A Method for the Bioclimatic Intervention in Porto

Introduction

A particular aim of contemporary urban renewal is to develop the cities' public space to be more pedestrian. Bearing in mind the additional effects of the urban heat island on the impacts of climate change, the improvement of urban environments is crucial to ensure the success of this urban renewal, as it will interfere with human thermal comfort and, as such, in the use of public spaces especially in summer. A global strategy to improve outdoors thermal comfort and to promote a reduction of CO_2 emissions in consolidated urban structures can be achieved by correlating morphologic and climatic parameters. This article explores a potential methodology for bioclimatic urban interventions, presenting how this correlation takes place in two spaces in Porto.

Subject's framework

Cities are the space where man has most evidently altered his environment (Gomez et al., 2004, p.94). Therefore the importance that the environmental subjects have on a city is more evident than in any other area. Climate change comes to accentuate this issue as there is the evidence that people's use of outdoor spaces is already changing due to climatic change (Handley and Carter, 2006b, p.58). Indeed, with the increase in air temperature people living in urban areas will need more open spaces during summer, as an increased demand for outdoor living is expected (Handley and Carter, 2006a, p.12). Therefore, urban environments must be improved. Public spaces come forward in this issue as the main stage for this action to take place, having urban renewal as its keyword.

As many methodologies and potential solutions have already been explored in the last decades, it is now necessary to put into practice forward-looking urban design solutions either by countering climate change or progressively reduce our dependency on fossil fuels.

Amongst other objectives, contemporary urban renewal policies in Europe are particularly aimed at pedestrianising the cities' public space, having urban centres as the main intervention field and the ideal of the 'compact European city' and the enhancement of the urban open spaces' ecological role (1996, p.167) as motivation. Indeed, the value of open space and of urban regeneration within consolidated urban centres has been progressively recognised in the last decades. Bioclimatic urban interventions (all the urban design projects concerned with creating more thermally comfortable open spaces) come into this category as one of the most recent answers to the environmental challenges presented to cities.

But improving a public space is not only about the accomplishment of functional, technical or infrastructural requisites. Thermal comfort - 'the absence of any sense of discomfort' (Gaitani et al., 2007, p.319) - and the urban environmental conditions have to be considered and improved as well as they affect people using public spaces (Katzschner, 2006, p.1).

Bearing in mind global warming, it is not very effective to conceive an attractive pedestrian public space if its thermal conditions are not favourable for people to walk, use a bicycle or public transport. As Nikolopoulou et al. (2001, p.235) argue, we should firstly be concerned on how to make people to come out of the buildings or to stop when they are passing through a space. In order to do so, thermal comfort outdoors must be ensured as it 'significantly influences the human activities in outdoor areas' and as such, 'the degree and intensity of such activities depend on the level of satisfaction or dissatisfaction under the prevailing climatic conditions' (Gaitani et al., 2007, p.319).

Urban planning and urban design should be more connected to site, climate and nature (Goulding and Lewis, 1997, p.9), especially when the improvement of summer thermal conditions (when higher temperatures are expected) is aimed. Therefore, urban designers should be aware of the climatic consequences of their proposals (Ochoa et al., 2006, p.1).

Additionally, the urban heat island accentuates the thermal conditions of urban centres for it has the potential 'to compound and accelerate temperature rises' in urban areas (Handley and Carter, 2006a, p.9). Thereby, it becomes clear that in Mediterranean climates the heat

island is a mainly negative phenomenon, especially during the day when people mostly circulate through the city.
As this phenomenon does not present uniform characteristics throughout a city and between cities in different latitudes, the microclimatic scale becomes paramount. As Nikolopoulou (2004, p.2) argue, the microclimatic conditions are 'of central importance for the activities that are carried out in the area and to a great extent determine their use'.
Basically, the microclimate is a direct reflection of the individual urban elements' (e.g. streets, squares or gardens) influence over the dominant climatic conditions and it is circumscribed to the urban canopy layer and with a dimension normally up to a hundred meters (Andrade, 2005, p.71). It is necessary to determine which microclimatic parameters can be manipulated in order to promote more pleasant open spaces and to enhance a more sustainable urban environment (Ochoa et al., 2006, p.1). This might involve 'the best use of structural and landscape design elements to maximize or moderate sunlight, shade and air movement' (Meerow and Black, 1991, p.1).
The parameters influencing microclimate can be basically divided in atmospheric – generally air temperature, relative humidity, wind velocity and global radiation - and morphologic – e.g. materials, green and blue areas or the layout of urban canopies (Santamouris, 2006, p.2). In addition to many 'non-physical factors' such as thermal preferences or motivation to be at place (Jones, 2001, p.120), these are the main parameters influencing thermal comfort outdoors.
Microclimate improvements also affect thermal comfort indoors for, as Santamouris (2006, p.2) argue, it resists 'the effect of heat island and temperature increase and the corresponding increase of the cooling demand in buildings'. Thus, if an outdoor space is thermally improved so is an indoor one as well. Reductions on CO_2 emissions can as such be achieved in what concerns to HVAC systems, for instance. Indeed, as buildings mostly use energy from nonrenewable resources and as these resources are less readily available and renewable sources are developed, the need of reducing buildings energy use becomes paramount (ASHRAE, 2005, p.17.2). As such, urban microclimate improvements can help promoting a low carbon urban environment.
In Portugal there is still a lack of experience in dealing with the environmental problems of inner cities; a need for studies highlighting the importance of thermal comfort in urban design; an overall lack of its application in the contemporary urban planning and design practice (Andrade, 2005, pp.75, 76); there are still not specific and direct mitigation measures to counter the urban heat island.
Nevertheless, some government documents that do not have the central aim of mitigating the heat island do have an indirect impact on the reduction of its intensity. We are referring to the promotion and restoration of green and blue areas, the pedestrianising of spaces within the urban fabric or the reduction of CO_2 emissions from some production sectors, for instance.
But it is at an academic level that the main and specific approaches to these issues have been developed. Investigations mainly undertaken by geographers on the urban heat island of five national cities (Lisboa, Coimbra, Porto, Bragança and Évora), urban climatology, urban climatology and its relation with urban pollution and health are the main outcomes (Góis, 2002, p.2.10).
We believe now is the time to put into practice the outcomes of previous studies. We lack of pragmatic approaches to the bioclimatic urban design area; we lack of more operational perspectives capable of guiding urban designers in their urban renewal projects under a straightforward, familiar and clear language.

Correlating morphology and climate in urban centres
To improve a microclimate is potentially more easily carried out in a new expansion area than in a consolidated (historical) central area as here 'the hard structure cannot be changed' (1996, p.178). Changes in orientation, density or other structural morphologic parameters (e.g. the demolition of an entire block to improve indoors and outdoors wind flows or solar access) are not so easily expected to take place in these areas. Thus, one must try to obtain the greatest benefit from the existing structures (1996, p.178).

This is mainly due to the fact that these areas are predominantly protected by strict regulations ensuring its historical integrity. These do not generally allow many interventions to take place as the intact historical centres of cities represent a link between people and local culture and heritage. Additionally, the indirect effects of tourism on historical central areas for instance, such as an increase in road traffic, more people circulating in the streets or more demand for leisure space in addition to the day-to-day activity of its inhabitants, make questions of thermal comfort outdoors here more important than in any other part of a city.

Thus, from amongst all the morphologic parameters influencing microclimate, facing materials and vegetation are potentially the most suitable to work with in urban centres for in often subtle (but fundamental) ways they can help improving the ambience of these places.

Focusing on Mediterranean climates where higher temperatures do mean an increase in people's discomfort, increased demand of buildings for energy and risks to health, the use of vegetation and high albedo materials makes sense as the best option to improve a microclimate basically because shade trees 'reduce the insolation on a surface' and cool surfaces 'absorb little of the incident insolation' (Rosenfeld et al., 1995, p.256). As such, 'raising the albedo of urban surfaces and increasing urban vegetation are easy ways to conserve energy, save money and probably to reduce air pollution' while mitigating or perhaps reversing the summertime heat island (Rosenfeld et al., 1995, p.260). A thermally comfortable low carbon built environment can thus be enhanced when these two parameters are correctly brought together.

As Santamouris (2001, p.12, 43) argues, 'if the temperature of an entire community drops by a degree thanks to lighter roofs and pavements and to the evapotranspiration from trees, then outdoors thermal comfort is enhanced and the 'air-conditioning load of all buildings may be reduced' as their surfaces are kept cooler.

Finally, approaches to this issue should adopt a familiar language to the envisioned audience according to their 'tangible experience' (Taylor and Guthrie, 2008, p.23), in this case with regard to the urban design field. Correlating morphology and climate in urban centres through a simple language to urban designers is therefore crucial.

This is so because the highly relevant outcomes of research on the urban climatology and thermal comfort areas are at the time either 'too complex, or not available to common design practice' (Nikolopoulou, 2004, p.12). Moreover, many of them are based on steady-state conditions that do not correspond to any real outdoors situation or are 'measures of specific case studies or simulations done with complex programmes' (Nikolopoulou, 2004, p.12). Besides, both architecture and urban design areas deal mainly with human based languages, methodologies and approaches rather than with mathematical ones. Field surveys undertaken by the RUROS Project have revealed 'the need for empirical data' on the (subjective) human parameter in outdoor spaces as this would provide 'a broader perspective from which to view comfort in urban spaces' (Nikolopoulou and Lykoudis, 2006, pp.1455, 1456).

Thus, it might be useful to find ways of developing these areas without unavoidably using complex mathematically-based models. More operational approaches in a closer and straightforward connection to the projectual language of urban design are needed to become the outcomes of previous studies more effective.

Poveiros Square and São Lázaro Garden

In order to illustrate how the correlation between morphologic and climatic parameters might take place, two spaces in Porto were analysed: Poveiros Square and São Lázaro Garden.

According to Monteiro (1997, pp.39-57), Porto occupies an area of approximately 4000ha and has been developed over a slightly aslope platform with the lowest point (0m) in the seacoast. In its turn, its highest point is at 160m. Porto core's southern limit present a particularly dramatic topography and a high density urban pattern constituted of old (built before 1945) and high (normally up to three or more floors) buildings as well as narrow streets and few green spaces.

The necessity of urban renewal in Porto is evident as it presents a core “desertification” process, common to other European cities. Technological innovations especially those related to means of communication and the relocation of activities reduced dramatically the city’s capacity to provide differentiated opportunities to its inhabitants as well as the velocity in the exchanges of goods, services and information (Monteiro, 1997, p.59). Generally and in the particular case of Porto, this lack of attractiveness lead to a reduction of population, the increase of abandoned spaces throughout the city core and the increase of void spaces waiting for qualification (Monteiro, 1997, p.59).

Porto has a Mediterranean temperate climate with an Atlantic influence, according to Köppen’s classification. According to Monteiro (1997, pp.81-136), in Porto July presents the highest temperatures so summer begins by later June till later August. However, considering the maximum temperatures, summer can be said to extend definitely and with some constancy from between the end of July to late August. The most probable maximum temperatures during this period are between 24ºC and 26ºC and temperatures above 32ºC and under 18ºC are not so probable to occur. In June, July and August rain values rarely go above 50 mm, while relative humidity presents high values (around 75%) all year-round. In what concerns to wind, there is a slow reduction of wind velocity during summer season with its minimum in August. In terms of dominant wind directions, from April to September the NW winds are the most frequent and strong.

Although Monteiro’s research on Porto’s urban climate (1997) has shown some order in the summer characteristics of this city, the author suggests the evidence of climatic changes in Porto in the past few years. It was observed a gradual rise in air temperatures and higher levels of rain during the wet season as well as lower levels during the dry season. The worsening of ‘local greenhouse effect’ caused by the urbanization phenomenon in the last decades is pointed out by the author as the main reason for such changes (Monteiro, 1997, p.294). Therefore, Monteiro (1997, p.206) concludes that human urban activities have been strongly affecting Porto’s urban ecosystem.

It is worth mentioning also that at a planetary level, due to its latitude, Porto will much probably be seriously affected by climate change (Monteiro, 1997, p.39). Correspondently, at the national scale the SIAM II Project has verified a considerable increase and in the same magnitude in the average maximum and minimum temperatures in Continental Portugal in the last twenty-five years of the 20th century (Santos and Miranda, 2006, p.51).

Field surveys undertaken by Góis (2002) on Porto’s heat island have shown that the city’s central core and central core’s periphery systematically exhibited the highest temperatures during the period of analysis. This is mainly due to the high urban and populational density of the central core of Porto, to the near absence of green areas (Góis, 2002, p.7.5) and to its low altitude (Monteiro, 1997, p.388). Faced with this evidences, thermal conditions can be expected to be problematic during summer in Porto.

The case studies herewith presented are focused on the city’s historical core and therefore relate to its heat island. This is quite clear when the site plan is overlapped with the ‘*cartographic representation of temperatures spatial distribution in a typical summer day*’ proposed by Góis (2002, p.6.11), as shown in the figure below.

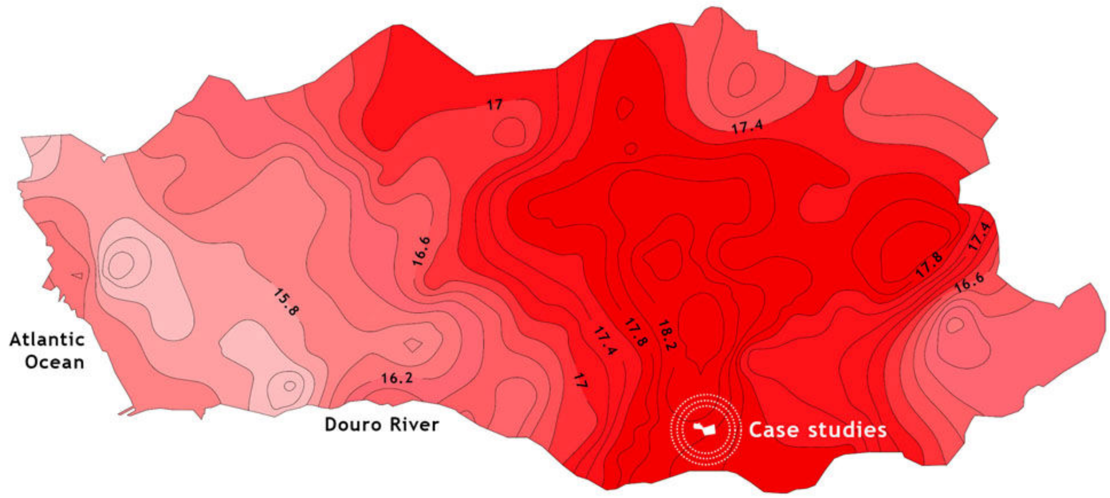

Figure 1: Case studies position in Porto's heat island.
Source: adapted from Góis (2002) by João Granadeiro Cortesão.

Figure 2: Aerial photo of Poveiros Square and São Lázaro Garden site.
Source: GoogleEarth (26.06.2007).

Poveiros Square (Figure 2 and 3) is a compact 10.700m^2 space with a slightly trapezoidal shape orientated towards the south and bordered by a consolidated urban fabric of high density. This built-up surrounding is mainly composed of a sequence of buildings defining a regular urban front around the Square; the upper floors fulfil housing functions whereas commercial activities are held on the ground floors in a total average of three to five floors; the main facing materials are soft-coloured ceramic tiles, mixed-coloured plasters and granite applications.
The Square's present form dates back some 10 years, to the time that the underground public car park was built. This car parking came to replace the former surface one, releasing that area to pedestrians. Its main effective use is as a passage. Its main horizontal facing materials are granite stone cubes and vegetation and water surfaces are concentrated in its eastern and northern edges.

São Lázaro Garden (Figure 2 and 3) is a typical Romantic garden conceived to promote a major link between people and nature in an urban context. Presenting the characteristics of a

“proximity” garden (i.e. a space with frequent use by people due to its proximity to the place of residence), this is the city’s first public garden, opening to the public in 1834.
Its main characteristics are that it is enclosed and densely vegetated. Initially, this garden was characterized by a rigid geometric composition but in a second phase it became more irregular as it still is (Madureira, 2000, p.41). Furthermore, it is a fundamental part of a local public green system of vegetated streets (Madureira, 2000, p.51).
Like Poveiros Square, this 22.300m^2 space has a slightly trapezoidal shape towards the south and is surrounded by a consolidated urban fabric with the same characteristics as Poveiros Square. The only exception to this is that its southern and eastern edges are bordered by two single public buildings. Its main function is as a place for meeting/leisure activities. The main horizontal facing materials of this garden are bare soil, grass and seasonal flowers and there is a water feature at its geometric centre.

Figure 3: A perspective of Poveiros Square (left) and São Lázaro Garden (right).
Source: João Granadeiro Cortesão (June 2009).

The field surveys were carried out between the 24th and the 29th July 2009 (except the 26th and 27th due to unusual bad weather conditions). The methodology adopted for these surveys felt over the correlation of a physical characterization, questionnaires and climatic measurements held in both spaces, as well as main bioclimatic urban design principles gathered from several references such as Nikolopoulou (2004), Santamouris (2001) or Rosenfeld (1995).

The morphologic analysis has shown that the main morphologic differences between both spaces are the facing materials of the horizontal surfaces and vegetation cover. While Poveiros Square has hard impermeable facing materials and the near absence of vegetation, São Lázaro Garden presents soft permeable natural facing materials and intense vegetation. Therefore, it was observed that the sky view factor is total in Poveiros Square and almost nil in most of São Lázaro Garden. It was also necessary to use shade devices to block excessive solar radiation in Poveiros Square whereas in São Lázaro Garden none were used. Moreover there is a total exposure of the buildings facing south to solar radiation in Poveiros Square while in São Lázaro Garden the facades facing south are partially in shadow at least for some time of the day as a result of the garden’s vegetation.

With respect to the questionnaires, 110 people (55 per space) were interviewed between 11am and 3pm during the four days of field surveys. The main outcomes from the questionnaires were that while in São Lázaro Garden 78% of the interviewees were resting at place and only 16% were just passing by towards somewhere else or simply strolling, in Poveiros Square only 27% were resting whereas 60% were passing by.
9% of people referred to the fact that the most unpleasant climatic parameter at the time of the interview in São Lázaro Garden was wind while 85% answered none of the climatic variables. In its turn, in Poveiros Square, 27% answered sun as the most unpleasant parameter at the time of the interview whereas 65% answered none of the climatic variables.
Even when directly exposed to sun, 76% of the interviewees were thermally comfortable at Poveiros Square while only 24% were uncomfortable. Nevertheless, 80% of them considered the square as usually an uncomfortable place during summer, as it is too exposed to solar

radiation. We attribute this to the temperatures felt during the field surveys period, unusually lower than the expected for that season. In its turn, in São Lázaro Garden 98% of the interviewees were comfortable and all of them described it as a comfortable space during summer, so people feel motivated to use it during that season whereas in Poveiros Square they do not.
As expected, due to the exposure to the open sky and the main facing materials used, 96% of São Lázaro users considered it to be neither dark nor bright but rather possessing a pleasant shadowed ambience provided by trees. Unsurprisingly, 98% of the users answered not to be glared at all at that space. In its turn, Poveiros Square was considered by 85% of the interviewees to be a bright space and by 13% to be too bright. Therefore, 53% are usually glared by the pavement and 14% by the surrounding buildings facades.
With respect to the vegetation, 94% of people considered São Lázaro Garden to have enough trees whereas in Poveiros Square 93% answered that the space has little vegetation. Additionally, 95% of the interviewees referred to the fact that the few trees existing at the square present no effective protection from sun or wind, while in São Lázaro Garden 96% of the opinions were that the existing vegetation does present effective protection from sun and wind.
Finally it is worth mentioning that when three pictures of public spaces (Figure 4) were shown to people, 89% have chosen space C as the potentially most pleasant space, from the thermal point of view, in a typical summer day, while 83% considered space B as the potentially most unpleasant one. Space A was considered by 8% of the interviewees also as the most pleasant space and by 14% as the potentially most unpleasant one.

Figure 4: Space A, B and C (from left to right) presented during the questionnaire.
Source: João Granadeiro Cortesão (July 2009).

The climatic measurements were made using two Onset Computer Corporation's HOBO H8 data loggers, model RH/Temp. The data readout was made through the Onset Computer Corporation's BoxCar 3.7 software. Both instruments were kindly provided by the Building Physics Laboratory (LFC) of the Faculty of Engineering of Porto University. The measurements' were made to air temperature and relative humidity simultaneously in both spaces. The main outcomes are that effectively there are considerable differences between these two variables from one space to another.
As illustrated in Chart 1, independently when the measurements were made and the daily maximum and minimum temperatures, at the same date and time Poveiros Square and São Lázaro Garden always showed a gap between their air temperatures with the latter presenting the lower values. The maximum value of this difference reached 7ºC and the minimum difference is around 3ºC. In both cases, such values do mean different microclimates in terms of air temperature and therefore certainly justify why people were mostly found in São Lázaro Garden and not in Poveiros Square.

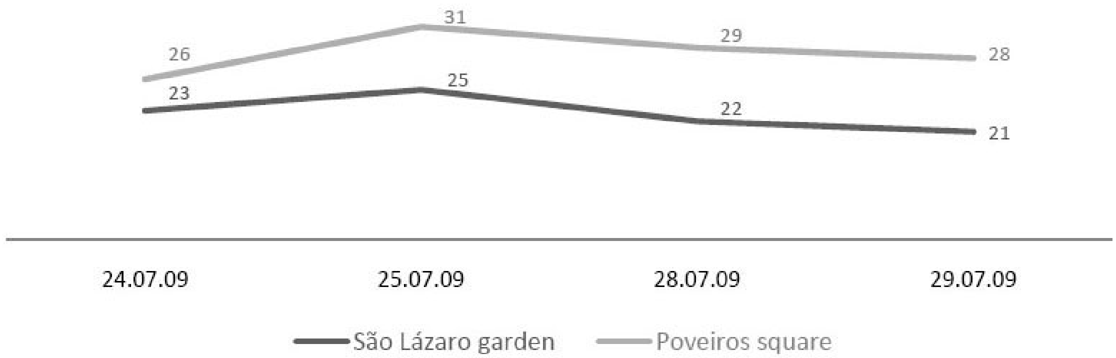

Chart 1: Average air temperatures (ºC) measured during the field surveys.
Source: João Granadeiro Cortesão (July 2009).

With respect to relative humidity, the situation is analogous with São Lázaro Garden presenting the highest values and Poveiros Square the lowest ones. By observing Chart 2, it becomes clear that the maximum value for this difference almost reached the double, from 32% in Poveiros Square to 63% in São Lázaro Garden.

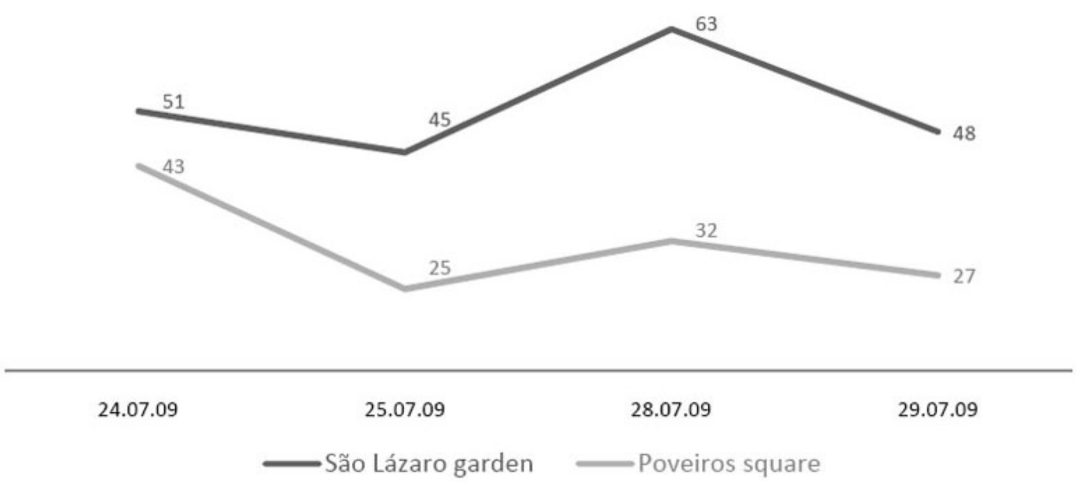

Chart 2: Average relative humidity (%) measured during the field surveys.
Source: João Granadeiro Cortesão (July 2009).

By correlating the results of the morphologic analysis, the questionnaires and the climatic measurements it became clear that São Lázaro Garden is a much more comfortable space than Poveiros Square during summer, and that this is mainly due to the presence of vegetation and to the nature of its pavement facing materials. For this reason, Poveiros Square was considered to be an interesting case to show how urban vegetation and materials can effectively interfere in human thermal comfort and thus in a space's usage.
Summarizing, the main problems revealed by Poveiros Square to thermal comfort are at the morphological level facing materials and vegetation and, at the climatic level, air temperature and solar radiation. Correlating this to the main bioclimatic urban design principles, one can induce more consistently about these bioclimatic negatives aspects of Poveiros Square as well as about potential ways of improving it from the thermal point of view. Only the principles with a direct relation to the above mentioned parameters are considered below.

To use light colours and reflective surfaces to prevent surface overheating. The type of horizontal facing materials used in the square is not the major problem but rather the extent of its use. The solution for this could be achieved by adding to the 0.40 albedo granite stone other high-albedo facing materials such as gravel (0.72), light coloured sand (0.60) or whitewashed stone (0.80).
To use a mix of impervious and porous materials or lighter coloured pavements. Mixing different facing materials has a major impact on the reflection of solar radiation and on the water cycle. Also, the thermal difference established between air masses in contact with both impervious and vegetated areas enhances convection breezes that cool down and purify the air. It is clear that Poveiros Square presents an excessively uniform paving solution, in this case totally impermeable and monochromatic that certainly makes worse the performance of solar radiation and water at the space. Again, a mixed pavement could potentially help controlling Poveiros Square microclimate.
To use trees or horizontal devices to provide shade. The few existing trees on Poveiros Square provide neither shade nor evapotranspiration as these are positioned on the eastern and northern edges rather than randomly throughout the space or in its southern and western edges, where they would be more effective.
To use trees to cool down the air. Trees present a higher capacity of long-wave radiation reflection and diffusion than the majority of the materials, cooling down the air. Local measurements made to air temperature have shown that air masses on São Lázaro Garden are cooler than those on Poveiros Square and this can only be due to vegetation. Probably if the latter space had more vegetation it would present lower air temperatures.
To use trees to purify the atmosphere. As they retain dust and toxic gases and absorb CO_2 while emitting oxygen and ozone through the chlorophyll function, trees help reducing atmospheric pollution and avoid the retention of UV radiation by the atmosphere. Bearing in mind that Poveiros Square is surrounded by some of the main traffic streets in Porto's downtown and that it is located within the city's heat island perimeter, trees would help this space to be more comfortable and healthy. Its near absence of vegetation means that this space has no way of controlling the pollution outcoming form the surrounding traffic.
To provide people with the potential to use the space all year round. Poveiros Square does not present any adaptation opportunity to use the space all year round. The almost total absence of vegetation or other shade devices reduces dramatically the square's capacity for offering people any microclimatic amenity in summer (shadowing) or winter (rain and wind sheltering).
To choose carefully the plant species most compatible with each place. One should pay attention to the characteristics of an urban climate when choosing a tree species. Also in Poveiros Square, for example, tree planting might be constrained by the underground car park. Thus alternative solutions to counter this challenge might be needed, such as potted trees.
To use water features. Although Poveiros Square possesses such features (a fountain and pond), they are of limited value in influencing the microclimate because of their position at the edge of the space, their small size and their inaccessibility (above the ground level).

From the above mentioned it becomes clear that Poveiros Square would have a much pleasanter microclimate in summer, and thus a higher usage, through the application of some of these principles. According to these, an improvement scenario for Poveiros Square could broadly pass by mixing-up the existing horizontal facing material with other paving materials; by increasing vegetation in the existent grass area; and by placing potted trees (as the underground car parking does not allow direct soil planting) and other shade devises such as pergolas throughout the square. In the end, this scenario would potentially mean an affordable, fast and sustainable way of improving an urban central space's thermal conditions without destroying its hard structure but rather working over it.

Conclusion

Creating more pedestrian spaces in Mediterranean urban cores means creating places for people to walk freely but also to do it in the most comfortable way possible during summer. Face to the impacts of a predicted and already evident climate change worsened by the urban heat island these conditions tend to be stressed.

As there is already quite developed research on urban climatology, microclimate improvement and thermal comfort it is now the moment to seek for straight-forward, simple and effective tools to adapt cities to the coming years. This article has put forward a potential way to achieve such a goal, using the city of Porto as a stage and the relationship between morphological and climatic parameters as the central argument. The two case studies allowed testing to what extent this relationship really takes place in a specific site and to understand how people feel about it.

The final outcome of the analysis is that the correlation between morphological and climatic parameters does affect a microclimate, a space's thermal comfort conditions and therefore people's motivation to use that space. In the case studies presented here it is clear that the absence of vegetation and the nature of the pavement's facing materials is producing quite dramatic differences in people's thermal comfort conditions and therefore in the degree to which these spaces are used.

These case studies clearly illustrate how the urban form affects CO_2 emissions as the negative bioclimatic aspects of Poveiros Square directly affect 'local greenhouse effect', namely at the level of sensible heat storage in the urban fabric: storage of solar energy within building mass during day and its subsequent release at night, concentration of anthropogenic heat and low evaporation rate by the soil and vegetation. This heat storage definitely increases the demand for cooling in buildings and consequently the emissions of CO_2 related to mechanical devises to control indoor air temperature.

In its turn, São Lázaro Garden presenting consistent microclimatic amenities in summer as a result of its vegetation enhances not only thermal comfort outdoors but indoors as well. Many of the interviewees living in buildings around this garden spontaneously mentioned that its vegetation cools the air entering their houses or at least at a visual/psychological level, these trees do cool air temperature.

Thus these spaces seemed to provide the ideal scenario to illustrate the correlation between a space's facing materials, vegetation and climate: two contiguous spaces of similar dimension, same placement, density of building, morphologic characteristics, centrality (with regard to pedestrian circulation), public services and facilities but still with a completely different pattern of use. The surveys undertaken confirmed that such a situation is due to differences in vegetation and facing materials.

Thermal comfort and low carbon built environments in Mediterranean urban cores can therefore be achieved through a simple but carefully balanced relation between these two morphological parameters. In this context, urban design, supported in contemporary urban renewal policies, plays the major role: the role of giving people the opportunity to move the notion of home from the boundaries of their houses into the liveability of urban spaces.

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