DESIGN GUIDELINES FOR THERMALLY COMFORTABLE AND ATTRACTIVE STREETSCAPES IN HARBOUR AREAS

CHRISTY TANG/ WIEBKE KLEMM/ SANDA LENZHOLZER
Department of Landscape Architecture, Wageningen University & Research Centre, The Netherlands

1. INTRODUCTION: URBAN HEAT AND HARBOUR AREA

Cities are facing environmental challenges due to deindustrialization, urbanization, and ongoing global warming. These problems also occur in many contemporary world port cities. Cities suffer from higher temperature in densely developed urban areas due to intensive human activities and large impervious surface covers in the form of roofing and paving. In consequence, the city centre is usually reported has the highest surface temperature as well as the industrial harbour locations (Fig. 1). This research aims to develop evidence-based based design guidelines for thermally comfortable and attractive streetscapes in harbour contexts based on people's perception of different greenery types.

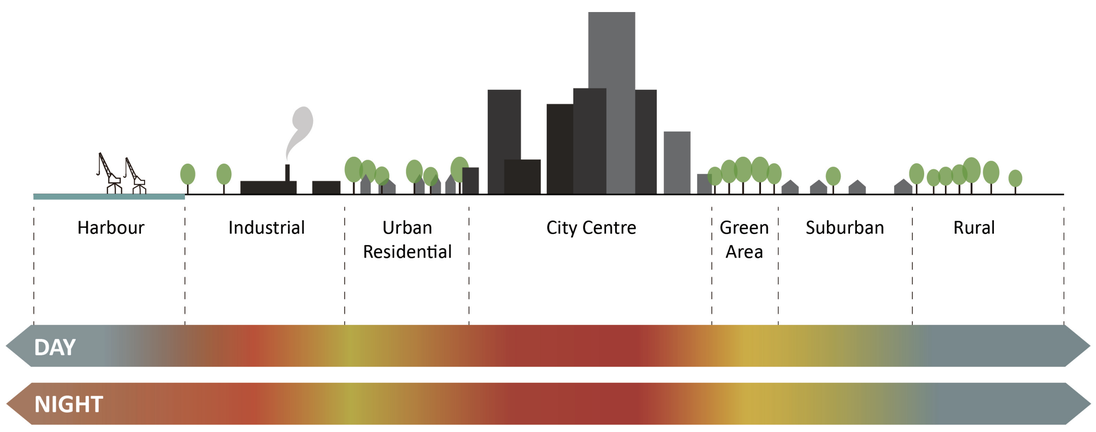

Figure 1. Urban heat island during the day and night (Adapted from EPA, 2008).

2. METHODS

We conducted a visual approach to investigate the impacts of different types of street greenery on people's long-term perceived thermal comfort and aesthetic appreciation. The four investigated types of urban vegetation at street level were: (0) no vegetation (1) low vegetation, (2) wall vegetation and (3) trees based on a categorization by Bowler (2010). Four functional zones in harbour contexts were categorised to represent the most common functions adapted to a former harbour area: (1) port-industrial, (2) new business, (3) residential and (4) residential waterfront.
Within the four harbour functional zones, all four greenery types were used to develop site-specific design alternatives. The design alternatives the were major part of our questionnaires, thus consisting of four series of 16 full-coloured images as visual stimuli which were created using Adobe Photoshop (Fig. 2).

We used the questionnaires in online and face-to-face surveys in the city of Rotterdam, the Netherlands, in 2014. We asked respondents to rank the images according to how thermally comfortable and attractive they would perceive the different streets under hot summer weather circumstances: "Imagine the air temperature is above 25°C and you are walking in this street…" Furthermore, they were asked to briefly describe the reasons for their preferences.

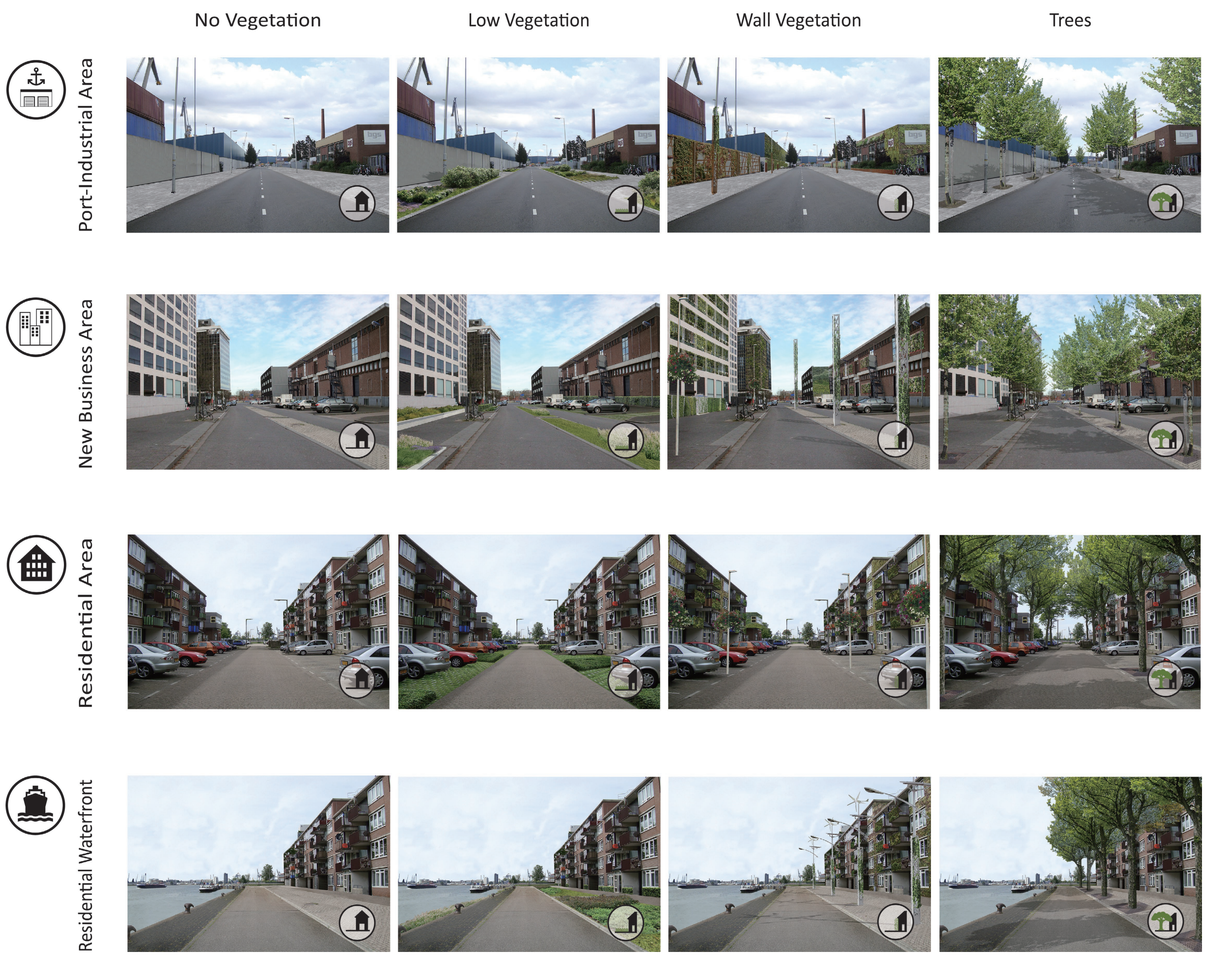

Figure 2. Series of visualisation images featured with different greenery types within four harbour functional zones.

[References]
1. EPA. (2008). Reducing urban heat islands: compendium of strategies: urban heat island basics.
2. Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: a systematic review of the empirical evidence.
3. Lenzholzer, S., & Koh, J. (2010). Immersed in microclimatic space: Microclimate experience and perception of spatial configurations in Dutch squares.
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3. RESULTS

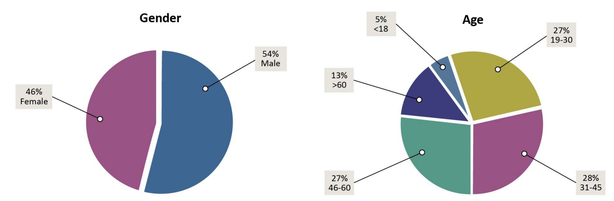

Figure 3-1.
Age and gender composition of the survey respondents (N=106).

We collected a total of 106 valid responses (N=106).
The survey respondents were between 13 and 83 years old (mean age was 41 years). The gender composition of survey respondents were almost equal (Fig. 3-1).

Among the four green types, 'trees' was top-ranked for improving perceived thermal comfort (mean 3.84) and attractiveness (mean 3.68) on a scale range from 1 to 4; whereas the streets without vegetation were ranked lowest. Low and wall vegetation was evaluated similarly in terms of thermal comfort and attractiveness depend on the spatial contexts (Fig. 3-2).

Functional Zone	Thermal Comfort				Attractiveness			
	No Vegetation	Low-Height Vegetation	Wall Vegetation	Trees	No Vegetation	Low-Height Vegetation	Wall Vegetation	Trees
Port-Industrial	1.13 (.46)	2.52 (.56)	2.42 (.63)	3.92 (.43)	1.38 (.71)	2.41 (.80)	2.50 (.81)	3.72 (.69)
New Business	1.09 (.38)	2.35 (.55)	2.74 (.67)	3.82 (.57)	1.36 (.73)	2.30 (.66)	2.76 (.93)	3.58 (.78)
Residential	1.08 (.39)	2.35 (.54)	2.70 (.62)	3.87 (.50)	1.27(.63)	2.37 (.71)	2.58 (.74)	3.77 (.65)
Residential Waterfront	1.22 (.62)	2.53 (.68)	2.52 (.69)	3.74 (.72)	1.44 (.81)	2.47 (.85)	2.42 (.76)	3.66 (.78)
Total	1.13 (.11)	2.44 (.07)	2.60 (.03)	3.84 (.12)	1.36 (.07)	2.39 (.09)	2.42 (.09)	3.68 (.07)

Figure 3-2. Mean points of the different greenery types in each of the four harbour functional zones; by using a scale range from 1 (least thermally comfortable to; least attractive) to 4 (most thermally comfortable; most attractive) (N=106, standard deviation in brackets).

Based on the survey results, it is recommend to use different types of street greenery, especially trees combined with other green elements, to design the streetscapes according to to the specific spatial harbour zone.

In the port-industrial area and on residential waterfront respondents valued 'open views' and 'harbour characters' with limited paved surfaces through ground and low-height vegetation. Apart from that, trees should be positioned concerning the view and the need for shaded areas that supports various outdoor activities on the waterfront. In the new business area and residential neighbourhoods trees and wall vegetation should be implemented to create inviting atmospheres that attracts people.

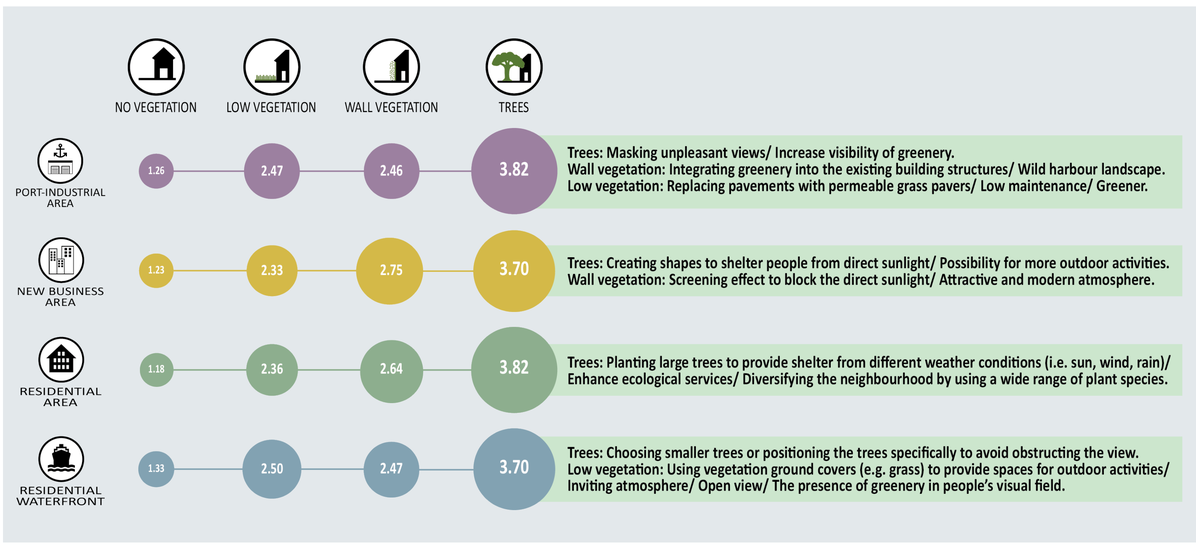

Figure 3-3. Design guidelines

The research findings indicate a positive impact of street greenery on long-term thermal comfort and attractiveness in a harbour area, which is in line with earlier studies. Based on earlier studies and the findings presented in this research, it is assumed that people's perceived thermal comfort and aesthetic appreciation are influenced by individual positive experience both spatially and visually related to street greenery. According to the results, enhancing the visibility of street greenery is expected to have positive effects on improving people's perceived thermal comfort and aesthetic appreciation.

Our results support landscape architects and urban planners to plan suitable types of street greenery within various harbour functional zones. This research contributes to the process of harbour redevelopments and post-industrial urban plans to develop climate-adaptive and more liveable urban environments in growing cities.

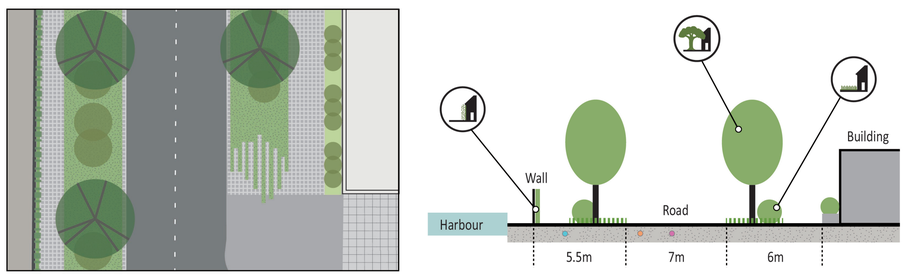

Figure 3-4. An example of implementation of design guidelines in port-industrial area.

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