OPEN SPACE DESIGN STRATEGIES BASED ON THERMAL COMFORT ANALYSIS

Lutz Katzschner

University Kassel, Department of Architecture and Urban Planning, Kassel, Germany

ABSRTACT: Design strategies for open spaces need detailed information about the thermal comfort conditions. The actual use of open spaces is analysed depending on the microclimatic conditions and activities. With measurements, observations and calculations with a thermal comfort model the results could be used for a open place design. The results are demonstrated at two open spaces in Kassel /Germany. The behaviour of the people in open spaces is correlated to the thermal comfort conditions.
Based on that a methodology for thermal comfort mapping is introduced, which gives ideas for an open space design. Evaluation criteria is a thermal index and its spatial variability. For calculation the models townsscope and enviment were used.

Conference Topic: Design strategies and tools
Keywords: open spaces, thermal comfort

1. INTRODUCTION

There is strong public interest to improve the quality of open 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. Therefore, in order to increase use of outdoor space and revitalise cities (new urbanity), the environmental conditions imposed on people using these spaces, which may improve or ruin their experience of them, have to be equally considered.

One the one hand urban development aims more and more in dense built up cities in order to avoid urbanisation in rural areas on the other hand the demographical development enables to use former industrial sites or not longer used unattractive residencial buildings. This effects heat island of the city and reduces the natural ventilation for the first case and gives possibilities for creating an attractive microclimate in case of the second cause. Both situations have to be evaluated towards thermal heat and cold stress situations.

The investigation has aimed s to produce a strategy for urban design that provides planners and decision makers with the appropriate means for effectively assessing the development of cities under consideration of the microclimate of outdoor spaces. By improving urban spaces it is possible to revitalize urban spaces for a new urbanity, which prevents people to move out of the cities. This is achieved by the investigations of thermal comfort with parallel interviews and presentations to planners from the municipalities and politicians.

Open space planning need a precise microclimatic analysis and an evaluation of peoples behaviour in open spaces in dependence of the thermal conditions and activities.

Therefore a methodology was developed for mapping comfort conditions in the urban context results from measurements and calculations. At two places in the city of Kassel /Germany these field surveys were done including measurements, interviews and observations. This is the basic knowledge for the proposed open space design

2. METHOD

The environmental parameters affecting thermal comfort conditions outdoors are dominated by the long and short wave radiation and the wind speed. With this a thermal index, based on the heat balance equation of man, was used and expressed in it's variability, temporally and spatially.

In all the attempts to understand thermal comfort conditions outdoors the physiological model has been used to calculate the thermal index PET. This model was developed by Höppe [1] and applied by matzarakis [2] using the thermoregulatory system of the human body. The results were compared with the subjective responses and observations.

It has said before that microclimatic parameters, especially wind and radiation, strongly influence thermal sensation and the use of open space throughout the year in a different way. Therefore investigations have to consider the daily and annual variation in dependency of the activity and space.

It can be seen from figure one how radiation influences the thermal index PET and that it is in some way sufficient to map sun and shadow to get enough information about radiation for the calculation of thermal comfort.

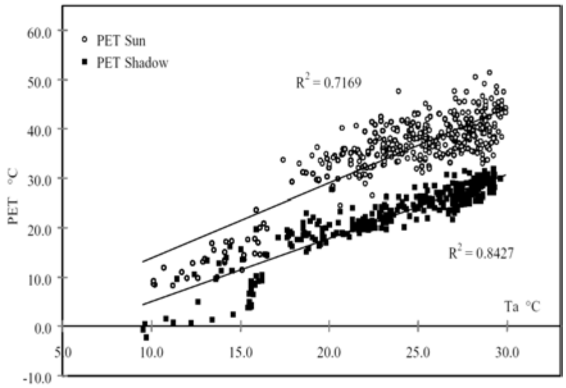

Figure 1: Correlation between Physiological Equivalent Temperature (PET) and air temperature (Tair) between measurements in sunny and shady sites [3]

2.1 Meteorological field surveys

Actual field surveys of open spaces provide detailed information of the microclimatic situation and the resulting comfort conditions. The case study sites have been identified in different city structures with different uses. The frequency and local distribution of the public use was part of the observations

The field surveys were scheduled to take place periodically within a year, to get the seasonal variation, which affects the use of space. People were studied in their natural environment through observations and personal interviews.

Figure 2: Measuring equipment

Objective thermal parameters investigated are later on related to peoples behavior. More specifically, in order to obtain information on air temperature, solar radiation, wind and humidity, dry and wet-bulb temperature is recorded, together with globe temperature, and wind speed. Date were raised in a spatial matter with four fixed points, which were measured regularly and other measurements next to the interviewed people.

The results were meteorological data in a spatial and time solution.

2.2 Mapping of thermal comfort conditions

Figure 4 shows the basic structure of the thermal comfort zoning process developed [4,5]. The most important aim was to focus on an easy-to-use and easy-to-understand tool/methodology addressed and dedicated to the special interest and needs of planners and architects. In consequence, for general use in the context of urban planning, it has been derived a „simple“ methodology taking into consideration three main influencing issues:

- morphology of the site (geometry of buildings, surfaces (ground / facades), vegetation, Fig. 3)
- meteorological parameters and
- time parameters.

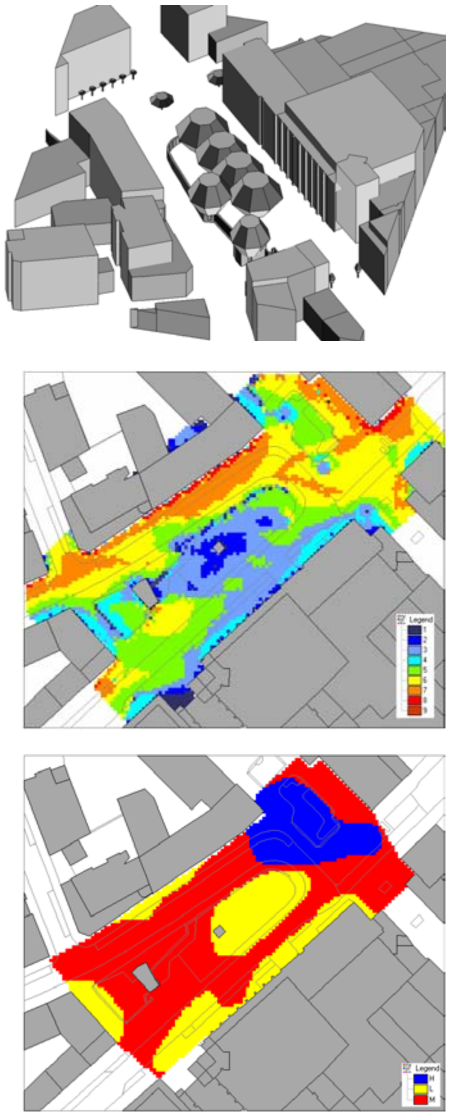

Figure 3: 3 D model with the results of radiation and wind classification

Concerning meteorological parameters there is a focus on solar/thermal radiation and wind speed. These two aspects have a high spatial and temporal variation, causing different comfort situations within one site at the same time. Air temperature and vapor pressure are more homogeneous, so they become important in the context of "calibration" and evaluation.

Concerning time parameters the analysis are concentrated on specific periods of time, to be defined in dependency of underlying questions. Finally a spatial distribution of zones with similar comfort conditions is given, followed by an evaluation in terms of risk or suitability.

The issues design and use of open space are considered as influencing factors/variables acting in two different "directions"; on the one hand they influence the mapping and evaluation results, on the other hand the evaluation can cause the need for changes/adaptation in design, use of space etc.

From the basic structure of figure 4 the interactions of planning, use of open spaces and the influencing factors for thermal comfort is qualitatively described. Especially the behaviour of people in relation to the thermal comfort conditions has to be evaluated and used for design.

In a second step the thermal comfort is mapped quantitatively in different steps. Calculation of spatial radiation and wind pattern with a geographic information system, calibration through measurements and other additional information like the sky view factor.

Figure 5 presents the mapping procedure in more detail. As mentioned before the meteorological parameters radiation and wind are the most influential. In dependency of morphological structure and surfaces these issues will be analyzed (using different tools) and classified. (E.g. short wave radiation can be calculated by TOWNSCOPE software easily; thermal radiation can be derived from global radiation in combination with surface characteristics, also reflected radiation is an important indicator.) The combination of the three thematic maps delivers a thermal zoning which has to be calibrated e.g. by comfort indices out of measurements. With this there is the possibility of adapting the methodology to different climatic zones. An additional consideration of the sky view factor gives important information and assistance in interpreting the comfort situation in the course of year or day.

In comparison with the calculation of state-of-the-art indices (e.g. PMV or PET) the described methodology is quite simple, but it seems to be appropriate in order to facilitate and guarantee the consideration of climatic aspects in planning processes as easily and often as possible.

The calculation of the comfort indices (PET) [6] was done together with parallel interviews and observations of the behaviour of people.

2.3 Interviews/Observations

People have been studied in their natural environment, to evaluate their perception of the thermal environment. Issues affecting the use of space (patterns of use, social groups of people using the space, etc.) were also investigated. For such evaluation, an integrated questionnaire was produced study thermal temptations and behaviour in space through observations [7].

Observations:
- age group, sex,
- activity and social grouping
- locality
- clothing
- consumptions

Questions about thermal sensation:
- very cold; cool; neither nor; warm; very hot
- sun sensibility
- wind sensibility
- humidity

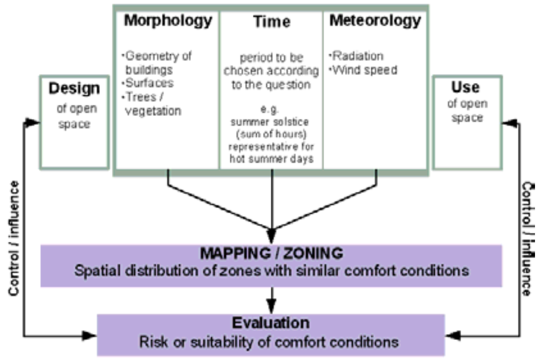

Figure 4: Principle mapping procedure

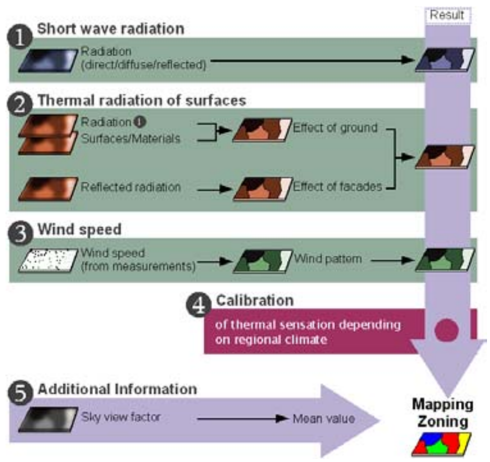

Figure 5: Calculation method for the spatial pattern of thermal comfort

3. RESULTS

From Figure 6, as results from the interviews during the complete case study, it can be seen how people react on the microclimatic conditions. At one place wind is judged always negativly, so that here never could be found any person in comfort even with warm acceptable weather conditions.

More observation in August, with warm conditions and a PET value of 32^{0}C and Oktober with an PET value of 8^{0}C in 2004, show the use of places in dependence from radiation (Figure 7 and 8).

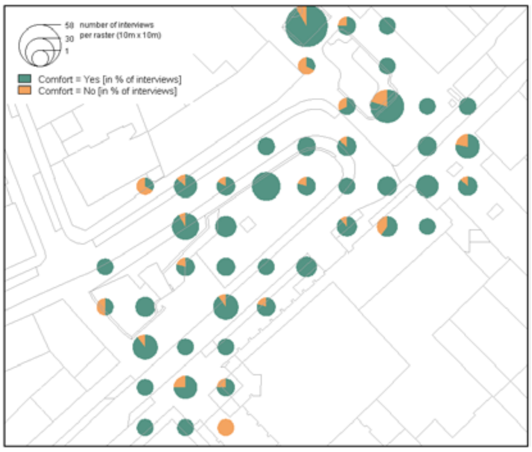

Figure 6: Percentage of people feeling in thermal comfort

How people react on their environment can be seen from figure 7. From the observation during one day in august and one day in October the behaviour of people are different depending on thermal comfort conditions. During the observation period in August the mean value of the thermal comfort index PET was 32^{o}C. Air temperatures around 30^{o}C and moderate wind speed of 2 – 3 m/s. In this situation people look for shadow and ventilation. Only few mainly younger people use the small walls sitting in the sun.

Differently is the situation during October with a thermal index PET of 8^{o}C with no wind and air temperature of 10^{o}C. At this situation sunny places were preferred. The main difference to August is also that people keep standing up even while eating.

At the examples of Kassel in Germany the descibed theoretical approach shall be illustrated by presenting the mapping results. The mapping procedure has been carried out using Townscope [8] and a GIS system.

The thermal comfort zones were derived from the thematic layers "radiation pattern" and "wind pattern". Figure 8 shows the respective maps and the emerging comfort zoning for the Florentiner Platz, referring to a sunny day at summer solstice. The thermal comfort situation is described by a range of several classes representing areas with similar comfort conditions and thermal sensation.

The relationship between the classes and the respective comfort vote depends on the regional climate and is devoted to a certain type of use. For Kassel it has been fixed due to the field survey results of interviews and observations and refers to staying activities, as sitting or standing etc..

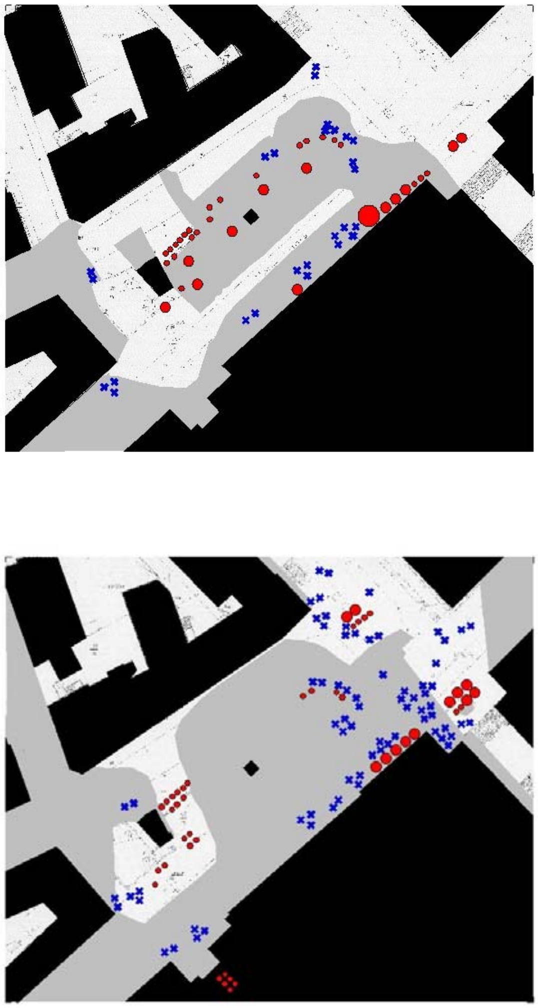

Figure 7: Peoples behaviour of an open space in August (top) and October during a midday situation, dark areas with shadow, blue spots mark standing people and red ones sitting people, circles sizes define amount of people

These results show that in August, warm thermal conditions are used for breaks and neutral thermal situations only for eating and drinking. In October with moderate thermal conditions nobody uses shadow parts for sitting in the bistro Windy places were avoided during all seasons.

The results of the thermal caclulations seen in figure 8 shows thermal classification system of11 classes ranging from cool to warm. Parallel to the calculations the measurements allow to affiliate a certain thermal index value of PET to each class and moreover these valueas were linked to an acitvity level as seen in table 1. The table is based on cameasurments and calculation from different investigation in germany [9]

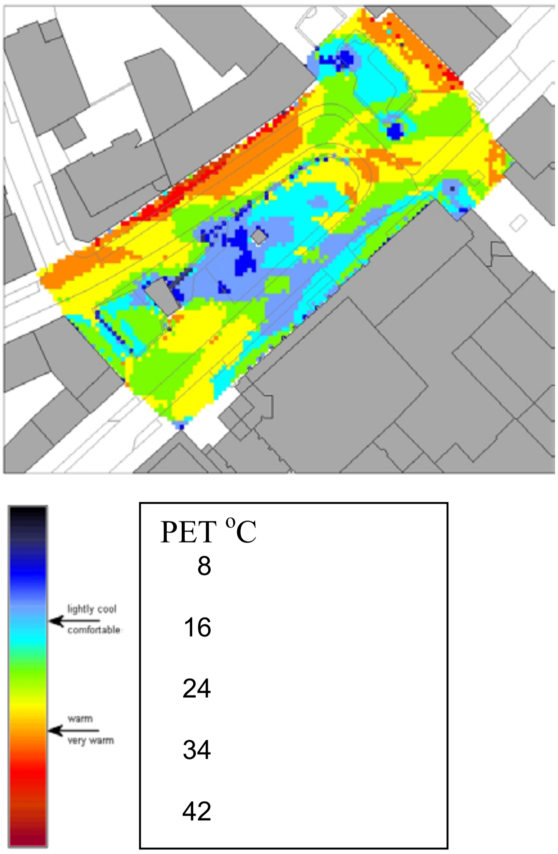

Figure 8: Results of the spatial thermal comfort pattern with 11 classes

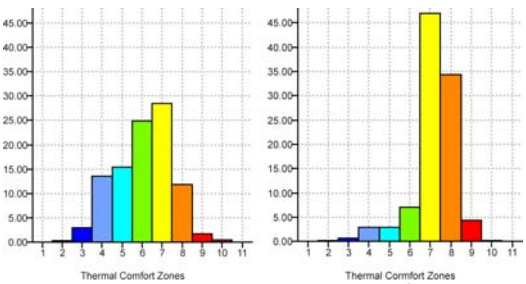

Figure 9: Microclimatic variability for two open spaces in Kassel expressed as frequancy of a thermal classification

For a planning evaluation and the design proposal the results from figure 8 are counted in occurance of there frequency so that the microclimate can be evaluated following a time-space variability (Fig. 9), which expresses the possiblitie of a open space for usage. From figure 9 the high variability's of the Florentiner Platz create more possibilities to choose acceptable places throughout all seasons, while the index of Bahnhofsplatz has a more unique microclimate.

Table 1: Activities and affiliated PET values with the thermal sensation

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

Later on these aspects of the use of places are evaluated for the open space design. In this context elements such as presence of vegetation and water proved beneficial for the microclimate of the space, encouraging the use of it at different seasons. It is apparent that the heavily planted part with a bistro gets particularly busy during warm periods. The same situation is with warm periods for well ventilated parts. In normal weather situation people in Kassel look for warm places. This corresponds with the results from the spatial analysis of the thermal situation from the measurement based calculation figure 8.

4. PLANNING ASPECTS

In this context, design and use of open space are considered as influencing factors/variables for planning aspects acting in two different "directions". On one hand they influence the open space plan in a microscale, on the other hand, the evaluation can cause the need for changes / adaptation in design. It could be seen that the frequency of using open spaces is very much depending from climate but the adaptation in terms of clothing is relevant. For open space planning a inhomogeneous urban climate structure is needed to create different microclimates which increases the use of space. The consideration of different climates and customs of people is important.

For discussion the Florentiner Platz is taken as an example with a widely spread microclimate conditions, which is seen as positive for people. The microclimatic pattern allows a high frequency of use of all places during different seasons and times of a day. This meet in a very sufficient way peoples needs and demand for that place. Planning proposals only have to be directed to wind problems in spring and autumn. There wind protection zones are needed .

A final conclusion with concrete proposals is derived in Fig 11.The proposal was based on the actual land use pattern, observations in relation to microclimate results.

Figure: 10: Picture of Florentiner Platz during August with a air temperature of 31°C and PET of 42 °C

People avoid sun during the situation seen in figure 11 but look for shadow with an PET of 32 °C

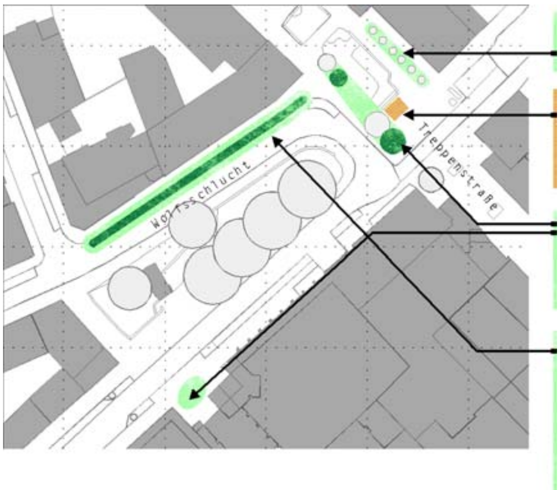

Figure 11: Design proposals arrows from top to down:

- vegeation with middle high bushes at the north eastern sitefor wind protection and reduction of glaring effects,
- creation of sitting facilities in the sun,
- wind protection with a mix of smaller vegtetion and trees
- establishing of a wind breaking obstacle
- change of sufraces and green faccades for a reduction of surface tmeperatures and shadow effects.

5. CONCLUSION

Concerning the interviewees perception and evaluation as well as use of space it can be stated from the field surveys, that people (in Kassel/ Germany) like to have a certain grade of physiological (heat) stress. Sunny areas (with PET values > 22^{0}C) have been requested and preferred almost all through the year. Only during really hot summer days more and more people complained about discomfort and the comparatively cooler (shady and windy) zones became frequented and evaluated as comfortable.

REFERENCES

[1] P. Höppe, The physiological euquivalent temperature – a universal index for biometeorological assessment of the thermal evironment, Int J Biometeorol 43 (1999) 71-75,
[2] A.Matzarakis, Die thermische Komponente des Stadtklimas, Berichte des Meteorologischen Institutes der Universität Freiburg Nr. 6, (2001)
[3] B. Bauer, Mikrometeorologische Analyse und Bewertung kleinräumiger Stadtstrukturen, UFZ Bericht, Nr. 18, Leipzig 3/1999
[4] L. Katzschner, 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)
[5] U. Bosch, L. Katzschner, M. Röttgen, Analyse der thermischen Komponente des Stadtklimas für die Freiraumplanung, UVP Report, Nr:3/2002
[6] Verein Deutscher Ingenieure, Richtlinie 3787/2. Environmental meteorology – Methods for the human-biometeorological evaluation of climate and air pollution for urban and regional planning – Part I, Düsseldorf, (1997)
[7] EU Ruros Project, design guideline compiled by CRES, Athen, (2004),
[8] Teller, J. and Azar, S. (2001). TOWNSCOPE II A computer system to support solar access decision-making, In Solar Energy, Vol. 70, No. 3, pp. 187-200
[9] L. Katzschner, U. Bosch, M. Röttgen,Behaviour of people in open spaces in dependency of thermal comfort conditions, In Design with the environment, Proceedings of the 19th International Conference PLEA (Passive and Low Energy Architecture), Toulouse-France, 22nd - 24th July 2002, pp. 411-415.