

## **THE VISITORS' ATTENDANCE ON A SQUARE ACCORDING TO THE THERMAL COMFORT CONDITIONS – CASE STUDY IN SZEGED (HUNGARY)**

Noemi Kantor, Lilla Egerhazi, Agnes Gulyas, Janos Unger  
University of Szeged, Department of Climatology and Landscape Ecology, Szeged, Hungary

### **Abstract**

To obtain a comprehensive picture on how the design of an urban square can influence the visitors' number and their spatial distribution, an observation-based human comfort examination project was conducted in the city of Szeged (Hungary, Central-Europe) in the spring of 2008. Parallel with unobtrusive observations, measurements of thermal comfort variables (air temperature, air humidity, wind speed and global radiation) were carried out. The aim of the study was to reveal the relationship between the thermal environment, the use of the square and visitors' behavioral patterns. Several subjective parameters were recorded to prove the supposed distribution-difference between the various groups of people.

**Key words:** urban square, human comfort, area usage

### **1. INTRODUCTION**

The quality of open urban spaces is a strong public interest, as parks and squares could play an important role in the recreation and outdoor activities of citizens. Besides air pollution, noise level, aesthetics and accessibility, human thermal comfort is one of the most critical parameter for the use of urban public places, therefore evaluation of thermal comfort and stress conditions of them is highly important (Mayer 2008). With this object, a detailed examination of an urban green space was performed which included thermal comfort index-based assessment (objective aspect) together with human monitoring (subjective aspect). The main objective of this paper is to present some of the issues of the above mentioned study aimed to reveal the pattern of use of the selected area as a function of the thermal comfort conditions.

### **2. MATERIALS AND METHODS**

#### **2.1. Study area**

Our thermal comfort examinations took place in the city of Szeged, located in the south-eastern part of Hungary, Central-Europe (46°N, 20°E) at 79 m above sea level, with a population of 160,000 (Fig.1). The climate of the region belongs to the Köppen's Cf (temperate warm climate with uniform annual distribution of precipitation) or the Trewartha's D.1 (continental climate with a long warm season) category. A green area locating by the University of Szeged in the heavily built-up city centre was selected for the investigations, which is approximately 4500 m<sup>2</sup> and it is divided by a pavement from southwest to northeast. The greater part with grass coverage lies on the southeastern side where some young (4-5 m tall) trees have planted along the pavement, which offer only scanty shade. This site is girdled around by a morphological step, so its ground surface is about 1 m lower as the ambient areas. The northwestern side is shaded by a plenty of 20-30 m tall trees, so it has quite different microclimate. 10 benches offer places for relaxation, two on the northeastern and southwestern end of the grassy area, and 8 along the pavement (Fig.1).

#### **2.2. Methods**

A case study was conducted in spring 2008 between 10<sup>th</sup> April and 15<sup>th</sup> May to reveal the use of the selected green area as a function of the thermal comfort conditions. The investigations consist of unobtrusive observations of the naturally occurring behavior of the visitors (human monitoring) and simultaneous meteorological measurements (environmental monitoring).

In the frame of the human monitoring occurred Tuesday, Wednesday and Thursday (except 1<sup>st</sup> May as a holiday) from 12 to 15 p.m. people were counted cumulatively in half hour periods, their positions were marked on the map of the examined square (Fig.1), and some of their personal features were also notice according to the following categories:

- gender: male / female
- age: child / young / middle aged / old
- type of activity: active e.g. walking or playing / passive e.g. lying, sitting or standing
- position: in the sun / in penumbra / in the shade (only when it was sunny)
- clothing insulation: < 0.5 clo / 0.5 – 1 clo / 1 clo <

As the aim was to study the recreational aspects of the area usage according to the thermal conditions, people passed only through the area were not included. Only people who linger relatively long time on the site became subjects of our investigations. On the whole this means 2448 visitors in the measuring period.

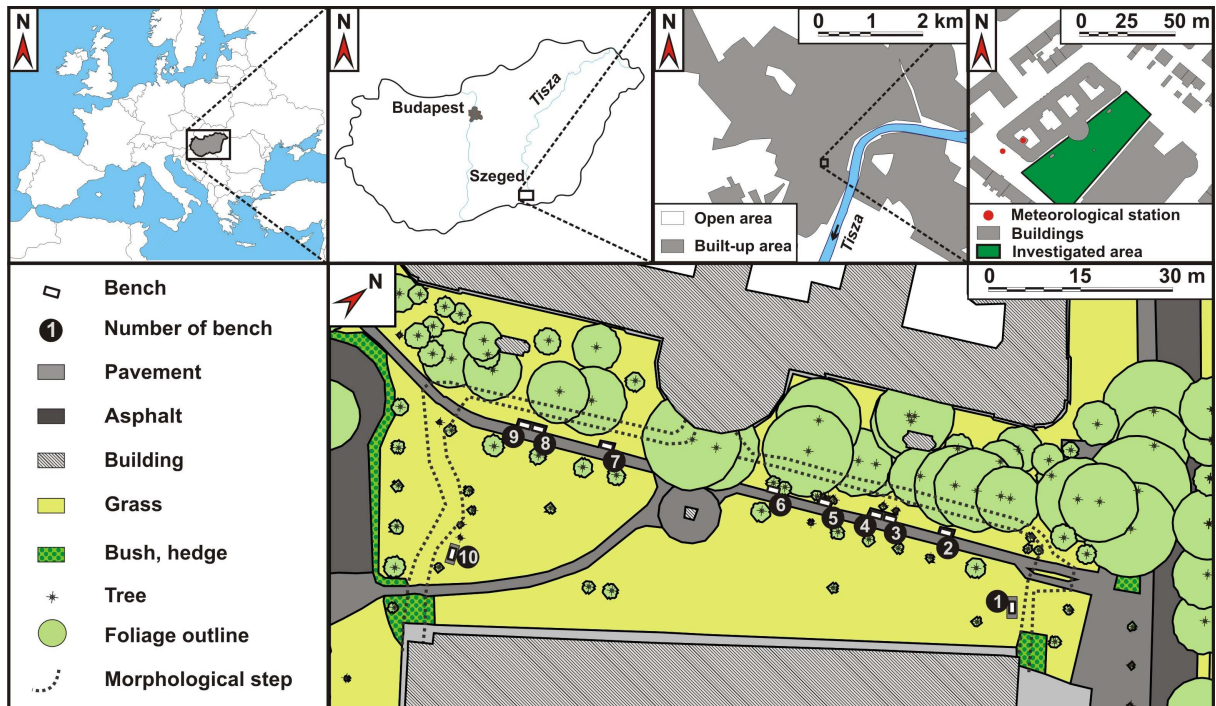


Fig. 1 Location of Hungary in Europe, Szeged in Hungary, the study area in Szeged as well as its detailed map

For objective thermal comfort assessments Fanger's Predicted Mean Vote (PMV) was calculated from the ten minute averages of air temperature, relative humidity, wind velocity and global radiation. This index represents the predicted mean vote of a large sample of humans exposed to given thermal conditions – at given activity level and at given clothing insulation – on a thermal sensation scale (Fig. 2), on which the neutral (comfortable) thermal sensation is assigned a PMV value of zero (Fanger, 1972).

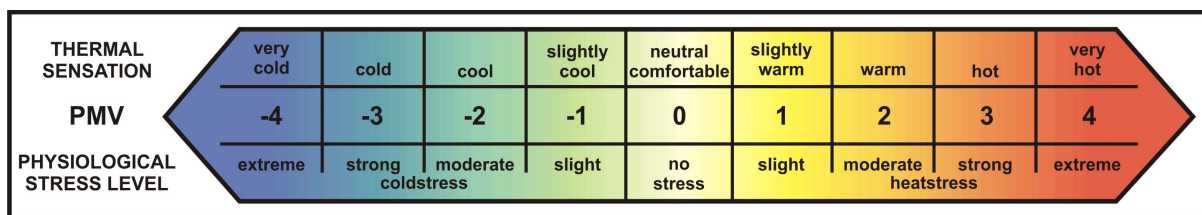


Fig. 2 PMV (Predicted Mean Vote) values for different thermal sensations as well as stress levels

Temperature and humidity data have been obtained by a stationary QLC 50 automatic station which is situated in the investigated green space near to the building of the University of Szeged. The wind velocity and global radiation sensors are located on the top of the building, so wind speed data had to be reduced to the reference height of 1.1 m (the average height of an adult's gravitation center) according to the next formula:

$$v_{1.1} = v_h \cdot (1.1/h)^\alpha \quad \alpha = 0.12 \cdot z_0 + 0.18,$$

where  $v_h$  is the wind speed ( $\text{ms}^{-1}$ ) at the height of  $h$  (m),  $\alpha$  is an empirical exponent, depending on the surface roughness,  $z_0$  is the roughness length. In our case  $h = 26$  m and  $z_0 = 0.42$ , as the sample area is in a densely built-up city center.

The PMV calculations were taken at all times on a 'standard European subject', a 35 years old, weight of 75 kg and 1.75 m high, sedentary man in light clothing (0.9 clo). The computation process took place with the help of the radiation- and bioclimate model RayMan developed according to guideline 3787 of the German Engineering Society (Gulyas et al., 2006). Two main cases of index calculations have to be distinguished: without and with environmental morphology.

The first one represents the situation if there would not been radiation modifying obstacles. This set of data is subservient to use at the start of an outdoor thermal comfort analysis to characterize the thermal comfort

conditions of the measurement days. This objective values can be compared with data from human monitoring, so the attendance on the whole or in the cases of different 'sectors' of the area can be analyzed as a function of the momentary PMV values.

To demonstrate the individual thermal conditions of the above mentioned sectors surface morphological data have to be taken account in the course of index-calculation (second case). This means the ambient buildings as well as trees with their radiation properties (albedo and emissivity) which modify the radiation fluxes. By this way the thermal characterization of some selected points on the area can be achieved without additional meteorological measurements.

### 3. RESULTS AND DISCUSSION

The subjects' distribution according to gender showed that there were roughly two times more female as male, furthermore the majority (more than 90%) rated to the 'young' age category. They belonged very likely to the students of the University of Szeged and came to the area to hang out between their lectures. The measuring period was characterized by a persistent warming, though the occurred PMV values reveal the versatility of the thermal comfort conditions in spring. The rainy days, 16<sup>th</sup> April and 23<sup>rd</sup> May for example, entailed the relapsing of the circumstances in the term of the common negative PMV values, meaning high probability of discomfort due to cold sensation. Occurrence of positive PMV values greater than 1 was attributable to the calm conditions, to the high air temperature and principally to the high global radiation values by the cloudless sky. Strong heat stress indicated by high PMV values occurred only on the last two measurement days (Fig.3). Examination of the attendance in accordance with the thermal comfort conditions (expressed in the terms of PMV values) revealed strong positive correlation ( $r = 0.85$ ). While in the case of cold-cool categories the attendance converges to zero, it shows a greater numbers and remarkable scatter by the slightly warm, warm and hot categories.

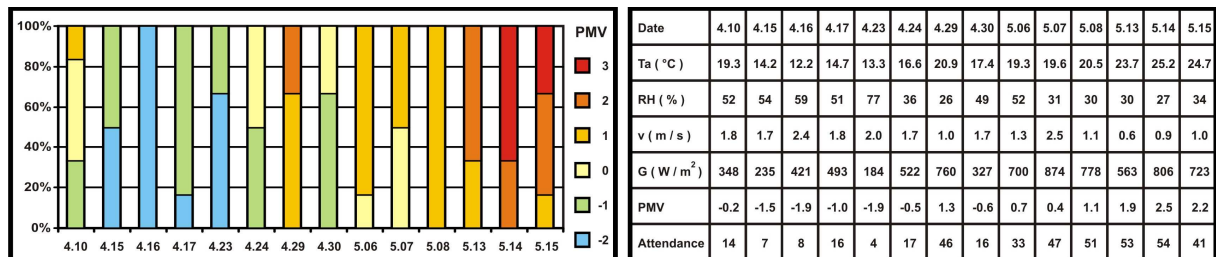


Fig.3 Thermal conditions of the measurement days in terms of the frequency distribution of the individual PMV categories, as well as in terms of the mean values of the thermal variables occurred between 12 to 3 p.m

Although the observed thermal conditions of 14<sup>th</sup> May were principally stressful considering the high frequencies of PMV values 2 and 3, the most visitors were found on this day. Such a high attendance in spite of these physiologically harmful circumstances can be explained by the mechanisms of the physical and psychological acclimation. Due to the area design, people had the chance to choose that 'sub-area' (sector) which offers the most supportive micro-bioclimate situation, so in the case of strong solar radiation visitors can move, for example, on the shaded morphological step. Fig. 4/A unequivocally shows the increasing proportion of subjects in the shade or in the penumbra with the higher PMV values. Besides this way of physical acclimation, visitors can decrease the heat strain affecting their body by changing their clothing as well as the level of activity. In warmer situations people tend to wear light clothing with decreased insulation values (Fig. 4/B), additionally the generally dominant passive forms of activity (i.e. sitting, lying or standing) became even more often, while the number of walking or playing subjects completely disappears (Fig. 4/C). Worthy to note, that the proportion of male subjects slightly decreased with the warmer conditions (Fig. 4/D).

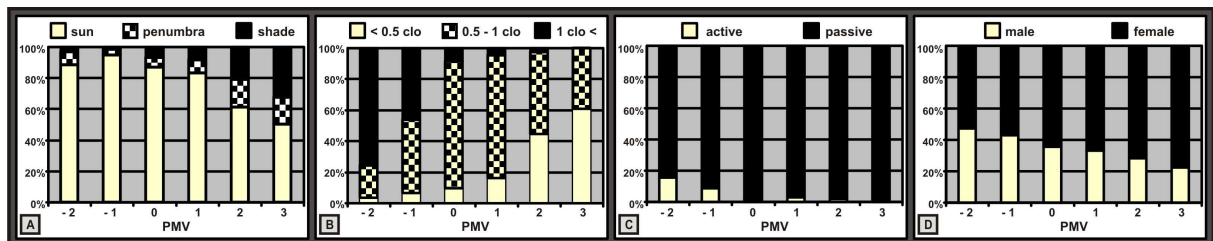


Fig. 4 The visitors' position (A), clothing (B), form of activity (C) and gender (D) according to the PMV categories

To study the spatial pattern of the area usage five sectors were defined in the examined square. The 1<sup>st</sup> one consist of the 10 benches, the 2<sup>nd</sup> is the pavement area, the 3<sup>rd</sup> is the great grassy area stretches on the southeastern side, since the remaining two sub-areas lie on the northwestern side of the pavement. The 4<sup>th</sup> includes the morphological step and the 5<sup>th</sup> sector locates under the tall, old trees. All sectors had the highest number of visitors (absolute attendance) when there were clear sky and warm thermal conditions, but the relative

attendance of the selected sub-areas showed remarkable tendencies according to the amount of sunshine and PMV values (Fig.5). The relative usage of the benches was dominant by cloudy sky and lower PMV values. With the increasingly amount of global radiation and by warmer (PMV > 0) situations the greater portion of visitors stayed on the grass as well as the relative attendance of the morphological step and the shady sector under the old trees become higher. This can be attributed to the fact that the seating capacity of the benches is obviously limited, so in the cases of warmer conditions (which can be characterized by greater number of visitors) more and more subjects had to take seats on the other sectors. On the other hand, by higher PMV values associated with sunny conditions many people came into the area to take a sunbath, furthermore the nature and extent of the grassy sector permitted to take place even in greater bunches. Physical acclimation of people in the cases of warm-hot circumstances is showed by the increasing percentage of subjects on the shady-penumbra sectors (4<sup>th</sup> and 5<sup>th</sup>). The distortion of the above mentioned tendencies in the case of the lowest PMV values (-2) is due to that by this situations the absolute attendance was significantly lower than in other cases.



Fig. 5 Percentage distribution of the visitors between the selected sub-areas according to the momentary PMV values and sky conditions

In the next stage of the examination the attendance of these sectors will be compared with their very own thermal conditions. They will be expressed in terms of PMV values calculated by using the measured air temperature and air humidity, the measured and reduced (to 1.1 m) wind velocity and the obstacles-modified radiation values. Latter will be simulated by means of the RayMan model from the measured global radiation data according to the method written in the section 2 as 'PMV calculation with environmental morphology'. First of all comparison of the 10 benches – as evident sitting places – will be performed, as well as the analysis of other sectors with considerably different morphology (large grassy area, the morphological step and the northwestern side of the area shaded by old trees).

#### 4. CONCLUSIONS

Even in the case of warm and hot thermal conditions a fair number of visitors stayed in the sun (Fig. 4/A), which advert the high importance of the psychological factors affecting the human thermal comfort. Viz. a large number of subjects came to the green area to enjoy the stimulating effects of the sunshine, to become refreshed and filling up both physically and psychologically, what is more, some of them took a sunbath by lying on the grass (Fig. 5). Referring to Nikolopoulou and Steemers (2003) and Thorsson et al. (2004), people expose themselves voluntarily to given thermal conditions, can leave the place when they wish as well as have the choice to select from various microclimatic opportunities within the place, become more tolerant to the thermal environment and dwell longer against even the physiologically stressful conditions.

In addition, there are two important facts needed to mention. Firstly, beside the friendly design the accessibility of the area affects also positively the number of people using them. On the other hand, harmful PMV values (PMV > 2) did not occur frequently during the investigations, as they were conducted in springtime, so a case when people took themselves to extreme stressful conditions for a relative long time did not eventuate.

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