THERMAL COMFORT IN OUTDOOR URBAN SPACES

Hocine BOUMARAF*
University Ferhat Abbas – Setif, Department of Architecture and Urban, Algérie
e-mail: hocineboumaraf@yahoo.fr

Abdelmalek Tacherift
University Ferhat Abbas – Setif, Department of Architecture and Urban, Algérie
e-mail: tacherift@hotmail.fr

Abstract: Microclimatic conditions are a critical parameter for the use of outdoor spaces in the urban environment. Responses to the microclimate may be unconscious, but they often result in a different use of open space in different climatic conditions. In this study thermal comfort conditions outdoors are examined through field surveys in Biskra (South-East of Algiers), where extensive environmental monitoring has been carried out in parallel to human surveys with interviews and questionnaires with the users of the spaces. Microclimatic parameters are examined in relation to subjective thermal sensation determining thermal comfort outdoors, along with an attempt to develop models for quantifying thermal comfort conditions, based on publicly available environmental data from meteorological stations. Refining such models for design purposes is also examined, investigating modification parameters on comfort models due to the microclimate for design purposes, in the form of correction factors.

Key words: outdoor thermal comfort, microclimate, field surveys

* * * * * *

INTRODUCTION

There is strong public interest in the quality of open urban spaces and it is acknowledged that they can contribute to the quality of life within cities, or contrarily enhance isolation and social exclusion. This relates to the physical (i.e. microclimate, thermal, visual and acoustic comfort, urban morphology, etc.) as well as social environment. Therefore, in order to increase use of outdoor space and revitalize cities, the environmental conditions imposed on people using these spaces, have to be equally considered. Recent research has shown that the microclimate of outdoor urban spaces is central to the way these spaces are used and the activities that are carried out, as thermal and by implication comfort conditions affect people’s behaviour and usage of outdoor spaces (Boumaraf & Tacherift, 2006). Responses to the microclimate may be unconscious, but they often result in a different use of open space in different climatic conditions. Thus, understanding the richness of microclimatic characteristics in outdoor urban spaces, and the comfort implications for the people using them, opens up new possibilities for the development of urban spaces.

* Corresponding Author

http://istgeorelint.uoradea.ro/Reviste/Anale/anale.htm
Currently, there are no large-scale studies available where the user has been thoroughly involved in evaluations of the microclimate and comfort conditions in the real world setting. Although it is acknowledged that microclimate is a very important parameter for comfort, we are not aware of the degree of such influence, as well as other parameters that may be involved. Such an approach points towards the creation of a common platform for the development of open spaces in the urban environment, combining the physical environment with user requirements and satisfaction. The study is unique in its kind, both for the issues it investigates as well as the wide range of climatic conditions examined and the surveys carried out. This paper presents findings from the field surveys in Biskra.

**OUTDOOR COMFORT**

The environmental parameters affecting thermal comfort conditions outdoors, even though similar to indoors, are encountered within a much wider range and are more variable. Therefore due to this complexity, in terms of variability, temporal and spatial, as well as the great range of activities people are engaged in, there have been very few attempts to understand comfort conditions outside. In most outdoors thermal comfort studies, a purely physiological model has been used, involving a mathematical model of the thermoregulatory system employed for calculating the thermal comfort conditions, whereas the subjective responses have not been considered. Thus, there is a need for empirical data for the subjective human parameter, which would provide a broader perspective from which to view comfort in urban spaces.

**METHODOLOGY**

In this framework, field surveys have been carried out at two different open spaces in Biskra, used as the medium for examining comfort conditions outdoors. Detailed microclimatic monitoring was taking place with a portable mini-weather station devised for the project, while people were studied in their natural environment through structured interviews and observations, to evaluate the comfort conditions people experience and their perception of the environment. Individuals' characteristics and behavioural patterns were also taken into account. The structured interviews, with standard questionnaires, aimed to represent the views of a broad range of users. The thermal aspects of the questionnaire enquired on people's evaluation of the thermal environment and satisfaction, as well as reasons for using the space, frequency of use, etc. The field surveys took place periodically within a year, to get the seasonal variation, which affects the use of space. The objective environmental parameters investigated are related to the thermal, visual as well as acoustic environment. More specifically air temperature, dry and wet bulb, and humidity were recorded, together with globe temperature, and wind speed. The sensors were carefully selected to conform to ISO 7726, 1985. For the visual environment horizontal and cylindrical illuminance levels were recorded, whereas for the acoustic environment sound pressure levels.

**RESULTS**

In order to ensure that data analysis would proceed in a uniform manner yielding all necessary information in a format tailored to meet the project's requirements, a Statistical Analysis Scheme was developed, to handle the bulk of the data for analysis. The analysis scheme included quality control of the data, descriptive statistics, investigating existing correlations and development of models for predicting thermal comfort conditions using the available data. Analysis was both site and season specific. The majority of population was found in age groups between 25 - 34 and 35 - 44 years, which account for around 50% of the interviewees, at a nearly equal split, followed by the >65 category that accounts for 20%. Regarding gender, there is 60:40 ratio in favour of females over males. Recorded microclimatic conditions varied widely for the period of the field surveys throughout the year. Mean air temperature was 21.9 °C, with a standard deviation of 5.89 °C, while maximum and minimum air temperature was 35.5 °C and 10.7 °C respectively. A summary of the thermal conditions recorded during the interviews is thermal conditions recorded during the interviews is presented in table 1.
Thermal Comfort in Outdoor Urban Spaces

Table 1. Summary of microclimatic variables, monitored during the field surveys in Biskra

<table>
<thead>
<tr>
<th></th>
<th>$T_{air}$, $^\circ$C</th>
<th>$T_{globe}$, $^\circ$C</th>
<th>V, m/s</th>
<th>RH, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>21.9</td>
<td>24.7</td>
<td>0.86</td>
<td>52.2</td>
</tr>
<tr>
<td>St.dev</td>
<td>5.89</td>
<td>5.24</td>
<td>0.65</td>
<td>13.17</td>
</tr>
<tr>
<td>Max.</td>
<td>35.5</td>
<td>41</td>
<td>4.5</td>
<td>85</td>
</tr>
<tr>
<td>Min.</td>
<td>10.7</td>
<td>10</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

In the summer, climatic conditions included high air temperatures, intense sunshine, relatively low wind speeds, whereas humidity was also influenced by the location of the sites.

Autumn temperatures recorded are close, if not lower, to those of the winter period, introducing a slight discrepancy regarding seasonal analysis.

**Thermal Sensation**

People’s thermal sensation was reported on a 5-point scale, varying from “very cold” to “very hot”, and has been defined as the Actual Sensation Vote (ASV). Analysing the data that has been collected, it has been possible to examine correlations between microclimatic parameters and ASV. Figure 1 presents the variation of ASV in relation to air temperature. Examining mean values of ASV, there is evident correlation between the two variables, as there is with globe temperature. As expected, with respect to wind speed there is a weak negative correlation with ASV, indicating that ASV reduces as wind speed increases. The relatively weak correlations between microclimatic variables and ASV indicate that one parameter alone is not sufficient for the assessment of thermal comfort conditions. The subjective data collected from the interviews was compared with the thermal index Predicted Mean Vote (PMV) (ISO 7730, 1994), calculated by taking into account the mean objective environmental parameters recorded for the duration of the interview, clothing levels and metabolic rate, for each interviewee.

![Figure 1](image)

Figure 1. Distribution of the Mean Actual Sensation Vote of the interviewees (ASV), with the respective deviation in relation to Air Temperature

Comparing the PMV for each interviewee with the corresponding ASV, revealed a great discrepancy between the two sets of data, as actual thermal comfort appears to be found at higher levels than implied by the existing mathematical model (figure 2).

More specifically, it is noticed that 93% of the actual votes fall within the comfortable categories (i.e. $-1 = ASV = +1$), with only 7% of the votes falling with the “very hot” region (+2). However, only 59% of the PMV falls within comfort ($-1 = PMV = +1$), implying that more than 600 people were dissatisfied with the thermal environment (figure 2).

Seasonal analysis is particularly interesting, as in the summer, only 17% of the actual votes falls in the “very hot” region (+2), whereas there is also a 28% in the “cool” region (-1), at conditions which
are beyond what has been traditionally been regarded as comfortable, with a mean air temperature of 30 °C and a maximum air temperature of 35 °C. On the other hand, PMV implies that the majority of the people, 54%, are in the discomfort zone, with 51% found in the hot discomfort.

Figure 2. Comparison of the Actual Sensation Votes (ASV) obtained from the questionnaires with the Predicted Mean Votes (PMV) calculated from the mathematical model, for each interviewee.

The wide range of microclimatic conditions in outdoor spaces strengthens the point that a purely physiological approach is inadequate to characterise thermal comfort conditions outdoors, whereas the issue of adaptation becomes increasingly important. This involves all the processes which people go through to improve the fit between the environment and their requirements, both at a physical and psychological level. In the outdoor context, it involves personal changes (Boumaraf & Tacherift, 2009), with the seasonal variation of clothing, changes in the metabolic heat with consumption of cool drinks, as well as changes in posture and position, whereas psychologically (Boumaraf & Tacherift, 2010), personal choice, memory and expectations prove to be a critical parameter for satisfaction with the thermal environment. The consistent discrepancy between actual and theoretical comfort conditions outdoors in Biskra is also in agreement with a previous study of thermal comfort in open spaces (Boumaraf & Tacherift, 2006), in a very different climatic context. This emphasises the need to investigate different ways to quantify comfort conditions outdoors, giving us ground to investigate and develop models for the thermal comfort conditions outdoors, based on the empirical data gathered from the field surveys, rather than based on existing theoretical models.

Model development

Aiming to investigate the relationship between ASV and the microclimatic data collected during the interviews, as well as to obtain ASV calculation models based on publicly available environmental data (presumably from nearby meteorological stations), multiple linear and stepwise regression was applied, using as independent variables air temperature (Tair, °C), the difference of Tglobe-Tair (Tga, °C) as a proxy for sunlight (Humphreys, 1977) wind speed (V, m/s) and relative humidity (RH, %):

\[\text{ASV} = 0.061 \times \text{Tair} + 0.091 \times \text{Tga} - 0.324 \times \text{V} + 0.003 \times \text{RH} - 1.455 \quad r = 0.39, p<0.001\]

All parameters are statistically significant at the 99% level, except for that of RH that is significant at the 92.5% level. An examination of the standardized parameters reveals that the model is mainly influenced by air temperature, while wind speed is the second important parameter. As a next step, it would be useful to develop simple models that could predict thermal comfort conditions, using readily available data. Simple linear models were developed using publicly available meteorological data, e.g. from a nearby station. These models could be very important if proven to be able to predict ASV in an adequate way, since they can be the platform on which outdoor thermal comfort nomograms and maps can be constructed.

Models based on hourly meteorological data were obtained, using multiple linear and stepwise linear regression, to predict ASV, based on the combined effects of air temperature (Tair\textsubscript{met}, °C), global solar radiation (Sol\textsubscript{met}, W/m\textsuperscript{2}), wind speed (V\textsubscript{met} m/s) and relative humidity (RH\textsubscript{met}, %):

\[\text{ASV} = 0.034 \times \text{Tair\textsubscript{met}} + 0.0001 \times \text{Sol\textsubscript{met}} - 0.086 \times \text{V\textsubscript{met}} - 0.001 \times \text{RH\textsubscript{met}} - 0.412 \quad r = 0.27, p<0.001\]
The reduced model indicates significant contributions only from Tair\_met and V\_met, although it does not seem to fit the ASV data as well as the model obtained with locally measured microclimatic parameters. However, separating the data for the two sites where surveys took place, the situation is different, as for one of the sites, r = 0.39, whereas for the second site, r = 0.2, which explains the lower coefficient for the combined set of data. This could be attributed to the fact that the second site has a great variety of spaces, ranging from dense vegetation and extensive shading, to areas completely exposed to the sun and wind. Clearly, the data from the meteorological station cannot adequately represent the microclimatic conditions in this site.

Therefore, as opposed to developing models, which could be in the form of a Comfort index for different parts of the city for different seasons, it would be of value to bring such models to the microscale for design purposes. The model presented above does not distinguish between sunny and shaded areas, or areas protected and exposed to the wind, which ultimately, directly affects thermal comfort conditions in a given space. It would therefore be of value to devise a way to include design related parameters into environmental data. The area which is currently under investigation includes identifying simplified correction factors between locally measured conditions and those of the nearby meteorological station, during the field surveys that could reflect the modification of the microclimate, such as the effect of shading, or wind protection. Such correction factors can be used as modification parameters on comfort models for design purposes and can be of value to urban designers.

**CONCLUSIONS**

This paper has thrown some light on the complexity of the issues involved in evaluation of thermal comfort conditions in open spaces. Although microclimatic conditions affect the use of open spaces, a purely physiological approach is inadequate in characterising thermal comfort conditions in outdoor spaces, emphasizing the need to investigate different ways to quantify comfort conditions outdoors. An attempt has been made to understand the relationship between thermal comfort and microclimatic parameters through the development of models, based on the empirical data collected from extensive field surveys. Furthermore, models were derived for the calculation of people’s sensation, based on publicly available environmental data from nearby meteorological stations. These form a kind of Comfort index for different parts of the city for different seasons, with no inclusion of microclimatic effects. A way to refine such models is to include correction factors, identified to exist between locally measured conditions and those of the nearby meteorological station, in order to take into consideration design related parameters. Such analysis would be of value to designers, as appropriate microclimatic planning and careful design of urban spaces can provide protection from negative aspects and exposure to positive aspects of the climate, therefore increasing the use of outdoor space throughout the year.

**REFERENCES**