THE CLIMATIC SKIN OF URBAN SPACES

J.G. Cortesão, F.B. Alves, H. Corvacho
Department of Civil Engineering
Faculty of Engineering of Porto University
Porto, Portugal

M. Rhodes
Welsh School of Architecture
Cardiff University
Wales, UK

ABSTRACT

In contemporary urban development, to improve the quality of public urban spaces has become one of the most outstanding goals of local urban policies, in order to increase pedestrian activities and people’s social interaction. In this context, to promote outdoor thermal comfort has an utmost importance, especially considering the heat island phenomenon.

This paper recalls the use of urban design as an instrument to the mitigation of the negative effects of heat islands, through the inclusion of microclimatic principles - namely based on the relationship established between the buildings and the public pavements facing materials and the vegetation with outdoor air temperature - in its projected process.

Key words: Thermal comfort, Microclimate improvement, Urban environment.
Introduction

One of the main objectives of the urban contemporary policies is urban revitalisation, regarding the increase of pedestrian outdoor activities as a consequence of a stronger «...public interest in the quality of open urban spaces...» [1].

The notion of urban revitalisation herewith presented is related to the European ideal of cities, which orientates urban policies towards the promotion of «...places that are confident rather than places with which people are dissatisfied and which people cannot wait to leave; (...) places that are compact rather than sprawling and with polarised car-based suburbs; (...) places that are convivial rather than boring with intimidating centres» [2]. Still, these are urban values that have been lost during the city’s modernisation and urbanisation process, especially regarding the increase of the motorized traffic and the consequent public spaces’ loss of importance to pedestrians [3].

This is the reason why cities must not be seen as places that only produce environmental and human stress. On the contrary, they present important advantages for inhabitants, namely high quality of life standards which, however, need to be improved in terms of public spaces liveability. Moreover, the hypothesis that the conditions (in this case environmental conditions) of a public space «...affect people's behaviour and usage of outdoor spaces» [1] underlie this notion.

The heat island phenomenon (phenomenon according to which air temperatures in urban environments are higher than those from the involving rural one [4]) plays in this context a very important role. Although it presents both positive and negative aspects according to each climate (higher air temperatures can be desirable in cold climates, inclusively enhancing outdoor pedestrian activities, whereas the opposite happens in hot climates), this paper will be focussed on the negative effects of heat islands in hot climates especially during summer, as the main consequences of global warming and thus of heat islands will be mainly felt in high air temperatures during summer (although other consequences are forecasted, e.g., more extreme and longer periods of rain in winter).

Effectively, the mitigation of the heat islands effects (moderating the excessive aspects of air temperature in summer) should be one of the most important vectors of present and future urban development, for it will interfere in human thermal comfort, therefore, in the definition of the individual behaviour over the public space. Furthermore, it will interfere as well in the major or minor necessity of mechanical devices to control indoor and outdoor air temperature, consequently potentially increasing CO2 emissions.

Considering that climate change «...will be most significant where people are concentrated - in our towns and cities» [5], outdoor thermal comfort is not indeed less important than, for instance, the promotion of equipment, trade, services, housing, etc.
Obviously, to achieve a completely qualified microclimate towards a more liveable city, it is important to incorporate in urban planning and design not only the herewith focused environmental aspect of sustainable development but also both economical and social aspects too.

Microclimate Improvement and Air Temperature

Thermal Comfort

The microclimate, as «the climate of a specific site or of a small area...» [6], stands out as a fundamental principle to integrate in urban design, specially when one considers that «in the past, climate has been a strong influence on urban planning» [6].

Considering the aforementioned about the heat island phenomenon, air temperature control should be a question of primary importance in new public spaces and housing programmes at design conception in order to create more comfortable places (indoor and outdoor) to inhabit.

Thermal comfort underlies this question as herewith understood. Being generally defined as the individual’s optimal thermal «...feeling (...) when the production of internal heat is equal to the thermal losses from the body» [6], thermal comfort has however a wide range of defining factors and has been ascribed as both physical demand and psychological process. The adaptation processes have here an utmost importance as «...processes which people go through to improve the fit between the environment and their requirements» [7]. Therefore, thermal comfort is «...a subjective sensation» [8].

Primarily it is, therefore, crucial that the urban designer knows the microclimatic characteristics of a place through, e.g., a «...temperature, sun and wind analysis...» or resorting to urban plans that might already have done it, so that afterwards he can choose between different design solutions, e.g., «building morphology, materials, vegetation, water elements, even urban equipment...» [1].

Basically, to think about a way of ensuring outdoor thermal comfort (as already happens with the indoor environment with several directives and norms such as, e.g., the international norm ISO 7730), is conceiving urban design as an efficient work tool, and the microclimate improvement as the basis for new urban development scenarios. It is although important to point out that «urban microclimates vary considerably from city to city and within cities as well» [9]. For this reason, a fix model for microclimatic improvement cannot be established worldwide nor within a same city, because a good urban design solution for microclimatic improvement may or may not be desirable in two places with a different climate.
Facing Materials and Vegetation

There are several factors that have influence over the microclimate, leading to a more or less thermally comfortable space. Effectively, the microclimates within a city «...can have significantly different temperature distributions, depending on their surface temperatures, which are affected by materials, geometries and vegetation» [10].

Bearing this in mind and considering the aforementioned importance of air temperature this paper will be focussed on the relation between air temperature and thermal properties of the facing materials (buildings facades and public pavements) and vegetation of a public space. These two factors (as well as shading devices – herewith not considered due to the more effective contribute of vegetation in controlling air temperature – see Fig. 2) are considered to have a more active and straight role on the microclimate modification and on the thermal comfort conditions [1], specifically through the definition of the local heat balance. This balance is induced mainly by their surface temperatures which, in its turn result from the interaction between its «...optical and thermal properties...», namely the «...albedo, emissivity and heat capacity» [10], with the solar radiation and the wind. Furthermore, facing materials and vegetation are clearly related to the environment surfaces modification, which is pointed out as one of the possible causes of the heat islands [4].

Thus, besides considering the space and use type and time as well, it is crucial to highlight the role of the facing materials (considering the energetic exchanges balance face to the solar radiation), jointly with the vegetation (namely its ability to shade surfaces as well as to slow down and diffuse the wind speed), for the outdoor thermal comfort improvement. More precisely, «...radiation can be influenced mainly by city structures, vegetation, materials and colours, whereas wind, as second dominating factor for thermal conditions, can be channelled or reduced with the use of vegetation» [1].

Reference Case – Greyfriars Road, Cardiff, UK

This reference case is to illustrate an area where problems have been identified and action has been taken to try to solve these, in this case by the local authority, resulting in an increased use of public spaces by people. Greyfriars Road is an important road for both vehicular traffic and pedestrians in central Cardiff as it is one of the main bus and taxi stops in the city (other than the main station) and is also a crossing point for pedestrians from the main parking area to the main shopping area of the city. It is a mixed use area with hotels, offices, bars, clubs and a theatre. The building height varies from between 4 storeys and 30 storeys. Moreover, its pedestrian character is also enhanced by the presence of a park and
restaurants/bars with outdoor seating. Consequently, Greyfriars Road is an area with an intense pedestrian activity where thermal comfort should be ensured in order to guarantee people’s satisfaction and encourage use of the space.

In this area the most evident climatic problems are related mainly to the wind conditions, although shading from the sun and shelter from rain are also necessary to maintain comfortable public use of the space. Although the local wind speed measured at 10m above street level is typically in the range <4.5m/s, the council identified a problem with near ground level wind causing pedestrian discomfort based on observation and complaints from pedestrians and businesses. This manifested itself in at times severe wind gusts that negatively affected the experience of the space for pedestrians and prevented the use of umbrellas for shading at the outdoor bar and café seating. Prior to the improvements implemented by the local authority, Greyfriars Road had little vegetation or variation in pavement height and building facades lacked any features designed to improve pedestrian comfort.

Measures to control and reduce the impact of this problem were introduced, namely through changes in vegetation, landscaping and changes to building facades. More precisely, trees (that work as efficient windbreakers, while providing shade in the summer as well as localised cooling) and other vegetation were planted. The trees selected were species such as hornbeam, plane trees and birch that are a suitable scale for the urban environment, require little maintenance and provide shade from the wind and sun. Low level shrubs / bushes were also planted to give ground cover and to disperse wind at ground level.

In addition to increased vegetation, changes were made to some of the building facades in an effort to prevent downdrafts from creating pedestrian discomfort. On several buildings canopy structures were added at first floor level to create a less windy environment at pavement level. Other features such as landscaping improvements (small walls and stepped down areas for seating) were also introduced to improve the outdoor environment and to encourage increased pedestrian use. Glazed shelters were also introduced at points to provide shelter from the wind and rain while maintaining a good level of visibility.

Other changes were introduced to improve pedestrian safety and to reduce the impact of vehicular traffic. These included altering the road surface to encourage slower driving and introducing bollards to prevent vehicles entering the pedestrian only areas.

The result of these changes was that pedestrian level wind speeds were reduced and provision of summer shading and shelter from rain was improved. Consequently this public space has become much more attractive for pedestrians, through adequate urban design options, as many more people now use it and in a much more comfortable way for longer periods of the year.
The Microclimate as an Urban Design Parameter

The Climatic Skin

Assuming that «the extreme diversity of microclimate can be attributed to the varied nature of the surfaces underlying the layer of air near the ground» [7], a more “tri-dimensional” understanding of the intervention on a public space would be useful, capable to ally public pavements, buildings facades and vegetation. In other words, it is crucial to separate the “climatic skin” of the urban spaces within the urban canopy layer understood from the public space’s «…ground surface up to the height of the buildings…» [4], with regard to a complete improvement of the microclimate and, thus, the thermal comfort of its users.

The climatic skin of the urban spaces should be herewith understood as the collection of all the exterior surfaces of a public space constituted by the buildings’ facades, the public spaces’ pavements and the vegetation that works as the external continuous covering of all the space, where public life happens. Conceiving this surface continuum in urban design will allow designers to better understand the consequences of changing surfaces in the urban environment on the microclimate conditions, for it integrates the three main factors that define it: horizontal and vertical surfaces and vegetation.

It is interesting to remark that the «…use of more appropriate materials, increased use of green areas, use of cool sinks for heat dissipation, appropriate layout of urban canopies, etc…» are seen as some of the most efficient measures to control the global warming/heat islands effects [11] and all of them are related to surface interventions. This might point out that to consider the climatic skin as a factor of the utmost importance to the outdoor thermal comfort is to look at the intervention in cities’ public spaces as a far extended process beyond a mere bi-dimensional approach towards a more tri-dimensional one (Fig. 1).

The usefulness of this would be to pass urban design from an intervention on the public space which considers, traditionally, public pavements, buildings facades and vegetation separately, to a more integrated intervention, from the thermal conditions point of view, where the three elements would be interrelated. This would define a unique intervention body capable to ensure that at least the benefits of a good solution in one of the surfaces is not obstructed by a bad solution of another surface.

The climatic skin will also influence indoor thermal comfort. Indeed, «the environmental quality of indoor spaces is a compromise between building physics (...), energy consumption and outdoor conditions» [4]. Therefore one can say that if outdoor thermal comfort is improved then the indoor one will be improved as well. For instance, «…when vegetation exists next to a building, apart from lowering the outside air temperature, it reduces convective and infiltration gains and acts as an
insulation, thus reducing inside air temperatures» [9]. Urban planning and new housing programs should therefore bear in mind that the environmental improvement of a city should consider public space and architectural form in an intimately connected way, namely through their skins/envelopes.

![Figure 1](image.jpg)

**Figure 1** The climatic skin of urban spaces as the set of facing materials and vegetation.

Basically, when an urban designer chooses a facing material and more or less vegetation (as well as types, species, etc.) he must consider that that has an impact over the microclimate definition and that, therefore, his apparently simple and harmless choice, merely technical/artistic, might affect the success or failure of a public space, from the comfortable pedestrian activities point of view.

No formulas to guarantee the success of a public space from the microclimatic point of view have been found. However, it is fundamental that urban designers, in the heat island context, understand at least the questions illustrated in the following figure.

Therefore when one talks about the microclimate as an urban design parameter, and considering the aforementioned in this paper, one is basically pointing out that if outdoor thermal comfort in the context of the enhancement of pedestrian activities is intended, urban designers and decision makers as well, must be aware that «the materials used in a city affect temperature», bearing in mind that «the more radiation a surface absorbs, the hotter gets the air, which surrounds it» [9]. Materials such as lawns, earth or low bushes, for instance, as they have high reflectivity to solar radiation, absorb less energy and consequently emit less heat, whereas materials such as asphalt or concrete absorb a much high amount of solar radiation and in consequence emit much heat [9].
The "public space’s envelope" influences indoor thermal comfort. Besides using light facing materials «...when vegetation exists next to a building, apart from lowering the outside air temperature, it reduces convective and infiltration gains and acts as an insulation, thus reducing inside air temperatures» [7].

Vegetation can be an effective «...windbreaker as branches and leaf will slow down the wind without creating a lot of turbulence» as more solid windbreaks do, e.g., walls and other solid structures [1].

Use of high-albedo materials reduce the amount of solar radiation absorbed through building envelopes and urban structures and keeps their surfaces cooler [4].

The "public space’s envelope" influences indoor thermal comfort. Besides using light facing materials «...when vegetation exists next to a building, apart from lowering the outside air temperature, it reduces convective and infiltration gains and acts as an insulation, thus reducing inside air temperatures» [7].

Once direct solar radiation is blocked, cooling effects are much increased [7].

Current Research

All the questions presented in this paper underlie an ongoing PhD research undertaken by João Granadeiro Cortesão, which aims to demonstrate how urban design can be an instrument able to contribute to the mitigation of the heat islands negative effects by proposing a set of project principles able to inform the urban designers as well as decision makers on how to guarantee effectively outdoor thermal comfort through the control of air temperature during summer.

These principles of simple character will be orientated towards the management and handling of the facing materials of buildings facades and public spaces pavements...
(considering the balance in the energetic exchanges face to solar radiation), as well as of the shading and control of the main air flows (wind’s slowing and diffusion) provided by vegetation.

In the end, this research will allow to position the knowledge of previous researches on the scientific domain where it fits in nearer from the urban design practice, by defining effective project principles. It will, therefore, contribute to the knowledge on how to improve the urban environmental quality, on how to completely revitalize public spaces regarding the enhancement of pedestrian activities.

Conclusion

The microclimatic improvement should consider public space and architectural form in a straight connected way. The “climatic skin” of the urban spaces comes in this context forward as an integrated way of seeing the public space’s horizontal and vertical surfaces and vegetation which will allow, on one hand to improve the microclimate thermal comfort conditions and, on the other hand to reduce the CO₂ emissions related to the mechanical devices used for controlling indoor air temperatures.

Regarding the utmost optimal interaction between this continuous surface of the public space with the atmosphere namely with the solar radiation and the wind, one is promoting well thermally balanced places for people.

The development of an urban design process that incorporates microclimatic parameters, in this case specifically regarding the improvement of the air temperature, is a step that should not be disregarded by decision makers and urban designers in the context of the contemporary cities’ urban revitalization.

There are several parameters to take into account and these should not be classified restrictively nor be transposed to rigid urban design principles. They are rather much better applied to urban design if they are assumed to be general orientations about the main question that an urban designer must be aware of in order to improve the microclimate. By doing so, one is guaranteeing that the parameters adopted are the best suited to each specific climate and microclimate and on the other hand, the creative freedom of each designer to choose which materials to use, which formal options to adopt relating both not only with technical requirements but also with environmental ones as well as other requirements such as social or cultural ones.

The parameters inclusion into the urban design process should be promoted by local authorities/decision makers with the support of qualified technicians, using urban planning as the way of communicating them to the urban designers that, according to
their individual design expressions, aesthetics for instance, will be responsible for “drawing” them.

Finally, decision makers and urban designers should bear in mind that the control of the materials and the vegetation that compose the climatic skin of urban spaces will also have an influence in indoor thermal comfort. This control might mean important savings in energy consumption namely through a major or minor demand for mechanical devices to control air temperature. So, in order to promote new housing programmes where comfort and energetic efficiency are the keywords (and economical savings to the house owner should be here considered too), one should start by thinking on how outdoor microclimate conditions can be improved. If these present natural amenities so will the indoor spaces present too, whereas if they don’t so the opposite will happen.

This paper aimed mainly to propose a set of reflections that could lead to new research paths towards outdoor thermal comfort. It was aimed to stand out the importance of controlling the urban surfaces modification as a way of guaranteeing that urban revitalization is orientated towards the mitigation of the heat islands negative effects, thus, to a real enhancement of pedestrian activities.

References

5. ASCCUE. ASCCUE Brochure. Centre for Urban and Regional Ecology, School of Planning & Landscape, University of Manchester, Manchester, 2003.


10. Alexandri, E. Investigations into Mitigating the Heat Island Effect through Green Roofs and Green Walls. Welsh School of Architecture, Cardiff University, Cardiff, 2005.