Research Through Designing: Bridging the gap between urban climate science and design practice


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Introduction: what's the problem?

In order to improve the existing urban climate conditions and prepare cities to face the challenges of climate change, cities need to be adapted urgently. This is not a simple task because existing urban fabrics cannot be changed easily and applicable knowledge relevant for design is direly needed. A deductive, empirical science approach that would inform designers about how to make city climates more thermally comfortable would take too much time. First of all, it would involve (re)constructing cities. As a second step it would involve measuring the effect that (re)constructions had on climate to determine if the theory that was deduced held up in practice. When such (re)construction 'experiments' do not yield the expected results the costs of failure can be very high. As this is not feasible in terms of time frames and costs, quicker and simpler research approaches are needed. Apart from that of easily applicable design guidelines, prototypes or models are needed that respond to urban climate issues.

Such change-oriented research for adaptation in cities needs to include designing as a part of the research methods because adaptation designs are the object of research (Glanville & Jonas, 2007). A combination of research and designing offers the possibility to experiment with adaptation measures before they are realized.

A class of research methods that has been identified to connect research and design successfully is 'Research Through Designing' (RTD). RTD methods evolved throughout the last decades. In his seminal-work Herbert Simon proposed that "design science could ... 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. (1972) suggested to bring the scientific empirical method into design. De Jong and van der Voordt (2002, p. 455) described RTD "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 recognized in this: Test→ Operate→ Test→ Exit." However, the term "test" was not specified for the case of design, even though this is a very important question: how to test design? Breen (2002, p.137) came up with a more specific view: "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." Later on, such approaches were also extended to urban planning and landscape architecture (Klaasen, 2007; Lenzholzer et al., 2013). However, there is a need for more knowledge about suitable RTD methods that would lead to the identification of effective ways of designing urban environments so that urban climate is positively modified.

Amongst the broad range of RTD approaches (Lenzholzer et al., 2013), appropriate ones need to be identified for urban climate issues. The major research issues in urban climate adaptation concern physical and functional aspects. These issues call for research methods which mainly belong to the methods known from natural sciences and engineering. Such methods combining designing and empirical research have been described as (post)positivist RTD (Lenzholzer et al., 2013). Within this group of RTD projects we were interested in identifying the existing ones that address urban climate issues, and comparing and evaluating them in order to derive learnings to choose appropriate RTD methods for different research assignments. Accordingly, our research questions were the following:

1. What methods have been used in post-positivist microclimatic urban design research?

2. What are the relationships between levels of com-

plexity, spatial scale and testing methods?

3. How do RTD studies compare with other urban microclimate design-related research?

Method

The three research questions were answered through a three step process. First a comprehensive literature review identified microclimatic urban design studies that were conducted within the roughness sublayer of the city (Oke, 2004) and that used quantitative methods such as physical measurements and numerical simulations. Coarser scales of urban climate were excluded as they cannot be substantially affected by design interventions (Brown & Gillespie, 1995) and would be considered planning studies. Scopus was used to search broadly in peer- reviewed scientific journals employing terms that related urban and landscape design with urban microclimate. Searched terms related urban and landscape design with urban microclimate in 'Article, Titles, Abstracts and Keywords'. Only studies that dealt with research and design projects were selected. Many works kept reoccurring under the different search terms and at some stage the literature search was yielding no new studies. However, we were acquainted with more studies documented in peer-reviewed articles than were shown in the Scopus searches. Therefore these studies were added to the search results. Secondly, the resulting literature was divided into categories based on three criteria: the level of complexity; the scale of the project; and the method of testing and were arranged in a matrix for analysis (see Fig. 1). Finally, to compare the studies to other design-related research the methods were assessed to determine if they included design iterations and would qualify as RTD in the literal sense.

Results

Research question 1: What methods have been used in post-positivist microclimatic urban design research?

The literature search yielded 36 studies in which research and design are combined to generate new knowledge for urban microclimate responsive design. All these studies employ methods that fit the post-positivist approach as described by Creswell (Creswell, 2009). The studies represented different scale levels from small (e.g. trees in parks) up to larger scales in the urban microclimate realm such as neighbourhoods. The studies also displayed various levels of complexity. Many differences in the use of methods were found. Some studies used physical models, either 1:1 mock- ups or scale models. These physical models were then tested on their performance through measurements, either in real weather situations or in wind tunnels. Other studies – about two third of the total – used numerical simulations, mostly computer simulations.

Research question 2: What are the relationships between levels of complexity, spatial scale and testing methods?

The results of the literature research were arranged in a matrix (Fig. 1) that shows the degree of complexity on the X- axis and the testing methods used on the Y-axis, separated according to the different types of simulations to show future states (physical and computer simulations). The colour coding indicates the scale of the studies.

When scale was related to complexity levels, it appeared that on the very fine scale, two studies dealt with low complexity and four with medium complexity. On the fine scale, six studies dealt with low complexity and six with medium complexity. On the medium scale four studies dealt with low and one with medium complexity. On the coarse scale level, two studies dealt with low complexity, five with medium complexity and two with higher complexity. Four studies that dealt with wind only (and thus low complexity) could not be assigned to a scale because these wind studies were scale-less.

When plotting the degree of complexity against the type of testing method, it appeared that approximately half of the studies with low complexity were done with physical models (full scale mock-ups or scale models) and measurements and the other half with numerical simulations (see the separation of Figure 1 in two parts). The group of studies with medium complexity contained some cases where scale models and measurements were used and many more cases where numerical simulations were used. The two studies that took into account a higher complexity were both tested with computer simulations. A frequently used computer simulation tool was ENVI-met.

Research question 3: How do RTD studies compare to other microclimatic urban design-related research?

Several studies dealt simultaneously with various design options, but only a few studies included iterations and testing loops as part of the research process to improve the performance of the design products according to the TOTE model. The studies that included iterations were a study on thermally comfortable squares in temperate climate zones (Lenzholzer, 2012), a study on heat in courtyards in the Nether-

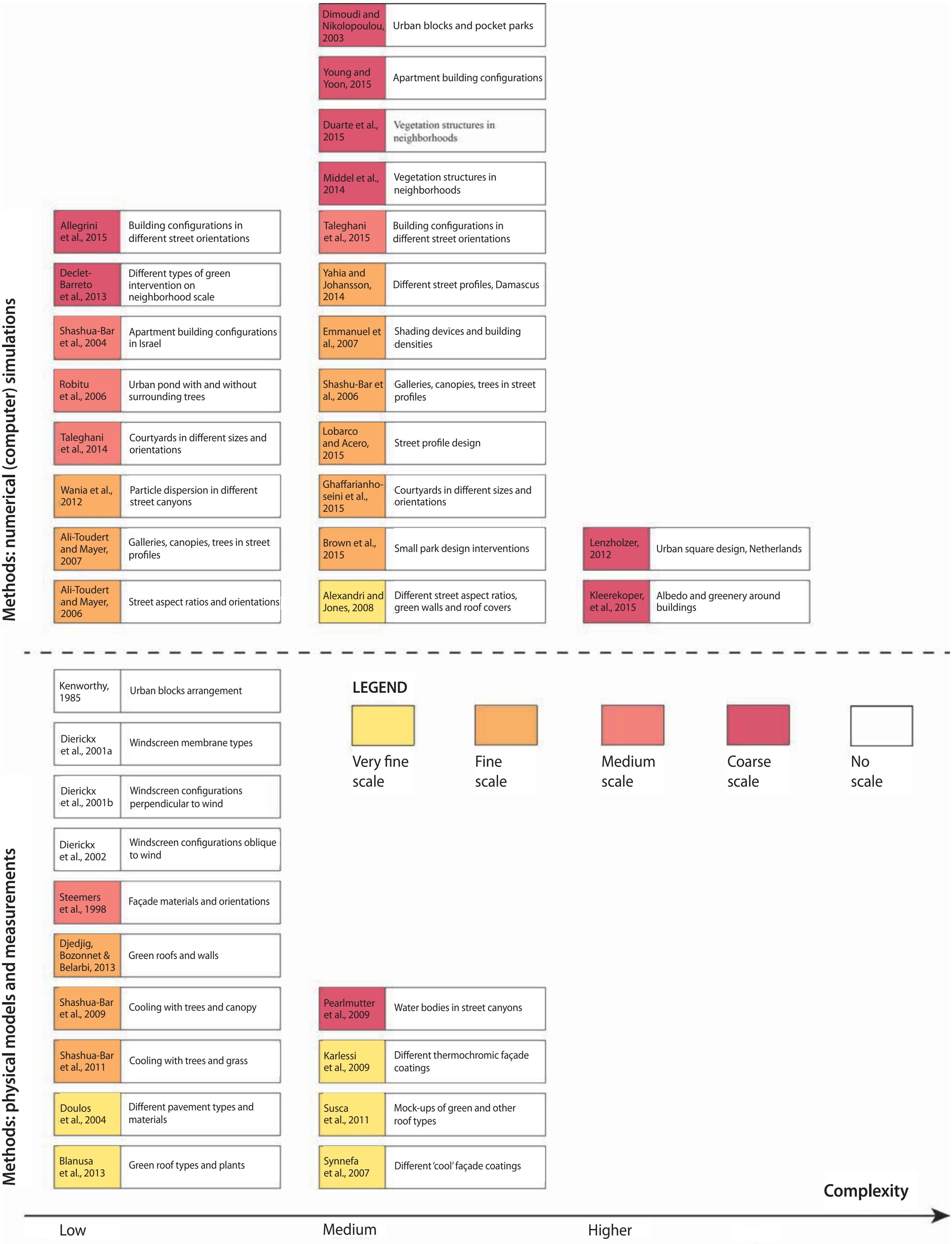

Figure 1. Overview of various (post)positivist RTD projects in landscape architecture and related disciplines for better urban microclimates.

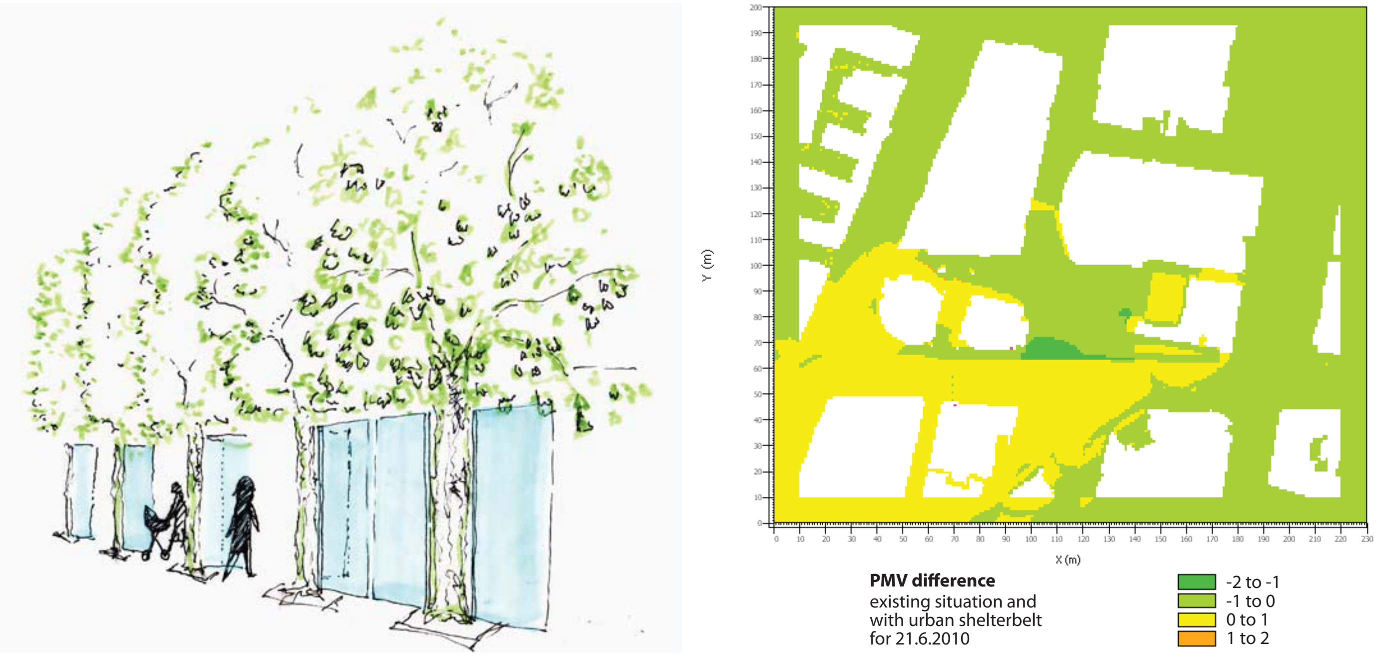

Figure 2. Left: Example of RTD process components for the study of Dutch squares (Lenzholzer, 2012). Right: an impression of the 'urban shelterbelt' and its effect on PMV in Envi-met.

lands (Taleghani et al., 2014) and a study on thermal performance of courtyards in hot and humid climates (Ghaffarianhoseini et al., 2015). Due to the iterations of designing and testing, these three studies qualify as RTD in the literal sense.

Discussion

Research question 1: What methods have been used in post-positivist microclimatic urban design research?

Urban microclimate modification is of growing importance in the context of global climate change and urban heat island intensification and clear design directives to adapt cities are required. Yet the number of studies in microclimatic urban design research to provide such design relevant knowledge was rather small (n=36).

The post-positivist methods such as measurements or numerical simulations were used to test the outcomes of design activities in the research process. Within the different simulation methods used to test the designs, numerical and computer simulations played a major role. A range of models that can simulate single parameters of design interventions was used, but in order to integrally simulate all the parameters that define thermal sensation of humans, only a few numerical models were deemed suitable. About two thirds of the numerical simulations were done with the ENVI-met software. The choice of this software seems to be motivated by the fact that ENVI-met is the only model that allows representation of three-dimensional spatial environments in high resolution, meeting the needs of architects, landscape and urban designers to test their designs. Moreover, it integrally represents all the parameters determining thermal sensation (Bruse, 2004). However, various studies also discussed the shortcomings of this software in terms of validity of the simulation results and that the simulation software is not sufficiently calibrated for all microclimate parameters (e.g. wind, turbulence, night-time situations). Many researchers are aware of these shortcomings, but the fact that this model displays the knowledge in a three dimensional way makes it the most commonly used model for spatial design.

Typical outcomes of the studies were design recommendations or 'rules of thumb'. Some recommendations were clear and directly applicable to design, but many were not explicit about how the information could be applied to design. Other studies developed 'prototypes' or spatial patterns that are generalizable design solutions for a specific type of spatial context and that were usually more fit for application. Some post-positivist methods can contribute to the generation of generalizable knowledge, but that depends on their relation to complexity and scale.

Research question 2: What are the relationships between levels of complexity, spatial scale and testing methods?

No clear relation was found between the scale of the studies and the degree of reducing complexity. On the very fine scale and the coarse scale, studies took into account higher complexity levels. But on the scales in between many more studies than expected displayed a low level of complexity.

Designing for urban microclimate involves dealing with a relatively high degree of complexity. Even in the small scale projects dynamics of microclimate required that many issues be taken into consideration (e.g. time of day or season of the year that the place will be used). Designing for different climate situations can confront the designer with wicked problems (Rittel & Webber, 1973). According to Coyne (2005), wicked problems occur through complexity of matters, not only in social contexts, but even in mathematics and natural sciences. This complexity based on the dynamic characteristic of climate was often not taken into account in the design research in this study. The studies regularly focused on one weather type (mostly hot days) or very few parameters of microclimate (e.g. wind only, air temperature only). Sometimes such reductionism is in order, for instance when climate situations in tropical regions do not change much and the designs have to be tested for these typical situations only. In most other climates it is usually necessary to test the designs on their functionality in various seasons and many studies had shortcomings in this respect. These reductionist approaches form a problem for designers because a design has to perform well in different weather and climate conditions. There were a few studies that did actually address different weather situations and seasons and took into account all parameters that matter for human thermal sensation.

Studies with a higher complexity level were not often tested with physical models although such models, when located in real-world settings, would offer more possibilities for testing on very different factors (e.g. aesthetics or compatibility with other functions).

There was a clear relation between the scale of the studies and the difference between physical and numerical testing methods. For smaller scales and low complexities it was quite simple to test design proposals and make valid and generalizable predictions about their effects. Such predictions were valid, especially when only one parameter of microclimate had to be designed for (e.g. wind). When the scale of the design proposals to be tested became somewhat broader, it was impossible to test designs physically with 1:1 models. In that case, three dimensional computer simulations were used.

Research question 3: How do RTD studies compare to other microclimatic urban design-related research?

Only three studies included design iterations as part of the research process and are thus typical examples of post-positivist RTD. These iterations involved 'preliminary tests' (e.g. Lenzholzer, 2012) and 'exclusion strategies' (e.g. Ghaffarianhoseini et al., 2015; Taleghani et al., 2014) to help set priorities, (e.g. which times of the day are most important for outdoor use, choosing spatial configurations that would be feasible) to reduce the large number of possible solutions. All three studies employed the same testing method: simulations through ENVI-met. This seems to be due to the fact that these simulations fit the iterative nature of RTD better than working with physical models and longitudinal measurements. Computer simulations were easier to change and they provide spatially explicit results quickly.

Conclusions

The main methods used in quantitative microclimatic urban design research were physical models and numerical simulations. Physical models were often tested in wind tunnels and the results were both accurate and precise but tend to be highly technical, time consuming, and expensive. The results from numerical simulations were much easier and less expensive to achieve, but they were also considered to be less accurate with several authors suggesting the need for further development and validation of the modelling software. Current improvements of modelling software open new avenues for more substantial application of the software in RTD processes.

Small scale and low complexity studies yielded outcomes that can be generalizable design guidelines or prototypes. When the scale and complexity of the design problems are coarser, though, the outcomes of the RTD represent partial knowledge that cannot be simply transferred to other sites because the boundary conditions would be very different. While they yield valid location-specific results, the generalizability of the outcomes is limited. For higher levels of complexity it might be necessary to conduct more iterations in the research and design process. When other issues need to be considered in a design that go beyond functional or physical matters, a combination with other types of RTD (e.g. constructivist or participatory) might be in order (Lenzholzer et al., 2016).

Most quantitative microclimatic urban design studies are not RTD in the literal sense, and only the three studies that included design iterations were RTD. These three studies provide a methodological model for future studies in microclimatic urban design that will investigate ways to ameliorate the negative effects of global climate change and urban climate improvement.

This contribution is an abbreviated version of the paper: Lenzholzer, S., & Brown, R. D. (2016). Post-positivist microclimatic urban design research: A review. *Landscape and Urban Planning*, 153, 111-121. (http://dx.doi.org/10.1016/j.landurbplan.2016.05.008)

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