Behaviour of People in Open Spaces in Dependence of Thermal Comfort Conditions

Lutz Katzschner

University Kassel, Environmental Meteorological Institute, Planning Department, Kassel, Germany

ABSTRACT: Urban planners and architects need detailed information about the thermal conditions of open spaces for their design. The actual use of open spaces is depending on the possibilities for adequate activities within the city structure and strongly supported by the thermal conditions. Investigations were carried out at two open spaces in Kassel /Germany with measurements observations and a calculation of thermal conditions in order to create a thermal comfort map and compare that with the behaviour of people.

Fundamental knowledge for thermal sensations came out of a European investigation project, which was carried out in 6 countries. As thermal index the physiological equivalent temperature (PET) was used. For the thermal comfort analysis with measurements a simplified methodology was developed for the thermal comfort conditions and the presentation in urban climate maps. In a well defined city fabric measurements were carried out to compare different sensors and transferred to the mean radiation temperature.

To get the results a simplified methodology was developed for urban climate mapping and measurements. In a well defined city fabric measurements were carried out to compare different sensors, which can be used easily.

Keywords: Thermal comfort, open space design

1 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 thermal physical as well as social environment. In the frame of many discussions about a new urbanity the issue becomes more and more important to revitalize cities. Therefore, in order to increase use of outdoor space and follow the idea of revitalising cities, the environmental conditions and thermal comfort, which effect people using these spaces, have to be considered and improved.
European urban development aims more and more in dense built up cities in order to avoid urbanisation in rural areas. This affects heat island and ventilation situation dramatically. Therefore urban climatology has to play a major role in the thermal analysis of open spaces in order to regain these open spaces for people.
The paper is based on a European project, which has aimed to produce a guideline for urban design that provides urban designers, planners and other decision makers with the appropriate means for thermal comfort conditions. This is achieved by the investigations of thermal comfort measurements with parallel interviews and presentations to municipalities and technical representatives.
Problem was to establish a common evaluating for thermal conditions throughout Europe as people showed a quite different behaviour and activities. Therefore it was taken into account the most influential microclimatic parameters for different areas, leading to slight variations of the same result in different climatic contexts. Open space planning need a precise microclimatic analysis which also evaluates people's behaviour in dependence of the thermal situation. Therefore a methodology was developed for mapping comfort conditions in the urban context results from measurements and observations. Moreover city planning needs an evaluation of analysis and a translation to planning.

2 THERMAL COMFORT DISCUSSION

To evaluate thermal comfort many different comfort standards and indices are use. Main purpose of these papers is to describe the influencing parameters and their input factors, so that any measurements and calculation of thermal comfort can be used for planning. The behaviour of people of urban spaces in dependence of the meteorological parameters are therefore used and developed towards a planning tool. The underlying thermo logical and physical processes based on heat balances of man are well known and described by [3]and others [4] to get the Predicted Mean Vote (PMV) or the Physiological Equivalent Temperature (PET). It is known that the main influencing parameters are wind velocity, long- and short wave radiation, humidity and air temperature.

In this paper the physiological equivalent temperature (PET) is used. In figure 1 the dependency of PET with sun radiation and air temperature is shown. There is a constant gap of nearly 5 °C between the PET values in sun and shadow independently from air temperature. Therefore the effect on thermal comfort by open space design using shadow can be calculated easily.

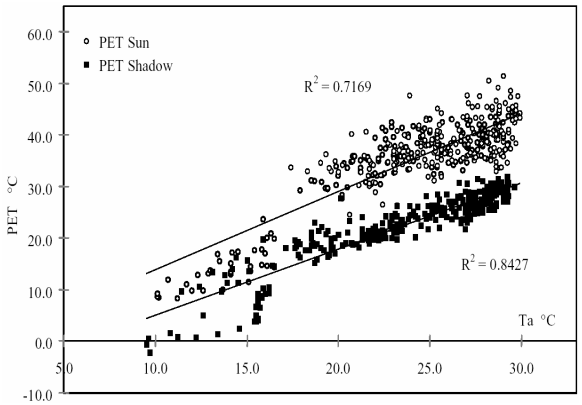


Figure 1: Relation between air temperature and the thermal comfort index PET in sun and shadow during case study measurements in Leipzig [1]

Another factor which should be considered in open space planning and urban design is activity. Thermal comfort conditions can be different depending from these activities as shown in table 1. The same phenomena were observed in the RUROS project [2] where the different reasons using places do need various thermal conditions. Social activities, cultural activities or breaks need warmer conditions than the others. From table 2 and 3 the different behaviour of people in different climatic regions can be seen.
Within tat European project data were raised and compared among European countries and the comfort indices could be compared to thermal sensations. Results are shown in table 3. Calculations of the physiological equivalent temperature (PET) and the neutral temperature were used to calibrate thermal sensations. These results were correlated with observation of people in their open space behaviour and finally brought to a specified calibration of thermal sensations.

Measurements of thermal comfort and parallel interviews in Germany show in the case of calm activities like sitting and slow walking that the neutral conditions are with a PET value of 18 to 21 °C and air temperatures around 19 to 21 °C. This is similar to the neutral temperature out of the RUROS project with mean temperatures of 18 °C, knowing that the neutral temperature does not include the wind speed, which is important for the thermal aspect of being in thermal comfort. This can be seen in table 2 were the effect of wind speed is connected to PET and thermal sensation.

Table 1: Thermal index and activity from measurements and interviews in Kassel/ Germany [6]

activities	**needed thermal conditions for use of open spaces**	**PET °C**
sitting	warm	30
calm activities	warm moderate	26-32
children play	warm moderate	24-26
recreation	neutral	16-24
light movement	neutral	16-26
shopping	warm moderate	26-32
movement	lightly cool	14-24
strong movement	cool to cold	12-24
garden activities	lightly cool	12-24
work outside	neutral to cold	16-22

Table 2: Thermal evaluation from interviews

values 13:00	PET ° C	thermal sensation with five categories	T air ° C	wind m/s
10.5.05	10,1	cool	13,5	0,6
18.5.05	13,5	slightly cool	14	0,8
7.6.05	14,8	slightly cool	16,5	0,9
3.5.05	18,0	neutral	23,2	1,8
13.5.05	20,1	neutral	18,2	0,8
19.5.05	21,0	neutral	20,2	0,3
21.5.05	25,0	warm	24,7	1,2

Over all one can learn from table 3, which is a conclusion out of a European project and a comparison between different cites, that there are different thermal sensations depending on regional climate [8]
All predictive errors between calculated thermal comfort values and behaviour have been mentioned already by Fanger, who explained it with mechanical cooling. Later investigations [7] indicate that also the expectation in temperature influences thermal comfort. For planning purposes it is important to consider and calibrate thermal standards with the subjective thermal comfort feeling. For evaluation in planning processes the tended use of a place also influences the expectation and thermal sensation.

Table 3: Neutral temperature in °C in Kassel / Germany in dependence of PET,(neutral feeling) in different European air temperature and wind speed cities [9]

Neutral air temperature year	summer - winter	cities
22,8	28-21	Athen
25,3	29-15	Thessaloniki
12,9	16-11	Fribourg
18,3	24-21	Mailand
17,8	17-11	Cambridge
15,3	16-11	Sheffield
18,5	22-15	Kassel

3 METHOD

Two steps were taken to discuss thermal comfort results for open spaces. First a one day experiment was carried out in a well defined urban area to measure different meteorological values in the course of the day and seconds an 11 weeks from April to June 2005 observation to study the behaviour of people in open spaces in connection to thermal comfort conditions. It is important to mention, that the local situation of investigation area is within the heat island with reduced ventilation of the city Kassel, which were taken out from the urban climate analysis as seen in figure 3 on the right. So the investigation deals with periods of heat stress and reduced cooling during the investigation period in June. The destination of thermal conditions is used to calibrate thermal sensations by an observation of the behaviour of people using the open spaces near a bistro. More detailed information also could be reached by counting people visiting the bistro inside or outside in dependence of the thermal surroundings.

I could be seen from the discussion in chapter 2 that thermal comfort has to be considered in a height spational, daily and seasonal variation, together with use of open spaces. Therefore any information needed for urban design to improve thermal comfort conditions have to combine physical results with subjective behaviour and well feeling of people. To do these simple measurements were used with parallel interviews. Especially the first parameter is sometimes difficult to derive. Calculations can not be done by everybody. To get the mean radiation temperature globe temperature measurement results are used with different correction factors in dependence of radiation and wind.

Results from Measurements

For one day 20th June 2005 meteorological measurements were recorded in a well defined area with a mobile system (figure 2). The recorded meteorological parameters in the investigation site were global radiation Rg [W/m^2], air temperature Ta [^{o}C], surface temperatures Ts [^{o}C], wind speed v [m/s], globe temperature big and small TGb and TGs and the correspondent PET values all in [^{o}C].

The results from the day of measurements are shown in figure 3. It was observed that the globe temperatures react very similar, with a slight faster reaction time of the small instrument depending on wind speed but equalised in a half hourly average. Globe thermometers react slowly against the change of global radiation, but in terms of the calculated PET value wind and radiation influence thermal conditions directly. In figure 4 one can see the course of air temperatures surface temperatures and globe temperature in connection to the calculations of PET. This should discuss weather it is possible to use simple temperature results for thermal conditions. Here the daily course of temperatures only represents the tendency but not the important short time changes. Surface temperatures there give a better understanding of the thermal situation.

Figure 2: Mobile measurement system (top), investigation area in Kassel

With all that in mind, and with a focus on thermal sensations on half hourly averages the mean radiation temperature can be used from globe thermometers and weighting factors similar. Therefore in table 5 very simple weighting factors to get the mean radiation temperature were developed. It has to be said that this is mainly based on a one day experiment together with the experience from different studies about heat island and city structures [5]. With this simple assumption for the mean radiation temperature from globe or air temperatures PET easily can be calculated as all other parameters can be taken directly from measurements. Even if there was only one day experiment in a well defined urban situation the results are considerable und show the possible use of simple transformations to analyse thermal comfort for open space design.

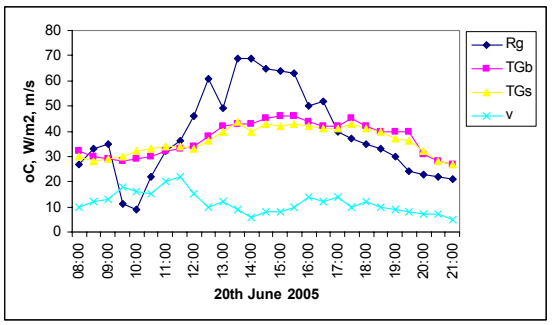
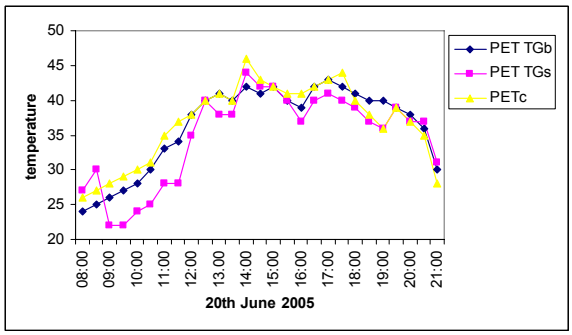


Figure 3: One day measurements of radiation Rg in W/m^2 x10, wind speed v in m/s /10 and two globe temperatures TGb TGs ^{o}C



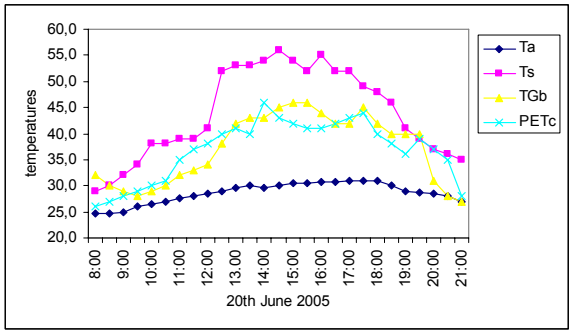


Figure 4: Daily variation of PET (top), air temperature (Ta), surface temperature(Ts), globe temperature (TGb) and PET (PETc) all in °C

Table 5: Correction factors to derive the mean radiation temperature /Tmrt,from air temperatures and globe temperature (TG); [10], Measurements University Kassel, FG Environmental Meteorology June 2005, and [8]

Tl	Tmrt =Tl +		radiationfactor	Tmrt= TG + windfactor	
	sunny	half cloudy	cloudy	v m/s	fact or
< 5	2	0	0	< 1	0
10	5	3	2	1-2	+1
15	10	6	2	2-3	+ 2
20	15	10	4	3-4	+ 3
25	20	13	6	4-5	+ 4
30	25	17	8	> 5	+ 5
> 30	30	20	10		

4 USE OF OPEN SPACES AND THERMAL CONDITIONS

Results from chapter 3 were used to calculate thermal comfort and combine this with observation how people react on thermal comfort conditions in their open space behaviour. As thermal index again PET was taken. During 11 weeks alls people were counted using a specific place just before a bistro. Parallel to that measurements were taken and PET was calculated from that. In figure 6 the weekly averages of PET, wind speed and the absolute number of people using that place are shown. First observation which was made is that more people like sitting outside with increasing PET values. In this example of a moderate but urban climate in the city of Kassel this is even true if the thermal heat stress occurs with more than 24 °C, which can be judged as neutral. Especially those people using the place during midday for a working break seek for warm thermal conditions, especially if they come out of a air conditioned office. The windy situations during the 5th week immediately lead to discomfort.

The same result can be derived from another observation concerning the outside or inside use of the bistro. Figure 5 demonstrates that behaviour. Even during the observations of a warm summer day with PET values above 24 °C not people look for shadow places inside the bistro, which was much cooler than, but want to be outside with warm or even heat stress conditions. This behaviour is very much in accordance to the expectation of the usual warm summer. Disturbing factor for this knowledge is mainly the activity shortly before, as here a thermal compensation is dominating. So business jobs in surrounding offices can stand warmer conditions than shopping. Warm sensation is correlated very much with high solar radiation and low wind speed.

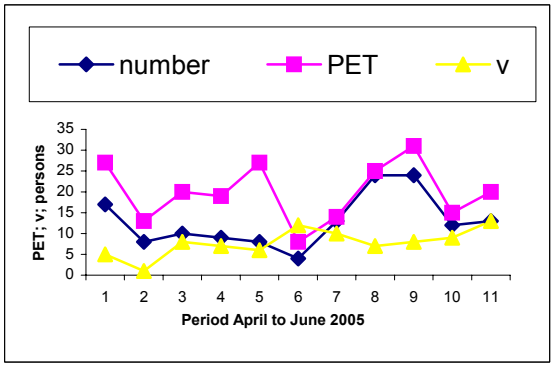


Figure 5: Thermal comfort, wind speed and frequency use of open spaces

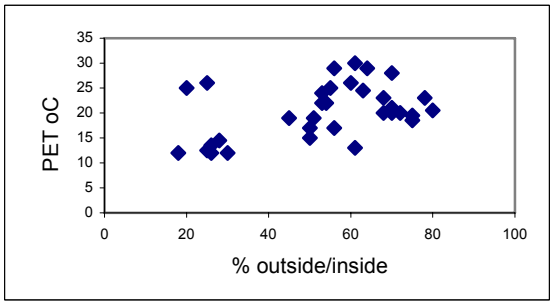


Figure 6: Percentage of people sitting inside / outside of a bistro; from weekly observations

In Figure 6 observations were taken from a bistro, where it was possible to choose between outside and inside. The bistro was mainly used for short breaks during work or shopping During the 11 week's

investigation period from April to June the normal behaviour was an increasing outdoor use with increasing PET. The two exception weeks were combined with rain and higher wind speeds. One can see that the absolute values of PET often exceed neutral conditions but still people were looking for sun in the outside.

5 CONCLUSION

The paper shows that people's behaviour is very much dependent on the thermal outside conditions, but is influence from the expectation of weather and the activities why open spaces are used. Also the paper shows that more simplified measurements and assumption meet the accuracy of results needed. With that planners have a more easy capability to use the urban climate tools for their evaluation. The description of the thermal conditions have to be easily understood and also easily to get. In terms of this evaluation of the thermal conditions it seems possible to use simple assumption to classify thermal sensations. People react on climate objectively in accordance with the calculated thermal indices, but their thermal sensations are combined with individual expectations. Especially as the results are used in an open space design the accuracy must adapted to that perspective and the accuracy showed here are enough to implement thermal comfort into open space design and urban planning processes. More investigations and information are needed for windy weather situations, as here the mean radiation temperature is not as dominant for the thermal sensations as wind speed.

REFERENCES

[1] Bauer, B. (1999), Mikrometeorologische Analyse und Bewertung kleinräumiger Stadtstrukturen, UFZ Bericht, Nr. 18, Leipzig

[2]EU Ruros Project (2004), Design guideline open space planning and comfort, CRES, Athen

[3] Fanger, P.O. (1970), Thermal Comfort, Danish Technical Press, Copenhagen

[4] Höppe, P. (1999), The physiological euquivalent temperature – a universal index for biometeorological assessment of the thermal evironment, Int. J. Biometeorol 43, 71-75

[5] Katzschner, L. (1995); Stadtklima und Stadtstrukturen, Arbeitsberichte der Gesamthochschule Kassel

[6] Katzschner, L. (2002), Bioclimatic Characterisation of Urban Microclimates for the Usage of Open Spaces, Ecole d'Architecture de Nantes (CERMA), International Workshop on Architectural an Urban Ambient Environment, Nantes, Proceedings 6 –8 February (2002)

[7] Nicol, F. (2004), Adaptive thermal comfort standards in hot humid tropics, Energy and Buildings, 36, 628 ff

[8] Nikolopoulou, Baker, Steemers (1998), Improvement of the globe thermometer for outdoor use, Architecural Science Review, Vol. 42 pp 2734

[9] Nikolopoulou, M., Lykoudis, S. (2005); Thermal comfort in outdoor urban spaces, Building Environment, in press

[10] Verein Deutscher Ingenieure (1997), Guideline 3787/2, Environmental meteorology – Methods for the human-biometeorological evaluation of climate and air pollution for urban and regional planning – Part I, Düsseldorf