) (see fig. 4.1).

### 6.2.1 The squares

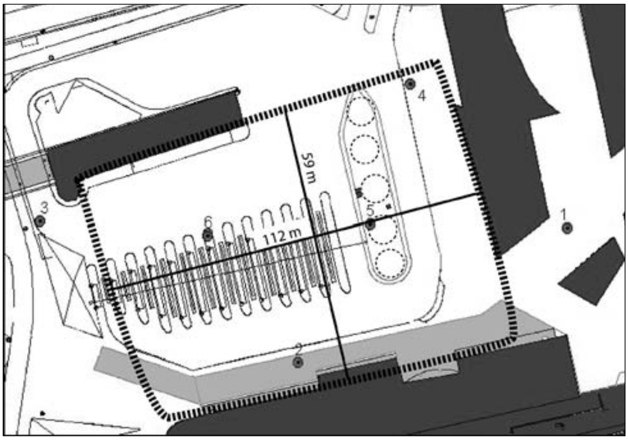
The three squares are relatively similar in size, but differ in most other ways. Spuiplein (52°04' N and 4°19' E; see fig. 4.2 and 5.2) is situated in the centre of Den Haag. Several pedestrian routes converge at the square, which is crossed by a main traffic artery. The eastern part of the square is restricted to pedestrians and cyclists, and is well connected to the public transport system. The central area of the square has a real eye-catcher in the summer: about a hundred little fountains spurting water into the air. Various weekend events and festivals are held in the square roughly once a month throughout the summer.

Neckerspoel (51°25'N and 5°28' E; see fig. 4.3 and 5.3) lies on the northern side of the central railway station and serves as Eindhoven's main bus terminal. The main waiting area for passengers is on the northern side of the railway building, where there are some snack bars and flower shops. There is limited automobile access to the square: taxis and private vehicles doing a 'kiss and ride' (picking up and dropping off passengers) are allowed on the eastern side. The rest of the square is reserved for buses.

Grote Markt (53°13' N and 6°34' E; see fig. 4.4 and 5.4) is Groningen's historic main market square. It lies in the centre of the city and forms part of a sequence of squares. The square is dominated by the Martini church tower, which is situated on the square's north-eastern corner. Vehicle access (buses and taxis only) is limited to the eastern side. The rest of the square is open to pedestrian and bicycle traffic and to deliveries to the market. Street markets are held in the square two mornings a week.

The squares differ concerning their fitness for longer sojourns. This fitness can also be expressed by 'sittability' (Whyte 1981). In Spuiplein, there are a few outdoor cafés where people can sit and a broad flight of stairs on which they can settle. There are no seats or other elements that can be used as seating in the centre of the square. Neckerspoel has numerous benches opposite the bus platforms for people who are waiting for their buses. Sittability in Grote Markt is restricted to the borders: the café terraces on the southern side of the square and the terrace of the *poffertjes* (tiny pancakes) kiosk provide many seats. The bus stops also have benches, and some people sit on the stairs to the old town hall. There are no seats or other elements in the central area that can be sat upon.

The squares also have differences in spatial structure and other parameters that might influence thermal comfort experiences. For example, they differ in terms of proportions. The proportions of a square are often expressed in terms of the height/width ratio (H/W). This ratio sets the height of the surrounding buildings in relation to the square's diameter (the surrounding buildings measured from wall to wall). The lower the H/W value of a square, the wider its proportions. The classic H/W ratio concept is based on a truly 'ideal' distribution of spatial boundaries. This distribution is only found in a square where the surrounding buildings are similar in height and the openings in the square are small and few. This is normally not the case: most squares have rather amorphous shapes, adjacent sub-spaces and large openings. The larger the size and the larger the number of these openings in a square's boundaries, the stronger the impression of wide proportions. The three squares studied have adjacent sub-spaces and openings of varying sizes. However, all three have a central area that has a more or less rectangular geometry and for which an average width can be described (see fig. 6.1-3).



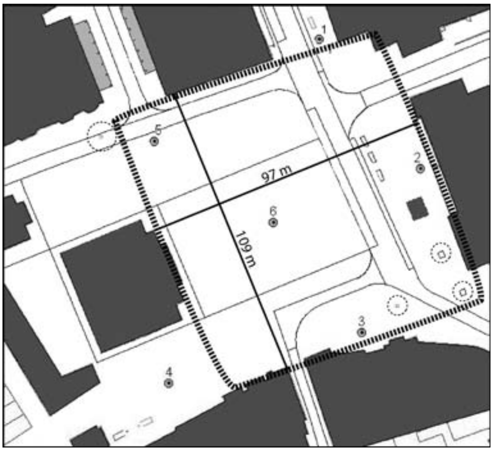


*Fig. 6.1 (upper left) Microclimate measurement points and central area boundaries of Spuiplein, Den Haag*

*Fig. 6.2 (upper right) Microclimate measurement points and central area boundaries of Neckerspoel, Eindhoven*

*Fig. 6.3 (lower) Microclimate measurement points and central area boundaries of Grote Markt, Groningen*

*Fig. 6.4 Analysis of circumference on open and closed boundary lengths and heights, Spuiplein, Den Haag*

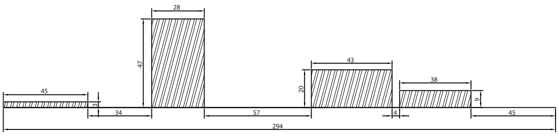


*Fig. 6.5 Analysis of circumference on open and closed boundary lengths and heights, Neckerspoel, Eindhoven*

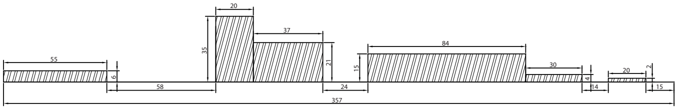
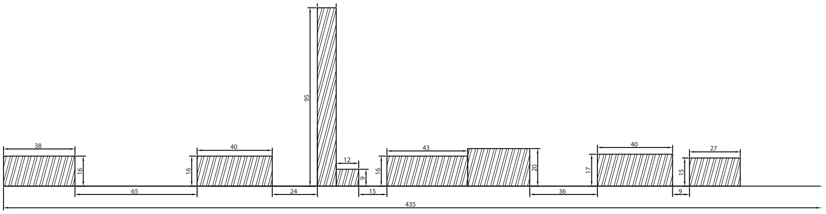


*Fig. 6.6 Analysis of circumference on open and closed boundary lengths and heights, Grote Markt, Groningen*



To establish the average height of the surrounding buildings, we applied a precise method that takes into account all the various heights and lengths of the vertical boundaries and the length of open boundaries. The entire perimeter of the boundary of the main space of each square was analysed according to the distribution of open boundaries and the lengths of vertical boundaries (mainly buildings and walls). The distribution was expressed in % of the total perimeter. The boundaries were individually analysed for their height (see figures 6.4-6).

This boundary height (height factor '0' was used for the open boundaries) was multiplied by the % factor for their length in relation to the whole perimeter. Adding up the boundary heights that had been set in relation to the total and dividing them by 100 resulted in a precise 'average height', which was then divided by the average width of the main space. This method resulted in an H/W ratio that took into account both the buildings' lengths and the open boundaries according to their relation to the whole perimeter. This in turn resulted in the H/W ratio of 0.14 for Spuiplein, 0.11 for Neckerspoel and 0.10 for Grote Markt.

Although all three squares have a rather high degree of openness (i.e. they are not equipped with much furniture, vegetation, etc.), there are differences. Spuiplein and Neckerspoel are subdivided to some extent by trees: young trees line the road bordering the south-western edge of Spuiplein, while on Neckerspoel a group of mid-sized trees divides the platform area in the eastern part of the bus terminal from the taxi stand (see fig. 6.1-3).

The squares also differ in terms of materials. Spuiplein is surrounded by buildings made of different materials. The most prominent is the town hall cum library and interior design shop, which are clad in white enamel panels. The concert hall cum dance theatre is covered with black reflecting glass, while Hotel Mercure has a facade of blue tiles. The western side of the square is bounded by the brick wall of the Nieuwe Kerk churchyard. The square's pavement consists of dark grey Belgian bluestone. Neckerspoel is bounded on its southern side by the station building, which is clad in beige and blue tiles; in front of the building is a glass canopy supported by steel poles. The western side of the square is bounded by earth mounds, and the northern side by a glass and concrete building that is built into the bus viaduct. On the eastern side there is a tall building that features a steel and glass facade, with some of the details in wood. Above the bus platforms is a tensile steel structure bearing the arrivals/departures screens. The pavement in the pedestrian areas consists of concrete tiles, while a few details in the bus platforms are made of cor-ten steel and asphalt. A great variety of materials can be seen in and around Grote Markt in Groningen. The southern side of the square is bordered by old brick houses, the northern side by modern buildings made of concrete and featuring quite large areas of glass, and the eastern side by modern buildings made of concrete and brick. The two historical landmarks – Martini church and the old town hall – are built predominantly of sandstone, with some parts in brick. The square's pavement is also varied: the central area is paved in grey granite, the pedestrian areas surrounding it are paved in red brick and the roads are asphalted.

### 6.2.2 The fieldwork

Structured interviews were conducted with respondents who were well-acquainted with the square; the population represented was thus predominantly local. Tourists, for example, were excluded from the survey. A test run showed that it was impossible for respondents to directly relate their feeling of long-term thermal comfort to the spatial structure and materiality of a square. Independent questions were therefore asked about respondents' long-term thermal comfort or discomfort in the sub-zones and places in the square, and about their perception of spatial and material parameters (see the questionnaire in fig. 6.7).

In total, 695 structured interviews were conducted (Spuiplein: 218; Neckerspoel 254; Grote Markt: 223). The respondents were chosen randomly; both sexes and all age groups (apart from children) were equally represented. The non-response rate was quite low: 15 people in Spuiplein, 34 in Neckerspoel and 21 in Grote Markt were not willing to answer the questions or for various reasons could not finish the interview.

The dependent variable was the respondents' thermal comfort or discomfort experience, which was calculated by adding the number of comfortable zones mentioned minus the number of uncomfortable zones mentioned ('balance comfort experience'). Per square, the respondents identified a maximum number of zones: 25 zones in Spuiplein, 17 in Neckerspoel and 31 in Grote Markt. Not every respondent gave his or her opinion about each zone. Most respondents judged a limited number of zones that they knew from, for example, their daily routines.

The independent variables were the perception of width, openness, and the warm or cold appearance of the materials. These variables were assessed by means of three main questions and the sub-questions (see under 'perception of the space' in fig. 6.7).

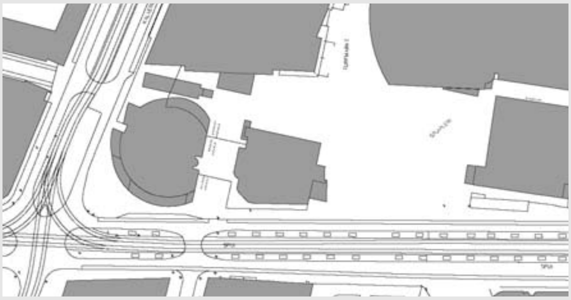
*Fig. 6.7 Questionnaire*

**A. Observations**

Description of subject: time, location in space, wind direction (locate both on map)

*Circle where appropriate*

- Age group: child, teenager,20-29, 30-39, 40-49, 50-59, 60-69, >70
- Sex: male, female
- Clothing - upper body: sleeveless, short sleeves, long sleeves
  - lower body: short trousers/skirt, long trousers/skirt
  - vest/cardigan, jacket, raincoat, overcoat,
- Accessories: sunglasses, cap/hat, umbrella
- Food/drink consumption: cold drink, hot drink, cold food, warm food
- Interviewee presently stays in sunlight: Yes, No



**B. Questions**

*Intro:* We are doing research about thermal comfort in this public space and how this is related to the spatial structure of this space. Do you know this square for longer and can we ask you a few questions about this?

*Thermal comfort, momentary:*

- At the moment, do you find it:

| | | | | |
|---|---|---|---|---|
| very cold | cool | neither cool nor warm | warm | very hot |

- What do you think of the sun at this moment?

| | | |
|---|---|---|
| I'd prefer more | OK | too much sun |

- What do you think of the wind at this moment?

| | | | | |
|---|---|---|---|---|
| stale | little wind | OK | windy | too much wind |

- Are you feeling comfortable?

| | |
|---|---|
| yes | no |

*Thermal comfort, long term:*
- Can you mark zones of thermal comfort and discomfort in the square or on the map that you experience over longer time?
- Can you explain why you find it comfortable or not in these zones, in terms of sun, wind, shade, rain protection, etc.?

*Perception of the space:*
- Do you think the proportions of this square are:

| | | |
|---|---|---|
| too wide | good | too narrow |

- What do you think about the openness of this square? (If people don't understand, explain that openness means that there are not many elements on the square, e.g. furniture, trees, etc.)

| | | |
|---|---|---|
| I like it | No opinion | I do not like it |

- If 'proportions/openness' is answered negatively: What would you change in the spatial structure?
- Which of the materials used in this square, in the facades, furniture, the floor, etc. in your opinion have a warm and which have a cold appearance? Where do you see these?

**Programming:**
Do you think the activities in this square (market, events, circulation, etc.) are appropriate?

| | | |
|---|---|---|
| yes | no opinion | no |

- As a possible addition: What other functions would you prefer or would you exclude some activities?

**General:**
- Why have you come here? .....................................................................
- Were you outdoors 5 minutes ago? a) yes b) no
- How frequently do you use the space? a) per day.... b) per week.... c) per month... d) per year.......
- Other remarks

The microclimate measurement series was conducted in order to gain insight into the common microclimate situations at each site and as a possible reference for the results of the interviews. The measurements included air temperature, globe temperature, short-wave radiation, wind speed and wind direction. The instruments used were a cup anemometer and a combined thermometer and hygrometer manufactured by Thies Company, a globe thermometer consisting of a black plastic ball with Pt100, and a pyranometer for short-wave radiation measurements manufactured by Kipp und Zonen Company. Measurements were taken at 09.00, 11.00, 13.00, 15.00 and 17.00 on each of the fieldwork days at five spots in Spuiplein and at six spots in Neckerspoel and in Grote Markt (see point numbers in fig. 6.1-3). The weather conditions on the fieldwork days were, in general, agreeable. It was not possible to measure the microclimate parameters in a very dense grid over the squares, which is specifically problematic for the analysis of sun and shade patterns. As an alternative, the patterns of sun and shade were simulated using SketchUp 3D software for days in the middle of the three seasons (i.e. 15 April, 15 July, 15 October; see fig. 6.8-10).

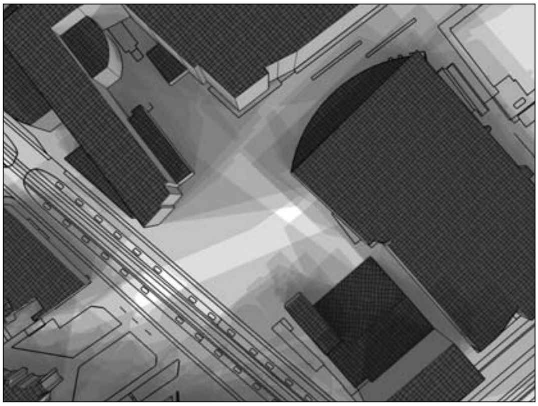
### 6.2.3 Data analysis

The interviews comprised several questions and observations that concerned factors of momentary experience, and other questions and observations regarding the clothing degree, which might influence long-term thermal perception. However, it became clear during the interviews that people's long-term experience of thermal comfort or discomfort was not related to these factors. Therefore, these factors were not analysed further.

To answer the research questions, we conducted ANOVAs on the dependent and independent variables. The results were then compared and discussed in relation to the measurement results and relevant literature on microclimate physics.

For all respondents, the 'balance comfort experience' ranged from -10 to +10. The dependent variable was normally distributed. The independent variables were transformed in order to be able to answer the research questions. To investigate the effect of width on the balance comfort experience, the respondents were divided into two groups: respondents who did not think that the square is too wide (which is a combination of the answers 'good' and 'too narrow') and respondents who did think that it is too wide ('too wide'). To investigate the effect of openness on the balance comfort experience, the respondents were again divided into two groups: respondents who considered the square to be too open ('I do not like the openness') and respondents who considered it not to be too open ('I like the openness'). Finally, to investigate the effect of appearance of the materials on the balance comfort experience, the responses of those who perceived cold materials and no warm materials were compared to the responses of those who perceived warm materials and no cold materials.

*Fig. 6.8 Shadow overlaps, Spuiplein, Den Haag*



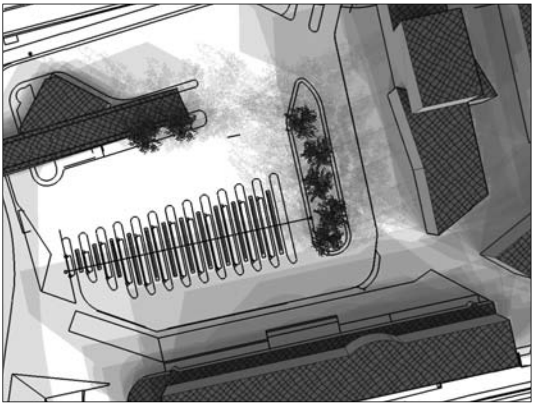


Fig. 6.9 (left) Shadow overlaps, Neckerspoel, Eindhoven

Fig. 6.10 (right) Shadow overlaps, Grote Markt, Groningen

The data from the microclimate measurements were evaluated for all the points in the central areas of the squares (measure points, see fig. 6.1-3). Point 6 in Neckerspoel was not evaluated because it proved to be not representative of the central area of a square. Too many measurements were taken between parked buses, which blocked the wind and cast too much shade.

The shade patterns derived from the shade study were superimposed for all the seasons and, as such, show the areas with the most and the least shade (see fig. 6.8-10).

## 6.3 Results and discussion

Here, the results of statistical analyses concerning the three research questions and the related sub-questions are described and discussed in relation to the literature on urban design and microclimate, and in relation to the local microclimate measurements.

Results for research question 1: 'Does the width of a square influence the thermal experience of Dutch people?'

This was tested by an ANOVA with the balance comfort experience as dependent variable and the width of a square ('width') as independent variable.

*Table 6.1 ANOVA results for research question 1*

| Square | Not too wide | Too wide |
|---|---|---|
| Spuiplein | -0.81 (n = 184) | -2.25 (n = 36) |
| Neckerspoel | -0.76 (n = 249) | -1.86 (n = 7) |
| Grote Markt | -0.91 (n = 182) | -1.63 (n = 43) |
| Total | -0.82 (n = 615) | - 1.91 (n = 86) |

The results show the following for all three squares: respondents who considered the squares too wide, mentioned more uncomfortable areas and fewer comfortable areas than the respondents who did not consider the square too wide (see table 6.1). This is significant for all three squares: F(1,700) = 9.121, p < .01.

An ANOVA with the three squares ('squares') and the width as two independent variables and balance comfort experience as dependent variable shows that the factor 'width' has the main effect: F(1,695) = 5.161, p < .05 and not the factor 'squares': F(2,695) = 0.230, n.s. The interaction of the two independent factors is also not significant: F(2,695) = 0.432, n.s. This indicates that the perceived width of the square causes differences in thermal discomfort, but that the influence of squares does not significantly differ with regard to thermal discomfort perceptions. Moreover, the effect of the width on the thermal comfort pertains to all three squares: people who considered the square too wide experienced less thermal comfort than those who considered the square not too wide.

It seems that people who perceive the squares as too wide and relate this to thermal discomfort, are actually quite sensitive to the microclimate situations that often occur on wider squares. For the physical microclimate of a square, its width plays a crucial role. In microclimate literature, squares with an H/W ratio with values lower than 0.25 are described as areas with 'isolated roughness flows' that can make them quite draughty (Alberts 1984; Oke 1987b). Our microclimate measurements and site analyses also show that wider squares are more prone to be windy: we found a relation between the H/W ratio, the number of openings and the orientation of these openings towards the prevailing wind directions on the one hand, and the average wind speeds derived from the measurements on the other hand (see table 6.2). Grote Markt shows this relation most clearly: a combination of a low H/W ratio, a larger number of openings and an orientation of these openings towards the prevailing wind direction, brings about the highest average wind speeds.

*Table 6.2 Relation of calibrated H/W ratios, relative proportions and orientations of open boundaries with wind speeds*

| | **Spuiplein** | **Neckers-poel** | **Grote Markt** |
|---|---|---|---|
| H/W ratio | 0.14 | 0.11 | 0.10 |
| Proportion of openings in circumference | 46% | 31% | 45% |
| Expos.openings prevailing wind dir. | + | - | ++ |
| Average wind speed all points | 1.54 | 1.41* | 1.79* |

**wind speeds calibrated according to wind speed zones, KNMI*

It seems that the interviewees who are more sensitive to thermal discomfort and who relate it to the width of a square have developed the ability to quite appropriately interpret these spatial proportions as distal cues. Here, it is worth taking a look at the idea of 'wide' squares as discussed in parts of the urban design literature mentioned in the introduction. Some of this literature describes explicit ‘ideal’ proportions of urban spaces. The H/W proportions that are typical of ‘wide squares’ and beyond which a square’s coherence begins to ‘dissipate’ are interesting in this context. The values indicated by the various authors range from 0.17 (Loidl and Bernard 2003) to 0.25 (Ashihara 1981; Moughtin 1992). This H/W ratio of 0.17–0.25 derived from visual studies coincides quite well with the H/W ratio of approximately 0.25 for uncomfortable wind patterns described in microclimate literature. The squares that we studied had even lower H/W ratios. We showed that increasing width combined with larger opening sizes and certain wind directions can make the wind climate increasingly uncomfortable. As the interview results show, there were always some interviewees who found the squares too wide, especially the Grote Markt (see tab. 6.1) – which is in fact the widest and windiest square. An H/W ratio of 0.25 or higher will ensure that these people do not find squares too wide. In addition, the percentage of open boundaries should not be too high, because in the Dutch climate context more open boundaries create more adverse wind effects. A combination of these measures will both provide a better wind climate and create a more enclosed visual impression of squares.

The openness of a square is a second factor in the spatial configuration of a square and is assumed to have a relation with thermal experience. This relation is discussed in the following.

Results for research question 2: ‘Does the openness of a square influence the thermal experience of Dutch people?’

This was tested by an ANOVA with the balance comfort experience as dependent variable and the openness of a square (‘openness’) as independent variable.

*Table 6.3 ANOVA results for research question 2*

| **Square** | **‘Not too open’** | **‘Too open’** |
|---|---|---|
| Spuiplein | -0.08 (n = 64) | -1.33 (n = 115) |
| Neckerspoel | 0.35 (n = 100) | -2.05 (n = 110) |
| Grote Markt | -0.36 (n = 89) | -1.55 (n = 116) |
| Total | -0.01 (n = 253) | -1.64 (n = 341) |

The results show that for all three squares, the respondents who considered the squares too open mentioned more uncomfortable areas and fewer comfortable areas than those who did not consider the square too open (see table 6.3). This is significant for all three squares: F(1,593) = 43.943, $p < .001$.

An ANOVA with the squares and openness as two independent variables and balance comfort experience as dependent variable shows that the factor ‘openness’ has the main effect: F(1,588) = 42.399, $p < .001$ and not the factor ‘squares’: F(2,588) = 0.328, n.s. This indicates that the perceived openness of a square causes differences in thermal discomfort, but that the squares themselves do not significantly differ with regard to thermal discomfort.

The interaction of the two independent factors is also not significant: F(2,588) = 2.643, n.s. This indicates that the effect of the perceived openness of a square on the thermal comfort pertains to all three squares in a similar way: people who considered the square too open experienced less thermal comfort than those who considered the square not too open.

People who perceived the squares as open and experience thermal discomfort seem to be quite sensitive to distal cues for microclimate. Open squares tend to be more frequently windswept due to low local terrain roughness. The occurrence of wind gusts is probably engrained in these people's memories (Lenzholzer 2010). In addition, a very open space offers no shelter or shade to the user who is in search of a comfortable microclimate zone in the square. This is also the case in the squares in our study, as the shade simulations show: the centres of all three squares have large areas that do not receive or receive hardly any shade during the outdoor seasons (see figs. 6.8-10). This can be problematic especially in mid-summer, because then shades are quite short due to the high sun angles. The averages of the globe temperatures we measured also support this. The globe temperatures represent the 'weighted average of radiant and ambient temperatures' (Thorsson et al. 2007b). They express the temperature as it is directly felt by humans more appropriately than air temperatures (Thorsson et al. 2007b). This difference becomes apparent when the averages of the globe temperatures in the central open areas of the three spaces are compared with the average values at measurement points in the adjacent spaces (see table 6.4): the average values for all seasons in the central areas are higher than in the adjacent spaces.

*Table 6.4 Average globe temperatures in the central and adjacent spaces of the squares*

| | **Spuiplein** | **Neckerspoel** | **Grote Markt** |
|---|---|---|---|
| Globe temperature central area | 24.21 | 24.88 | 19.63 |
| Globe temperature adjacent areas | 23.16 | 24.02 | 19.44 |

It is also valuable to analyse here the answers to the sub-question that was related to this hypothesis. People who found the square too open were asked to propose how this could be changed. Their proposals are presented in table 6.5.

Apart from the proposal 'more seats', all the proposals would have a direct effect on microclimate. People apparently have adequate ideas about how to create a layout that would lead to a comfortable microclimate. Flowers and grass influence temperature and humidity by evapotranspiration (Oke 1987a). By providing shade, trees strongly influence mean radiant temperature (Streiling and Matzarakis 2003) and UVA and UVB rays (Grant et al. 2002; Heisler et al. 2003). Trees affect humidity by evapotranspiration (Streiling and Matzarakis 2003) and can, depending on their shape and size, act as wind buffers (Nägeli 1941; Brown and Gillespie, 1995).

*Table 6.5 Respondents' proposals for improvements in the square*

| **Square** | **flowers /grass** | **trees** | **monu./ art** | **fount./ water** | **kiosks** | **wind/ rain/ screens** | **seats** | **others** |
|---|---|---|---|---|---|---|---|---|
| Spuiplein | 40 | 52 | 9 | 5 | 4 | 4 | 49 | 28 |
| Neckerspoel | 20 | 30 | 0 | 0 | 2 | 43 | 43 | 9 |
| Grote Markt | 15 | 65 | 1 | 17 | 4 | 8 | 52 | 23 |
| Total | 75 | 147 | 10 | 22 | 10 | 55 | 144 | 60 |
| % of total | 10.79 | 21.15 | 1.44 | 3.17 | 1.44 | 7.91 | 20.72 | 8.63 |

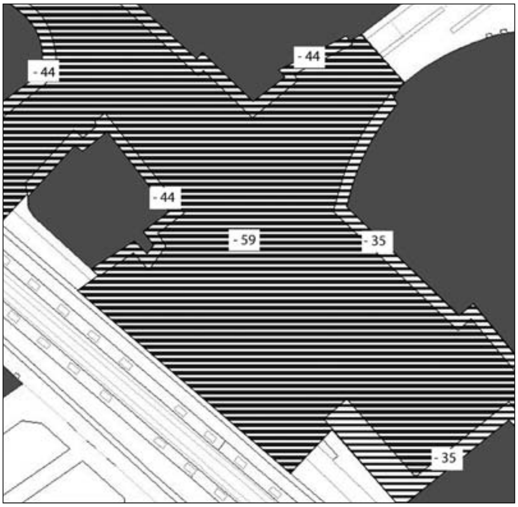
Monuments, again depending on their shape and size, can also cast shadows or act as wind buffers. Fountains always have an influence on humidity and air temperature in their vicinity (Nishimura et al. 1998). The shadow thrown by kiosks and other micro-architectures has a strong effect on mean radiant temperature and UVA and UVB rays, while wind or rain screens have a direct effect on wind and/or rain buffering. However, the request for more seats also has a relation to microclimate. When the degree of sittability (Whyte 1980) in a square is low, people cannot rest or choose a certain microclimatic environment that suits their needs. Thus, the addition of seats in different, well-chosen microclimatic situations has an important added value within the diversification of microclimate spaces.

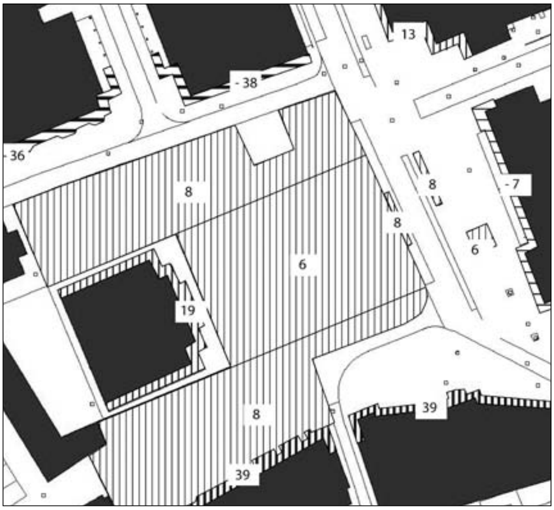
The answer to research question 2 (i.e. that when a square is perceived as too open, more thermal discomfort is experienced) provides a tentative guideline for public design in the Dutch context: we should not have too open, empty squares. A combination of spatial openness and such features as vegetation, furniture or other elements mentioned by the interviewees would better cater for different perceptions of spatial openness and thermal experience.

The materialization has also been assumed to influence thermal experience in urban outdoor spaces. The influence of the materials' appearance is elucidated in the following.
Results for research question 3: 'Do the materials in the outdoor space appear cold or warm to Dutch people, and how does this relate to thermal comfort?' We conducted an ANOVA with balance comfort experience as the dependent variable and the appearance of the materials ('warmth') as independent variable.

*Table 6.6 ANOVA results for research question*

| **Square** | **warm materials and no cold materials** | **cold materials and no warm materials** |
|---|---|---|
| Spuiplein | -0.55 (n = 33) | -1.53 (n = 95) |
| Neckerspoel | -0.11 (n = 28) | -1.51 (n = 93) |
| Grote Markt | -0.80 (n = 40) | -1.41 (n = 46) |
| Totaal | -0.52 (n = 101) | -1.50 (n = 234) |





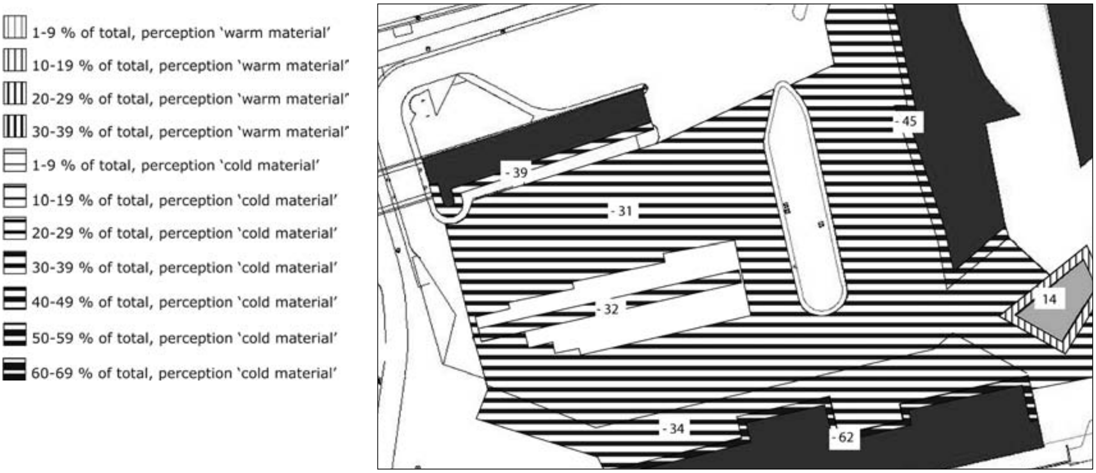


*Fig. 6.11 (upper left) Localization of material perceptions, Spuiplein, Den Haag*

*Fig. 6.13 (upper right) Localization of material perceptions, Grote Markt, Groningen*

*Fig. 6.12 (lower) Localization of material perceptions, Neckerspoel, Eindhoven*

This analysis shows that respondents who perceived cold materials and no warm materials expressed more thermal discomfort than those who perceived warm materials and no cold materials: F(1,334) = 7.844, $p < .01$, see table 6.6. An ANOVA with the squares and warmth as two independent variables and balance comfort experience as dependent variable shows that the factor 'warmth'has the main effect: F(1,329) = 7.806, $p < .01$ and not the factor 'squares': F(2,329) = 0.249, n.s. The interaction of the two independent factors is also not significant: F(2,329) = 0.387, n.s. This indicates that the effect of the factor 'warmth of the materials' on thermal comfort pertains to all three squares: people who perceived cold materials and no warm materials experienced less thermal comfort than those who perceived warm materials and no cold materials.

In order to derive clearer urban design recommendations, it is important to study which materials are actually perceived as cold or warm. This can be inferred from the answers to the open question: 'Where do you see cold or warm materials in this square?' Respondents related a warm or cold appearance to specific parts of the square, mainly the ground surfaces or certain facades. Their answers are mapped in figures 6.11 to 6.13.

Most respondents described Spuiplein as ‘very cold’. The materials in and around the square are predominantly bright and smooth: enamel, glass, tiles and the matte polished pavement of Belgian bluestone. The main colours are white, grey and blue. Some respondents caricatured the square as a ‘fridge’ or described the town hall as an ‘ice palace’. Neckerspoel was perceived as ‘quite cold’. Such materials as tiles, steel and glass were mostly rated cold, while the wood and cor-ten steel surfaces were mostly rated ‘warm’. The materials in and around Grote Markt are mixed, and the varied character of the square’s four main sides creates a varied picture: the eastern and northern sides of the square were generally rated ‘cold’, while the other two sides – which comprise buildings made of traditional Dutch materials, mostly brick – were rated ‘warm’.

A more general perception of materials can be deduced from these warm/cold ratings of the various facades, pavements and elements in and around the squares. Wood and brick were considered warm, as were materials that have warm colours. A cold appearance was assigned to steel, glass, enamel and concrete. Natural stone was rated either ‘cold’ or ‘warm’ depending on its smoothness and colour tone.

Many of the materials in and around the squares were quite distant from the places where people stood and thus did not assert a direct thermal influence on them. Nevertheless, people still evaluated them as though they were close to or even touching them. Thus, the materials seem to form a typical distal cue for thermal experience.

These distal cues can be explained by considering the properties of these materials as though they were in direct contact with the skin. There are clear relations between material properties and the thermal sensation that is felt when heat flux between human skin and material directly occurs. The main factors in this are emissivity, the heat conductivity of a material and, to some degree, the material’s albedo (Givoni 1998; Santamouris 2001; Parsons 2003). As we can infer from our study, people from the Dutch climate context generally consider such materials as brick and wood to have a warm appearance. These materials have more thermally comfortable surfaces when touched, also in different seasons. The physical properties of these materials, such as their emissivities and heat conductivities, produce a lower heat transfer to the human skin. These materials cause burns at higher temperatures than, for instance, metals. Moreover, in colder conditions they require a lower temperature to cause freezing (Parsons 2003). However, stone can cause adverse thermal effects much sooner than wood.

Smooth, shiny materials with higher albedos and higher heat conductivities (such as glass, enamel and steel) were evaluated as ‘cold’. This is surprising, because some of the materials – especially the metals and enamel (being a metal with a coating) – can become very hot in summer. On the other hand, they are even colder in winter, as indicated above. Although glass actually has properties that are rather similar to those of stone, it is also rated ‘cold’. It seems that people do not always characterize these materials appropriately in relation to their thermal properties and that other factors are influential here.

For example, the colour tones of materials seem to play an important role. Cool colours (such as blue, grey and white) probably raise the symbolic association of water and ice as cooling elements, and warm colours (such as red, orange and brown) with the associations of fire and sun as warming elements (Gage 1999). Yet the perception of colours is also closely linked to our temperature senses and experience within our geographical and cultural context (Tuan 1974). The responses of some of our interviewees who originate from the Middle East's hot and arid climate zones present an interesting example of these culturally influenced perceptions. These people preferred the materials that Dutch people consider to be cold because they have cool colours, shiny surfaces and high albedos, as in the desert climate these materials create agreeable temperatures for human beings and associations of cool environments through their 'cool' colour tones. The different interpretations of material cues by people from different climate zones indicate that perception patterns are based on the physical environments people originate from. These people probably learnt to interpret the distal cues in the climate zone they grew up in and still use the same interpretation patterns in an entirely different climate zone. This indicates how deeply the interpretation of distal cues is rooted in people's minds.

However, physics does not support the difference between warm and cold colour tones. As inquiries into colours and materials have shown, the thermal behaviour of a material is not influenced by whether it has a warm or a cold colour tone: what matters is the degree of brightness and its influence on albedo (Doulos et al. 2004, Karlessi et al. 2009). This means that in urban design one can use warm colour tones to manipulate people's perceptions of the thermal comfort of a material despite the material's thermal properties.

## 6.4 Conclusions

First, there are some main, direct conclusions that are of special interest to the design professions, because they lead to some guidelines for a climate-responsive design of public squares in the Netherlands.

To summarize these:

A square that is considered too wide is also considered thermally uncomfortable. The people who rated the squares as too wide and related this to thermal discomfort seem to have developed an acuity for adverse microclimate and space proportion. The studies on the square's proportions in relation to the wind fields show that there is a relation between a square's wideness and its windiness. This corresponds with general knowledge from urban microclimate research, where squares with an H/W ratio lower than 0.25 are indicated as being more windswept. Literature on the visual perception of urban space also suggests that wide squares with H/W ratios below 0.17 are considered problematic due to a lack of visual boundaries.

It might therefore be advisable for urban designers to use the H/W ratio of 0.25 as a very rough guideline for square proportions. This offers a safe 'no regret' solution to the problem of windy squares, and will also help to attract people who are more critical about the width of a square.

A square that is considered too open is also considered thermally uncomfortable. Also in this respect people who perceived the square as too open and related thermal discomfort to this seem to have this acuity for microclimate and spatial structure. Their perception can be supported by the measurements and shade simulations for the sites. The perception of a too open square can be mitigated simply by equipping the space with such elements as vegetation, screens, special furniture, fountains, etc. in order to buffer adverse microclimate effects. The wind and shade patterns should also be taken into account in placing these objects, as this substantially increases the effectiveness of interventions. Open spaces should also be offered in squares in order to provide microclimates for various needs. Microclimatically diverse spaces should also be made sittable to enable longer sojourns in public squares.

A square that is considered as consisting of cold materials is also considered thermally uncomfortable. The materials perceived as cold often have high heat conductivities, high albedos and cool colour tones. Warm materials often have lower heat conductivities, lower albedos and warm colour tones. These materials should therefore be preferred for the design of Dutch outdoor spaces. In addition, the colour tones of the materials used is important: warm colours should be preferred to cool colours in order to enhance the feeling of thermal comfort.

A second conclusion is that it seems that the interpretation of distal cues by the people who found spaces too wide or too open is often surprisingly appropriate when this is compared to microclimate reality. This is the case for the assessment of the harsh microclimate of the wide squares and the undifferentiated microclimate of very open squares. To some extent the material perceptions are also appropriate. Concerning the material perceptions, it is important to bear in mind that this knowledge of cues for microclimate is deeply rooted in the regional climate and physical environment in which a person learnt to interpret cues. Thorsson and colleagues already stated that thermal comfort experience depends on the climate region a person comes from (Knez and Thorsson 2006; Thorsson et al. 2007a).

This study has indicated that in the Dutch context, such environmental cues as the proportions and openness of and the materials and colours used in and around urban squares influence thermal comfort or discomfort. All these cues can be manipulated by urban design interventions, and thus influence thermal experience. Interventions that comprise manipulating width, openness, materials and colours can also enhance each other; if one or more types of interventions are not feasible, they might substitute for each other. For instance, in public design projects it is often not possible to influence the width of a square; however, the furnishing and the use of materials can be changed according to their expected effect on thermal comfort.

Generally speaking, since thermal comfort is such an important factor for sojourn quality in public spaces, the parameters discussed above should always be taken into account in order to facilitate climate-responsive design. We have described some possible design interventions for public squares in the Dutch situation, but the question remains whether similar relations between the spatial cues and long-term thermal comfort also exist in other climate regions and cultures. We expect that spatial cues are interpreted quite differently in other climates and cultures, and this certainly deserves further research.

## 6.5 Acknowledgements

The authors would like to thank Sjerp de Vries for helping to set up the questionnaires and for preparing the statistical analyses.

# 7

# ‘Research by design’ in academic landscape architecture

## 7.1 Overview

In this chapter I try to develop a design method to generate new landscape architectural and urban design knowledge in the form of design guidelines or recommendations. Such guidelines are expected to be reliable, valid and applicable in many different circumstances – and these three criteria resemble the criteria of empirical scientific knowledge. Therefore, I suggest a scientifically oriented approach within the academic practice of landscape architecture and urban design. To arrive at such an approach, I first discuss the relation of research and design in the literature. Based on this, I develop a 'research by design' method for landscape architecture and urban design. Here, I use suggestions for 'research by design' made for architecture and develop them further into a method that is expected to be applicable in landscape architecture and urban design. I round off with a specific design procedure that is meant to yield generalisable design knowledge in the form of design guidelines. The 'research by design' method presented in this chapter will be exemplified with a 'research by design' for a model of climate-responsive public squares in chapter 8.

## 7.2 What is 'Research by design'?

A major question within design disciplines is whether or not design can be science or research. Actually, two rather diametric schools of thought exist on this question.

Many authors deny the possibility that design can be scientific or 'research'. Jones posits that "designing should not be confused with ... science, or with mathematics" (1970, p. 10). He emphasized that "when they [designers, S.L.] deal with the future itself, as opposed to the present, scientific doubt is of no use" (1970, p. 11). Lang asserts that "by definition, design cannot be scientific" (1987, p. 19) even though it should be based on scientific knowledge (Lang 1987, 1994, 2005). Nigel Cross has repeatedly contended that design is neither science nor research. He claims that in scientific epistemology (relating to Popper's and Kuhn's scientific philosophy) a range of logical shortcomings makes the concept of the empirical scientific method itself contestable and thus not valid as a model for design (Cross et al. 1981). Throughout his work as a design theorist, he aims to develop design as a 'third area', next to science and the arts. In his influential article *designerly ways of knowing* (1982) he lays the foundation for this 'third area' and he develops a specific approach to design that is based on experience and expertise. His approach is solution-oriented, and uses both knowledge and techniques from science and art, but is neither of both (Cross 2004, 2007). Independent from these design theorists, Donald Schön approached similar questions from a more general perspective in his seminal book on the 'reflective practitioner'. He advances that a scientific approach in design has very limited use, and that artistry and 'reflection in action' are the major characteristics in creative and design processes (1987). A recurrent argumentation against design as scientific research is based on Rittel's notion of 'wicked problems' (Lang 1987 p. 43-44, 59; Cross 2007; de Jonge 2009, p. 38). These authors maintain that design cannot be science or research due to the ill structuredness of many design problems, which does not allow for the classical analytical scientific approach.

The opposite is a rational, science oriented approach that has had a tradition in design since modernism. Many architects, one of them being the prominent figure Le Corbusier, regarded architecture as a science (Le Corbusier, in Cross et al. 1981) and within the Athens charter, for instance, urbanism is described as a "three-dimensional ... science" (Athens charter, 1943 paragraph 82). In the early years of his career, Christopher Alexander pursued a strictly rational, mathematically inspired approach to design in his Notes on the Synthesis of Form (1964). Shortly after Alexander, Simon proposed a 'Rational Problem Solving' (RPS) approach to design, saying that design should be "the discovery of a partially concealed pattern' in a rigorous and objective way ... design science could then become 'a body of intellectually tough, analytic, formalizable, partly empirical, and teachable doctrine about the design process" (Simon in Dorst 1997, p. 50). In the 1970s, Hillier et al. suggested to introduce the scientific empirical method into design. After them, several theorists who considered embedding this scientific empirical method into design also used Popper's new scientific philosophy in their approach; replacing 'hypotheses' by 'conjectures' and the old 'analysis-synthesis' design models with 'conjecture-test' models (Cross et al. 1981; Bamford 2002; Zeisel 2006, p. 19-25). This trend of combining scientific knowledge and scientific method was later carried further as 'design science' (Hubka and Eder in Love 2000) being a "system of logically connected knowledge in the area of design, ... [which, S.L.] contains concepts of technical information and of design methodology" (Hubka and Eder 1987, in Cross 2007, p. 122).

Research and design can also be combined in 'research by design' where the design process itself is used to generate new design knowledge. 'Research by design' or 'ontwerpend onderzoek' (in Dutch) has recently been coined as a term at the Technical University of Delft, which houses many designing, 'form-giving' disciplines. In the fields of architecture (and, less explicitly so, in industrial design), the overarching term 'research by design' was introduced and certain design criteria were related to this method.

With respect to scientific research criteria, the scholars from TU Delft think that "design...can only pass muster as a science if the usual criteria for scientific activity have en obeyed...: inter-subjectivity, reliability and verifiability in an empirical sense" (de Jong and van der Voordt 2002, p. 25). These criteria, together with generalisability are furthermore generally considered as the main criteria of scientific knowledge (O'Hear, 1989; Gutting 2005).

In procedural terms, scholars in TU Delft understand 'research by design' "as the development of knowledge by designing, studying the effects of this design, changing the design itself or its context, and studying the effects of the transformations. The 'TOTE model' from systems analysis may be

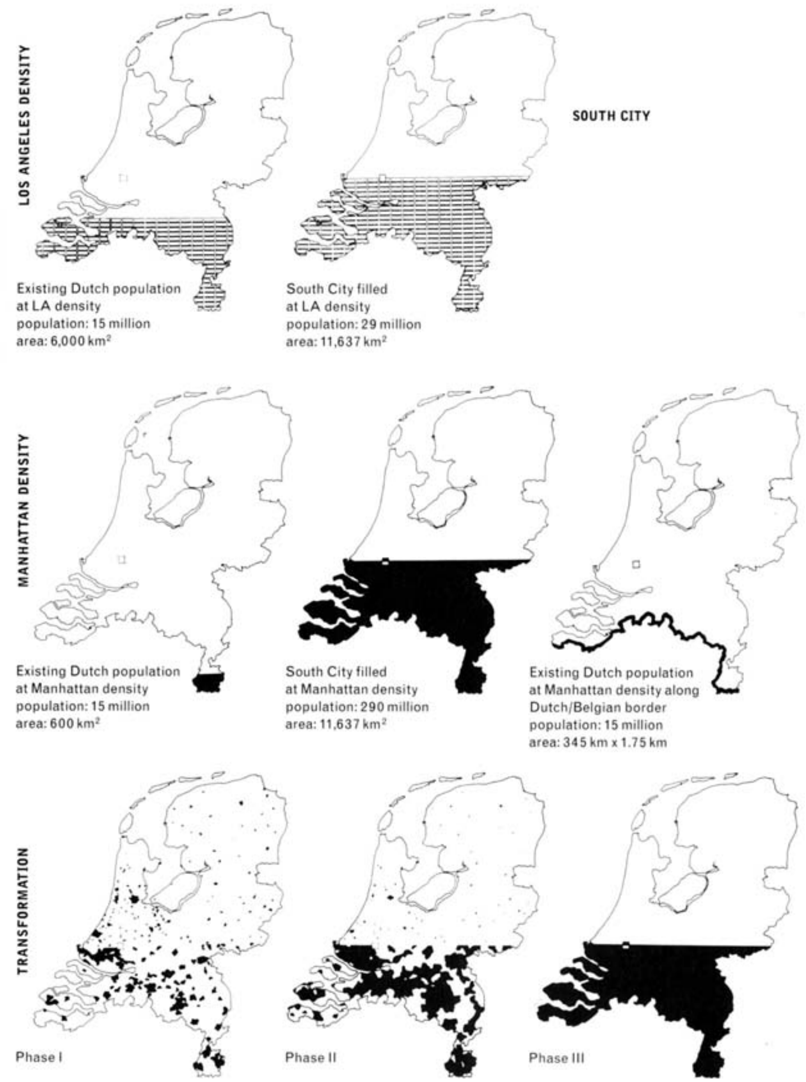


*Fig. 7.1 example of Unlearning Holland-studies, OMA 1995*

recognized in this: Test ▸ Operate ▸ Test ▸ Exit" (de Jong and van der Voordt 2002, p. 455). The resemblance to experiments in empirical research is quite obvious. However, the term 'test' is not specified for the design part, although this is a very important question: how to test design? Other scholars in Delft came up with a similar model and claimed that 'research by design' is literally the same procedure as the one used in the 'classical' empirical sciences: "From a general scientific point of view, there appears to be, on closer examination, no essential difference between the steps in the empirical research cycle (statement of problem – analysis – generation of possible testable answers – formulation of hypotheses) and those of design research (task – analysis – generation of schematic ... models – design)" (Steenbergen et al. 2002, p. 25). Although Steenbergen et al. stop at the point of hypothesis development, both in the 'empirical research' and 'design' process model, missing out the important part of hypothesis/design testing, their model still shows a strong relation to empirical science. Interestingly, while Steenbergen et al. themselves do not consider hypothesis/design testing, they quote authors that indeed do include this part in the idea of 'research by design': "So, first there is the hypothesis, the idea, the image. Then there will be strategies of refutation – in fact. The real job." (Ungers 1997, in Steenbergen et al. 2002, p. 24). Jack Breen comes up with a deeper view on 'research by design' methods: "The most 'scientific' approach would be one whereby targets and course of action are clearly specified beforehand, allowing for systematic evaluation of outcomes and the drawing up of unambiguous conclusions" (Breen 2002, p.137). He describes one of the typical processes as the "design activity ... incorporated into the development of technical applications or product innovation. Such an approach is similar to the practice of *research and development* (R&D) common in industry" (Breen 2002, p. 139). A typical example in this regard is vehicle design, where the forms of different car shapes are continuously tested in wind tunnels or simulations, then are redesigned, tested again, and so forth, until they reach a satisfying shape. Breen also emphasizes the necessity of rigorous, conscientious design methods that clearly show all design decisions. As interesting examples of this kind of proceeding in design projects, he mentions the work of the Dutch architecture firms OMA and MVRDV (Breen 2002, p.140).

On closer inspection, their work indeed shows an experimental, explorative approach that they claim to be tightly related to scientific research, where daring hypotheses are posed and then tested in different scenarios. The work of OMA in exploring large-scale urbanization scenarios in The Netherlands (fig. 7.1) is a typical illustration of this approach. Here, design hypotheses on certain density patterns are pushed to their maximum, resulting in surprising patterns. In the work of MVRDV this experimental approach was used even more explicitly through 'datascaping'. MVRDV describe their 'datascapes' in this way: "under maximized circumstances, every demand, rule or logic is manifested in pure and unexpected forms that go beyond artistic intuition or known geometry and replace it with 'research'. Form becomes the result of such an extrapolation or assumption as a 'datascape' of the demands behind it ... Artistic intuition is replaced by 'research': hypotheses that observe, extrapolate, analyze and criticize ..." (Maas et al. 1998, p. 103). Their 'datascapes' are very literal translations of numerical information into spatial information or 'envisioned informations' (Tufte, 1990) that are projected on a site. By testing the 'datascapes' within a site context or a building programme, they serve as tools to examine a design. The 'noisescape' in fig. 7.2 exemplifies a 'datascape', where the 'noisescape' is a housing development along a highway that is configured around the noise-contours of 65 dBA (which is the threshold of noise

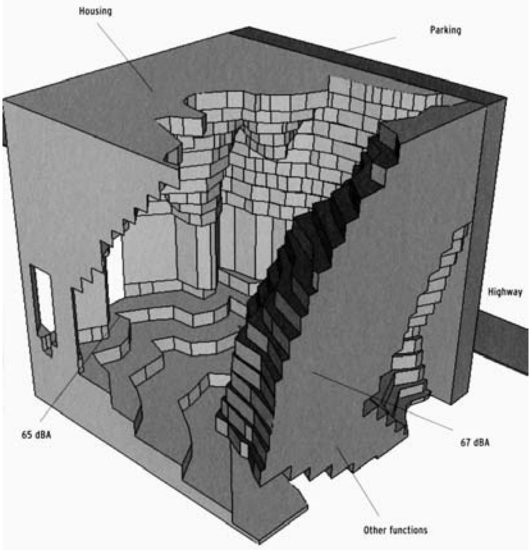


*Fig. 7.2 example of a 'datascape': noisescape, MVRDV and Penelope Dean, 1998*

nuisance within which building programmes for living are prohibited in The Netherlands). MVRDV have developed many more of these 'datascapes' and used them as a design tool to analyze and test their designs on their implications.

The outcomes of 'datascaping' do not yield final designs, but as a testing tool in the design process 'datascapes' can help to analyze interim design solutions on their effects. Apart from that, due to their often surprising outcomes, they can also stimulate 'out-of the box-thinking' and creativity.

The authors from Delft discussing 'research by design', however, did not explicitly make this link to datascapes and hypotheses. This is probably due to the fact that they are all unclear about the way design hypotheses could be tested. I consider this to be a significant deficiency in their argumentation.

After this outline of the two contrasting views on the relation of science, research and design, it is necessary to discuss authors who have developed thought on both approaches. Christopher Alexander is a specifically interesting figure in this context since his work spans both paradigms. His first major work, *Notes on the Synthesis of Form,* has a clear rational and mathematic approach. Later, Alexander became less rigid. His 'Pattern Language', which he claimed to be based on empirical observations, was even criticized for not meeting the standards of empirical science (Dovey 1990). Alexander eventually explicitly distanced himself from the idea that design has resemblances to empirical sciences (Dorst 1997, p. 65). Different from Alexander, who displayed a paradigm shift in his thinking on design – from a 'scientific' towards a 'subjective, intuitive' method – various authors tried to combine both paradigms. For instance, both approaches occur in John Zeisel's design theories featured in his book *Inquiry by Design.* He describes the rational approach as similar to scientific methods in the chapter *research: concepts, hypotheses and tests,* but he also acknowledges that design always has a heuristic side, including creative leaps, imagination and decisions that are not clearly rational or logical. Love (2000) as well claims that both 'Design as Creative Process' (which resembles artistic production) and 'Design as Information Processing' (which resembles science) are never purely the one or the other. Dorst researched both approaches in empirical experiments with designers. Based on his findings he proposes that the two approaches are, and should be, applied in different phases of the design process. In the first analytic, informative phase of a design process a more 'rational', scientific method is useful, whereas in the synthesizing design phase where all issues have to be combined, a hermeneutic, 'reflective' approach is more suitable (Dorst 1997).

This brief overview has shown that there are diametric approaches to research and design. The majority of theories on the relation of scientific research and design originate from the disciplines of architecture, product and industrial design. It is important to acknowledge this, because different disciplines and types of design assignments require different approaches to design. Unfortunately, there is very little theory about 'research and design' within landscape architecture and urban design and the role of 'research by design' is not even mentioned at all. I consider this a great deficiency for landscape architecture and urban design, as I think that within these two disciplines the role of a scientific approach is very important. Therefore, the next subchapter will be devoted to an argumentation for 'research by design' within landscape architecture and urban design.

## 7.3 'Research by design' in landscape architecture and urban design

In various design disciplines, a range of parameters is very important in the design products and processes. The importance of these parameters strongly varies amongst the disciplines and their typical design assignments. To illustrate some of the main differences, I give an overview of these parameters in figure 7.3 for different design disciplines (middle). The parameters are shown in the sliding scale on the left, which depicts how the importance of these parameters roughly relates to the different disciplines (exceptions excluded). It shows that from the very small scale of, for instance, graphic design up to the large, complex scale of landscape and urban design, there is a growing influence of context-relatedness, cost of failure, sustainability and the involvement of other parties/the public.

The greater importance of these parameters in landscape architecture and urban design requires specific ways of working in a design process. The large scale and strong relation to the context ask for a deep understanding of the location and its inherent natural and social processes. This understanding can generally only be achieved through very rigid and exhaustive

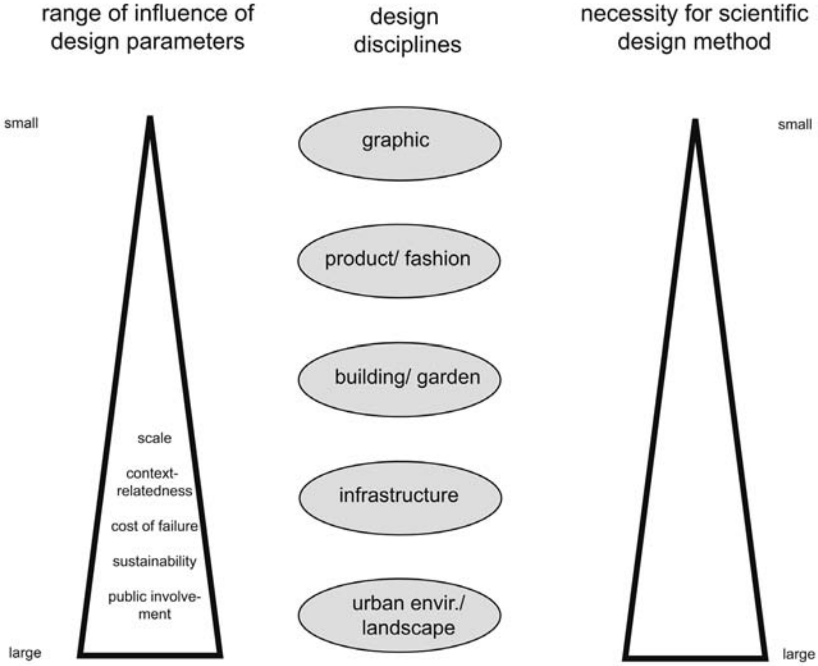


*Fig. 7.3 the importance of empirical research methods in research by design for different disciplines*

analyses, resembling scientific analyses. The issues of the costs of failure and sustainability require a very thorough simulation and testing of design decisions, similar to the testing of hypotheses in science. Within landscape architecture and urban design, scientific justification of design decisions is increasingly called for. A broad public, politicians, ngo's and other interest groups are often involved in the typical large-scale design processes in landscape architecture and urban design (Milburn et al. 2001). The need to publicly justify design decisions in a more scientific way has also arisen because of societal developments in the present Western 'knowledge society' (Schön, 1987, p. 8-12; Nowotny et al. 2001). A highly reliable design method is the best way to legitimize design decisions. All these requirements show the growing necessity for scientific design methods (indicated in fig. 7.3 on the right hand side).

In a scientific design method, similar to the process in empirical science, analysis should be carried out logically and conscientiously. Design hypotheses/conjectures should be clearly articulated, then tested and evaluated in a cyclic process until the design results are likely to meet as many requirements as possbile. If such a thorough and reliable method is not followed, it is more likely that problems will come up, and if they do, the consequential costs – in financial, but also in ecological and social terms – can be immense. Generally, I think that the larger scale design processes and products in landscape architecture and urban design, which have to be highly reliable and justifiable, should be based on a scientifically oriented method.

Unfortunately though, there have been only a few recent explorations for landscape architecture (Milburn et al. 2001; developed further in Milburn and Brown 2003) and urban design (Forsyth 2007) explicitly addressing the relation of research and design. All the authors state that there is a shortage of theory on this issue, and come up with different ideas on this relation. Milburn and Brown conducted a broad inquiry on the relation of research and the design processes amongst American scholars in landscape architecture. Based on this inquiry they attempted to make an evaluation of different models of design procedures that ranged from 'artistic/intuitive' to 'research-oriented'. Their results showed that it was not actually possible to assign 'artistic inspiration' and 'research' to different design phases. Partly, this was because the term 'research' was not clearly defined semantically. 'Research' in this context could be understood as site visits, library research, precedent study or the application of scientific knowledge. This vagueness on the concept of 'research' was also criticized by some of the interviewees (see footnote p. 60 in the article) and acknowledged by the authors. They also recognize that according to Zube's definition, "library research or on-site inventories as contribution to a larger body of knowledge is contested". They conclude that even though there are various definitions of research in relation to design, the inclusion of rationality and objectivity in design as criteria of 'research' processes should be strengthened in landscape architecture.

Forsyth (2007) lays the main connection between research and design knowledge production through the application of sound scientific knowledge in the design process. She elaborates on the problems that arise from the lacking research base to tackle large-scale “emerging problems of the urban world- from environmental damage to infrastructure for the poor …”. She concludes that research-based design – the application of scientific research – is the solution to close the gap between design and research. Forsyth thus highlights an important issue here again: the structural use of sound scientific knowledge. Other authors are also critical about the fact that in many design processes the structural use of scientific knowledge in the design is not properly taken into account, even though this is possible. The structural inclusion of knowledge from the natural sciences into the design process with respect to landscape ecology demonstrates this (Ahern 2002; Johnson and Hill 2002) or social sciences (Rapoport 1977; Whyte 1980; Lang 1987, 1994, 2005).

These articles on research and design in landscape architecture and urban design do not explicitly address more scientific, explorative design methods. As I discussed earlier, this can be problematic considering the necessity for a more reliable and justifiable design process in landscape architecture and urban design, when the results of the design process are design guidelines. Alternatively, I suggest that the ‘research by design’ methods for architecture as described by the authors in Delft, should be transferred to landscape architecture and urban design, with some additions. I think that it is possible to make this transfer because architecture has many commonalities with landscape architecture and urban design. However, due to the fact that design decisions in landscape architecture and urban design need to be very reliable and justifiable, the process of ‘research by design’ has to be more rigorous. I think that the design processes should include the generation of clear design hypotheses based on scientific knowledge. These hypotheses need to be thoroughly tested. This can be done in cyclic processes where design hypotheses are tested, adjusted, and tested again until a satisfactory hypothesis or design solution is found, based on objective grounds. Alternatively, this can be done in processes where design hypotheses are tested parallel to each other and the satisfactory hypothesis or design solution is selected through comparison.

Up to now the generation of design hypotheses or ‘conjectures’ was not a problem in design processes in landscape architecture and urban design since basically every design proposal can be considered a hypothesis (Zeisel, 2006, p. 19-25). More problematic was the possibility to test the design hypotheses on their outcomes because of the complexity of assignments in landscape architecture and urban design.

In recent years, increasingly progressive computer simulation techniques have offered solutions to this problem. For example, within the design disciplines the 3-D renderings from AutoCAD, 3D Studio Max and other software applications are well-known tools to show the visual impacts of design ideas. Other simulation tools are gaining importance to test other effects as well. For instance, simulations are also used to show the effects on behavioural, climatological, hydrological, ecological, and many other systems. These simulation tools, if well developed, scientifically validated and calibrated, offer the chance to test designs on their effects concerning many different aspects. These can be the modeling of dynamic processes, impacts or performances of the designs.

For the fields of landscape architecture and urban design, the role of these simulation techniques has not been widely explored, apart from a broad body of literature on visual simulations. The visual simulation tools have achieved a high standard, but simulations in other fields in science are also in continuously developed to simulate environmental factors ever more realistically. The potentials of these tools should be explored more extensively in landscape architecture and urban design academia.

Since simulations from other fields of science can be used as testing tools for design hypotheses, they can play a pivotal role in making design processes meeting scientific criteria. Design proposals that have been thoroughly tested in various simulations, for instance on their ecological, hydrological and climatological effects, are more reliable.

Through the inclusion of such testing and evaluating of design proposals, the risks of failure are largely diminished. Moreover, the predictions from simulations can help justify the design decisions taken.

This researching approach to design and the inclusion of high-tech simulation tools can be increasingly found within design practices, for example within consulting firms that specialise in fields such as hydrology and climate control, or in the R&D departments of firms that develop new technologies. However, within the academic context of landscape architecture and urban design, the possibilities of these technologies (apart from visual simulations) have not been broadly recognized for their role in design processes. It is surprising that there is no literature on this, because in the academic context a scientific approach to design, using the latest simulation tools seems obvious.

Especially the production of new academic landscape architecture and urban design knowledge, which often is the generation of design guidelines, requires very rigorous scientific 'research by design' methods and a procedure that offers generalizable results.

## 7.4 'Research by design' procedure in landscape architecture and urban design for new design guidelines

The creation of new design guidelines based on scientific knowledge has been identified to be very important to close the manifold 'utility gaps' (Kantrovitz 1985; Eliasson 2000; Nassauer and Opdam 2008) between science and design practice. To enhance the use of scientific knowledge in design, it is crucial to provide practitioners with easily applicable, 'preprocessed' scientific knowledge. In the following I will suggest a way of generating design guidelines that comply with the criteria of scientific research results, especially the possibility of generalization.

In the subchapters above I have outlined how the criteria for scientific design can be answered for different designs. But when the aim of the design process is to generate design guidelines, another aspect needs attention: generalizability. Design guidelines that are supposed to be applicable to many situations should obviously have been tested for more than only one case. So the process of hypothesis testing needs to be conducted for different places of a similar type. When the testing process 'proves' the design hypoyhesis for all the different cases, the design might qualify as a more generalizable design guideline or recommendation.

Yet, for the generation of generalizable design guidelines within landscape architecture and urban design, some important remarks have to be made. Due to the complexity of landscape architecture and urban design assignments, it will be impossible to generate design guidelines that match very different contexts. This is in contrast to industrial or building design, where generalizable designs do exist, mostly in the form of prototypes that can be applied in many places. In the highly context- dependent design fields of landscape architecture and urban design, a more sectoral or issue-specific approach seems more appropriate. It will be possible to generate new design guidelines for certain 'sectors' or for specific types of spaces. Such guidelines, for instance, have been developed for landscape ecology where certain habitat types are assigned to certain sizes of spaces. Similarly, certain types of spaces in hydrological systems areas were assigned with design guidelines. A typical example is the guidelines within the Dutch 'Space for the River' system. Since these design guidelines are issue-specific, they are not representative for integrated designs where all issues that have to be addressed in a design are brought together. These guidelines rather represent a 'half-product' that can become part of an integrated design.

In order to generate design guidelines that do not 'lose touch' with applicability through the procedures of 'datascaping' and hypothesis testing within the research by design process, a continuous feedback with 'reality' might be advisable in the practical design processes. This can be accomplished by conducting a 'normal' integrative design on the same places parallel with the 'research by design'. Furthermore, consulting with practitioners or representatives of commissioners of these design assignment types can help to warrant the applicability of the hypothesized design guidelines.

As I argued above, the design recommendations generated for the complex assignments in landscape architecture and urban design will be issue-specific or what I call 'sectoral half-products'. An integrated design, as demanded in practical non-academic circumstances, however, has to address many more issues. Such a design process will always be a process of blending and negotiating more of these 'sectoral' design guidelines, special local factors and demands of political and societal actors. This practical integration process can no longer meet the strict criteria of empirical science. De Jonge extensively addresses this problem and she mainly bases her discussion on Rittel's wicked problem theory (2009, pp. 134-140). Dorst, a design theorist in industrial design, saw similar problems, even for design that deals with much smaller scaled products that do not have to adapt to very specific contexts the way that landscape architectural and urban designs do (Dorst 1997). Consequently, although the value of scientific 'research by design' to generate design guidelines is high, it should be acknowledged that in the synthesizing part of integrated practical design processes, this method cannot be applied in its pure form. This becomes more of an artistic and political activity – or as Schön calls it: 'reflection-in action'.

I hope I have demonstrated that we can come up with design processes in landscape architecture and urban design, which deserve the label scientific 'research by design'. This 'research by design' needs more consideration, specifically in academic landscape architecture and urban design, in which design knowledge production is one of the core assignments of research. Such design knowledge often consists of issue-specific design guidelines or recommendations that can be combined and integrated in practical design processes.

# 8

# Designing for thermal comfort in Dutch urban squares

## 8.1 Introduction and overview

As I argued earlier in this dissertation, design of public squares without specific attention to microclimate is problematic. I think that this, amongst other reasons, is caused by insufficient knowledge about microclimate processes amongst many landscape architects and urban designers. Others have identified this problem before (Eliasson 2000; Katzschner 2006). In order to make climate knowledge more accessible and understandable and translate it into spatial design configurations, more efforts still have to be made. Easily applicable design guidelines should be generated in order to encourage a better inclusion of microclimate issues is public space design. This 'research by design' study represents one more little building block in the design recommendations for thermal comfort in Dutch public squares: an optimized model pattern. The main question of this 'research by design' study was if it is possible to generate such an easily usable design pattern for microclimate responsive public design and I assumed that it is.

In the following, I describe the path of generating such spatial model patterns for climate-responsive design and testing of these patterns on their effects. Firstly, I specify the underlying typical Dutch climate situations for outdoor sojourn and I show how they are represented in simulations. Secondly, I outline the relevant scientific microclimate knowledge. Eventually, the design process is described. Several alternatives of spatial patterns were generated, based on the relevant existing knowledge, assuming that they affect microclimate positively. These preliminary patterns were integrated and then projected on two different case-squares, being the Spuiplein in The Hague and the Grote Markt in Groningen (which appeared to be most problematic in the interviews with users). The pattern was then tested with ENVI-met® microclimate simulations on its effects, and then improved by subsequent adjustments tested through simulations again until an optimized result was achieved. From this, I draw conclusions on possible model patterns for microclimate responsive design of Dutch urban squares.

## 8.2 Method

In the preceding chapter I have proposed a 'research by design' method for landscape architecture. In this chapter I illustrate how I worked with this method to generate patterns for microclimate-responsive plaza designs.

Refining the process to derive such microclimate-responsive patterns was a long journey of learning by doing, of designing with detours, dead ends and open avenues. It took some time and different trials to come up with a process that could be labeled a 'research by design' according to the criteria sketched in chapter 7. I went through different design processes that showed the pitfalls as well as the more promising routes to follow. In 2008, for example, I tutored a design studio where climate-responsive refurbishment proposals were made for the two squares Spuiplein and Grote Markt in an ‘Academic Master Cluster’. Regional planning and landscape architecture students worked on climate-responsive designs for two squares. I noticed, however, that students did not have sufficient knowledge on microclimate to be able to formulate sharp design hypotheses. Therefore, the design could not be tested properly and the design process was too intuitive to qualify as a rational ‘research by design’. Another detour in this quest was an attempt to test the design guidelines derived from the interviews on the three Dutch squares. For example, the perception of spaces being too wide, places being too open and colour being ‘cold’was related to the perception of thermal discomfort. People also perceived certain spatial configurations as being too windy. This indicates that the results consisted of many negative recommendations or ‘don’ts’ and only a few ‘do’s’. The first problem in that respect was that results from the interviews did not provide really accurate design guidelines on how microclimate should be improved when people perceive discomfort. The possible solutions based on these guidelines were manifold and there would be too little certainty that these would indeed have the desired effect on microclimate. The next problem was that it is basically impossible to test the results of a design process concerning people’s perceptions in the design process itself without actually having it built. People’s changed perceptions of a newly designed situation can only be tested through changes in the real-world situation and by conducting a post-occupancy evaluation. This, of course, is impossible to achieve within a PhD research project due to financial and time limitations. Therefore, I decided that this avenue would not lead me further and I did not continue with a design process that only responded to people’s perceptions.

Yet, that does not mean that people’s perceptions were excluded. As indicated in the chapters on the results of the interviews, people’s probabilistic microclimate assessments were often quite in line with microclimate physics. So I could conclude that through proper use of the existing microclimate physics knowledge, it is possible to create places we can expect to be perceived as thermally comfortable. The only clear exception in people’s experience is the use of colour tones, which does not always have an impact on microclimate physics. Hence I decided to follow a somewhat different avenue, making use of available knowledge on microclimate physics and testing this with microclimate simulation software on its impacts. This method can be considered more ‘scientific’, since the three criteria described in the preceding chapter can be met: existing scientific knowledge is used and design hypotheses are formulated based on this knowledge. This is followed by microclimate simulations in ENVI-met® that sharpen the hypothesis testing process. Eventually, since the designs are developed for more than one incidental case, the patterns derived from the process can be the starting point for more generalizable design patterns.

### 8.2.1 Relevant Dutch climate situations

Before I describe the design process itself, I should give a detailed description of the main climate situations that have to be addressed in the designs to create thermally comfortable places.

Not only physical microclimate itself is important for thermal comfort, but also the perception of microclimate. Chapter 4 showed that people's perception of microclimate relates to the more salient or extreme situations. This mainly concerned wind problems because these occur quite often in the Dutch situation. In the future we can expect that the Netherlands will be subject to more heat waves because of climate changes and that these will also affect people's long-term microclimate perceptions. Deduced from that, I assume that hot situations will become salient in the future as well. Hence, the two situations 'windy' and 'hot' form the starting point for the analysis of situations relevant for thermal comfort in outdoor spaces.

During the outdoor seasons in the Netherlands, two types of situations can be representative for salient situations: when it is rather windy and air temperatures are cool (but not too cold, because then people avoid being outdoors) and when it is very hot and sunny in the summer, with little wind. These two quite contrary situations and their impact on the two squares in Den Haag and Groningen were simulated in the microclimate simulation software ENVI-met® for the existing situation of the squares' spatial settings.

The microclimate simulation software used is ENVI-met®, developed by Prof. Dr. Michael Bruse and colleagues. They describe it as "a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environment with a typical resolution of 0.5 to 10 m in space and 10 sec in time. ENVI-met® is a prognostic model based on the fundamental laws of fluid dynamics and thermo- dynamics. The model includes the simulation of: flow around and between buildings, exchange processes of heat and vapour at the ground surface and at walls, turbulence, exchange at vegetation and vegetation parameters, bioclimatology, particle dispersion." (envi-met website: www.envi-met.com). I chose this software because this is the only software where all the factors influencing thermal comfort like wind speed and direction, and $T_{mrt}$, air temperature are simulated integrally to derive thermal comfort indices (in this case PMV).

The simulations require a careful selection of meteorological and geographical input data. The climate data used are based on the average data from the Royal Dutch Climate Institute KNMI (www.knmi/klimatologie/normalen1971-2000/per_station) for the weather stations close to the respective cities. For Den Haag the data from airport Valkenburg were used and for Groningen the data from airport Eelde. The first input dataset describing a 'windy' day is a typical day at the beginning or end of the outdoor seasons, when normally stronger winds occur and the sun altitude is lower. In this case the 15th of November was chosen, because around that time shadows tend to be longer than at the beginning of the outdoor season. For the wind situation, a typical (and in the Netherlands predominant) situation was chosen. In the Netherlands the prevailing wind direction is south-west and the winds coming from SW are generally stronger than from other directions (see windroses and temperatures www.knmi/kd/normalen1971-2000/station_gegevens.html). Figure 8.1 contains the entire set of input data for the windy situation.

```
% ---- Basic Configuration File for ENVI-met  Version 3.0---------------
% ---- MAIN-DATA Block -------------------------------------------------
Name for Simulation (Text):                =DenHaag
Input file Model Area                     =[DenHaag]\denhaag-input\denhaag ohne
treppen-grob.in
Filebase name for Output (Text):           =DenHaag_1511-windy
Output Directory:                         =[DenHaag]\output
Start Simulation at Day (DD.MM.YYYY):       =15.11.2006
Start Simulation at Time (HH:MM:SS):        =06:00:00
Total Simulation Time in Hours:            =12.0
Save Model State each ? min               =60
Wind Speed in 10 m ab. Ground [m/s]         =6
Wind Direction (0:N..90:E..180:S..270:W..)  =232
Roughness Length z0 at Reference Point      =0.1
Initial Temperature Atmosphere [K]          =282
Specific Humidity in 2500 m [g Water/kg air] =7
Relative Humidity in 2m [%]                =84
Database Plants                           =[DenHaag]\Plants.dat

      ( -- End of Basic Data --)
      ( -- Following: Optional data. The order of sections is free. --)
      ( -- Missing Sections will keep default data. --)
      ( Use "Add Section" in ConfigEditor to add more sections )
      ( Only use "=" in front of the final value, not in the description)
      ( This file is created for ENVI-met V3.0 or better )
[POSITION]________________________________________Where the area is
located on earth
Longitude (+:east -:west) in dec. deg:       =4.19
Latitude (+:northern -:southern) in dec.deg: =52.04
Longitude Time Zone Definition:            =15.0
[PMV] ____________________________________________Settings for PMV-
Calculation
Walking Speed (m/s)                       =0.0
Energy-Exchange (Col. 2 M/A)               =58
Mech. Factor                           =0.0
Heattransfer resistance cloths             =0.75
[LOCALDB] ___________________________________________
Filename additional plants                =[HOLLAND]\Plants_nl.dat
Filename additional sources                =
[PLANTMODEL] ___________________________________________Settings for
plant model
Stomata res. approach (1=Deardorff, 2=A-gs)  =2
Background CO2 concentration [ppm]          =350
[BUILDING]_______________________________________Building properties
Inside Temperature [K]                    = 293
Heat Transmission Walls [W/m²K]            =1.94
```

*Fig. 8.1 ENVI-met® input data, example Den Haag, windy situation*

```
Heat Transmission Roofs [W/m²K]          =6
Albedo Walls                        =0.5
Albedo Roofs                        =0.3
[NESTINGAREA]__________________________________Settings for nesting
Use aver. solar input in nesting area (0:n,1:y) =1
Include Nesting Grids in Output (0:n,1:y)      =0
[TIMESTEPS] __________________________________________Dynamical Timesteps
Sun height for switching dt(0) -> dt(1)      =40
Sun height for switching dt(1) -> dt(2)      =50
Time step (s) for interval 1 dt(0)          =1.0
Time step (s) for interval 2 dt(1)          =1.0
Time step (s) for interval 3 dt(2)          =1.0
[SOLARADJUST] ___________________________________________
Factor of shortwave adjustment (0.5 to 1.5) =0.8
```

The second input dataset represents a summer day during a heat wave. On days like these the impact of the direct sun radiation and heat emission from the environment can be problematic. The chosen day is the 21st of June, because it is the longest day of the year and it is also the day with the shortest shadow patterns. For the wind situation, I selected a typical anticyclonic weather situation with the rather soft easterly winds that are typical for these situations. The entire set of input data can be seen in fig. 8.2.

*Fig. 8.2 ENVI-met® input data, example Den Haag, hot situation*

```
% ---- Basic Configuration File for ENVI-met  Version 3.0--------------
% ---- MAIN-DATA Block -----------------------------------------------
Name for Simulation (Text):              =DenHaag
Input file Model Area                  =[DenHaag]\denhaag-input\denhaag ohne
treppen-grob.in
Filebase name for Output (Text):          =DenHaag_2106-hot
Output Directory:                       =[DenHaag]\output
Start Simulation at Day (DD.MM.YYYY):       =21.06.2006
Start Simulation at Time (HH:MM:SS):        =06:00:00
Total Simulation Time in Hours:            =12.0
Save Model State each ? min               =60
Wind Speed in 10 m ab. Ground [m/s]         =2
Wind Direction (0:N..90:E..180:S..270:W..)  =90
Roughness Length z0 at Reference Point      =0.1
Initial Temperature Atmosphere [K]         =302
Specific Humidity in 2500 m [g Water/kg air] =7
Relative Humidity in 2m [%]               =60
Database Plants                         =[DenHaag]\Plants.dat
        ( -- End of Basic Data --)
        ( -- Following: Optional data. The order of sections is free. --)
```

```
      ( -- Missing Sections will keep default data. --)
      ( Use “Add Section” in ConfigEditor to add more sections )
      ( Only use “=” in front of the final value, not in the description)
      ( This file is created for ENVI-met V3.0 or better )
[POSITION]____________________________________Where the area is
located on earth
Longitude (+:east -:west) in dec. deg:      =4.19
Latitude (+:northern -:southern) in dec.deg: =52.04
Longitude Time Zone Definition:           =15.0
[PMV] ________________________________________Settings for PMV-
Calculation
Walking Speed (m/s)                    =0.0
Energy-Exchange (Col. 2 M/A)              =58
Mech. Factor                        =0.0
Heattransfer resistance cloths           =0.75
[LOCALDB] _______________________________________
Filename additional plants               =[HOLLAND]\Plants_nl.dat
Filename additional sources               =
[PLANTMODEL] ______________________________________Settings for
plant model
Stomata res. approach (1=Deardorff, 2=A-gs)  =2
Background CO2 concentration [ppm]        =350
[BUILDING]____________________________________Building properties
Inside Temperature [K]                  = 293
Heat Transmission Walls [W/m²K]           =1.94
Heat Transmission Roofs [W/m²K]           =6
Albedo Walls                        =0.5
Albedo Roofs                        =0.3
[NESTINGAREA]_______________________________Settings for nesting
Use aver. solar input in nesting area (0:n,1:y) =1
Include Nesting Grids in Output (0:n,1:y)      =0
[TIMESTEPS] _____________________________________Dynamical Timesteps
Sun height for switching dt(0) -> dt(1)      =40
Sun height for switching dt(1) -> dt(2)      =50
Time step (s) for interval 1 dt(0)          =2.0
Time step (s) for interval 2 dt(1)          =2.0
Time step (s) for interval 3 dt(2)          =1.0
[SOLARADJUST] ____________________________________
Factor of shortwave adjustment (0.5 to 1.5) =0.8
```

The outcome of the ENVI-met® simulations for these salient situations in terms of ‘windiness’ and ‘heat’ in the existing spatial configuration in its turn is compared with the ‘mental microclimate maps’ of the interviewees. This demonstrates that the areas people describe to be problematic in terms of wind also appear as problematic in the simulations for the windy day with wind speeds well above 2 m/s, which is uncomfortable for calm activities and sojourn (see examples, fig. 8.3 and 4, for all maps, see electronic supplements on CD).

So, for the wind situation, the simulations can be used as a reliable basis that also covers people's perceived problem areas. For the sun/shadow situation it is not possible to compare the perceptions and simulations, for the reason that the analysis of people's mental maps established no significant sun-related problems. One can only assume that in the future, people will also find places with too much sun impact thermally uncomfortable. Nevertheless, I assumed the same for the 'hot day' situations, since the good match between wind perception and the simulation already suggested that the outcome of the simulations was a valid predictor of people's probable microclimate perceptions.

*Fig. 8.3 (right) areas perceived 'too windy' by the public on Grote Markt, Groningen*

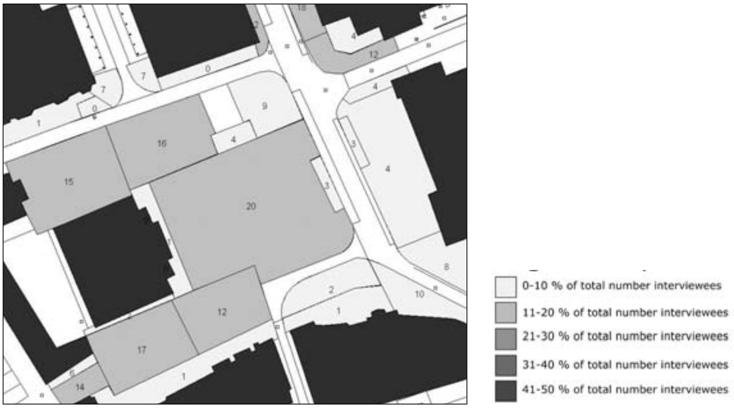
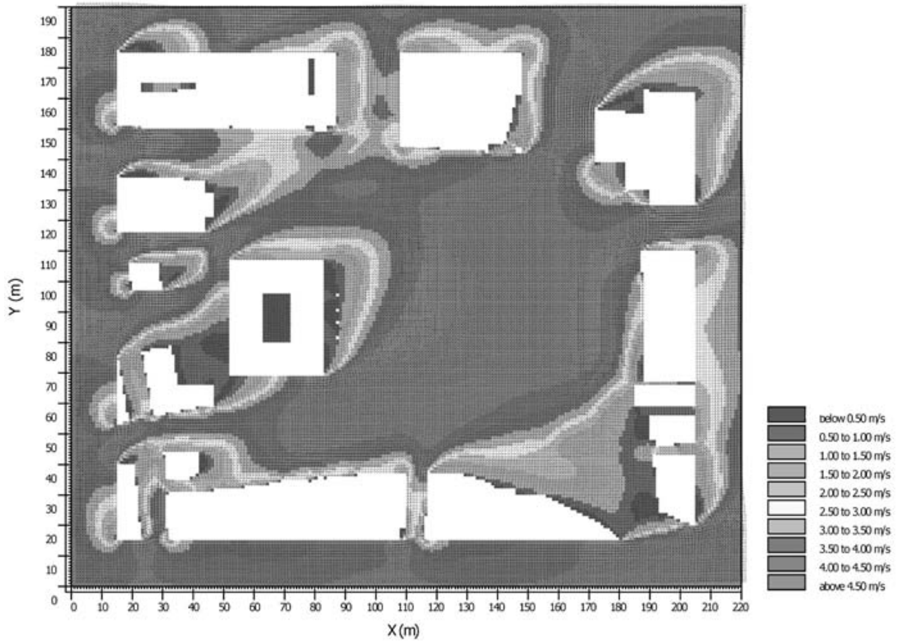


*Fig. 8.4 (lower) wind simulation for the windy day on Grote Markt, Groningen, simulation 15.11, 9 hrs (other simulation settings, see fig. 1)*



### 8.2.2 Scientific knowledge basis for microclimate comfort patterns

To generate optimized spatial patterns for thermal comfort in Dutch squares, the relevant existing microclimate knowledge first had to be reviewed. This concerned the purely physical as well as the perceptional aspects of thermal comfort that were described in earlier chapters.

For the physical aspects of thermal comfort, several climatic parameters are important, such as relative humidity, air temperature, $T_{mrt}$ and wind speed. The parameters of air temperature and relative humidity can hardly be influenced through small-scale urban design interventions due to their dependence on larger scale meteorological and urban meso-climate influences. The factors that smaller scale urban design can influence are wind and mean radiant temperature (Brown and Gillespie 1995, pp.10, 71). Therefore, I will review the relevant literature on adaptation measures that influence wind and mean radiant temperature. This review is done separately because wind and radiant temperature have different dynamics and spatial patterns relating to their processes (that can eventually be used for translation into spatial patterns). After that I will also give a brief summary of the factors of thermal comfort that are not necessarily influenced by physics. These factors result from the research described in chapter 6 on the influence of materials and colours on thermal comfort perception.

*Wind*

In a coastal country like the Netherlands, wind speeds are generally higher than in inland regions, which often generates problems with thermal comfort as the preceding chapters showed. In the Dutch climate, wind protection can help to achieve better thermal comfort in outdoor places. This wind protection is most effective when it buffers south-westerlies because these winds are often quite strong and south-west is also the prevailing wind direction in the Dutch context.

In order to generate simple patterns for wind protection elements, basic quantitative knowledge is used to specify the cavity and wake areas around wind shelter elements. The literature I found describes the shelter effects of trees and other wind screening objects. The most common general guideline is based on Nägeli (1946) and appears in Robinette and McClennon (1983, p. 22), Oke (1987, p.244), Brown and Gillespie (1995, p. 130) and Littlefair et al. (2000, p.109). It describes the general effects of wind screening objects with different densities on the size of the sheltered area at the leeside, depending on the height of the screening objects (see fig. 5.21).

Typical air stream patterns occur around a windbreak, consisting of the displacement zone in which air molecules are deflected from the continuous horizontal flow they would have without a windbreak. In a small area before the windbreak and a larger area behind it, the cavity zone shows a negative pressure with low wind speeds. Further leeward in the wake area the stream speed is still weakened until it regains the same strength of the undisturbed flow at about 10-15 x height (h) of the obstacle.

However, this description of wind around a windbreak gives no clear indications about sizes and qualities of the wind screening elements and what the notion of different ‘densities’ entails. When this description is compared to Van der Linde’s guidelines in Robinette and McClennon (1983, p. 23, fig. 34), contradictions occur for medium dense screens. This can be exemplified by an instance for a ‘very dense’ windbreak at the distance of 10x h, where the wind speed behind a break is shown in relation to the initial speed of the undisturbed flow. According to Nägeli, the wind speed is supposed to have 60% of the intial wind speed, whereas according to Van der Linde this is supposed to be 85%. In other literature the effects on impermeable windbreaks also show contradictions. Jacobs’ (1983, p. 29) measurements result in different general patterns from the ones that Boutet (1987, p. 79-82) describes based on O’Hare and Kronauer. For instance, in a spot at 5x h distance from the obstacle at the height of the top of the screen, Jacobs measured values of 55% reduction whereas O’Hare and Kronauer assert it to be 80%. Similarly, for less dense screens with opening percentages of 50% differences come to light. When the wind field behind slat fences as described by Boutet (1987, p. 79-82) is compared to the effects of windscreens that were tested by Dierickx et al. (2001), again differences occur. It goes beyond the scope of this dissertation to discuss all these differences. I acknowledge that this uncertainty is a problem for design as design hypotheses can be tested most efficiently when they are based on a solid scientific knowledge basis.

I chose to follow the predictions developed by Nägeli because many authors, as indicated above, adopted them. However, one important question still remains: the length of an ‘ideal’ windbreak. Nägeli suggested that to be the most efficient, the length of the windbreak should be at least 12x h. Unfortunately, he did not give quantitative information about how much lower the efficiency is when the windscreen is shorter than 12x h. Therefore, I used the general information given by Nägeli (see fig. 5.21), bearing in mind that the wake areas will probably somewhat smaller.

*Mean radiant temperature, $T_{mrt}$*

The most important parameter for the influence of mean radiant temperature is sun and shadow (Brown and Gillespie 1995, p. 112-117; Matzarakis 2001, p.160-198). Nowadays, the patterns of sun and shadow can easily be simulated in 3D-design software, such as SketchUp and AutoCAD. These computer programmes are very commonly used in design processes, and they simulate shadow patterns reliably in all geographic regions and at all times of the day. By using this kind of simulations it is possible to quickly generate shadow patterns and for this reason SketchUp shadow simulations were used as a tool in this research by design to conduct first studies on sun and shadow patterns.

*Perception based guideline: materials and colours*

Next to the physical requirements, the experiential aspects of urban space and the feeling of thermal comfort are important. As the research results in chapters 4-6 showed, the microclimate perceptions of people compare quite well to climate physics. Yet, one aspect only partly corresponded to the physical parameters: the perception of materials and colours. From the research in chapter 6, I deduced that Dutch people are supposed to feel more thermally comfortable when more ‘warm’ materials are present in the environment, such as wood or brick stone. The physical influence of materials can be tested as an integral factor within the ENVI-met® simulations. The psychological influence of ‘warm’colour tones, however, cannot be tested in these simulations and is therefore added as a complementary independent design guideline.

### 8.2.3 Preliminary spatial patterns for microclimate comfort

Based on the literature on wind discussed above and through SketchUp shadow simulations, I translated the requirements for optimized sun- and shadow situations and wind adaptation into spatial patterns. Within the options for wind and sun responsive design there was a plethora of solutions. Some of them were suitable for the scale and use of urban outdoor places and some were not. For instance, placing a roof over the whole square would strongly affect the impression of an outdoor place. Similarly, placing very high (and thus very efficient) windscreen walls on a square would probably damage the scale and functionality of the square.

In order to select the more suitable solutions, the two squares were also designed in a more ‘normal’ integrative way to be able to identify the restrictions that such places often create, taking into account the functional, social and aesthetic factors that are important in design of public squares. I will not give a detailed description of the design processes, but only the important conclusions for the microclimate adaptation elements. The results of the integrated design processes showed that if a square contains too many pergolas, roofs, trees or other objects, this will cause problems with functions such as festivals, fun fairs, and markets, where open spaces are needed for tall elements like stages and fun fair attractions. Moreover, routes for deliveries and emergency access have to remain open. The shadow-casting or wind-buffering elements should not visually subdivide the place too much at eye-level, for this can have a negative effect on people’s feeling of safety. Elements of human scale or the scale of the urban surroundings are preferable to very big elements.

*Generation of preliminary patterns for wind protection*

From the literature outlined in the preceding subchapter, several patterns for wind-buffering elements could be derived. The ‘windy’ day simulations for the two squares demonstrated that the wind speeds in the central areas of the squares can easily reach 4m/s and higher. In order to create a comfortable situation for sojourn, the wind speed has to be reduced at least 50%. Therefore, wind-buffering breaks are selected, which – when distributed in a proper sequence – are expected to bring wind speed reductions of 50% over the whole area. All of these breaks should be directed perpendicular (Dierickx et al. 2002) to the south-west in order to block the prevailing (and also strongest) winds in the most efficient way. Since vegetative materials or other permeable elements are more efficient for creating longer wakes (Nägeli 1946) I decided to use these permeable elements. Two models (fig. 8.5 and 8.6) that use these types of wind-blocking element received further consideration. One is a 15 m tall row of trees with transparent ‘medium dense’ windscreens in the trunk areas. This transparent screen is chosen because it does not hinder the possibility to oversee the square, which is important for the public’s feeling of safety. This lower screen can be made from a material like glass or plastic and should have a perforation with the same wind permeability as ‘medium dense’ vegetation – I call this an ‘urban shelterbelt’ (fig. 8.5). The other type of wind break consists of lower elements in the form of hedges that are about 1.5m high, so that people can still see the whole square from eye-level (fig. 8.6).

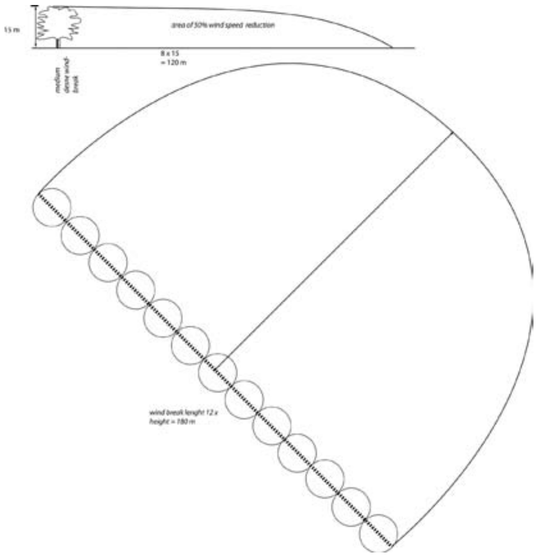
For the suggested wind screening elements I hypothesize that:

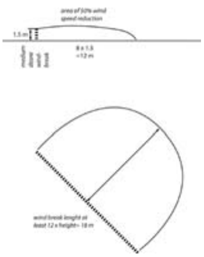
- The urban shelterbelt creates a wake area where wind speeds are lower than 50% up to 120 m behind the obstacle (fig. 8.5).
- Lower wind breaking elements, such as hedges or medium dense slat fences, of 1.5 m height, distributed in a pattern of approximately 12 m depth will offer 50% wind reduction behind them. (fig. 8.6).

The pattern of the urban shelterbelt seems promising for the usability and visual impact within an urban square and will be considered in the further design process.

*Fig. 8.5 (left) urban shelterbelt with typical wake area according to Nägeli*

*Fig. 8.6 (right) 1.5 m hedgerow with typical wake area according to Nägeli*





The pattern for small-scaled windbreaks of a 1,5 m height shows a wake of only 12 m behind the objects where a wind speed reduction of 50% can be achieved. When a square should be protected by these elements this would imply that the square would be filled with a dense pattern of hedgerows or other similar medium-dense elements. This would be detrimental for the usability of a square. In order to achieve some functionality for routes, places to put up markets, podia, et cetera the hedge pattern would have to be disrupted in many places. This, in turn, would negatively affect the wind protection function and in the openings even higher wind speeds would occur. Therefore this low hedge windbreak pattern was considered of little use and was excluded for the further research by design process.

*Generation of preliminary pattern for sun- and shadow comfort*

Since I was not able to acquire sufficient positive information from the 'research for design' (chapters 4-6) about people's preferred patterns of sun and shadow elements, some assumptions had to be made. I assumed that people would consider a place thermally comfortable when it has a small-scaled distribution of sunny and shaded areas on the square. This way it would be easy for people to choose between sunny or shady places without having to walk long distances. On the other hand, the place may not get overshadowed by too densely placed shading elements. It does not make sense, for example, to place so many trees or roofs that they shade each other and create a very uniform shaded situation.

Series of shadow simulation patterns were generated with the help of SketchUp-software for common shading devices that can be placed in many squares without hindering the functions. These elements were small-scaled roofs of 5 x 5 m with a height of 5 m and mid-sized trees (15m high and 15m crown diameter). The trees are of the types that are often planted in cities with a moderate scale and dense crowns, e.g. Acer platanoides or Platanus acerifolia (sunlight transmissivity in summer approx. 10%, see Brown and Gillespie, p.116). The times represented in the shadow studies are of March 30th, June 21st and Oct 30th at 9, 13 and 17 hrs. They depict times around the beginning and end of the outdoor season, as well as the height of summer with the shortest shadow patterns. Since the shadow lengths change considerably throughout the seasons, two first patterns were developed. One pattern focused on the summer situation with the typical short shadows and one in the spring/autumn situation where shadows are longer. The shadow casting elements were placed at such a distance from each other that the shadows did not overlap, but just 'touched' the shadow of the neighbouring element. In the autumn situation, the late afternoon shadows grew extremely long and they reached even beyond the edges of a mid-sized to large square of 100 x 100 m (see fig. 8.13). For this reason, these late autumn afternoon shadows were not included in the evaluation for an 'ideal' pattern for spring/autumn. The study results in different patterns for the ideal summer and spring/autumn situations (see fig. 8.7-8 for roofs and fig. 8.10-11 for trees). They were eventually fused into one pattern that compromises the patterns for all seasons (see fig. 8.9 for roofs and fig. 8.12 for trees). This was considered the most suitable pattern because it shows benefits throughout the whole outdoor season.

From the comparison of the shadow benefits of trees and roofs in these shadow diagrams it became apparent that the roofs have to be placed in a very dense grid (10 m E-W and 15 m N-S distance) to provide a denser shadow pattern as opposed to the trees that can be placed much further apart (40 m E-W and 40 m N-S distance) because they cast much larger shadows

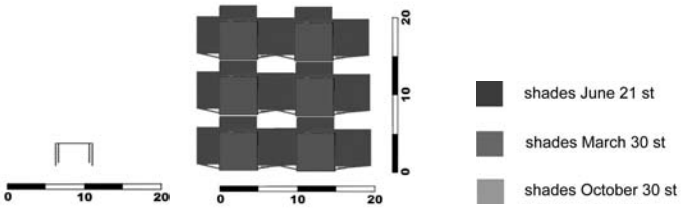


*Fig. 8.7  side view roof and roof-shadow pattern for summer*

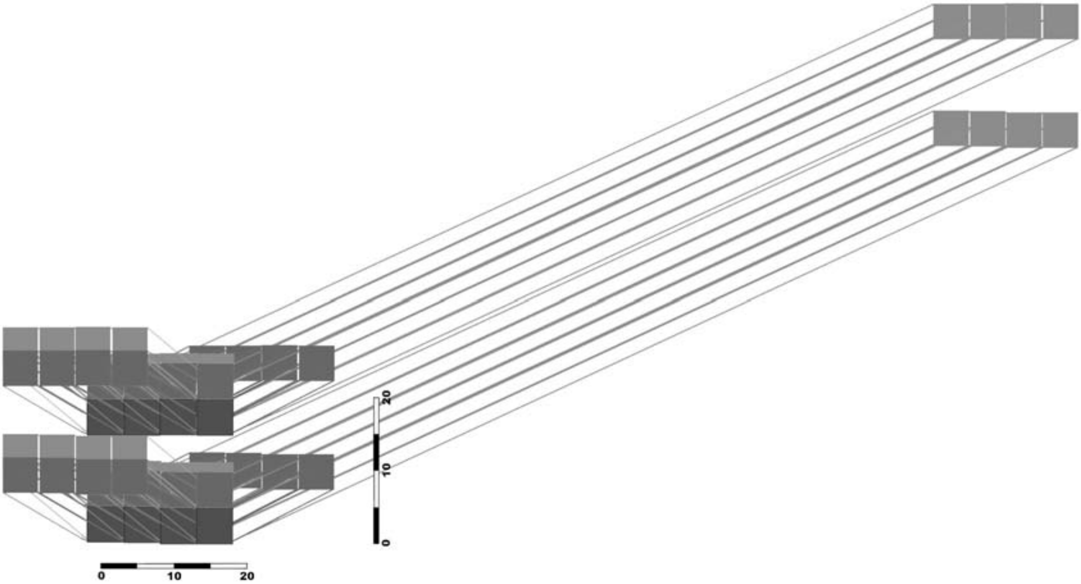


*Fig. 8.8  roof-shadow pattern for spring/autumn*

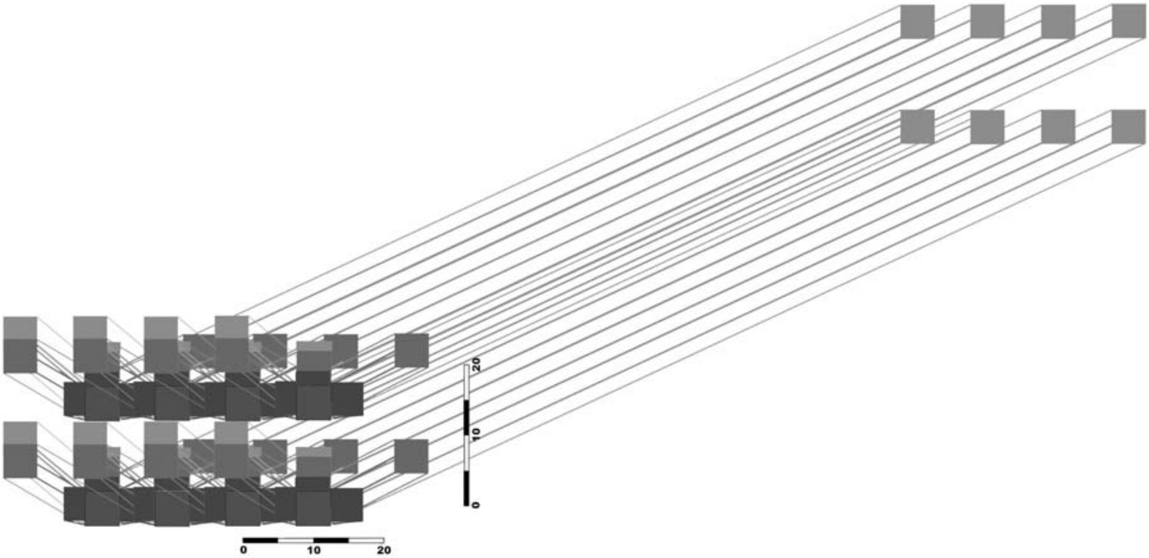


*Fig. 8.9  compromised roof- shadow pattern*

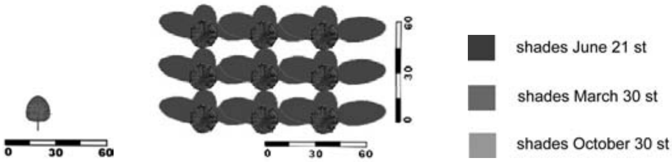


*Fig. 8.10 side view tree and tree-shadow pattern for summer*

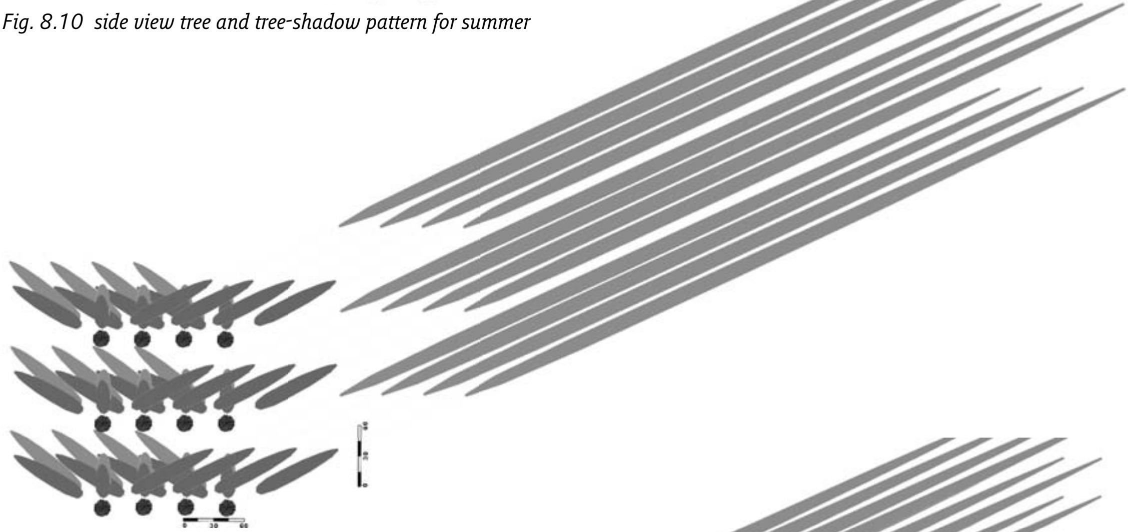


*Fig. 8.11 tree-shadow pattern for spring/autumn*

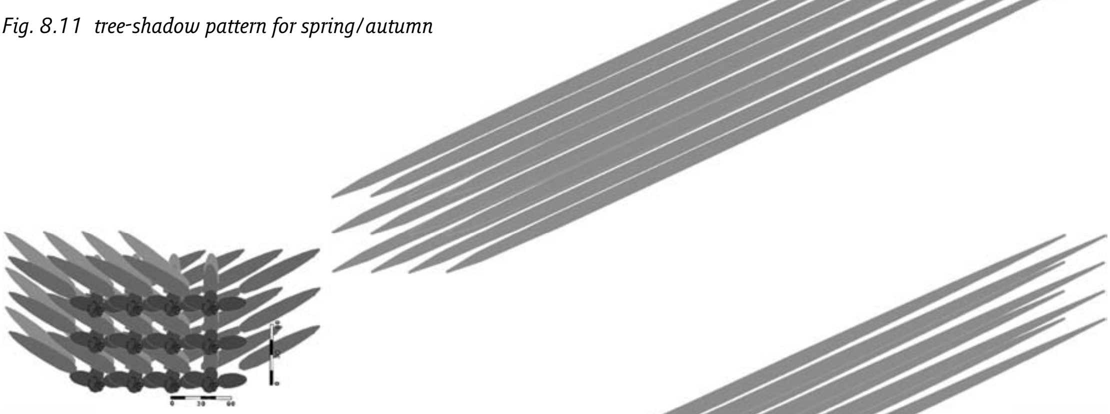


*Fig. 8.12 compromised tree-shadow pattern*

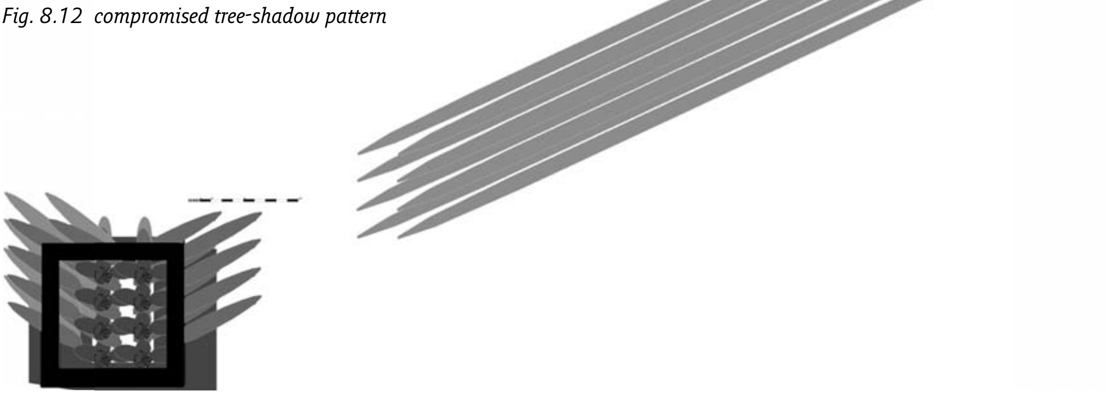


*Fig. 8.13 compromised tree-shadow pattern projected in non-shaded areas of square of 100 x 100 m width*

due to their height and larger three-dimensional volume. Since such a dense grid of roof objects in a square will substantially hamper a square's usability for events or markets, I decided not to investigate the option of these further. Roofs, pergolas or other horizontal artificial shading elements should only be used as a substitute for trees in places where it is not possible to plant trees.

These preliminary patterns of the beneficial wind and shadow effects for thermal comfort of these interventions were the first rough hypothesis in this 'research by design', leading to some first conclusions such as the exclusion of the hedge- or roof-options. Of each of the selected options I believed that they could improve the microclimate on squares in the Dutch climate situation. The preliminary patterns that were selected as promising will be combined in the next step and then be tested further in ENVI-met® microclimate simulations.

## 8.3 Testing alternatives on the case-squares

### 8.3.1 General remarks

In this subchapter I document the process of generating and testing climate responsive patterns for Dutch squares of a medium to large size. Different patterns based on the preliminary patterns described in the preceding subchapter were combined and projected on the squares Spuiplein, Den Haag and the Grote Markt in Groningen. The functional requirements for the spatial layout of the squares, such as streets or other places that should be left open (e.g. for circulation, markets, events) or for aesthetical reasons (e.g. for lines of sight) were not considered. The places were now designed for microclimatological aspects alone, because the functional and other issues had already been taken into account in the selection of most suitable preliminary patterns.

The alternatives for new patterns were simulated on their microclimatolocigal effects with the same input data that were used to simulate the existing situation in the squares described (see fig. 8.1 and 8.2). The simulation results of the existing situation and the alternatives were compared for five points in time per day: 9, 11, 13, 15 and 17 hrs. One exception was made for the autumn situation in Den Haag, where due to the fact that darkness had fallen at about 16 hrs, the last values were simulated for that point in time. In order to evaluate the effects of the new alternatives, simulations of the different alternatives were compared to the simulations of the existing situation. This is described separately for the alternatives (an overview is given in tables 8.1 to 8.3).

Concerning the representation of the patterns in ENVI-met® a few remarks are necessary, because the simulation software has some limitations in terms of grid resolution and material-settings. The software cannot simulate very small scaled or thin elements and elements that consist of different materials at different heights. Therefore some adjustments had to be made to the urban shelterbelts in the simulation input. The urban shelterbelt's thin windscreen element and the two different materials – glass or an equally transparent material in the trunk space and vegetation above cannot be represented in ENVI-met®. As a substitution, a tree-row with branches reaching down to ground level was chosen to represent a similar expected wind effect.

The layout of the sites themselves was also part of the reason why the projected preliminary patterns required some adjustments. In Groningen, for example, the urban shelterbelt had to be subdivided into two pieces because a building was also situated on this ideal location for the urban shelterbelt (see fig. 8.15).

The alternatives were hypothesized to improve thermal comfort. In this testing phase, the Predicted Mean Vote (PMV) value became the most important indicator for improvement. This index combines all the important microclimate factors. This PMV index thus also shows, for instance, the effects shadow-casting elements have on the wind field and the shadows that the wind-buffering elements cast. The PMV index has been criticized as an index for outdoor comfort, as discussed in earlier chapters, but for assessing the integrated physical microclimate impact of the preliminary patterns, this index is suitable. Apart from that it was the only index within the ENVI-met® simulation software package that was available when I started the simulations.

### 8.3.2 Developing and testing alternative 1

The first alternative pattern derives from the preliminary patterns explored in subchapter 8.2. The preliminary patterns selected for wind- and sun/shadow adaptation that could also be easily embedded in an integrated design of a square were a combination of a single urban shelterbelt and the 'compromised' shadow patterns for the shadow casting trees (see fig. 8.13). It thus consists of a combination of a medium dense urban shelterbelt of 15 m height and a 40 x 40 m grid of 15 m tall shadow trees with an open trunk space and a dense crown. The patterns include an 'overlap' of one shadow tree included in the shelterbelt. Apart from this, the pavement material in the Spuiplein-case was changed because it consisted of a material that was perceived as 'cold'. Instead, a pavement of reddish brick stones was proposed. The plans of the squares with the projections of the preliminary patterns are shown in fig. 8.14 and 8.15.

The impacts of the first pattern (15 m high medium dense shelterbelt and 40 x 40 m grid of 15 m tall dense trees) were then simulated for their effects on microclimate over whole days in the 'windy' and 'hot' situation for the two locations in Den Haag and Groningen. The differences in PMV on pedestrian level (1.60 m) are graphically depicted in the electronical supplements for this chapter (see CD) and table 8.1 includes a textual discussion of the comparison results.

From the simulations of this alternative projected on both squares, some conclusions could be drawn, which had an impact on the development of the second alternative. Concerning the shadow patterns of the trees, the shades

*Fig. 8.14 Alternative 1: urban shelterbelt 15 m tall and 40 x 40 m grid 15 m tall shadow trees projected on the Spuiplein, Den Haag*

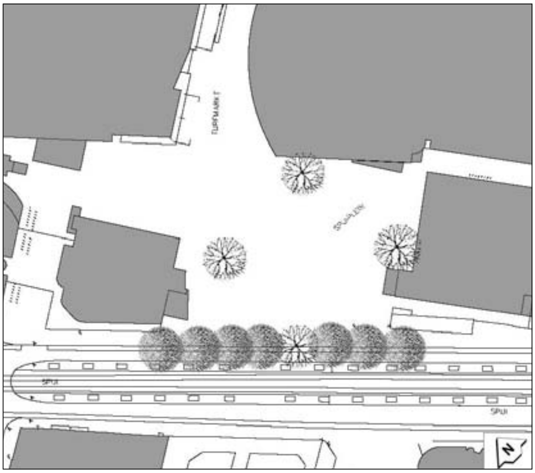


*Fig. 8.15 Alternative 1: urban shelterbelt 15 m tall and 40 x 40 m grid 15 m tall shadow trees projected on the Grote Markt, Groningen*

*Table 8.1 Alternative 1, Evaluation matrix, all evaluations expressed in PMV units (existing situation – new situation)*

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **'windy day'** | **'hot day'** | **'windy day'** | **'hot day'** |
| 9 | *shadows:*<br>dusk,tree shades vague and very long: 0 to -1,<br>*wind:*<br>behind shelterbelt +1 to +2, interrupted by wind channel under inserted shade tree<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>tree shades medium length: -2 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1 | *shadows:*<br>dusk tree shades vague and very long: 0 to -1,<br>*wind:*<br>behind shelterbelt + 1 to +2, behind shadow trees few small areas with + 1 to +2 | *shadows:*<br>all tree shades medium length: -3 to -4,<br>*wind:*<br>no remarkable wind effect |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **‘windy day’** | **‘hot day’** | **‘windy day’** | **‘hot day’** |
| 11 | *shadows:*<br>tree shades quite long: - 1 to -3,<br>*wind:*<br>behind shelterbelt +1 to +2<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>tree shades largely ‘over-rule’ wind protection of shelterbelt; | *shadows:*<br>tree shades, short: -2 to >-4 , shelterbelt has small effect of -1 to -2 on very small area<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>tree shades quite long: -1 to -3,<br>*wind:*<br>behind shelterbelt: +1 to +2 in smaller areas, , behind shade trees +1 to +2<br>*general remarks:*<br>tree shades partly ‘over-rule’ wind protection of shelterbelt, | *shadows:*<br>all tree shades, short: -3 to -4 ,<br>*wind:*<br>less ventilation in few spots behind single trees: 0 to +1 |
| 13 | *shadows:*<br>tree shades quite long: -1 to -3,<br>*wind:*<br>small sheltered areas +1 to +2<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>tree shades largely ‘over-rule’ wind protection of shelterbelt; | *shadows:*<br>tree shades, short: -2 to >-4, shelterbelt has small effect of -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, also inexplicable effect of material change with lower PMV 0 to -1! | *shadows:*<br>tree shades quite long: -1 to -3, wind protection behind shelterbelt: 1 to +2,<br>*wind:*<br>behind shelterbelt: +1 to +2 in smaller areas<br>*general remarks:*<br>tree shades partly ‘over-rule’ wind protection of shelterbelt; east of shade trees inexplicable cooler spots occur | *shadows:*<br>all tree shades, short: -3 to -4 ,<br>*wind:*<br>less ventilation in more spots behind single trees: 0 to +1 |
| 15 | *shadows:*<br>tree shades very long: -1 to -2,<br>*wind:*<br>small sheltered areas +1 to +2<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>tree shades largely ‘over-rule’ wind protection of shelterbelt; | *shadows:*<br>tree shades, short: --2 to >-4, shelterbelt has small effect of -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, , also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>tree shades very long: -1to -2, wind protection behind shelterbelt: 1 to +2,<br>*wind:*<br>behind shelterbelt +1 to +2 in small areas<br>*general remarks:*<br>tree shades largely ‘over-rule’ wind protection of shelterbelt; east of shade trees inexplicable cooler spots occur | *shadows:*<br>all tree shades, short: -3 to -4 ,<br>*wind:*<br>less ventilation in larger spots behind single trees: 0 to +1 |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **‘windy day’** | **‘hot day’** | **‘windy day’** | **‘hot day’** |
| 17<br>(16) | *shadows:*<br>dark<br>*wind:*<br>behind shelterbelt +1 to +2, smaller places than at 9 hrs, interrupted by wind channel under inserted shade tree<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>tree shades medium length: -2 to >-4<br>*wind:*<br>no significant effect on PMV<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>dark<br>*wind:*<br>behind shelterbelt 1 to +2<br>*general remarks:*<br>east of shade trees inexplicable cooler spots occur | *shadows:*<br>tree shades medium length: -4 to> -4<br>*wind:*<br>less ventilation in larger spots behind single trees: 0 to +1 |
| **Conclus. Alt. 1** | **Overall PMV slightly improved in comparison to existing situation** | **Overall PMV slightly improved in comparison to existing situation** | **Overall PMV slightly improved in comparison to existing situation** | **Overall PMV slightly improved in comparison to existing situation** |

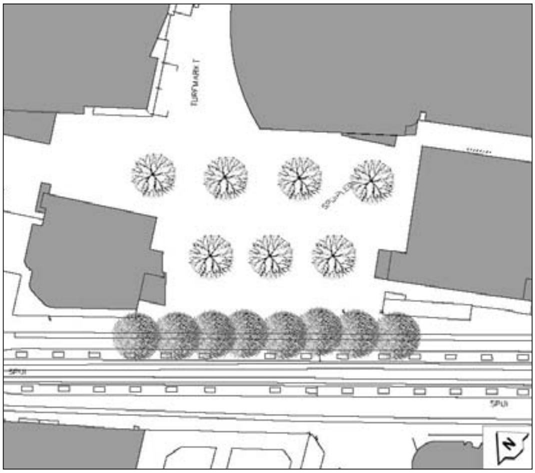
in the autumn situation showed unexpectedly low PMV values. This seemed somewhat unrealistic because around that time trees have lost their foliage and cast less shadow. For the second alternative, I therefore decided to simulate the trees both in a foliated and a defoliated state.

The wakes of the urban shelterbelt were considerably smaller than expected. This had consequences for the settings in alternative 2 as well.

In alternative 1, the PMV values in both cases improved slightly for the entire square and its surroundings, when compared to the existing situation. In the hot situation, the PMV values changed up to one PMV unit towards comfortably cooler, and in the windy, cooler situation the PMV values changed up to one PMV unit towards comfortably warmer in large areas of the two squares. From the simulations it is not possible to conclude why this general improvement occurs. It seems that this effect is based on a greater roughness in the wind field, as well as the general climate buffering effect of vegetation on air temperature. Since I wanted to find out if this effect of vegetation is important, I used more vegetation in the development of alternative 2.

### 8.3.3 Developing and testing alternative 2

Since the simulations for alternative 1 showed that the wind shelter effects of the urban shelterbelt of 15 m height did not have a long enough reach, in alternative 2 the shelterbelt was heightened to 25 m. Also, in the second alternative the shelterbelt was entirely closed, as opposed to the first alternative, which had a shade tree with an uncovered trunk area that showed a too strong funneling effect. For the autumn days, the shadow effect of the



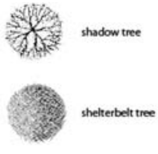


*Fig. 8.16 (left) Alternative 2: urban shelterbelt 25 m tall and 25 x 25 m grid 15 m tall shadow trees projected on the Spuiplein, Den Haag*

*Fig. 8.17 (right) Alternative 2: urban shelterbelt 25 m tall and 25 x 25 m grid 15 m tall shadow trees projected on the Grote Markt, Groningen*

trees in alternative 1 was too strong, so more attention was given to the selection of the tree species. The selection of species for the shadow trees was now based on the starting times of foliation. For spring and autumn, trees that cast little foliage shade are the most useful. Thus, tree species that develop foliage late in the year and cast it early are suitable. In summer the foliage should be as dense as possible for efficient shading. Tree species that have all these properties are Acer rubrum, Fraxinus pennsylvatica, Juglans nigra, Liriodendron tulipifera and Tilia cordata (Brown and Gillespie 1995, p. 116).

I adjusted the simulation- input data for the autumn situation in order to represent the seasonal foliage properties appropriately. The shadow trees were given a lower leaf area density (LAD) value of LAD 0.2 and the urban shelterbelt was simulated with slightly more foliage of LAD 0.5, representing a species such as Fagus sylvatica that keeps some foliage over winter and is thus assumed to bring about better wind protection than a completely leafless tree. I chose these LAD values after personal consultation with the creator of the ENVI-met® simulation software. Since I assumed that the trees have an overall positive effect on PMV, I also decided to densify the shadow tree pattern to 25 x 25 m. The plans of this alternative projected onto the two squares are shown in Fig. 8.16 and 8.17. The resulting differences in PMV of this alternative in relation to the existing situation on pedestrian level (1.60 m) can be seen in the electronical supplements for this chapter (see CD) and table 8.2 includes the specified discussion of comparison results.

The impacts of the second alternative (25 m high medium dense shelterbelt and 25 x 25 m grid of 15 m tall dense trees) were then simulated for effects of microclimate over whole days in the ‘windy’ and ‘hot’ situation for the two locations in Den Haag and Groningen. The differences in PMV on pedestrian level (1.60 m) can be found in the electronical supplements for this chapter (see CD) and table 8.2 includes a textual discussion of the comparison results.

*Table 8.2 Alternative 2, Evaluation matrix, all evaluations expressed in PMV units (existing situation – new situation)*

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **'windy day'** | **'hot day'** | **'windy day'** | **'hot day'** |
| 9 | *shadows:*<br>dusk, tree shades vague and very long: 0 to -1,<br>*wind:*<br>in small unshaded area behind shelterbelt +1 to +2, rest of wake 'balanced out' with shade influence of grid trees<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>inexplicable cooler area in unshaded areas with higher (!) $T_{mrt}$ | *shadows:*<br>tree grid shades medium length: -3 to >-4, very small area of shadow effect in shelterbelt area, -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>dusk, tree shades vague and very long: 0 to -1,<br>*wind:*<br>no clear wake effect behind shelterbelt (!), no effect behind single trees | *shadows:*<br>all tree shades have medium length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>inexplicable small warmer areas (no relation with $T_{mrt}$ or wind speed detectable) |
| 11 | *shadows:*<br>influence of shelterbelt -2 to -3, grid trees 0 to -2 in large parts of the square<br>*wind:*<br>in larger unshaded area behind shelterbelt +1 to +2, rest of wake 'overruled' with shade influence of grid trees<br>*material change:*<br>no significant effect on PMV | *shadows*:<br>tree shades short length: -3 to >-4, , very small area of shadow effect in shelterbelt area , -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades bring inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>influence of shelterbelt -1 to -3, grid trees 0 to -2 in parts of the square<br>*wind:*<br>in few unshaded areas behind shelterbelt +1 to +2, some part of wake 'overruled' with shade influence of shelterbelt, some parts have balanced out wind and shade influence | *shadows:*<br>all tree shades have short length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>inexplicable small warmer areas (no relation with $T_{mrt}$ or wind speed detectable) |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **‘windy day’** | **‘hot day’** | **‘windy day’** | **‘hot day’** |
| 13 | *shadows:*<br>influence of shelterbelt -2 to -3 in large areas (!), grid trees 0 to -2<br>*wind:*<br>in small unshaded area behind shelterbelt +1 to +2, rest of wake ‘overruled’ with shade influence of grid trees<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>tree shades short length: -3 to >-4, , very small area of shadow effect in shelterbelt area , -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>influence of shelterbelt -1 to -3, grid trees 0 to -2 about half of square affected<br>*wind:*<br>in large parts of shelterbelt wake is ‘overruled’ with shade influence, some parts have balanced out wind and shade influence | *shadows:*<br>all tree shades have short length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>numerous inexplicable slightly warmer areas (no relation with $T_{mrt}$ or wind speed detectable) |
| 15 | *shadows:*<br>influence of grid trees and shelterbelt -1 to -2 in large areas,<br>*wind:*<br>in small unshaded area behind shelterbelt +1 to +2, rest of wake ‘overruled’ with shade influence of shelterbelt and grid trees<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>tree shades short length: -3 to >-4, , very small area of shadow effect in shelterbelt area , -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades bring inexplicably slightly higher PMV 0 to +1, inexplicably ‘overrule’ the shadows of trees shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>influence of all trees -1 to -2, about 2/3 of square affected<br>*wind:*<br>in some parts of shelterbelt wake is ‘overruled’ with shade influence, some parts have balanced out wind and shade influence | *shadows:*<br>all tree shades have short length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>some inexplicable slightly warmer areas (no relation with $T_{mrt}$ or wind speed detectable) |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **‘windy day’** | **‘hot day’** | **‘windy day’** | **‘hot day’** |
| 17 (16) | *shadows:*<br>dark<br>*wind:*<br>in small area behind shelterbelt +1 to +2<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>other wake areas have inexplicable cooler PMV 0 to -1 | *shadows:*<br>tree shades short length: -3 to >-4, very small area of shadow effect in shelterbelt area, -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades bring inexplicably slightly higher PMV 0 to +1, inexplicably ‘overrule’ the shadows of trees shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>dark<br>*wind:*<br>no wake effect<br>*general remarks:*<br>few wake areas have inexplicable cooler PMV 0 to -1 | *shadows:*<br>all tree shades have medium length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>inexplicable small warmer areas (no relation with $T_{mrt}$ or wind speed detectable) |
| **Conclus. Alt. 2** | **Overall PMV slightly improved in comparison to existing situation. Only small improvement in comparison to alternative 1 (also due to effect of defoliated trees in simulation of alternative 2)** | **Overall PMV slightly improved in comparison to existing situation.**<br>**Clear improvement in comparison to alternative 1** | **Overall PMV slightly improved in comparison to existing situation.**<br>**No improvement in comparison to alternative 1 (also due to effect of defoliated trees in simulation of alternative 2)** | **Overall PMV slightly improved in comparison to existing situation.**<br>**Clear improvement in comparison to alternative 1** |

The results of the simulations for alternative 2 indicate that there is again a slight improvement on PMV for the whole square and its surroundings, but this is not significantly more than in alternative 1. In the hot situation the PMV values improved up to one PMV unit (cooler) and in the windy, cooler situation the PMV values changed up to one PMV unit (warmer). So the assumption that more trees bring a significant effect for PMV cannot be confirmed.

Furthermore, the results show that the effect of shade overruling wind-buffering effects of trees is still prominent, even though seasonal differences in leaf densities were now taken into account in the simulations.

Moreover, with respect to the wind situation, the weak buffering effects in alternative 1 occurred again in this alternative, showing much shorter wakes than expected. A medium dense shelterbelt of 25 m height still seems to be insufficient to keep the wind speeds considerably lower for the entire squares.

### 8.3.4 Developing and testing alternative 3

In the preceding simulations one important effect occurred between the influence of shade and wind shelters: the shadows of the trees seem to have such a strong local effect on PMV that they can balance out their own wind buffering effects or the wind buffering effects of other trees. This effect was evident in the 'windy autumn day' situations and especially in the second alternative where significantly more shadow trees were used than in the first alternative. In the cooler seasons, the shadow trees, even though they have little foliation, seem to have a strong negative effect on PMV. Therefore, in the third alternative I disregarded trees that only serve to cast shadow. For trees that also buffer wind, the situation is different. Their shadows also create cooler areas in spring and autumn, even though their wind shelter effect might be minimized by the shadow. On the other hand, they also generate wind protected areas that are largely situated in the sun and are therefore much more comfortable in spring and autumn.

The earlier simulations showed that the wind buffering effects of the vegetation seem to have a smaller spatial extension than was expected based on the scientific literature. For example, increasing the height of the urban shelterbelt in the second alternative had rather limited effects, whereas according to the literature a shelterbelt of this height should have been more than sufficient to create a 50% wind reduction for the entire squares. This might have to do with the fact that the shelterbelt had shorter length extensions than 12x h, the value that Nägeli used as a recommendation for the best efficiency of shelterbelts. Therefore, I decided to use a sequence of several urban shelterbelts to improve the wind situation. The chosen distance between shelterbelts was based on the lower foliage density values during spring and autumn when the wind situation is most problematic. I assumed that a distance of 50 m between the urban shelterbelts, which is only 2 x h of the shelterbelt itself, should offer ample wind protection.

Apart from that, the shadows of the shelterbelts at a distance of approximately 50 m in this proposal, offer people enough shade for the hot situations. Ideally, these linear tree elements could be combined with main walking routes, as well as elements to sit in the shade. This way, people can still choose to walk in the shade in many parts of the square. The projection of these patterns in the two squares can be seen in figures 8.18 and 8.19.

*Fig. 8. 18 (left) Alternative 3: urban shelterbelts 25 m tall with 50 m distance projected on the Spuiplein, Den Haag*

*Fig. 8.19 (right) Alternative 3: urban shelterbelts 25 m tall with 50 m distance projected on the Grote Markt, Groningen*

● shelterbelt tree

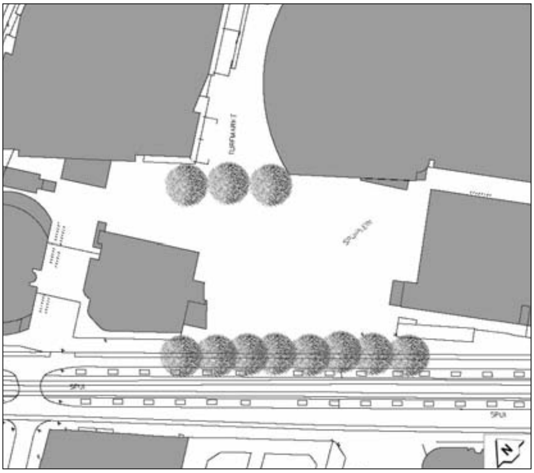


*Table 8.3 Alternative 3, Evaluation matrix, all evaluations expressed in PMV units (existing situation – new situation)*

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **'windy day'** | **'hot day'** | **'windy day'** | **'hot day'** |
| 9 | *shadows:*<br>dusk, tree shades vague and very long: 0 to -1,<br>*wind:*<br>slight effect behind shelterbelts 0 to +1<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>shades medium length, very small area of shadow effect in shelterbelt area, -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>some areas with higher wind speeds show inexplicably higher PMV 0 to +1, building shades have inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably cast only very small shadows | *shadows:*<br>dusk, tree shades vague and very long: 0 to -1,<br>*wind:*<br>small areas behind shelterbelts slightly warmer: +1 to +2 | *shadows:*<br>all tree shades have medium length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect |
| 11 | *shadows:*<br>longer shadows of shelterbelts -1 to -3,<br>*wind:*<br>in some areas behind shelterbelt +1 to +2, rest of wake effect on PMV 'overruled' with shade influence of the shelterbelt<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>shelterbelt shades short: -1 to -2,<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>shelterbelt shades medium length -1 to -2, in small spots -2 to -3<br>*wind:*<br>in few unshaded areas behind shelterbelt +1 to +2, rest of wake areas 'overruled' with shade influence of shelterbelt,<br>*general remarks:*<br>inexplicable building shade areas (no relation with $T_{mrt}$ or wind speed detectable) | *shadows:*<br>shelterbelt shades short: -2 to >-4,<br>*wind:*<br>few small areas in displacement zones in front of shelterbelts are slightly warmer: +1 to +2 |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **‘windy day’** | **‘hot day’** | **‘windy day’** | **‘hot day’** |
| 13 | *shadows:*<br>shelterbelts cast longer shadow: -1 to -3 in large areas!<br>*wind:*<br>in small unshaded area behind shelterbelt +1 to +2, rest of wake ‘overruled’ with shade<br>*material change:*<br>no significant effect on PMV | *shadows:*<br>shelterbelt shades short: -1 to -2,<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades bring inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadows (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>shelterbelt shades medium length -1 to -2, in small spots -2 to -3<br>*wind:*<br>in very small unshaded areas behind shelterbelt +1 to +2, rest of wake areas ‘overruled’ with shade influence of shelterbelt,<br>*general remarks:*<br>inexplicable building shade areas (no relation with $T_{mrt}$ or wind speed detectable) | *shadows:*<br>shelterbelt shades short: -2 to >-4,<br>*wind:*<br>few small areas in displacement zones in front of shelterbelts are slightly warmer: +1 to +2 |
| 15 | *shadows:*<br>very long shades shelterbelt -1 to -2 in large areas,<br>*wind:*<br>in small unshaded area behind shelterbelt +1 to +2, rest of wake ‘overruled’ with shade of shelterbelt<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, | *shadows:*<br>shelterbelt shades medium length: -1 to -2,<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades have inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadow (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>almost entire square shaded: 0 to -1, small areas with -1 to -2<br>*wind:*<br>no remarkable wind effect<br>*general remarks:*<br>inexplicable building shade areas (no relation with $T_{mrt}$ or wind speed detectable) | *shadows:*<br>all tree shades have medium length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect |

| **Time** | **Den Haag** | | **Groningen** | |
|---|---|---|---|---|
| | **'windy day'** | **'hot day'** | **'windy day'** | **'hot day'** |
| 17 (16) | *shadows:*<br>dark<br>*wind:*<br>in small area behind shelterbelt +1 to +2, other areas behind shelterbelt 0 to -1 (!)<br>*material change:*<br>no significant effect on PMV<br>*general remarks:*<br>some wake areas have inexplicable cooler PMV 0 to -1 | *shadows:*<br>shelterbelt shades medium length: -1 to -2,<br>*wind:*<br>no remarkable wind effect<br>*material change:*<br>PMV in some areas 0 to -1, although $T_{mrt}$ is higher!<br>*general remarks:*<br>building shades bring inexplicably slightly higher PMV 0 to +1, shelterbelt trees inexplicably do not seem to cast shadows (also no detectable lowering of $T_{mrt}$), also inexplicable effect of material change with lower PMV 0 to -1 | *shadows:*<br>dark<br>*wind:*<br>shelterbelt shows slight positive effect: 0 to +1 | *shadows:*<br>all tree shades have medium length: -3 to >-4,<br>*wind:*<br>no remarkable wind effect |
| **Conclus. Alt. 3** | **Overall PMV slightly improved in comparison to existing situation. Less improvement in comparison. to alternative 1 (also due to effect of use of foliated trees in simulation of alt. 1), some improvement in comparison to alternative. 2** | **Overall PMV slightly improved in comparison to existing situation. Clear improvement in comparison to alternative 1, less improvement in comparison to alternative 2** | **Overall PMV slightly improved in comparison to existing situation. Less improvement in comparison. to alternative 1 (also due to effect of foliated trees in simulation of alt.1)**<br>**Similar improvement as alternative. 2** | **Overall PMV slightly improved in comparison to existing situation. Clear improvement in comparison. to alternative 1 and 2** |

The impacts of the third alternative (25 m high medium dense urban shelterbelt in a 50 m sequence) were then simulated for microclimate effects over whole days in the 'windy' and 'hot' situation for the two locations in Den Haag and Groningen. The differences in PMV on pedestrian level (1.60 m) can be found in the electronical supplements for this chapter (see CD) and table 8.3 includes a textual discussion of the comparison results.

In comparison to the other two alternatives, alternative 3 shows the best effects. There is still room for improvement though. The simulated wind-buffering effect is not as strong as expected, but this also might be attributed to the way the urban shelterbelt was simulated. As mentioned earlier, due to the limitations of the simulation software it had to be substituted with a vegetation element, whereas the actual urban shelterbelt should consist of trees and an artificial transparent windscreen in the trunk space. Considering all the literature consulted (even though it shows some conflicting assertions), in an area of 2 x h behind a windbreak, the wind protection should anyhow be more efficient than the simulations suggest.

I could continue to study and refine more options through 'research by design'. However, due to the limitations of the simulation software as well as the inexplicable results of some simulations (see 'general remarks' in the overview of simulation results) I doubt if the simulation tools are sufficiently developed to conduct such a refined research. The uncertainties about causes and effects make it increasingly difficult to generate fine-tuned design hypotheses, and it is uncertain if the simulations will truthfully predict the effects and verify or falsify the design hypotheses. Therefore, I decided to stop this process after generating this third alternative, because it shows better results than the first alternatives and is a very clear improvement of the existing situation. For that reason it can be called an optimized model for a climate-responsive design of a Dutch square. This pattern with its focus on wind protection is also expected to appeal to people's spatial microclimate expectations in a positive way. As was discussed in chapter 4, Dutch people's microclimate perception is mainly focused on wind effects. An important conclusion was that in urban design responding to microclimate perception, strong images should be offered that suggest wind protection. This optimized model is expected to offer such cues for wind-protection due to the smaller scaled rhythm of spatial enclosure and clear visual suggestion of wind protection.

## 8.4 An optimized model from 'research by design'

The main question posed in this chapter – is it possible to generate an optimized model pattern that can easily be incorporated in the design process? – can be answered positively. This optimized model pattern (alternative 3) can be easily used as a design 'layer' for microclimate response at the beginning of the design process. In general, this pattern can be used in all parts of north-western European cities that have climates similar to the Dutch climate. It is vital that the model pattern is introduced at the beginning of the design process of a square refurbishment or design of a new square. When this pattern is not included at an early stage, it will be very difficult to introduce the required structural changes in a later design phase. The model can be compromised with other design issues and offers some flexibility. For example, the urban shelterbelts can be placed on a slightly larger distance from each other or their orientation can be changed with some degrees without losing too much of their effects. When circulation needs require this, also some smaller areas can be opened in the shelterbelts. Moreover, if the transparent wind screens under the trees are mobile, this will enable the passage of vehicles (e.g. when a market has to be installed) and slow traffic flows. As long as this urban shelterbelt pattern does not get entirely disrupted in the integrated design process, this pattern will always help to improve the local microclimate. Since this model will be adjusted to a particular site through 'carving' or 'twisting', 'clustering' et cetera in the further integrated design process, the results will always be site-specific solutions and no square that was designed according to this model will be like the other.

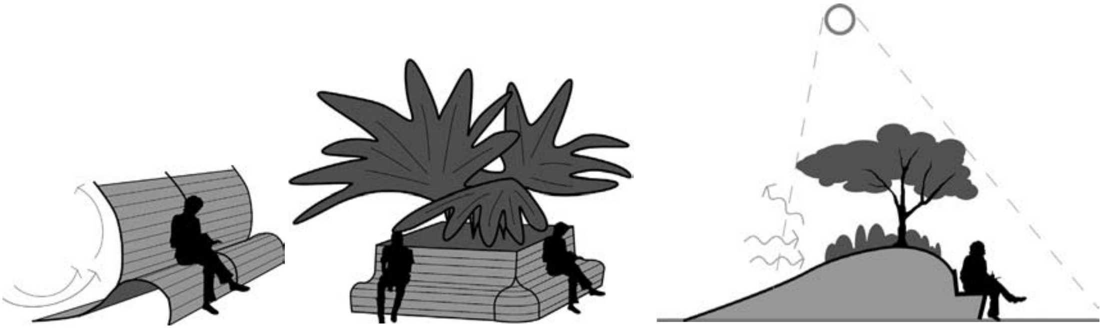
Although the generation of such models, as shown in this example, generally seems a clear and straightforward process, this is often not the case. In this 'research by design', for example, the generation of a model with the help of scientific literature was already problematic due to knowledge gaps and conflicting assertions in the scientific literature. For designers (who have not developed this fundamental knowledge) it is not possible to make sense of these contradictions. Similarly, ambiguous simulation results can make it difficult to generate clear design hypotheses on cause and effect relations of design interventions. Although simulations can be very useful tools for predicting microclimate situations, they are only as precise as their underlying mathematical models and the way these are integrated in the simulations. Even so, these simulation tools are in constant development and are calibrated to make better predictions. In the future, it will be increasingly useful to integrate simulations into 'research by design' processes.

I have demonstrated that a research by design process can help to generate optimized design patterns. The optimized climate responsive design model I developed can be helpful for many Dutch square design or refurbishment projects. This pattern can supplement the design guidelines described in the preceding chapters. However, there are also public space design projects where it is impossible to apply this pattern or where it has to be compromised to such an extent that it loses its effect. In those cases, designers can come up with other small-scale design solutions. I am convinced that these can be very effective as well, but they cannot be tested with the existing microclimate testing tools and therefore they cannot go beyond the level of 'design hypotheses'. I will give a brief overview of possible alternative solutions to round up this chapter.

## 8.5 Alternative climate-responsive design

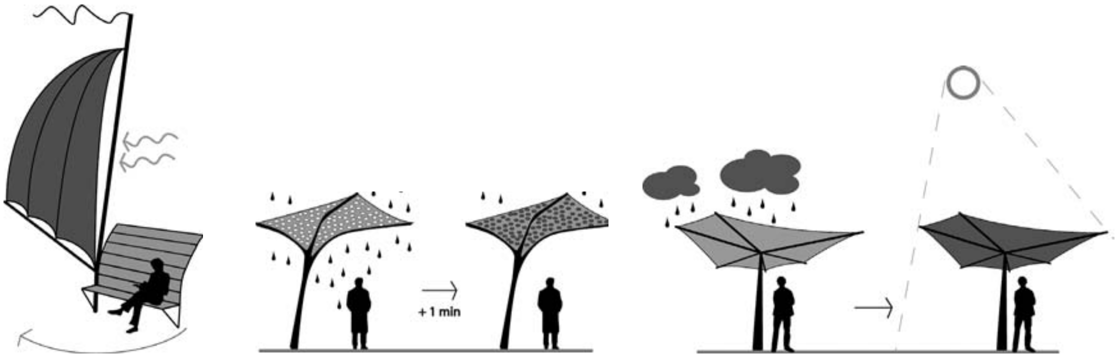
Small-scale design solutions can be a useful alternative to larger scale patterns as the one I introduced above. They can have many forms and I distinguish three types of microclimate-responsive interventions. Firstly, some small elements relate directly to bodily perceptions of microclimate. The second type consists of small elements that can change with the forces of

*Figs. 8.20-22 (left to right): 'aerodynamic bench', 'gunnera-bench', 'dune-bench'*



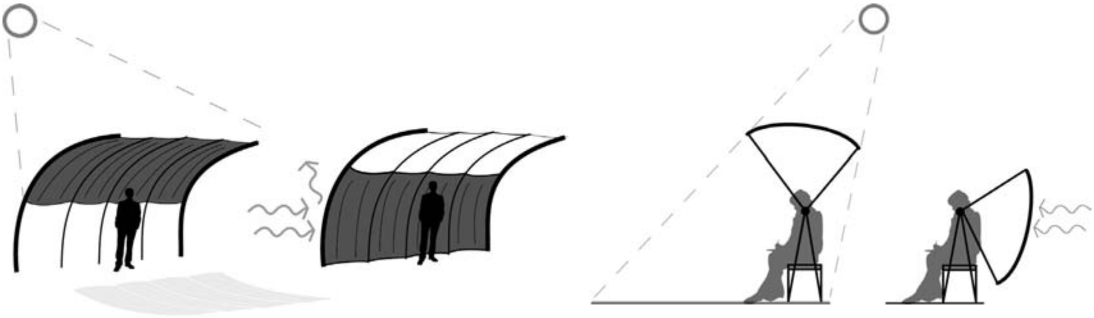
microclimate, because they are wind- or sun-driven. I call these the climate-revelatory elements. Thirdly, certain elements can reflect the interaction of people with these elements to create thermal comfort circumstances: climate-interaction objects.

The first group – the body-related solutions – can be urban furniture like the 'aerodynamic bench' (fig. 8.20) that has its back to the main wind direction and deflects the wind from the rear with a high, bent back. A very different type is the gunnera-bench (fig. 8.21) planted with the perennial plant Gunnera manicata that acts as a natural parasol because of the enormous leaves of the plant, which unfold in summer when shadow is needed. Combined effects for sun and wind filtering can be seen in the dune-bench, offering natural shelter through a soil sculpture and vegetation (fig. 8.22). These are only a few examples of many that can be conceived of. These elements are fixed, and thus highly dependent on the spatial and microclimate context.



*Figs. 8.23- 25 (left to right): 'sail-bench', 'rain-tree', 'sunglass-umbrella'*

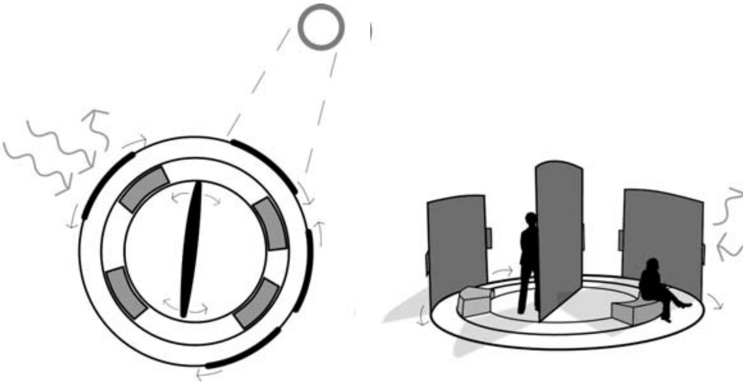
The flexible 'climate-revelatory' elements are less dependent on the context. They move and change with the forces of microclimate and use these forces to create more comfortable conditions. The sail-bench (fig. 8.23), for example, has a sail that (supported by a motor) rotates the bench, featuring a high wind-protecting back to the lee-side so that people can always be protected from the wind. The rain-tree (fig. 8.24) unfolds artificial leaves when it rains, creating shelter from the rain. The 'leaves' consist of a fabric that reacts to moisture. They shrink through drying and unfurl when they are wetted by rain. The sunglass-umbrella (fig. 8.25) consists of transparent glass sheets that let the light penetrate in cloudy conditions and protect the area underneath from rain. When there is a lot of sunshine and shadow is wanted for, the self-tinting glass becomes dark and protects people against the sun's radiation. These kinds of climate-revelatory elements can show the ever-changing patterns of microclimate; make them more 'experience-able' and thus also raise people's awareness of the microclimate.



*Figs. 8.26-27 (left to right): 'sun-wind rouleau', 'turning screens'*

With microclimate-interaction objects people can manipulate the microclimate directly according to their own wishes. For the Dutch climate situation this mainly concerns two situations: the hot situations with little wind where people want to be shielded from the sun and a windy situation (which is often related to rather cloudy circumstances) where a windbreak is needed.

Using one mobile screen for both situations is a simple solution. This screen can be as tall as a standing person, like the 'sun-wind rouleau' (fig. 8.26). It can also be adjusted to the scale of a sitting person through turning screens that can be fixed to a bench, but also to other elements close to places where people like to repose (fig. 8.27). But this can also encompass solutions with independent manipulations for sun and wind, as in the case of the microclimate-carousel (fig. 8.28)



*Figs. 8.28 The 'climate carousel'*

In all cases, the interactions of people with microclimate are manifold: one person might pull up screens, another person pulls them down, someone else shifts the windbreak and not the sun protection, and yet another leaves the windbreaks and shifts the sun protection, and so forth. It is a ceaseless 'ballet' of people and microclimate, with the one responding to the other. The spatial configurations occurring represent the microclimate perceptions of people, but also the differences in microclimate perceptions.

Even though these small-scale proposals are not the result of a rigorous 'research by design', they exhibit an interesting potential that requires further studying. To acquire initial knowledge about people's responses to such small-scale elements, it would be very interesting to build some of these objects and make people's perception of them and their interaction with them a new object of explorative research on urban microclimate.

# 9

# General conclusions

**Since this PhD project had three distinct phases – research on, for and by design – I will discuss my conclusions in relation to these different phases. The phases of the project were based on developments throughout the process, because the conclusions from one phase fed the next phase, through which these conclusions were specified, refined and supplemented in the subsequent phase. Consequently, I will repeat the main questions studied, discuss methodological conclusions and main conclusions on the newly generated knowledge for each of the different phases. This final chapter concludes with general considerations on theoretical implications and future research.**

## 9.1 'Research on design'

I wondered why public opinion is often quite negative about the atmosphere and microclimate of public spaces. Therefore, I examined the status quo of design paradigms for Dutch squares in this phase. I noticed that many public space designs were based on an architectural and visually oriented design paradigm. The problem with this paradigm is that the city is considered as a building and urban squares as 'rooms' in that building. This is problematic because the city is also still part of the natural landscape, where natural processes such as climatic, hydrological and ecological processes are ubiquitous. In my opinion, a different design paradigm in urban design, more inclusive of the climate processes and people's perceptions, would be more suitable. To concretize this idea with scientifically more reliable knowledge I moved to the next phase: 'research for design'.

## 9.2 'Research for design'

Design can be of influence on several factors of the 'atmosphere' of a place, such as microclimate, spatial layout and the materials used. I wondered in how far these three factors are related to thermal perception. Specifically, I wanted to know how people experience and remember microclimate and how these experiences and memories relate to various factors of spatial and material perception. I also wanted to know more about the relation between microclimate reality and people's mental constructs about microclimate and the urban environment. It is important to know whether a design solution should respond to real or rather illusionary impressions of people.

I used different methods to study this, some of them being proven methods in the field of microclimate perception research, such as interviews and microclimate measurements. I also introduced a new method in the field of microclimate perception research: cognitive map analysis. I thought this method would be very suitable for a research that concerned space and perception. The method of cognitive mapping showing the knowledge of 'the public' yielded very clear and interesting results that matched quite well with the measured data. I would recommend this method for similar research. It is also a useful method within practical urban design projects to acquire an approximate knowledge of a place's microclimate. People's microclimate knowledge is often sufficiently precise, and when proper use is made of this knowledge, it can save time that would otherwise have to be spent on long and expensive interviews or series of measurements (also see Lenzholzer 2008b).

The results of this empirical research showed that, in the Dutch context, long-term microclimate perception mainly concerns the wind. The situations that get engrained in people's long-term memory are the windier instances and not the common calmer situations. For design interventions in public space this means that wind-protection is very important in the Dutch situation. It also revealed that Dutch people assign specific microclimate characteristics to certain spatial configurations. When these spatial configurations were examined for their real microclimate properties, it became apparent that the spatial configurations were interpreted quite appropriately (although somewhat overestimated for wind). It became clear that people assigned negative microclimate connotations to large open spaces and positive microclimate connotations to protected places with a smaller scale. For urban design this means that more places of this type should be offered on the Dutch squares.

The perception of materials used in public places in the Dutch context appeared to be related to thermal comfort or discomfort. The perception of 'warm' and 'cold' materials was partly based on both factual physical properties of the materials and partly on the symbolic or associational value of cold or warm colours that influence thermal perception. For urban design this means that a 'warm' feeling can be enhanced by not only using materials that really have a low conductivity and a high emissivity making them feel warmer when touched (e.g. wood) but also the use of warmer colour tones, suggesting the illusion of warmth.

This 'research for design' has demonstrated that although people tend to misinterpret some urban design modifiers (such as the influence of colour) they generally have a sharp acuity to interpret the urban environment with respect to microclimate. This is one of the most interesting outcomes of this 'research for design' phase. I did not expect that people's microclimate interpretations of the urban fabric, and especially the reading of spatial configurations in relation to microclimate, would be that precise. For me this was surprising since microclimate is mostly invisible and therefore not easily intelligible; and people in the street – say – are not supposed to know microclimate processes from scientific literature. It proves again, that the experience of 'the public' is a very valuable source of knowledge. The acuity of people to combine the climatic and spatial aspects in their perceptions shows that they have perhaps understood this very inclusive concept of 'atmosphere' better than urban designers or landscape architects. For the designers this implies that creating an 'atmosphere' has to be taken much more seriously in the design of urban outdoor places. It should take into account spatial layout, material use and especially microclimate-responsive design.

In this ‘research for design’ phase, the deductions from the first ‘research on design’ phase – that tight relations exist between built and microclimatic environment and people’s sensory perceptions – were justified. The empirical research thus supported the theoretical model of these interactions that were also specified in the introduction (fig. 1.1).

The ‘research for design’ has substantially enriched, nuanced and refined these first conjectures of the ‘research on design’. Although the findings from this phase do provide some design recommendations, it actually revealed more ‘don’ts’ than ‘do’s’, so the designer would still be left with many questions about how to do things ‘right’ for microclimate perception. This gave cause for the generation of more microclimate design knowledge in the next phase: the ‘research by design’ phase.

## 9.3 ‘Research by design’

In this phase I tried to generate a more specific ‘positive’ guideline for climate-responsive design of Dutch squares in the form of an optimized plaza design pattern for microclimate comfort. I used the ‘research by design’ method, which I had refined based on the existing literature on ‘research by design’ within the field of architectural research. In my ‘research by design’ it was possible to generate scientifically informed design hypotheses and test these with simulation tools for different cases, thus conforming to the criteria of scientific research of reliability, hypothesis testing and generalizability. So, ‘research by design’ as a method to generate new design knowledge has proved to be feasible within landscape architecture and urban design. However, one has to be aware that there are also difficulties for designers who want to conduct ‘research by design’. Often, the scientific information basis is not adequate or it is contradictive, and the simulation tools to test the design hypotheses are not always as reliable as one would like them to be. But since simulation tools are constantly developed and their reliability is continually improved, their value for design hypothesis testing within ‘research by design’ continuously increases. This also opens new avenues for more ‘research by design’ in the academic field of landscape architecture and urban design in the future.

The result of this ‘research by design’ is an optimized model that can be easily introduced into the design of Dutch squares. It consists of a pattern of ‘urban shelterbelts’ placed perpendicular to the main wind direction in the square. As long as this pattern is not compromised too much in the design process, it will have positive effects on the microclimate in different seasons.

The results of the empirical ‘research on design’ and ‘research by design’ phases complement each other and provide the landscape architect or urban designer working in the Dutch context with a new body of easily applicable design knowledge. For the future, it will be of great importance to disseminate this knowledge in the community of landscape architects and urban designers, and to motivate them to apply this knowledge in the design of

Dutch squares. Furthermore, the community should be encouraged to include the issue of microclimate-responsive design in their work in more general terms.

## 9.4 Theoretical implications

Having shown that this research has contributed to a body of practical design 'guideline' knowledge concerning thermal comfort in public spaces, I would like to address a few theoretical implications of this project. I now return to the notions that I had sketched as my inspirations from phenomenological philosophy in chapter 2. I described three central notions of phenomenological thought as influential on my research. I now reflect on how my research results can be related to these notions and indicate what this might imply for design and general theory.

The first notion concerned the issue of ocularcentrism. In my research I noticed that people are well aware of their thermal senses and that these play an important role in their experience of urban environments. This supports the criticism of ocularcentrism - that more senses than vision alone play an important role in perception and that the proximal senses deserve more consideration. For urban design theory this means that designers should pay more attention to thermal perception as another non-visual sense in their designs. They should leave the well-trodden path of vision-centred design paradigms for a more inclusive design approach relating to more senses. Consequently, microclimate aspects should always be taken into consideration as a part of designing for the total atmosphere in urban outdoor places. For the Dutch context, the inclusive concept of 'gezelligheid', of cozyness deserves to be reintroduced into urban design: spaces that offer shelter and contentment. Smaller scales and warmer atmospheres should become more important in the design of Dutch outdoor urban places. This requires the courage of the urban designer or landscape architect to break with the 'cool' design paradigms of the 'supermodernism' era using 'voids', hard and cool places in urban square design. In my opinion, the city should not be an empty 'void', a desert of hard, stony places; it is full of 'atmosphere', both in a literal and in a metaphorical sense.

This research also has more general implications. I have shown anew that thermal perception is very important in people's experience. It still surprises me that thermal perception, even though it is such a vital sense for human beings, has received such little attention in general and in phenomenology in specific. I would even go so far as to posit that thermal perception should actually be given a place next to the 'classical' five senses.

The second inspiring notion in phenomenology is 'embodiment' and its dependence on multisensory perception of the environment. My research has highlighted that there are clear relations between different sensory perceptions with the example of the thermal sense in relation to vision and touch. So, the results of this research strongly support that thermal perception is another important sense within multisensory perception, and that it is part of ‘embodiment’ or ‘atmosphere’ in the definition of Gernot Böhme. Although Böhme’s defintion of ‘atmosphere’ seems very inclusive, I think that he missed out one of the most important aspects of ‘atmosphere’: the climatic aspect. This is surprising because even the etymology of the Greek word ‘atmosphere’ combines the climatic aspect ‘atmos’ being haze, mist or vapour with a spatial term ‘sphaira’, a sphere. My own and other researchers’ studies showed that thermal perception and microclimate, as the Greek term already suggests, are actually very important aspects within ‘atmosphere’. I think that more attention for the climatic connotations in Böhme’s philosophical term ‘atmosphere’ would strengthen his argument on the embodied interactions between human beings and their environment. I suggest including microclimate and thermal perception in Böhme’s definition of ‘atmosphere’.

The third phenomenological concept that was influential for this research concerned the ‘phenomenological reduction’: the relation between the experienced and factual ‘reality’. I was interested in this relation because for design it matters whether a design response should address the ‘real’ physical circumstances or people’s image of the environment, or even ‘illusions’. The research results suggested that most of people’s microclimate perceptions in relation to space are quite accurate, when compared to physical measurements. That means that we can expect a climate-responsive design to also lead to a positive experience when it is based on physical microclimate knowledge. I did, however, also find exceptions in my study of people’s experiences, where the physical circumstances and perception were not congruent. This concerned for instance people’s overestimation of wind influences and their association of ‘cold’ colour tones with a cold thermal experience, which is not necessarily based on physical reality.

Balancing all these issues and taking into account the theories of environmental psychology, which emphasize that behavioural response of people is based on people’s image of reality and not ‘reality’ itself, I think that people’s perceptions of the world should be the basis for design decisions. This attitude basically resembles Husserl’s ‘bracketing out’: focusing on people’s perceptions and not on ‘measured reality’.

Based on these thoughts from phenomenology, I would like to suggest that as designers we should broaden our perspective; that we should take all sensory perceptions into account, acknowledge people’s mental images, and start to think in an embodied ‘atmosphere mode’. When we extend Böhme’s term ‘atmosphere’ with the climatic aspects, as suggested by the etymology of the Greek word, this term can be a guiding principle in urban design and landscape architecture. I am convinced that when all the aspects of ‘atmosphere’ are considered in landscape architecture and urban design, we can provide more liveable, thermally comfortable, delightful places.

## 9.5 Future research

Within this project, I was able to make some new contributions to design guidelines for the design of urban squares in the Dutch climate context, but more research is necessary to create a larger body of usable knowledge for the design of climate-responsive squares.

From my research on the spatial configurations in relation to thermal comfort, for example, it was difficult to generate sufficient knowledge on configurations that are experienced positively. It was not possible, within the limited number of cases, to derive reliable volumetric measures. To realize this, many more places would have to be studied. Therefore, it would be helpful to study other Dutch outdoor places with the properties people probably evaluate rather positively. Suitable places could be, for example, quite small squares, very green squares or squares with many small-scale elements. This could possibly produce more positive design knowledge.

The study on perceptions of spatial setup and materials in relation to thermal comfort also indicated that these perceptions differ, depending on people's origin and cultural background. Hence, it would be very interesting to conduct similar inquiries in other climatic and cultural contexts. This might reveal results quite different from the ones generated for the Dutch context.

The basic question on the fundamental diametric relationship between the 'real' and the 'perceived appearances', as addressed in chapter 2, also calls for further research. Designers are hardly able to predict the impact of their projects on people's perceptions, however thoroughly they might have tested it in the design process, unless a project is built. Notwithstanding, an experimental method, for which provisional experimental 'imitations' of a project are built, could perhaps be used to solve this dilemma. When you immerse people in environments that are, for instance, built as 'props' or temporary installations to imitate a new future environment, their perceptions in these spaces might very well resemble the ones in the 'real' future environment.

Basically, when people express their experiences in these imitation environments, designers could use this as a sort of preliminary post-occupancy evaluation. With the use of this method, designers would be in a better position to formulate and test design hypotheses, because in this environment people can have an 'immersive' experience where all sensorial perceptions and mental conceptions are combined. This would simultaneously offer the opportunity to deepen the empirical knowledge about people's experiences of diverse spatial and material settings or 'atmospheres'.

I see very interesting opportunities in the field of simulation research as well. When it is not possible to work with the experimental 'imitations' to provide designers with a better insight in their designs before they are built, virtual reality tools can be of help. Some well-known, highly sophisticated visual and audio simulation techniques already exist. Simulators for other senses (e.g. haptic and fragrance simulators), however, need further development and it should also be possible to simulate climate. It would be a great achievement if a designer could move through a virtual world where one would also feel the impact of climate of a planned environment with all senses.

These are only few ideas that relate quite directly to the research done in this project. Still, the general urge to conduct more studies on urban climate and climate-responsive design becomes increasingly pressing through the challenges that await us because of climate change. Fortunately, urban climate research within the Dutch context has finally commenced, in order for us to be able to deal with these challenges. In the future, I will gladly contribute to the development of more urban climate knowledge and the dissemination of this knowledge in the community of landscape architects and urban designers. All efforts combined can make Dutch cities more climate-proof and thermally comfortable.

# References

**A** Abrahamse, J. E. (2007). “De ruimtelijke ontwikkeling van Amsterdam in de zeventiende eeuw en de opkomst van de stedenbouw als wetenschap”, in B. Bakker and E. Schmitz, (eds.), *Het aanzien van Amsterdam.* Bussum: THOTH.

Ahern, J. F. (2002). *Greenways as strategic landscape planning: theory and application,* [S.l.: s.n.].

Alberts, W. (1981). *De faktor wind in het stedelijk klimaat.* Planologisch Studiecentrum TNO, Delft.

Alberts, W. (1984). *Bouwwijzer met wind.* Delft: Planologisch studiecentrum and ministry VROM.

Alexander, C. (1964). *Notes on the Synthesis of Form,* Cambridge MA: Harvard University Press.

Alexander, C., Ishikawa, S., and Silverstein, M. (1977). *A pattern language : towns, buildings, construction,* New York: Oxford University Press.

American Society for Heating Ventilating and Air-Conditioning Engineers (1966) “Thermal Comfort Conditions”. New York: ASHRAE.

American Society for Heating Ventilating and Air-Conditioning Engineers (1989) ASHRAE *Fundamentals handbook,* New York: ASHRAE.

Anonymous. (1943). “The Athens Charter”, in D. Watson, A. J. Plattus, and R. G. Shibley, (eds.), *Time-Saver Standards for urban design.* New York: Mc GrawHill, pp. 2.5-1- 2.5-16.

Appleton, J. (1975). *The experience of landscape,* Chichester [etc.]: Wiley.

Ashihara, Y. (1981). *Exterior design in architecture,* New York [etc.]: Van Nostrand Reinhold.

Ashworth, P. D., and Cheung Chung, M. (2006). “The Meeting between Phenomenology and Psychology”, in P. D. Ashworth and M. Cheung Chung, (eds.), *Phenomenology and Psychological Science.* New York: Springer.

Auliciems, A. (1981). “Towards a psycho-physiological model of thermal perception.” *International Journal of Biometeorology,* 25(2), 109-122.

**B** Bachelard, G. (1958). *The poetics of space,* M. Jolas, translator, Boston: Beacon Press.

Bakker, B., Schmitz, E., and Abrahamse, J. E. (2007). *Het aanzien van Amsterdam : panorama’s, plattegronden en profielen uit de Gouden Eeuw,* Bussum [etc.]: THOTH [etc.].

Bamford, G. (2002). “From analysis/synthesis to conjecture/analysis: A review of Karl Popper’s influence on design methodology in architecture.” *Design Studies,* 23(3), 245-261.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., and Vohs, K. D. (2001). “Bad Is Stronger Than Good.” Review of General Psychology, 5(4), 323-370.

Bechtel, R. B. (1997). *Environment & behavior : an introduction,* Thousand Oaks [etc.]: Sage.

Beranek, W. J. (1982). *Beperken van windhinder om gebouwen,* Den Haag: Kluwer Technische boeken.

Berleant, A. (2004). *Re-thinking aesthetics : rogue essays on aesthetics and the arts,* Aldershot [etc.]: Ashgate.

Blocken, B., and Carmeliet, J. (2004). “Pedestrian wind environment around buildings: Literature review and practical examples.” *Journal of Thermal Envelope and Building Science* 28(2), 107-159.

Blok, T. (1998). “Stadterneurung in Apeldoorn, Niederlande.” *Topos* (22), 106.

Blumenfeld, H. (1954). “Scale in civic design.” *The town planning review* (24), 35-46

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

Bosselmann, P., Arens, E., Dunker, K., and Wright, R. (1995). “Urban form and climate: case study, Toronto.” *Journal - American Planning Association,* 61(2), 226-239.

Bottema, M. (1993). *Wind climate and urban geometry.* Ph.D. Dissertation, University of Eindhoven, Wibro, Helmond.

Bottema, M. (1999). “Towards rules of thumb for wind comfort and air quality.” *Atmospheric Environment,* 33(24-25), 4009-4017.

Boutet, T. (1987). *Controlling air- movement,* New York: Mc Graw Hill.

Breen, J. (2002). “Design driven research”, in T. M. de Jong and D. J. M. van der Voordt, (eds.), *Ways to study and research urban, architectural and technical design.* Delft University Press, Delft, pp. 137-146.

Brewer, W. F., and Treyens, J. C. (1981). “Role of Schemata in Memory for Places.” *Cognitive Psychology,* 13(2), 207-230.

Broadbent, G. (1990). *Emerging concepts in urban space design,* London [etc.]: Van Nostrand Reinhold.

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

Brunswik, E. (1956). *Perception and the representative design of psychological experiments,* Berkeley: University of California Press.

Brunswik, E., Bruner, J. S., and Festinger, L. (1957). *Contemporary approaches to cognition : a symposium held at the university of Colorado,* Cambridge: [s.n.].

Bruse, M. (2005). “Assessing urban microclimate from the user’s perspective: multi-agent systems as a new tool in urban meteorology.” *Ann Meteorol* (41), 137-140.

**C**

Carmona, M. (2003). *Public places - urban spaces : the dimensions of urban design,* Amsterdam [etc.]: Architectural Press.

Carr, S., Francis, M., and Rivlin, L. G. (1992). *Public space,* Cambridge: Cambridge University Press.

Coeterier, J. F. (2000). *Hoe beleven wij onze omgeving? Resultaten van 25 jaar omgevingspsychologisch onderzoek in stad en landschap,* [S.l.]: Coeterier.

Confurius, G. (1997). “Der Theaterplatz- die endlose Planungsgeschichte des Schouwburgplein in Rotterdam.” *Bauwelt* 43/44, 2446- 2451.

Conrads, L. A. (1975). *Observation of meteorological urban effects- the heat island Utrecht,* Rijksuniversiteit Utrecht, Utrecht.

Cross, N. (1982). “Designerly ways of knowing.” *Design Studies,* 3(4), 221-227.

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

Cross, N. (2007). *Designerly ways of knowing,* London: Springer.

Cross, N., Naughton, J., and Walker, D. (1981). “Design method and scientific method.” *Design studies,* 2(4), 195-201.

**D** de Jong, T. M., and van der Voordt, D. J. M. (2002). “Criteria for scientific study and design”, in T. M. de Jong and D. J. M. Van der Voordt, (eds.), *Ways to study and research urban, architectural and technical design.* Delft: Delft University Press, pp. 19-30.

de Jong, T. M., and van der Voordt, D. J. M. (2002). “Types of Study by Design”, in T. M. de Jong and D. J. M. Van der Voordt, (eds.), *Ways to study and research urban, architectural and technical design.* Delft: Delft University Press, pp. 455- 457.

de Jonge, J. M. (2009). *Landscape Architecture between Politics and Science,* PhD dissertation, Wageningen University, Wageningen.

de Josselin de Jong, F. (2003). “Boompleinen en Pleinbomen”, *Het Pleinenboek.* Utrecht: Hogeschool voor de Kunsten, Utrecht, pp. 141-142.

de Josselin de Jong, F. (2004). “External space is given botox treatment”, in H. Harsema, (ed.), *Landscape architecture and town planning yearbook 01-03.* Bussum: Thoth, pp. 148-157.

de Josselin de Jong, F. (2006). “Historische binnensteden-Den Haag: De Kern gezond.”, *Het ontwerp van de openbare ruimte.* Amsterdam: Sun uitgevers, pp. 205-216.

Dettingmeyer, R. (1991). “Het nieuwe stadspark. Opvallende vormen en pakkende scenarios”, in T. Boersma and G. ter Haar, (eds.), *Het nieuwe stadspark. Opvallende vormen en pakkende scenarios.* Rotterdam: NAi publishers, pp. 21-22.

Dierickx, W., Gabriels, D., and Cornelis, W. (2001). “A wind tunnel study on wind speed reduction of technical textiles used as windscreen.” *Geotextiles and Geomembranes,* 19(1), 59-73.

Dierickx, W., Gabriels, D., and Cornelis, W. M. (2002). “Wind tunnel study on oblique windscreens.” *Biosystems Engineering,* 82(1), 87-95.

Dordregter, P. (2003). “Pleinen, een inleiding”, *Het Pleinenboek.* Utrecht: Hogeschool voor de Kunsten, pp. 15-16.

Dorst, C. H. (1997). *Describing design : a comparison of paradigms,* [S.l.: s.n.].

Doulos, L., Santamouris, M., and Livada, I. (2004). “Passive cooling of outdoor urban spaces. The role of materials.” *Solar Energy,* 77(2), 231-249.

Dovey, K. (1990). “The pattern language and its enemies.” *Design Studies,* 11(1), 3-9.

Dufour, R. (1979). *De recreatieve stad,* ‘s-Gravenhage: Staatsuitgeverij.

**E** Eliasson, I. (2000). “The use of climate knowledge in urban planning.” *Landscape and Urban Planning,* 48(1-2), 31-44.

Eliasson, I., Knez, I., Westerberg, U., Thorsson, S., and Lindberg, F. (2007). “Climate and behaviour in a Nordic city.” *Landscape and Urban Planning,* 82(1-2), 72-84.

Esefeld, J. (1994). “Barcelona - Stadtraum im Aufbruch”, in H. J. Aminde, (ed.), *Plätze in der Stadt.* Ostfildern: Hatje.

Eysenck, M. W. (2006). *Fundamentals of cognition,* Hove [etc.]: Psychology Press.

Fanger, P. O. (1970). *Thermal comfort : analysis and applications in environmental engineering,* Copenhagen: s.n. **F**

Forsyth, A. (2007). "Innovation in urban design: Does research help?" *Journal of Urban Design,* 12(3), 461-473.

Francis, M. (2001). "A Case Study Method for Landscape Architecture." *Landscape Journal* 20(1), 15-29

Gage, J. (1999). *Colour and meaning : art, science and symbolism,* Berkeley, CA [etc.]: University of California Press. **G**

Gagge, A. P., Fobelets, A. P., and Berglund, L. G. (1986). "A Standard predictive index of human response to the thermal environment" *ASHRAE Transactions.* City, pp. 709-731.

Gehl, J. (1987). *Life between buildings : using public space,* New York: Van Nostrand Reinhold.

Geiger, R. (1965). *The climate near the ground,* Cambridge: Harvard University Press.

Geuze, A. (1995). "Moving beyond Darwin", *Modern park design.* Bussum: Thoth, pp. 42-47.

Geuze, A. (1996). *West 8 Landscape Architects - Colonizing the Void,* Rotterdam: NAi publishers.

Geuze, A. (2000). "Accelerating Darwin", in H. Ibelings, (ed.), *The artificial landscape* Rotterdam: NAi publishers, pp. 256.

Geuze, A. (2001). "Triumph der künstlichen Natur"*Neue Zürcher Zeitung.* City: Zürich.

Gibson, J. J. (1979). *The ecological approach to visual perception,* Dallas [etc.]: Houghton Mifflin.

Girot, C. (2006). "Vision in motion", in C. Waldheim, (ed.), *The Landscape Urbanism Reader.* New York: Princeton Architectural Press.

Givoni, B. (1998). *Climate considerations in building and urban design,* New York [etc.]: Wiley.

Givoni, B., Noguchi, M., Saaroni, H., Pochter, O., Yaacov, Y., Feller, N., and Becker, S. (2003). "Outdoor comfort research issues." *Energy and Buildings,* 35(1), 77-86.

Goffman, E. (1959). *The presentation of self in everyday life,* Garden City, N.Y.: Doubleday.

Golledge, R. G. (1992). "Place Recognition and Wayfinding - Making Sense of Space." *Geoforum*, 23(2), 199-214.

Golledge, R. G., and Stimson, R. J. (1997). *Spatial behavior: a geographic perspective,* New York [etc.]: Guilford.

Gould, P. (1973). "On mental maps", in R. Downs and D. Stea, (eds.), *Image and environment-cognitive mapping and spatial behavior.* Chicago: Aldine, pp. 182-220.

Grant, R. H., Heisler, G. M., and Gao, W. (2002). "Estimation of pedestrian level UV exposure under trees." *Photochemistry and Photobiology,* 75(4), 369-376.

Grimmond, C. S. B., and Oke, T. R. (1999). "Heat storage in urban areas: Local-scale observations and evaluation of a simple model." *Journal of Applied Meteorology,* 38(7), 922-940.

Grimmond, C. S. B., and Oke, T. R. (2002). "Turbulent heat fluxes in urban areas: Observations and a local-scale urban meteorological parameterization scheme (LUMPS)." *Journal of Applied Meteorology,* 41(7), 792-810.

Gutting, G. (2001). *French philosophy in the twentieth century,* Cambridge, U.K., New York: Cambridge University Press.

Gutting, G. (2005). *Continental philosophy of science,* Malden, MA [etc.]: Blackwell.

***H*** Hajer, M., and Reijndorp, A. (2001). *In search of new public domain : analysis and strategy,* Rotterdam: NAi Publishers.

Hall, E. T. (1966). *The hidden dimension,* Garden City: s.n.

Harsema, H., Cusveller, S., Bijhouwer, R., van Bolhuis, P., van Keulen, N., and Meyer, F. (1998). *Jaarboek landschapsarchitectuur en stedebouw 95-97,* Bussum: THOTH.

Havlicek, J., Saxton, T. K., Roberts, S. C., Jozifkova, E., Lhota, S., Valentova, J., and Flegr, J. (2008). "He sees, she smells? Male and female reports of sensory reliance in mate choice and non-mate choice contexts." *Personality and Individual Differences,* 45(6), 565-570.

Heisler, G. M., Grant, R. H., and Gao, W. (2003). "Individual- and scattered-tree influences on ultraviolet irradiance." *Agricultural and Forest Meteorology,* 120(1-4), 113-126.

Herzog, T. R. (1992). "A cognitive analysis of preference for urban spaces." *Journal of Environmental Psychology,* 12(3), 237-248.

Herzog, T. R., Kaplan, S., and Kaplan, R. (1976). "The prediction of preference for familiar urban places." *Environment and Behavior* (8), 627-645.

Herzog, T. R., Kaplan, S., and Kaplan, R. (1982). "The prediction of preference for unfamiliar urban places." *Population and Environment,* 5(1), 43-59.

Heschong, L. (1979). *Thermal delight in architecture.,* Cambridge, Mass: MIT Press

Höppe, P. (2002). "Different aspects of assessing indoor and outdoor thermal comfort." *Energy and Buildings,* 34(6), 661-665.

Houben, F., Richters, C., and Mecanoo (2001). *Compositie, contrast, complexiteit,* Rotterdam: NAi Uitgevers.

Huet, B. (1995). "Park design and urban continuity", *Modern park design.* Bussum: THOTH.

Humboldt, A. v. (1845). Kosmos : *Entwurf einer physischen Weltbeschreibung,* Stuttgart [etc.]: Gotta.

Husserl, E. (1960). *Cartesian Meditations- an introduction to phenomenology,* D. Cairns, translator, Den Haag Martinus Nijhoff.

Husserl, E., and Biemel, W. (1962). *Phaenomenologische psychologie : Vorlesungen Sommersemester 1925,* Den Haag: [s.n.].

***I*** Ibelings, H., Hoogewoning, A., Verstegen, T., and Jong-Dalziel, R. d. (2000). *The artificial landscape,* Rotterdam: NAi Publishers.

Irigaray, L. (1993). *An ethics of sexual difference,* Ithaca, N.Y.: Cornell University Press.

Irigaray, L. (1999). *The forgetting of air in Martin Heidegger,* Austin: University of Texas Press.

Ittelson, W. H., Proshansky, H. M., and Rivlin, L. G. (1974). *An introduction to environmental psychology,* New York [etc.]: Holt.

**J**

Jacobs, A. F. G. (1983). *Flow around a line obstacle,* Wageningen: Jacobs.

Jay, M. (1993). "Sartre, Merleau- Ponty, and the Search for a New Ontology of Sight." in D.M. Levin (ed.), *Modernity and the Hegemony of Vision.* Berkeley: University of California Press, pp. 143-185.

Johnson, B. R., and Hill, K. (2002). *Ecology and design : frameworks for learning,* Washington, DC [etc.]: Island Press.

Johnson, G. T., and Hunter, L. J. (1999). "Some insights into typical urban canyon airflows." *Atmospheric Environment,* 33(24-25), 3991-3999.

Jones, J. C. (1970). *Design methods : seeds of human futures,* London [etc.]: Wiley.

**K**

Kantrowitz, M. (1985). "Has Environment and Behavior Research Made a Difference." *Environment and Behavior,* 17(1), 25-46.

Kaplan, S. (1973). "Cognitive maps in perception and thought", in R. M. Downs and D. Stea, (eds.), *Image and environment-cognitive mapping and spatial behavior.* Chicago: Aldine, pp. 63-78.

Karlessi, T., Santamouris, M., Apostolakis, K., Synnefa, A., and Livada, I. (2009). "Development and testing of thermochromic coatings for buildings and urban structures." *Solar Energy,* 83(4), 538-551.

Katzschner, L. (2004). "Open space design strategies based on thermal comfort analysis", M. H. d. Wit, (ed.) *PLEA Conference on Passive and Low Energy Architecture.* TU Delft, TU Eindhoven: Eindhoven, pp. paper 590.

Katzschner, L. (2006). "Behaviour of People in Open Spaces in Dependence of Thermal Comfort Conditions", R.Compagnon, P. Haefeli, and W. Weber, (eds.), *PLEA 2006 - The 23rd Conference on Passive and Low Energy Architecture.* Université de Genève, Haute Ecole Spécialisé de Suisse occidentale: Geneva.

Katzschner, L., Bosch, U., and Röttgen, M. (2002). "Behaviour of people in open spaces in dependency of thermal comfort conditions"*PLEA, International Conference on Passive and Low Energy Architecture.* Université de Toulouse: Toulouse, pp. 411-415.

Kesser, C. (1984). "Plätze- Zeichen der Gemeinschaft." *Archithese*, 4(24).

Kitchin, R. M. (1994). "Cognitive Maps - What Are They and Why Study Them." *Journal of Environmental Psychology,* 14(1), 1-19.

Kitchin, R. M. (1996). "Increasing the integrity of cognitive mapping research: Appraising conceptual schemata of environment behaviour interaction." *Progress in Human Geography,* 20(1), 56-84.

Kitchin, R. M., Blades, M., and Golledge, R. G. (1997). "Relations between psychology and geography." *Environment and Behavior,* 29(4), 554-573.

Knez, I. (2005). "Attachment and identity as related to a place and its perceived climate." *Journal of Environmental Psychology,* 25(2), 207-218.

Knez, I., and Thorsson, S. (2006). "Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square." *International Journal of Biometeorology,* 50(5), 258-268.

Knez, I., Thorsson, S., Eliasson, I., and Lindberg, F. (2009). “Psychological mechanisms in outdoor place and weather assessment: towards a conceptual model.” *International Journal of Biometeorology,* 53(1), 101-111.

Knuijt, M., van Ophuis, H., and Saane, P. (1995). *Modern park design,* Bussum: Thoth.

Koerse, W. (2003). “Pleingedachten”, *Het Pleinenboek.* Utrecht: Hogeschool voor de Kunsten.

Koolhaas, R., Mau, B., Sigler, J., and Werlemann, H. (1995). *Small, medium, large, extra-large : Office for Metropolitan Architecture,* Rotterdam: 010 Publishers.

Kratzer, A. (1956). *Das Stadtklima,* Braunschweig: F. Vieweg.

Krop, H. (1989). “Openbare ruimte of openbare leegte?” *de Architect*(19), 11

***L***

Landsberg, H. E. (1981). *The urban climate,* New York [etc.]: Academic Press.

Lang, J. (1987). *Creating architectural theory: the role of the behavioral sciences in environmental design,* New York: Van Nostrand Reinhold.

Lang, J. (1994). *Urban design- the American experience,* New York: Van Nostrand Reinhold.

Lang, J. (2005). *Urban design- a typology of procedures and products,* Burlington: Elsevier Architectural Press.

Leach, N. (1997). *Rethinking architecture : a reader in cultural theory,* New York: Routledge.

Lee, T. (1973). “Psychology and living space”, in R. M. Downs and D. Stea, (eds.), *Image and Environment-Cognitive Mapping and Spatial Behavior.* Chicago: Aldine, pp. 87-108.

Lefebvre, H. (1974). *The production of space,* D. Nicolson-Smith, translator, Oxford: Blackwell.

Lenzholzer, S. (2008a). “A city is not a building-architectural concepts for public square design in Dutch urban climate contexts.” *Journal of Landscape Architecture*(5), 44-55.

Lenzholzer, S. (2008b). “Microclimate perception analysis through cognitive mapping”, P. Kenny, V. Brophy, and J. O. Lewis, (eds.), PLEA 2008 – 25th *Conference on Passive and Low Energy Architecture.* City: Dublin, pp. PLEA proceedings 2008 (on CD and online).

Lenzholzer, S. (2010). “Engrained experience-a comparison of microclimate perception schemata and microclimate measurements in Dutch urban squares.” *International Journal of Biometeorology,* 54(2), 2010, 141-151.

Lenzholzer, S., and Koh, J. (2010). “Immersed in microclimatic space: Microclimate experience and perception of spatial configurations in Dutch squares.” *Landscape and Urban Planning,* 95, 1-15.

Levin, D. M. (1993). “Decline and Fall- Ocularcentrism in Heidegger’s Readings of the History of the Metaphysics”, in D. M. Levin, (ed.), *Modernity and the Hegemony of Vision.* Berkeley: University of California Press, pp. 186-217.

Littlefair, P. J. (2000). *Environmental site layout planning: solar access, microclimate and passive cooling in urban areas,* London: CRC BRE Publications.

Loidl, H., and Bernard, S. (2003). *Opening spaces : design in landscape architecture,* Basel [etc.]: Birkhäuser.

Louwerse, D. (1995). “Why talk about park design? “, *Modern park design.* Bussum: THOTH.

Love, T. (2000). “Philosophy of design: A meta-theoretical structure for design theory.” *Design Studies,* 21(3), 293-313.

Lynch, K. (1960). *The image of the city, Cambridge* (Mass.): s.n.

Lynch, K. (1990). “Reconsidering The Image of the City”, in T. Banjeree and M. Southwork, (eds.), *City Sense and City Design - Writings and Projects of Kevin Lynch.* Cambridge: MIT Press.

**M**

Maas, W., van Rijs, J., and Koek, R. (1998). *FARMAX : excursions on density,* Rotterdam: 010 Publishers.

Mark, D. M., Freksa, C., Hirtle, S. C., Lloyd, R., and Tversky, B. (1999). “Cognitive models of geographical space.” *International Journal of Geographical Information Science,* 13(8), 747-774.

Matzarakis, A. (2001). *Die thermische Komponente des Stadtklimas,* Habilitationsschrift, Universität Freiburg, Freiburg.

Matzarakis, A., Mayer, H., and Iziomon, M. G. (1999). “Applications of a universal thermal index: physiological equivalent temperature.” *International Journal of Biometeorology,* 43(2), 76-84.

Mayer, H. (1993). “Human Biometeorology - Urban Bioclimatology.” *Experientia,* 49(11), 957-963.

Mayer, H., and Höppe, P. (1987). “Thermal Comfort of Man in Different Urban Environments.” *Theoretical and Applied Climatology,* 38(1), 43-49.

McDonald, T. P., and Pellegrino, J. W. (1993). “Psychological perspectives on spatial cognition”, in T. Gärling and R. G. Golledge, (eds.), *Behavior and environment.* Amsterdam: North-Holland.

Merleau- Ponty, M. (1992). *The phenomenology of perception,* London: Routledge.

Merleau-Ponty, M. (1964). *The visible and the invisible,* A. L. (1987), translator, Evanston: Northwestern University Press.

Messinger, S., Sampson, H., and Towne, R. (1962). “Life as theatre.” *Sociometry,* 25, 98-100.

Milburn, L. A. S., and Brown, R. D. (2003). “The relationship between research and design in landscape architecture.” *Landscape and Urban Planning,* 64(1-2), 47-66.

Milburn, L. A. S., Brown, R. D., and Paine, C. (2001). “”...Research on research”: research attitudes and behaviors of landscape architecture faculty in North America.” *Landscape and Urban Planning,* 57, 57-67.

Montgomery, J. (1997). “Cafe culture and the city: the role of pavement cafes in urban public social life.” *Journal of Urban Design,* 2(1), 83-102.

Moriwaki, R., and Kanda, M. (2004). “Seasonal and diurnal fluxes of radiation, heat water vapor, and carbon dioxide over a suburban area.” *Journal of Applied Meteorology,* 43(11), 1700-1710.

Moughtin, C. (1992). *Urban design : street and square,* Oxford [etc.]: Butterworth.

**N**

Nägeli, W. (1941). “Untersuchungen über die Windverhältnisse im Bereich von Windschutzstreifen.” *Mitteilungen Schweizerische Anstalt Forstliches Versuchswesen*, 29(2).

Nägeli, W. (1946). “Weitere Untersuchungen über die Windverhältnisse im Bereich von Windschutzstreifen.” *Mitteilungen Schweizerische Anstalt Forstliches Versuchswesen*(24), 659-737.

Nassauer, J. I., and Opdam, P. (2008). “Design in science: extending the landscape ecology paradigm.” *Landscape Ecology,* 23(6), 633-644.

Neisser, U. (1976). *Cognition and reality : principles and implications of cognitive psychology,* San Francisco: Freeman.

NEN. (2006). “Windhinder en windgevaar in de gebouwde omgeving “. *NEN-standard 8100.* Delft: Dutch Standardization Institute.

Nikol, F., Wilson, E., A. Ueberjahn-Tritta, Nanayakkara, L., and Kessler, M. (2006). “Comfort in outdoor spaces in Manchester and Lewes”*Comfort and Energy Use in Buildings.* Windsor: NCEUB.

Nikolopoulou, M. (2004). “Outdoor comfort”, in K. Steeemers and M. A. Steane, (eds.), *Environmental diversity in architecture.* London: Spon Press, pp. 101-120.

Nikolopoulou, M., Baker, N., and Steemers, K. (2001). “Thermal comfort in outdoor urban spaces: Understanding the human parameter.” *Solar Energy,* 70(3), 227-235.

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

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

Nishimura, N., Nomura, T., Iyota, H., and Kimoto, S. (1998). “Novel water facilities for creation of comfortable urban micrometeorology.” *Solar Energy,* 64(4-6), 197-207.

Norberg-Schulz, C. (1979). *Genius Loci- towards a phenomenology of architecture,* New York: Rizzoli.

Nowotny, H., Scott, P., and Gibbons, M. (2001). *Re-thinking science : knowledge and the public in an age of uncertainty,* Cambridge [etc.]: Polity.

**O** O’Hear, A. (1989). *Introduction to the philosophy of science,* Oxford: Clarendon.

Oke, T. R. (1987). *Boundary layer climates,* London [etc.]: Methuen.

Olgyay, V. (1963). *Design with climate: bioclimatic approach to architectural regionalism. Some chapters based on cooperative research with Aladar Olgyay,* Princeton, N.J.: Princeton University Press.

Oliviera, S., and Andrade, H. (2007). “An initial assessment of the bioclimatic comfort of an outdoor public space in Lisbon.” *Int Journal of Biometeorology* 52, 69-84.

Oosterman, J. (1992). “Welcome to the pleasure dome. Play and entertainment in urban public space: the example of the sidewalk cafe.” *Built Environment,* 18(2), 155-164.

**P** Pallasmaa, J. (2005). *The eyes of the skin- architecture and the senses,* Chichester: Wiley and Sons.

Parsons, K. C. (2003). *Human thermal environments : the effects of hot, moderate, and cold environments on human health, comfort, and performance,* London ; New York: Taylor & Francis.

Peutz. (2000). *Spuiplein te Den Haag, windhinderonderzoek: huidige en nieuw te verwachten omliggende bebouwingssituatie.* Peutz & Associes, Zoetermeer.

Pezdek, K., Whetstone, T., Reynolds, K., Askari, N., and Dougherty, T. (1989). "Memory for Real-World Scenes - the Role of Consistency with Schema Expectation." *Journal of Experimental Psychology-Learning Memory and Cognition,* 15(4), 587-595.

Pickup, J., and de Dear, R. (1999). "An outdoor thermal index (OUT_SET*)-part 1. The model and assumptions"*15th International Congress of Biometeorology and International Conference on Urban Climatology,* pp. 279-283.

**R**

Rapoport, A. (1977). *Human aspects of urban form : towards a man-environment approach to urban form and design,* Oxford [etc.]: Pergamon.

Reijndorp, A. (1996). "Designing for ambivalence", *Jaarboek landschapsarchitectuur en stedebouw* 93-95. Bussum: THOTH, pp. 12-23

Reijndorp, A., and Nio, I. (1996). *Het stedelijk theater : ruimtelijk beleid en openbare ruimte,* Bussum: Uitgeverij THOTH.

Rijgersberg, E. (1967). *Beknopte kleurenleer : en de toepassing van de kleuren in architectuur en binnenhuiskunst,* Amsterdam [etc.]: Elsevier.

Robinette, G. O., and MacClennon, C. (1983). *Landscape planning for energy conservation,* New York [etc.]: Van Nostrand Reinhold.

Rodermond, J. (1996). "Design of duurzaamheid." *de Architect*(11), 81-82

Rohles, F. H. (1980). "Temperature or temperament- a psychologist looks at thermal comfort"*ASHRAE transactions,* pp. 541-551.

Rozin, P., and Royzman, E. B. (2001). "Negativity bias, negativity dominance, and contagion." *Personality and Social Psychology Review,* 5(4), 296-320.

RUROS. (2004). *Rediscovering the Urban Realm and Open Spaces, Report of the European research project within key action 4 'City of Tomorrow and Cultural Heritage'.* CRES, Athens.

**S**

Salingaros, N. (2005). *Principles of urban structure,* Amsterdam: Techne Press.

Santamouris, M. (2001). "Appropriate materials for the urban environment", in M. Santamouris, (ed.), *Energy and climate in the urban built environment* London: James & James, pp. 160-180.

Schäfer, R. (2002). *Urban squares,* Munich/Basel: Callwey/Birkhäuser.

Schmalz, J. (1984). *Das Stadtklima : ein Faktor der Bauwerks- und Staedteplanung : Unter besonderer Beruecksichtigung der Berliner Verhaeltnisse, mit Beispielen aus Planungsgebieten der "Internationalen Bauausstelling Berlin 1987"*, Karlsruhe: Mueller.

Schneider, J. (2002). "Barcelona Plätze", in K. Selle, (ed.), *Was ist los mit den öffentlichen Räumen?* Dortmund: AGB, pp. 218-227.

Schön, D. (1987). *Educating the reflective practitioner,* San Francisco: Jossey-Bass/ Wiley & Sons.

Sennett, R. (1994). *Flesh and stone: the body and the city in Western civilization,* London [etc.]: Faber and Faber.

Sennett, R. (2008). *The craftsman,* New Haven/ London: Yale University Press.

Sitte, C. (1889). “City planning according to artistic principles”, Camillo Sitte: *The Birth of Modern City Planning. 1986.* New York: Rizzoli.

Sokolwski, R. (2000). *Introduction to Phenomenology,* Cambridge, UK: Cambridge University Press.

Stathopoulos, T. (2006). “Pedestrian level winds and outdoor human comfort.” *Journal of Wind Engineering and Industrial Aerodynamics,* 94(11), 769-780.

Steemers, K., Ramos, M., and Simou, R. (2004). “Urban diversity”, in K. Steeemers and M. A. Steane, (eds.), *Environmental diversity in architecture.* London: Spon Press, pp. 85-100.

Steenbergen, C., Mihl, H., and Reh, W. (2002). “Introduction; Research, Research by Design”, in C. Steenbergen, H. Mihl, W. Reh, and F. Aerts, (eds.), *Architectural Design and Composition.* Bussum/ Delft: Thoth publishers/ Faculty of architecture TU Delft.

Stevens, H. (1989). “Lege ruimten op vitale plaatsen in een stad.” *Bouw*(12), 40-42

Streiling, S., and Matzarakis, A. (2003). “Influence of single and small clusters of trees in the bioclimate of a city: a case study.” *Journal of Arboriculture* 29(6), 769-780.

***T*** Tacken, M. (1989). “A Comfortable Wind Climate for Outdoor Relaxation in Urban Areas.” *Building and Environment,* 24(4), 321-324.

ten Cate, G. (1990). “Straatmeubilair bij gemeenten en vogue - de opkomst (na neergang) van de straat en het plein.” *Bouw*(25), 11.

Thorsson, S., Honjo, T., Lindberg, F., Eliasson, I., and Lim, E. M. (2007a). “Thermal comfort and outdoor activity in Japanese urban public places.” *Environment and Behavior,* 39(5), 660-684.

Thorsson, S., Lindberg, F., Eliasson, I., and Holmer, B. (2007b). “Different methods for estimating the mean radiant temperature in an outdoor urban setting.” *International Journal of Climatology,* 27(14), 1983-1993.

Thorsson, S., Lindqvist, M., and Lindqvist, S. (2004). “Thermal bioclimatic conditions and patterns of behaviour in an urban park in Goteborg, Sweden.” *International Journal of Biometeorology,* 48(3), 149-156.

Trancik, R. (1986). *Finding lost space : theories of urban design,* New York: Nostrand Reinhold.

Tuan, Y. F. (1974). *Topophilia : a study of environmental perception, attitudes, and values,* Englewood Cliffs: Prentice Hall.

Tufte, E. R. (1990). *Envisioning information,* Cheshire: Graphics.

Tversky, B. (2003). “Structures of mental spaces - How people think about space.” *Environment and Behavior,* 35(1), 66-80.

***V*** Van Dijk, H. (1999). *Twentieth - Century Architecture in The Netherlands,* Rotterdam: 010 publishers.

Van Dooren, N. (1999). “Modern ambachtelijk.” *Blauwe Kamer* (4), 22-25.

Van Duren, A. J. (1992). “Changes in the attraction of Amsterdam city centre.” *Built Environment,* 18(2), 123-137.

Verkaik, J. W. (2006). *On wind and roughness over land,* PhD dissertation, Wageningen University.

**W**

Wagenaar, M. (1999). "Pleinen, parken en boulevards - Vorm en vulling van het publieke domein", *De stad op straat.* Den Haag: Sociaal en Cultureel Planbureau, pp. 41-44.

Walton, D., Dravitzki, V., and Donn, M. (2007). "The relative influence of wind, sunlight and temperature on user comfort in urban outdoor spaces." *Building and Environment,* 42(9), 3166-3175.

Westerberg, U. (1994). "Climatic planning- physics or symbolism? ." *Architecture & Behavior,* 10(1), 49-71

Westerberg, U., and Glaumann, M. (1991). "Design Criteria for Solar Access and Wind Shelter in the Outdoor Environment." *Energy and Buildings,* 15(3-4), 425-431.

Whyte, W. H. (1980). *The social life of small urban spaces,* Washington: Conservation Foundation.

Wiegersma, L. (2007). "Het heringerichte Museumplein herinrichten?" *Blauwe Kamer*(6), 77.

Willemsen, E., and Wisse, J. A. (2007). "Design for wind comfort in The Netherlands: Procedures, criteria and open research issues." *Journal of Wind Engineering and Industrial Aerodynamics,* 95(9-11), 1541-1550.

Woodruff-Smith, D. (2008). "Stanford Encyclopedia of Philosophy", http://plato.stanford.edu/entries/phenomenology.

**Z**

Zacharias, J., Stathopoulos, T., and Wu, H. (2001). "Microclimate and downtown open space activity." *Environment and Behavior,* 33(2), 296-315.

Zeisel, J. (2006). *Inquiry by design : environment/behavior/neuroscience in architecture, interiors, landscape, and planning,* New York [etc.]: W.W. Norton & Company.

## Websites relating to chapter 3

[1] http://extra.volkskrant.nl/interactie/ruimtelijkeagenda/vraagstukken.php.#In_de_meeste_steden_is_een_groot_gebrek_aan_vriendelijke_openbare_ruimtes%2C_zoals_parken [accessed 11.01.2008]

[2] http://www.rotterdamveilig.nl/do.php?fct=pages&op=showPage&pageId=314 [accessed 11.01.2008]

[3] http://www.beintema.net/groenlinks/programma/thuis [accessed 11.01.2008]

[4] http://www.haagwonen.nl/info.asp?ID=148 [accessed 11.01.2008]

[5] http://www.classic.archined.nl/news/0101/rotterdam_2001.html [accessed 11.01.2008]

[6] http://www.skyscrapercity.com/showthread.php?t=457852&page=2 [accessed 11.01.2008]

[7] http://www.noorderbreedte.nl/onder.php3?artikel=2719 [assessed 11.01.2008

[8] http://www.liwwadders.nl/data/nieuws/items/EEFlVypEuEnVvxOqIs.php [accessed 11.01.2008]

[9] http://www.eenarchitect.web-log.nl/ [accessed 11.01.2008]

[10] http://www.leiden.pvda.nl/nieuwsbericht/3231 [accessed 11.01.2008]

[11] http://hengelo.hyves.nl/forum/452135/WGRq/Waarom_is_onze_marktplein_kut/ [accessed 11.01.2008]

[12] http://www.hengelo.nl/pdf/actueel/rapportage9_toel8.pdf [accessed 11.01.2008]

[13] http://www.haagsestadspartij.nl/column.php?collum=43 [accessed 11.01.2008]

[14] http://archief.volkskrant.nl/artikel?text=spuiplein&FDOC=0&SORT=presence&PRD=20y&SEC=%2A&SO=%2A&DAT=%2A&ADOC=0 [accessed 11.01.2008]

[15] http://www.ad.nl/denhaag/article119072.ece [accessed 11.01.2008]

[16] http://www.enschede-stad.nl/forum/viewtopic.php?p=20954&sid=8f9f56d5731571606c94a09408191550 [accessed 11.01.2008]

[17] http://stationsweb.brinkster.net/nieuws.asp?rec=1062 [accessed 11.01.2008]

[18] http://gmb.exception.nl/volledig.php?m=200107 [accessed 11.01.2008]

[19] http://gmb.exception.nl/archief/publieksavond250601.php [accessed 11.01.2008]

[20] http://www.dsg.nl/logs/gl/index.php?m=200605 [accessed 11.01.2008]

[21] http://bkinfo.bk.tudelft.nl/bsc5/websites/Atelier%2007/The%20observers/week2/Pagina3.html [accessed 11.01.2008]

[22] http://zoetermeer.sp.nl/weblog/2006/10/25/pleinvrees/ [accessed 11.01.2008]

[23] http://zoetermeer.sp.nl/weblog/2006/11/17/discussie-stadhuisplein/ [accessed 11.01.2008]

[24] http://www.novatv.nl/index.cfm?ln=nl&fuseaction=artikelen.details&achtergrond_id=8814&CFID=34913497&CFTOKEN=15502739 [accessed 11.01.2008]

[25] http://neerlandswelzijn.web-log.nl/neerlandswelzijn/2005/12/de_heuvel_rond_.html [accessed 11.01.2008]

[26] http://www.novatv.nl/index.cfm?ln=nl&fuseaction=artikelen.details&achtergrond_id=8795 [accessed 11.01.2008]

[27] http://archief.trouw.nl/artikel?REC=tr-19970623-000018856 [accessed 11.01.2008]

[28] http://zoek.volkskrant.nl/artikel?text=hilde%20de%20haan&FDOC=120&SORT=presence&PRD=20y&SEC=%252A&SO=%252A&DAT=%252A&ADOC=124 [accessed 11.01.2008]

[29] http://www.novatv.nl/index.cfm?ln=nl&fuseaction=artikelen.details&achtergrond_id=8814 [accessed 11.01.2008]

[30] http://www.haagsestadspartij.nl/column.php?collum=43 [accessed 11.01.2008]

[31] http://archief.volkskrant.nl/artikel?text=spuiplein&FDOC=0&SORT=presence&PRD=20y&SEC=%2A&SO=%2A&DAT=%2A&ADOC=0 [accessed 11.01.2008]

[32] www.tilburg.com/upload/Stadskerndebat/Stadskerndebat6.pdf [accessed 11.01.2008]
[33] http://archeonet.nl/index.php?itemid=9493 [accessed 11.01.2008]
[34] http://www.ad.nl/denhaag/article119072.ece [accessed 11.01.2008]
[35] http://bkinfo.bk.tudelft.nl/bsc5/websites/Atelier%2009/Groep_010/week4/toelichting.html [accessed 11.01.2008]
[36] http://www.volkskrant.nl/binnenland/article146480.ece [accessed 11.01.2008]
[37] http://www.scholieren.com/werkstukken/7755 [accessed 11.01.2008]
[38] http://archief.trouw.nl/artikel?REC=tr-19970221-000006050 [accessed 11.01.2008]
[39] http://www.observant.unimaas.nl/default.asp?page/jrg23/obs1/art16.htm [accessed 11.01.2008]
[40] http://archief.trouw.nl/artikel?REC=tr-19920330-000008202 [accessed 11.01.2008]
[41] http://www.zoover.nl/nederland/overijssel/deventer/beoordelingen [accessed 11.01.2008]
[42] http://www.destentor.nl/deventer/article567554.ece [accessed 11.01.2008]
[43] http://www.enschede-stad.nl/forum/viewtopic.php?t=184&start=0&sid=5b1d58cfe30ee6df9f7dbed6196c77ab [assessed 11.01.2008]
[44] http://stationsweb.brinkster.net/nieuws.asp?rec=1049 [assessed 11.01.2008]
[45] KNMI:http://www.knmi.nl/klimatologie/normalen1971-2000/wind_jaargemiddelde.html [assessed 11.01.2008]

## Permissions

| | |
|---|---|
| Fig. 3-8 | Reprinted with permission of Gelders Archief |
| Fig. 3-9 | Reprinted with permission of Goudappel Coffeng bv |
| Fig. 3-18 | Reprinted with permission of Rijksmuseum Amsterdam |
| Fig. 3-20 | Reprinted with permission of Gelders Archief |
| Fig. 7-1 | Reprinted with permission of OMA architects |
| Fig. 7-2 | Reprinted with permission of Penelope Dean |
| Fig. in ‘About the Author’ | Reprinted with permission of Serge Chamuleau |

# Summary
# Samenvatting

# Summary

The first time I was confronted with the questions surrounding microclimate and the way people experience it, was when I was working as a project leader on a design for a public space, the square Canadaplein in the city of Alkmaar. In 2001 the plan was realised and put into use. After the first outdoor season had ended, people complained about the wind on the square, a problem no one had thought of – neither the commissioners from the municipality nor the designers. This got me thinking and ever since this project I have been more focused on the subject of microclimate.

The concept of experience has always been important to me as well. As a designer of public spaces, I continually wondered how people perceived the spaces I designed. The philosophical movement of phenomenology, to which the idea of human experience is central, was very inspiring to me in this respect. In their quest for ideas of what experience is and how it works, various philosophers have produced a number of principal ideas that fascinated me. It mostly concerns multi-sensory, synaesthetical experience, the neglect of the proximal, sensory perception, and the connections between experience and reality. Within this philosophical movement also the idea of 'atmosphere': the relation between personal, psychological factors and physical factors of the environment, emerged in the book *Atmosphären* ('atmospheres') by the German philosopher Gernot Böhme, which enters deeply into this subject. This was very inspirational for me, which has to do with the fact that he explicitly mentions the designers of spaces as the ones creating 'atmosphere' ('ästhetische Arbeiter') - by using their designs to speak to all senses and influence people's psyche as well. Unfortunately, Böhme took no notice that the idea of microclimate is an important part of 'atmosphere', despite the fact that the etymology of the Greek word mainly refers to a connection between climate and space.

For me as a designer, this body of thought was another motive to gain a deeper understanding of the experience of space and 'atmosphere'. Combined with my experience with the microclimatic problems at the Canadaplein, I became intrigued  with the question whether there might be connections between people's spatial experience and their experience of the microclimate.

I decided to study this theme of microclimate perception and design further in this PhD research. Seeing that design and research can be connected in different ways, I divided my project into three phases, which represent the various relations between design and research. This concerns 'research on design', a reflection on design, 'research for design', empirical research to generate guidelines for design, and 'research by design', for which designing itself is used to gain new knowledge, in this case design guidelines.

To obtain a better image of spatial and microclimatic perception in the Dutch public spaces, I conducted a preliminary study ('research on design'): a first analysis of the opinions on public space in relation to the experience of microclimate, 'atmosphere' and space. A great number of weblogs and a large-scale survey by one of the biggest Dutch newspapers revealed that there are problems with the Dutch public spaces. These sources showed that there was much discontent with, amongst other things, the microclimate of squares. People formulated their discontent with words suggesting an unpleasant microclimate, such as ‘cold’ or ‘windy’. These were often bracketed together with characteristics of space or ‘atmosphere’. I found it remarkable that in the design of squares so little attention was given to the theme of microclimate and the experience thereof, even though many publications on urban design demonstrated that the microclimate is an important factor for people to use public spaces or avoid them.

A search for ways to make better designs with respect to microclimate for public spaces in the Netherlands was not very successful. I found there are various problems that make it hard to create microclimate-responsive designs for urban places. I noticed that there were hardly any design guidelines for the Dutch context, and that designers and commissioners were not aware of these problems. Moreover, I found that most research on microclimate and thermal comfort was aimed at physics, and did not take the synaesthetical perception of people into account, their thermal comfort in relation to ‘atmosphere’ and space.

I therefore decided to study these questions through empirical research: ‘research for design’. I concentrated this research on the generation of design guidelines that could be expected to improve people’s microclimate experience. I focused on factors that can be influenced by urban design interventions such as spatial configuration, proportion and use of materials. I wanted to study these in relation to people’s thermal comfort an microclimate experience.

The first principal assumption I wanted to study was that the ‘atmosphere’ of a square and the perception of its microclimate are closely connected, so that measures influencing the ‘atmosphere’ of a place also affect the experience of the microclimate. This means that changes in designs can have an effect on microclimate experience, both on a physical and a psychological level. I mainly based the phrasing of my research questions on the theory of ‘schemata’, on the way people experience and remember things, and the theory of ‘environmental cues’, the human interpretation of spatio-physical characteristics. The most important questions to reveal the relationship between the experience of space and microclimate I considered to be these:

1. How do people perceive urban microclimate?
2. How do people perceive microclimate in relation to spatial configurations or places?
3. How do people perceive microclimate in relation to proportions, openness and materials?

I studied these questions using existing methods from the fields of urban climatology and environmental psychology/urban geography. Through fieldwork I made an inventory of various indicators of the spatial ‘atmosphere’ influences and microclimate. The fieldwork was conducted during the outdoor seasons from spring to autumn in the years 2005 and 2006. I concentrated on Dutch squares of different types: an historical market square, the Grote Markt in Groningen; a busstation, Neckerspoel in Eindhoven; and a square that is used for events, the Spuiplein in Den Haag. The fieldwork consisted of interviews asking people about their long-term experience of the microclimate, and what situations influence it the most. The interviewees were also asked to point out places on the squares they associated with a certain kind of microclimate. From these interviews ‘collective mental maps’ could be generated, reflecting the ‘collective microclimate-memory’ for various areas on the squares. General conclusions could also be drawn on whether people found the squares thermally comfortable or less so. Furthermore, people were given concrete questions about the way they perceived the squares’ design: what they thought of the proportions, the level of openness of the square and the appearance of the used materials.

Parallel to the interviews, I conducted a series of measurements on a number of fixed, microclimatically characteristic places on the squares. On four days in each of the three outdoor seasons, measurements were taken at 9, 11, 13, 15 and 17 hrs. With these data I could generate microclimate-maps that could be used as a comparison for the data of the research on experience.

I then analyzed the data on the basis of the fieldwork results. As regards the first question – How do people perceive urban microclimate? – I was able to conclude that in this respect wind nuisance is very important in the Dutch context. Especially the windy moments seem to be ‘engrained’ in people’s memories, and they tend to overestimate wind-effects. This mirrors typical psychological phenomena: people remember the more salient situations and the more negative experiences often come to the fore (‘negativity bias’). For designers this implies that the wind factor should always be taken into account in designs of Dutch outdoor spaces. A different implication is that computer simulations for thermal comfort should address this experience of the more extreme situations as well. This was an important conclusion for the third part of my research, in which I worked with these kinds of simulations.

The research into the second question – How do people perceive microclimate in relation to spatial configurations or places? – revealed that people link marked microclimatic phenomena to spatial configurations, even though these microclimatic phenomena do not always occur. Many people, for instance, consider open spaces on squares, street entrances, passageways and areas at the base of high buildings to be ‘windy’, while they think of more enclosed spaces, such as those at the base of lower buildings or half-enclosed spaces, as being more pleasant in terms of wind or ‘pleasantly sunny’. On the whole, people’s findings matched the results of the measurements in characteristic spatial configurations reasonably well. It surprised me how well the interviewees were able to point out this connection between microclimate and simple spatial configurations, even without conducting series of measurements or knowing from scientific literature which types of areas have typical wind-flows. At the same time, this is an alarming proof of designers’ current disregard of microclimate issues and consequential inability to prevent microclimate problems with their designs. The fact that people have so much knowledge of the microclimate, also makes the method of creating ‘mental maps’ interesting for obtaining insight into the microclimate without having to conduct long and complex series of measurements. I can therefore recommend this method for the analysis phase in refurbishment projects of urban public spaces, to gain a general knowledge of the local microclimate.

With regard to the third question – How do people perceive microclimate in relation to proportions, openness and materials? – I made a statistical analysis (with help of a specialist). It became apparent that people have more negative impressions than positive ones. For this reason I concentrated on the negative impressions. It turned out that there were clear connections between the experience of thermal discomfort and 'too wide' and 'empty' squares. People's experiences and the measured data matched here as well. When the interviewees indicated that they found these areas to be too empty, they were also asked how they would suggest to improve the situation. Many of them came up with proposals that had a clear effect on a more varied and sheltered microclimate (more trees, green, water, windbreaks and such). Besides, thermal discomfort proved to be related to the sight or feel of materials with a 'cold' appearance. This often concerned materials that do indeed feel 'cold' when they are touched, due to their rapid thermal conduction. The factor colour also played a role here and this factor could not always be supported with physical laws. For instance, for the temperature of spaces or objects it makes no difference if something has a light-red colour or a light-blue one, but for the way people perceive the temperature, it apparently does. Cultural symbolic values probably play an important role in these misinterpretations. Designers could use these misinterpretations of colour to suggest 'cool' or 'warm' outdoor spaces, without actually making changes in the physical microclimate.

The overall conclusion I could draw from this first part of the empirical research, is that people have a very clear image of the microclimate, even though it is often a little too negative. As a result, I was not able to distil as many design guidelines as I had hoped from this empirical research based on my fieldwork. With respect to guidelines for design, the outcome of this part contained many 'don'ts' and not so many 'do's'. It is this last, positive category, however, that is more important for designers, since they are expected to offer an optimal solution.

With this in mind, I started with the 'research by design' in order to come to a more positive design guideline – an 'optimized' model of a Dutch square, with a focus on thermal comfort.

'Research by design' as a design method is a term that recently originated at the TU Delft in the architecture department. 'Research by design' is based on a rational approach to design that has much in common with an empirical, scientific way of conducting research. Unfortunately, the colleagues in Delft were not very clear about an important factor in such a method that resembles empirical science: how to test design solutions (which basically can be considered hypotheses). Therefore, I proposed to clearly formulate design solutions as hypotheses, and to test them in a rational, objective manner, according to strict criteria. New computer simulation techniques, which can simulate the effects of designs that have not been realized yet, are especially appropriate for this objective. From such a process a 'best' or optimized model can be derived. For the fields of landscape architecture and urban design, I also added that these models ought to be developed 'sectorally', for the large sensitivity to context makes it impossible to generate a universal 'prototype', which could for instance integrate climatic, hydrological and social factors. For this reason, such models should rather be considered as ‘half products’, which the designers then have to combine with other models and demands in an integral design process.

In my ‘research by design’ I chose a method with simulations that could reveal the future effects of my designs. I worked with the simulation programme Envi-Met®. This programme generates the effects of microclimate and thermal comfort on the basis of meso- and microclimatic arithmetic models. Based on the knowledge from the literature, I started out with a design hypothesis on how to layout a Dutch square in an ‘optimal’ way to be able to offer thermal comfort in different seasons. I subsequently simulated these for the most ‘engrained experience’ situations: a windy situation and a quite hot situation during a heatwave. By choosing these two rather extreme situations, I simultaneously tested the more ‘average’ situations in between. I then refined the model on the basis of the conclusions from the simulation results. I repeated this process several times, until I arrived at a result that could serve as a generic model for a thermally comfortable Dutch square. This model contains a sequence of lines of 25 m tall trees in a northwest-southeast orientation. These lines are placed at approximately 50 m from each other. In the space between the trunks, transparent windshields are placed (forming an ‘urban shelterbelt’ together with the trees). This ‘urban shelterbelt’ offers sufficient protection against the strong southwesterlies in the Netherlands, yet simultaneously provides enough shadow to have cooler places at a small distance from each other on the square during the warmer periods. It is a simple, easily implementable model, which can also be adapted somewhat to various situations, without losing its effects for an improved thermal comfort in different seasons.

This ‘research by design’ thus enabled me to create a more specific and positive design guideline for a Dutch square of average size. Together, the ‘do’s’ and ‘don’ts’ I generated in my research offer a number of easily applicable guidelines for design, which landscape architects, urban designers and designers of public spaces can use without much prior knowledge of microclimatic processes. The fact that there is no need for specific knowledge about the microclimate, strongly improves the usability. It is important now to inform the designers that have to design or refurbish the Dutch squares of these simple design guidelines, and to motivate them to actually apply these, so that in the future, there will be less complaints about the thermal discomfort and unpleasant ‘atmosphere’ of the squares.

This study resulted in a number of insights on a more theoretical level as well. Looking back at the three inspiring ideas from the phenomenology, I can now say that my empirical research supports these ideas in every aspect.

People revealed to have a highly developed thermal perception, so a non-visual sense is crucial to them as well. Therefore, it is essential to oppose an ‘ocularcentristic’ mind-set with the designers of public space. This is not an easy task, because now more than ever, it is the visual media that communicate and ‘sell’ spatial design. Nevertheless, more attention to the other senses is in order, especially people’s thermal perception.

This research also supports the idea of ‘embodiment’ or Böhme’s ‘atmosphere’ – the combination of the surroundings, the sensory perception thereof and the human psyche. I demonstrated the close relations between sensory perceptions (thermal, haptic, visual) and mental concepts. For designers it is therefore important to combine the various aspects of ‘atmosphere’ in their designs. This calls for a thinking about design that encompasses both the different senses and the connected mental schemata. The creation of thermally comfortable spaces thus comes with spatially ‘cosy’ configurations and a use of ‘warm’ colours and materials, something not easily found in many designs for outdoor spaces. For many designers, this calls for a change in mentality from a somewhat distant, supermodernist ‘cool’ attitude to a more obliging and humane one.

Finally, my research again highlighted the interesting aspect of the ‘phenomenological reduction’: the difference between ‘reality’ and human perception. In the comparison of the perceptions and the measured data, there were many similarities, but also a number of striking differences. Seeing that a designer works for people and their experiences, it is usually more important to use design measures in reaction to the human perception and not to a quantifiable reality.

I would like to finally conclude with an encouragement for colleagues in landscape architecture and urban design: when we take into account all different aspects of ‘atmosphere’ – and especially the microclimatic aspects thereof – in the design of public spaces, we can make an important contribution to more liveable and comfortable cities.

# Samenvatting

Ik kwam met de probleemstelling van microklimaat en de beleving hiervan voor de eerste keer in aanraking toen ik als landschapsarchitecte aan het ontwerp van een openbare ruimte werkte. In het jaar 2001 was het ontwerp gerealiseerd voor het Canadaplein in Alkmaar, waaraan ik als projectleider meewerkte, en werd het plein in gebruik genomen. Na het eerste buitenseizoen klaagden de bezoekers van het plein over problemen met wind en tocht, een probleem waar niemand aan had gedacht – de opdrachtgevers niet en de ontwerpers ook niet. Dit heeft me aan het denken gezet en ik ben sindsdien meer gespitst op het thema microklimaat.

Ook het thema beleving vond ik altijd al zeer belangrijk. Continu vroeg ik me als ontwerper van openbare ruimtes af hoe mensen de door mij ontworpen ruimtes beleefden. De filosofische stroming van de fenomenologie waarin het idee van de menselijke beleving centraal staat vond ik heel inspirerend om dit thema beter te doorgronden. Verschillende filosofen hebben in hun zoektocht naar wat beleving is en hoe beleving werkt gezamenlijk een aantal hoofdideeën voortgebracht die ik zeer boeiend vond. Het gaat daarbij met name om de multi-sensorische, synesthetische beleving, de verwaarlozing van de proximale zintuigelijke beleving en de verbanden tussen beleving en realiteit. In deze filosofische stroming komt ook het idee van de 'sfeer' aan de orde: het samenspel tussen persoonlijke, psychologische en fysieke factoren van de omgeving. Het boek *Atmosphären* (Sferen) van de Duitse filosoof Gernot Böhme, waarin dit onderwerp uitvoerig wordt behandeld, was hierin voor mij een grote inspiratiebron. Dit heeft ook ermee te maken dat hij de vormgevers van ruimtes heel expliciet benoemt als degenen die 'sfeer' maken ('ästhetische Arbeiter') door met hun ontwerpen alle zintuigen aan te spreken en ook de psyche van de mens te beïnvloeden. Helaas heeft Böhme het idee van het microclimaat als belangrijke onderdeel van 'sfeer' niet in acht genomen, ondanks het feit dat de etymologie van het woord vooral naar een verbintenis tussen klimaat en ruimte verwijst.

Voor mij als ontwerper was dit gedachtegoed nog een drijfveer om me te verdiepen in de beleving van ruimte en 'sfeer'. Samen met de ervaring die ik had opgedaan in verband met de problemen met het microklimaat op het Canadaplein in Alkmaar raakte ik geïnteresseerd in de vraag of er misschien dwarsverbanden te vinden zijn tussen ruimtelijke beleving en die van het microklimaat.

Ik besloot om dit thema van microclimaatbeleving en ontwerp verder te bestuderen in dit promotieonderzoek. Omdat ontwerp en onderzoek op verschillende manieren kunnen samenhangen heb ik mijn project in drie fases ingedeeld die verschillende relaties tussen ontwerp en onderzoek vertegenwoordigen. Het gaat om 'onderzoek over ontwerp', een reflectie op ontwerp, 'onderzoek voor ontwerp' empirisch onderzoek om tot ontwerprichtlijnen te komen en 'ontwerpend onderzoek', waarbij het ontwerpen zelf wordt gebruikt om nieuwe kennis te genereren, in dit geval eveneens ontwerprichtlijnen.

Om een beter beeld van ruimtelijke en microklimaatbeleving in Nederlandse openbare ruimtes te verkrijgen, heb ik een verkennend onderzoek

(‘onderzoek over ontwerp’) gedaan: een eerste analyse van meningen over de openbare ruimte met betrekking tot beleving van microklimaat, ‘sfeer’ en ruimte. Uit een groot aantal weblogs en een grootschalige enquête van een van Nederlands grote kranten kwam naar voren dat er problemen zijn met de Nederlandse openbare ruimte. De bronnen toonden aan dat er veel ontevredenheid was, onder meer over het microklimaat op de pleinen. Mensen gebruikten bewoordingen die een onaangenaam microklimaat suggereerden zoals ‘koud’ of ‘winderig’. Deze werden vaak in een adem genoemd met ruimtelijke of ‘sfeer’ karakteristieken. Ik vond het opmerkelijk dat bij de inrichting van stadspleinen niet meer rekening werd gehouden met het thema microklimaat en de beleving daarvan, terwijl in veel literatuur over stadsontwerp is aangetoond dat het microklimaat een invloedrijke factor is voor het gebruik dan wel mijden van openbare ruimtes.

Een zoektocht naar manieren hoe je dan kunt komen tot microklimatisch betere ontwerpen voor de Nederlandse openbare ruimte, was niet erg succesvol. Ik merkte dat er verschillende problemen spelen die microklimaat-gericht ontwerp moeilijk maken. Ik merkte dat er voor de Nederlandse situatie nauwelijks ontwerprichtlijnen bestonden en dat men in de wereld van ontwerpers en bestuurders ook niet bewust was van deze problemen. Bovendien merkte ik dat veel onderzoek over microklimaat en thermisch comfort erg op natuurkunde gericht was en geen rekening hield met de synesthetische waarneming van mensen, van thermisch comfort in relatie tot ‘sfeer’ en ruimte.

Daarom besloot ik deze vraagstellingen verder te bestuderen door middel van empirisch onderzoek: ‘onderzoek voor ontwerp’. Ik concentreerde mijn onderzoek op het genereren van ontwerprichtlijnen waarvan ik een beter effect op de microklimaatbeleving verwachtte. Ik heb me gericht op factoren die beïnvloedbaar zijn door stedelijke ruimtelijke vormgeving: ruimtelijke configuraties, proporties en materiaalgebruik. Deze wilde ik onderzoeken in relatie tot hun effect op het thermisch comfort en de microklimaatbeleving van mensen.

De eerste hoofdaanname die ik wilde onderzoeken was dat de ‘sfeer’ van een plein en de beleving van het microklimaat nauw samenhangen, dus dat ingrepen die de ‘sfeer’ van een ruimte beïnvloeden ook van invloed zijn op de microklimaatbeleving. Dit houdt in dat ontwerpingrepen effect kunnen hebben op de microklimaatbeleving – zowel op een fysiek als op een psychologisch niveau. Hier heb ik de formulering van mijn onderzoeksvragen vooral gebaseerd op de theorie van ‘schemata’, over de manier waarop mensen iets beleven en herinneren en de theorie van de ‘environmental cues’, de interpretatie van fysiek-ruimtelijke kenmerken door de mens. De belangrijkste vraagstellingen om achter de relatie tussen ruimte en microklimaatbeleving te komen waren voor mij de volgende:

1. Hoe beleven mensen microklimaat in de stad?
2. Hoe beleven ze microklimaat in verband met ruimtelijke configuraties of plekken?
3. Hoe beleven ze microklimaat in verband met proporties, openheid en materialen?

Deze vraagstellingen heb ik met bestaande methodes uit de stadsklimatologie en de omgevingspsychologie/stadsgeografie verder onderzocht. Voor de ruimtelijke ‘sfeer’ invloeden en het microklimaat heb ik verschillende indicatoren benoemd die ik door veldwerk heb geïnventariseerd. Het veldwerk werd verricht in de buitenseizoenen van de lente tot de herfst in 2005 en 2006. Ik heb me geconcentreerd op Nederlandse pleinen van verschillende soorten: een historisch marktplein: de Grote Markt in Groningen, een busstation: Neckerspoel in Eindhoven en een evenementenplein: het Spuiplein in Den Haag. Het veldwerk omvatte interviews waarin mensen naar verschillende factoren van hun microklimaatbeleving werden gevraagd. Ze werden gevraagd naar hun lange-termijn beleving van het microklimaat en welke situaties daarin de belangrijkste rol spelen. Zij moesten ook op de pleinen aanwijzen of er plekken waren waarmee ze een bepaald soort microklimaat verbonden. Hieruit konden ‘mental maps’ gegenereerd worden die het ‘collectieve microklimaat-geheugen’ voor verschillende plekken op de pleinen weerspiegelden. Daaruit kon ook algemeen geconcludeerd worden of mensen de pleinen in thermisch opzicht meer of minder aangenaam vonden. Ook werden mensen concreet naar hun beleving van de vormgeving van de pleinen gevraagd: wat ze van de proporties, de mate van openheid van het plein en de uitstraling van de materialen dachten.

Parallel aan de interviews voerde ik een serie metingen uit op een aantal vaste microclimatisch karakteristieke plekken op de pleinen. In elk van de drie buitenseizoenen werden op 4 dagen metingen gedaan om 9, 11, 13, 15 en 17 uur. Hieruit kon ik data en microklimaatkaarten genereren die als vergelijkingsmateriaal voor de data van het belevingsonderzoek konden dienen.

Ik heb de data vervolgens geanalyseerd aan de hand van de resultaten van het veldwerk. Wat betreft de eerste vraag – Hoe beleven mensen microklimaat in de stad? – kon ik concluderen dat in de beleving van het stedelijke microklimaat het thema windoverlast heel belangrijk is in de Nederlandse context. Mensen lijken vooral de winderige momenten in hun geheugen te hebben ‘gegrift’ en ze hebben de neiging de invloed van de wind te overschatten. Dit weerspiegelt typische verschijnselen in de psychologie: dat mensen de meer opvallende situaties onthouden en dat daarbij de negatievere ervaringen vaak op de voorgrond staan (‘negativity bias’). Dit heeft als implicatie voor ontwerpers dat de factor wind in Nederlandse ontwerpen voor openbare ruimten altijd in acht genomen moet worden. Maar het heeft ook een andere implicatie: computersimulaties die het thermisch comfort simuleren zouden ook op deze ervaring van de wat extremere situaties moeten inspelen. Dit was een belangrijke conclusie voor het derde deel van mijn onderzoek, waarin ik met zulke simulaties heb gewerkt.

Uit het onderzoek naar de tweede vraag – Hoe beleven mensen microklimaat in verband met ruimtelijke configuraties of plekken? – is gebleken dat mensen duidelijke microklimatische verschijnselen aan ruimtelijke configuraties koppelen, ook al zijn die microklimatische verschijnselen niet altijd aanwezig. Zo vinden veel mensen ruimtes als open pleinvlakken, straatingangen, passages en gebieden aan de voet van hoge gebouwen ‘winderig’ en wat meer besloten ruimtes zoals rond de voeten van lagere gebouwen of half-omsloten ruimtes aangenamer qua wind of ook ‘aangenaam zonnig’. De bevindingen van mensen strookten over het algemeen redelijk goed met de resultaten van de meetreeksen in typische ruimtelijk configuraties. Ik was verbaasd hoe goed mensen deze relatie van microklimaat en simpele ruimtelijke configuraties konden aangeven, terwijl ze geen meetreeksen uitvoeren of uit de wetenschappelijke literatuur weten welke gebieden bijvoorbeeld typische windstromingspatronen hebben. Tegelijkertijd is dit ook een alarmerend bewijs van het onvermogen van ontwerpers om problemen op het gebied van microklimaat met hun ontwerpen te voorkomen. Het feit dat de mensen op straat zo'n goede kennis van het microclimaat hebben, maakt ook de methode van het maken van 'collectieve mental maps' interessant voor het verkrijgen van inzicht in het microklimaat zonder lange en gecompliceerde meetreeksen uit te moeten voeren. Ik kan deze methode dan ook aanbevelen voor de analysefase in herinrichtingsprojecten van openbare stedelijke ruimtes om algemene kennis over de plaatselijke microklimaten te krijgen.

Met betrekking tot de derde vraag – Hoe beleven mensen microklimaat in verband met proporties openheid en materialen? – heb ik (met de hulp van een deskundige) een statistische koppeling gemaakt. Het werd duidelijk dat mensen meer negatieve dan positieve impressies hadden. Om deze reden heb ik me geconcentreerd op de negatieve impressies. Het bleek dat er duidelijke verbanden waren tussen de beleving van thermisch discomfort en 'te weidse' ruimtes en 'lege' of 'kale' ruimtes. Ook hier strookten de ervaringen van mensen met de gemeten data. Als geïnterviewden deze ruimtes te kaal vonden werden zij ook gevraagd hoe ze een plein dan beter in zouden richten. Vele van hen kwamen met voorstellen die een duidelijk effect op een gevarieerder en meer beschermd microklimaat hadden (meer bomen, groen, water, windschermen en dergelijke). Daarnaast bleek dat het thermisch discomfort van mensen ook gerelateerd was aan het zien of voelen van materialen die een 'koude' uitstraling hadden. Vaak ging het daarbij om materialen die inderdaad bij aanraking 'koud' aanvoelen door hun snelle warmteconductie. Hierin speelde ook de factor kleur een rol en deze was juist niet altijd te onderbouwen met natuurkundige wetten. Het maakt voor de temperatuur-eigenschappen van ruimtes of objecten bijvoorbeeld niet uit of iets een licht rode of licht blauwe kleur heeft, maar voor de temperatuur-beleving blijkbaar wel. In deze misinterpretatie spelen culturele symbolische waarden waarschijnlijk een belangrijke rol. Ontwerpers kunnen deze verkeerde interpretaties van kleur wel gebruiken om een suggestie van 'koele' of 'warme' buitenruimtes te wekken zonder feitelijk iets aan het fysieke microklimaat te veranderen.

De algemene conclusies die ik uit dit eerste deel van empirisch onderzoek kon trekken is dat mensen een heel duidelijk beeld van microklimaat hebben, ook al is het vaak wat te negatief getint. Dit had tot gevolg dat ik uit het empirische, op mijn veldwerk gebaseerde onderzoek niet zo veel ontwerprichtlijnen kon destilleren als ik had gehoopt. De uitkomst van dit deel bevatte qua ontwerprichtlijnen wel veel 'don'ts', maar niet zo veel 'do's'. Juist deze laatste, positieve categorie is voor ontwerpers belangrijker, omdat zij geacht worden een optimale oplossing te bieden.

Vanuit deze gedachte heb ik het 'ontwerpend onderzoek' gestart om zo tot een positievere ontwerprichtlijn te komen – een soort geoptimaliseerd model van een Nederlands stadsplein met focus op thermisch comfort.

Het ‘ontwerpend onderzoek’ als ontwerpmethode is een term die recent aan de TU Delft in de architectuur opleidingen is ontstaan. Het ‘ontwerpend onderzoek’ is gebaseerd op een rationele benadering van ontwerpen die veel met een empirische, wetenschappelijke manier van onderzoek gemeen heeft. Helaas werd in Delft niet duidelijk gemaakt welke stappen nodig zijn om ontwerpen, die hypothesen zijn, te kunnen toetsen om tot goed beredeneerbare resultaten te komen. Om deze reden heb ik voorgesteld om ontwerpoplossingen duidelijk als aanname te formuleren. Deze zouden vervolgens op een rationele en objectieve manier volgens streng vastliggende criteria getoetst moeten worden, om tot een geoptimaliseerd model te komen. Hiervoor zijn vooral nieuwe computersimulatie-technieken geschikt die de effecten van nog niet bestaande ontwerpen kunnen simuleren. Voor de vakgebieden landschapsarchitectuur en stedebouw heb ik ook toegevoegd dat deze modellen ‘sectoraal’ ontwikkeld moeten worden, omdat door de grote contextgevoeligheid van ruimtelijke ingrepen nooit een overal toepasbaar ‘prototype’ kan komen, waarin bijvoorbeeld klimatologische, hydrologische en sociale factoren geïntegreerd kunnen worden. Daarom zijn zulke modellen in ons vakgebied meer als een ‘halfproduct’ te beschouwen die de ontwerpers in een integraal ontwerpproces nog met andere modellen en eisen bijeen moeten brengen.

Ik heb in mijn ontwerpend onderzoek ook voor een methode gekozen waarbij ik met simulaties de toekomstige effecten van mijn ontwerpen in beeld kon brengen. Ik heb met het simulatieprogramma Envi-Met® gewerkt dat de effecten van microklimaat en thermisch comfort op basis van meso- en microclimatische rekenmodellen genereert. Om te beginnen heb ik, gebaseerd op de kennis uit de literatuur, een eerste ontwerp-hypothese opgesteld over hoe een Nederlands plein ‘optimaal’ moet worden ingericht om in verschillende seizoenen thermisch comfort te bieden. Deze heb ik vervolgens gesimuleerd met simulaties voor de meest ‘ingegrifte’ winderige situaties en een andere vrij extreme situatie tijdens een hittegolf. Door voor deze twee situaties te kiezen heb ik tegelijkertijd ook de daartussen liggende, meer ‘gemiddelde’ situaties getoetst. Op basis van de conclusies uit de simulaties heb ik vervolgens het model weer aangescherpt tot een verbeterde versie. Dit proces heb ik nog meerdere keren doorgevoerd tot ik een resultaat had bereikt dat geschikt was om als generiek model voor een thermisch comfortabele Nederlands plein te werken. Dit model omvat een sequentie van 25 m hoge bomenrijen op een plein in noordwest-zuidoost orientatie. Deze rijen komen op circa 50 m afstand van elkaar te staan en in de ruimte tussen de boomstammen worden transparante windschermen geplaatst (‘urban shelterbelt’). Deze ‘urban shelterbelt’ biedt voldoende bescherming voor de sterke zuidwestenwinden in Nederland, maar tegelijkertijd ook voldoende schaduw om het plein tijdens hete periodes met koelere plekken op een geringe afstand van elkaar te voorzien. Het is een simpel, makkelijk toe te passen model dat ook enigszins aangepast kan worden aan verschillende situaties zonder zijn werking voor een beter thermisch comfort in verschillende seizoenen te verliezen.

Dit ontwerpend onderzoek stelde mij dus in staat om met een meer specifieke en positieve ontwerpleidraad voor een Nederlands plein van gemiddelde grootte te komen. Samen geven de ‘do’s’ en ‘don’ts’ die ik in mijn onderzoek heb gegenereerd een aantal makkelijk toe te passen ontwerprichtlijnen, die ook landschapsarchitecten, stedenbouwers en ontwerpers van openbare ruimtes zonder kennis van microklimatische processen kunnen toepassen. Het feit dat hiervoor geen specifieke kennis over het microklimaat nodig is, verbetert de toepasbaarheid sterk. Het is nu zaak om ontwerpers, die Nederlandse stadspleinen moeten ontwerpen of herinrichten, over deze simpele ontwerprichtlijnen te informeren en te motiveren deze ook toe te passen, zodat we in de toekomst minder klachten van mensen op de pleinen hebben over het thermische discomfort en een onaangename 'sfeer'.

Ook op een meer theoretisch vlak heeft dit onderzoek een aantal inzichten voorgebracht. Terugkijkend op de drie inspirerende hoofdgedachten uit de fenomenologie, kan ik na afronding van dit onderzoek zeggen dat mijn empirisch onderzoek deze gedachten in ieder opzicht onderstreept.

Het bleek dat mensen in de buitenruimte een sterk ontwikkelde thermische waarneming hebben, dus dat een niet-visueel zintuig voor hun ook cruciaal is. Het is daarom belangrijk om een 'ocularcentristische' houding bij de ontwerpers van openbare ruimte tegen te werken. Dit is geen eenvoudige taak, omdat ruimtelijk ontwerp, nu meer dan ooit, door visuele media wordt gecommuniceerd en 'verkocht'. Desalniettemin moet er meer aandacht voor de andere zintuigen komen en met name voor de thermische beleving van mensen.

De gedachte van 'embodiment' of Böhme's 'sfeer' – de vereenzelviging van de omgeving, de zintuiglijke waarneming daarvan en de menselijke psyche – is eveneens door dit onderzoek ondersteund. Ik heb laten zien dat er nauwe verbanden tussen verschillende zintuiglijke waarnemingen (thermisch, haptisch, visueel) en mentale schema's bestaan. Voor ontwerpers is het daarom belangrijk om de verschillende aspecten van 'sfeer' in hun ontwerpen mee te nemen. Dit vergt een ontwerp-denken dat zowel veel verschillende zintuigen in acht neemt en de daarmee verbonden mentale schemata. Het creëren van thermisch comfortabele ruimtes gaat dan ook gepaard met ruimtelijke 'gezellige' configuraties en 'warm' materiaal- en kleurgebruik, iets wat in veel ontwerpen voor de buitenruimte ver te zoeken is. Voor veel ontwerpers vergt dit een mentaliteitsverandering van een wat afstandelijke, supermodernistische, 'coole' houding naar een meer gedienstige en humane.

Tenslotte is in mijn onderzoek ook weer het interessante aspect van de 'fenomenologische reductie' – het verschil tussen de 'realiteit' en de menselijke beleving – naar voren gekomen. Bij het vergelijken van de belevingen en de gemeten data viel op dat er veel overeenkomsten waren, maar ook een aantal opvallende afwijkingen. Aangezien een ontwerper voor mensen en hun beleving werkt, is het meestal belangrijker om met ontwerpingrepen op de menselijke waarneming te reageren en niet op een meetbare realiteit.

Graag wil ik concluderen met een impuls voor mijn collega's in landschapsarchitectuur en stedebouw: door het in acht nemen van alle verschillende aspecten van 'sfeer' – en vooral de microklimatische aspecten daarvan – in het ontwerp van de openbare ruimte kunnen wij een belangrijke bijdrage aan meer leefbare en aangename steden leveren.

# Completed training and supervision plan

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

**CERTIFICATE**

The Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment
(SENSE), declares that

Sandra Lenzhölzer

Born on: 22 November 1967 at: Bensberg, Germany

has successfully fulfilled all requirements of the
Educational Programme of SENSE.

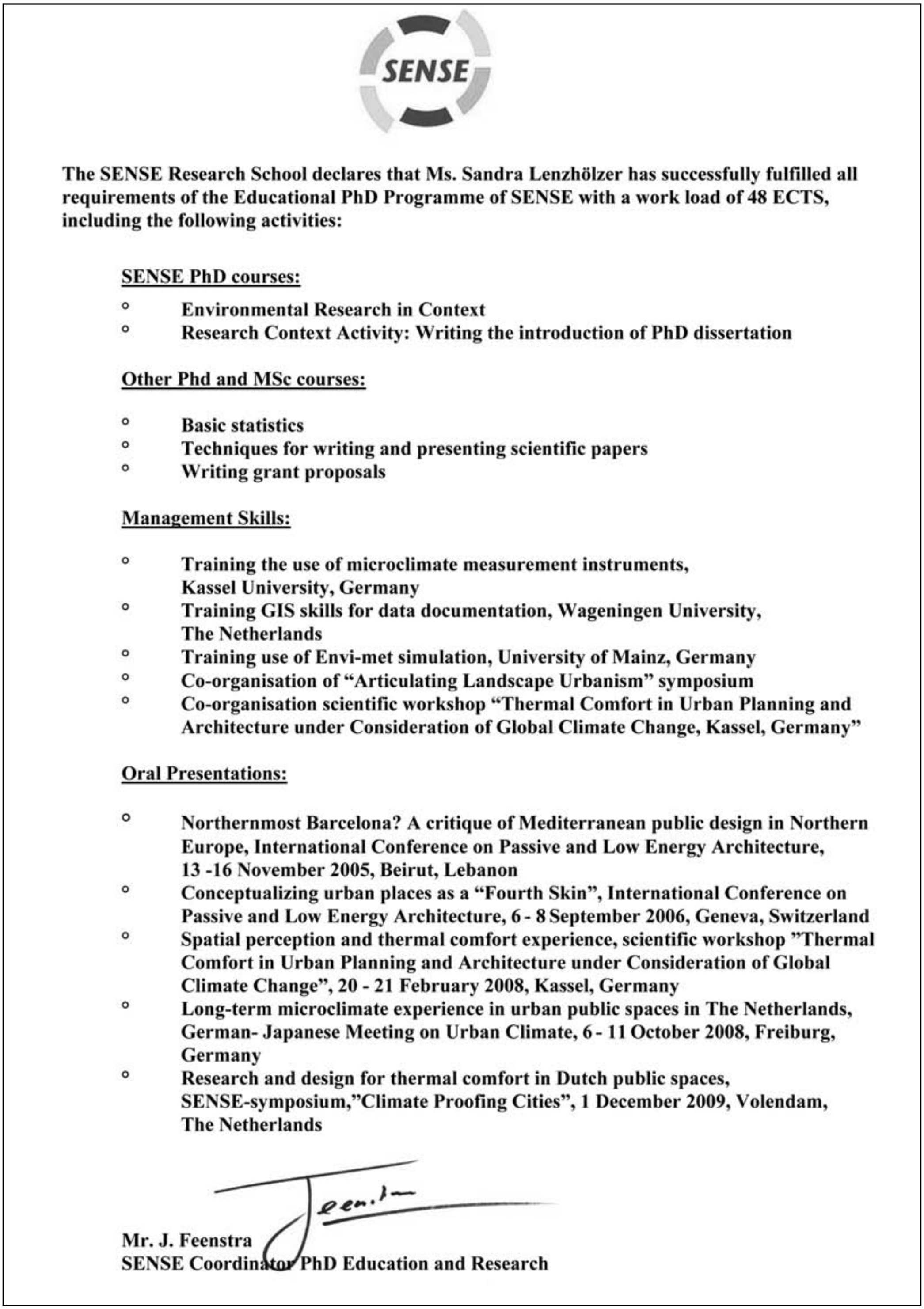
Place: Wageningen Date: June, 18th 2010

the Chairman of the
SENSE board

Prof. dr. R. Leemans

the SENSE Director
of Education

Dr. A. van Dommelen



The SENSE Research School declares that Ms. Sandra Lenzhölzer has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 48 ECTS, including the following activities:

**SENSE PhD courses:**

- Environmental Research in Context
- Research Context Activity: Writing the introduction of PhD dissertation

**Other Phd and MSc courses:**

- Basic statistics
- Techniques for writing and presenting scientific papers
- Writing grant proposals

**Management Skills:**

- Training the use of microclimate measurement instruments, Kassel University, Germany
- Training GIS skills for data documentation, Wageningen University, The Netherlands
- Training use of Envi-met simulation, University of Mainz, Germany
- Co-organisation of “Articulating Landscape Urbanism” symposium
- Co-organisation scientific workshop “Thermal Comfort in Urban Planning and Architecture under Consideration of Global Climate Change, Kassel, Germany”

**Oral Presentations:**

- Northernmost Barcelona? A critique of Mediterranean public design in Northern Europe, International Conference on Passive and Low Energy Architecture, 13 -16 November 2005, Beirut, Lebanon
- Conceptualizing urban places as a “Fourth Skin”, International Conference on Passive and Low Energy Architecture, 6 - 8 September 2006, Geneva, Switzerland
- Spatial perception and thermal comfort experience, scientific workshop ”Thermal Comfort in Urban Planning and Architecture under Consideration of Global Climate Change”, 20 - 21 February 2008, Kassel, Germany
- Long-term microclimate experience in urban public spaces in The Netherlands, German- Japanese Meeting on Urban Climate, 6 - 11 October 2008, Freiburg, Germany
- Research and design for thermal comfort in Dutch public spaces, SENSE-symposium,”Climate Proofing Cities”, 1 December 2009, Volendam, The Netherlands

Mr. J. Feenstra
SENSE Coordinator PhD Education and Research

# About the author

Having finished secondary school in 1987, she did an apprenticeship as a surveyor before starting her studies in Landscape Architecture and Planning in 1990 at Hannover University, Germany. In the final year of her studies, she spent a few months at Wageningen University as an exchange student. She graduated as a Diplom Ingenieur (Dipl. Ing.) in Landscape Architecture in 1996. After having worked in landscape architecture practice for a year, she attended the Architectural Association School in London with a scholarship of the Deutsche Akademische Austauschdienst. There she graduated as a Master of Arts (MA) in 'Housing and Urbanism' in 1998. Since her stay in Wageningen as an exchange student in 1996, she was attracted by the idea of living and working in the Netherlands. As a consequence, she came to the Netherlands in 1998 and worked at design offices (Sant en Co, Mecanoo) where she focused on the interface between landscape architecture and urbanism. In 2001, she began teaching in the Master's course for Landscape Architecture in a part time position at Anhalt University of Applied Science in Germany and in 2003 she started working at a landscape architecture office in Germany (ST Freiraum). Around that time she began contemplating conducting a PhD research, because she wanted to reflect upon developments in the field of landscape architecture and urban design. In 2004, she was offered a position as assistant professor at Wageningen University, which gave her the opportunity to conduct such a research next to her teaching activities. In her teaching, she focuses on the relation of landscape architecture and urbanism, with a focus on design studios and on climate responsive design. Recently, she got involved in various external projects as a consultant for climate responsive design.

# Propositions S. Lenzhölzer

1. Outdoor thermal comfort is based on physiological and psychological factors. In the latter, the perception of the environment and its “atmosphere” plays an important role (this dissertation).
2. Both- the physiological and the psychological factors of thermal comfort can be influenced by urban design and landscape architecture interventions (this dissertation).
3. If scientific climate knowledge is not communicated in a more understandable way to the planning and design professions, this knowledge will less likely be applied and our environment will not be designed in a more climate- responsive way.
4. Urban climate has to be understood as an interaction of climate processes of different scale levels (macro, meso and micro- level) that can be addressed with design interventions on different scales and planning levels.
5. Dutch urban environments need to be designed in a more resilient way with respect to climate. Such resilience can respond to the divergent climate scenarios of both global warming advocates and scepticists.
6. The cult of stardom in architecture, landscape architecture and urban design based on ingenious use of visual media alone has often worked detrimental on the quality of our built environment.
7. Designing intelligently is a greater challenge than talking about design intelligently.

Propositions belonging to the thesis, entitled
Sandra Lenzhölzer
Designing Atmospheres, research and design for thermal comfort
in Dutch urban squares

*Wageningen, June 18th 2010.*