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ATTENDANCE OF A GREEN AREA IN SZEGED ACCORDING TO THE THERMAL COMFORT CONDITIONS

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Summary − The object of the present study is the assessment of the thermal comfort conditions of an urban green area at Ady square in the city of Szeged (Hungary) using modern human-biometeorological methods. Human monitoring was conducted on the study area three times a week (Tuesday, Wednesday and Thursday) from 10th April to 15th May 2008. This includes the counting of the visitors from 12 to 3 p.m., marking their position on a map as well as recording some personal features. These subjective data sets were compared with objective human-biometeorological index values reflecting the thermal comfort conditions of the area created from meteorological data measured on the site. This examination throws some light on which the most suitable thermal conditions are for staying in the area as well as which parts of the place are preferred to the others according to the actual thermal situation. It is also discussed how area design could affect positively the number of people staying longer on the site.

Key words: urban green area, thermal comfort investigation, environmental monitoring (meteorological measurements), human monitoring (observation of people)

1. INTRODUCTION

Because of the increasing urbanization the number of people affected by the strains of the urban environment rapidly increased in the last century. It is very important to predict the effects of the changes occurring through the intervention of various strategies of urban planning, because they affect the micrometeorological characteristics and therefore the well-being, performance and health conditions of the citizens. To make such predictions the physiological aspects of thermal conditions in existing urban microenvironments (e.g. streets, squares, courtyards) need to be examined at the first stage. This can be performed by means of thermal indices, which are able to quantify the effects of measured meteorological parameters on the human thermal sensation, consequently on the state of comfort-level.

According to regional climate models heat waves will be more frequent, more intense and permanent in the future (Bartholy and Pongrácz 2006), so human-biometeorological aspects with the aim to optimize human thermal comfort and reduce the hazard of heat stress gain prestige in the field of urban planning. The best way to improve the disadvantageous bioclimatic conditions is the establishment of urban greenery e.g. parks and squares. The planting of trees is a good solution even in the case of old 'inherited' city structure (Gulyás et al. 2006).

The quality of open spaces in urban areas 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 parameters for the use of urban public places, therefore the evaluation of thermal comfort (and stress) conditions of these is highly important (Mayer 2008). With this objective, a detailed examination of a green space in the centre of Szeged was performed, which, in accordance with the recent human bioclimatolological methods, included thermal comfort index-based assessment (objective aspect) together with human monitoring (subjective aspect).

The main objectives of the present paper are:

(i) to throw some light on the topic of human thermal comfort and its evaluation with human-biometeorological methods, and

(ii) to present some of the issues of the above-mentioned study in Szeged aimed to reveal the pattern of use of an urban green area as a function of the thermal comfort conditions.

2. HUMAN-BIOMETEOROLOGICAL METHODS FOR THERMAL COMFORT ASSESSMENT

2.1. Human thermal comfort

First and foremost the term ‘human thermal comfort’ needs to be clarified. There are three main aspects of the topic based on psychological, thermophysiological as well as physical (energetic) approaches. According to the first one, thermal comfort is a condition of mind which expresses satisfaction with the thermal environment. The lack of thermal comfort (neutral thermal sensation) eventually results in feeling either warm or cold.

The thermophysiological definition states that when thermal comfort exists the firing of the thermal receptors in the skin and in the hypothalamus is minimal. The third approach is based on the energy balance of the human body. According to it human thermal comfort can be achieved when the heat generated by the metabolism added to the heat gain from the environment are balanced with the heat loss to the environment. Any heat gain or loss beyond this generates the sensation of thermal discomfort (Höppe 2002, Mayer 2008).

Besides the thermal environment, human thermal comfort depends on a number of other (mainly subjective) factors, therefore it is almost impossible to predict thermal comfort for individuals; it is mostly related to a group of people.

2.2. Objective methods for assessing thermal comfort

To estimate the thermal comfort conditions of a site in an objective way, energy-balance model based indices have to be calculated from weather parameters influencing the thermal sensation. These factors – namely air temperature, air humidity, wind velocity as well as (solar and terrestrial) thermal radiation – are obtained either by field measurements or by numerical simulations.

Up to now several indices were created which describe the thermal comfort (or stress conditions) of indoor or outdoor environments. The first ones combined only two or three from the above-mentioned meteorological agents empirically and ignored the body parameters. The recent indices are based on the energy-balance model of the human body which contains the most important mechanisms of thermoregulation (contraction and dilatation of peripheral blood vessels, sweat secretion and shivering). They also take into account the insulation of clothing and the level of activity besides the meteorological factors (Höppe 1993). In the last decades several models have been developed, of which Fanger's (1972) comfort equation and the Munich Energy-balance Model for Individuals − MEMI (Höppe 1984) are the best known. The resulting complex comfort indices are the Predicted Mean Vote (PMV) and the Physiologically Equivalent Temperature (PET), which evaluate the thermal conditions and the thermal stress affecting the body in a physiologically significant manner.

PMV was derived originally from Fanger's comfort-equation for indoor climate, but after Jendritzky incorporated this equation in his Klima-Michel Model, the resulting PMV became suitable for assessing the different outdoor thermal environments too (Mayer 1993). It represents the predicted mean vote of a large sample of humans exposed to given thermal conditions on a thermal sensation scale, on which the neutral (comfortable) thermal sensation is assigned a PMV value of zero (Fig. 1).

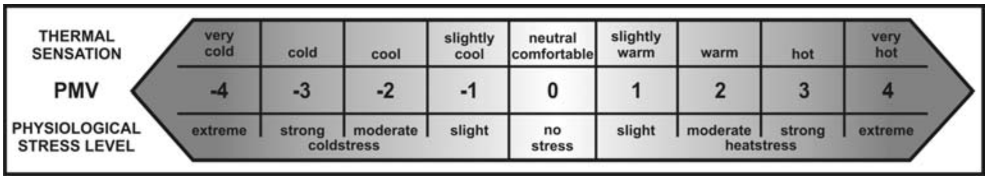

Fig. 1 PMV (Predicted Mean Vote) values for different thermal sensations as well as stress levels

2.3. Subjective methods

A thorough thermal comfort examination should include subjective approach besides the objective ones, because thermal comfort, especially outdoors, depends not only on the above-mentioned physical factors (air temperature, humidity, wind velocity thermal radiation, as well as activity and clothing insulation), but also on different subjective features (e.g. personal characteristics and general feelings). They influence the acclimation and acclimatization of people to climate and weather conditions through physiological and psychological effects (Fig. 2) (Nikolopoulou and Steemers 2003, Nikolopoulou and Lykoudis 2006, Knez and Thorsson 2006).

There are two main types of methods to obtain additional information about subjects included in a thermal comfort study: social surveys (questionnaires, structured interviews) and unobtrusive observations. By means of questionnaires more detailed information could be obtained about the visitors' thoughts, preferences and intentions, but since this kind of method can be both reactive and unrealistic, unobtrusive observations of the natural behavior may be preferable (Thorsson et al. 2004).

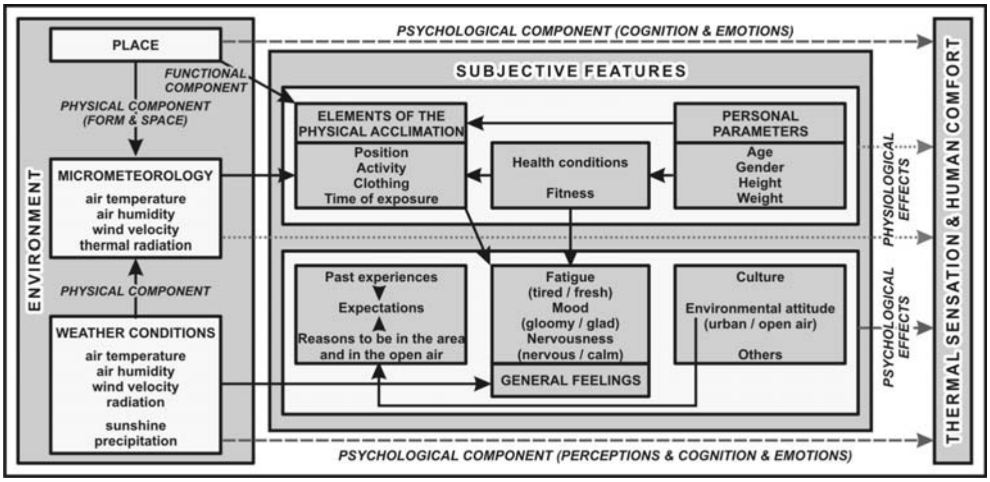

Fig. 2 Factors influencing the thermal sensation and comfort and their relationships with each other

3. MATERIALS AND METHODS

3.1. Description of the study area

Our thermal comfort examinations took place in the city of Szeged, located in the south-eastern part of Hungary (46ºN, 20ºE) at 79 m above sea level, with a population of 160,000 (Fig. 3). The climate of the region belongs to Köppen’s Cf (temperate warm climate with uniform annual distribution of precipitation) or Trewartha's D.1 (continental climate with a long warm season) category (Péczely 1979). Since both the great attendance and the adjacent position to the meteorological station by the university were important considerations for the investigations, a green area situated between the five-storey building complex of the University of Szeged and the József Attila Study and Information Centre (in the heavily built-up city centre) were selected (Fig. 3).

The study area is approximately 4500 m^2 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 been planted along the pavement, which offer only scanty shade. This site is surrounded by a morphological step, so its ground surface is about 1 m lower as the ambient areas. The northwestern side is shaded by a group of 20-30 m tall trees, so it has a 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.

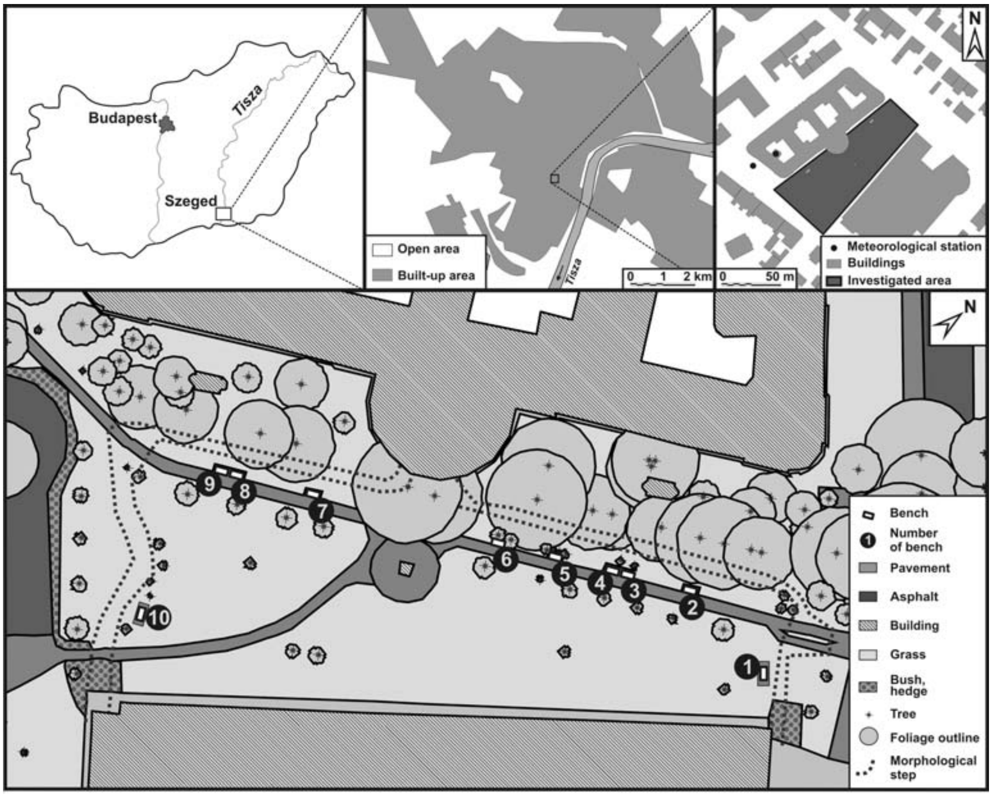

Fig. 3 Location of Szeged in Hungary and the study area in Szeged as well as its detailed map

3.2. Methods

A case study was conducted in spring 2008 between 10th April and 15th 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 natural behavior of the visitors (human monitoring) and simultaneous meteorological measurements (environmental monitoring). 22nd April was later excluded from the database, as the attendance did not primarily depend on the thermal conditions but on the organized outdoor programs on the occasion of Earth's Day, which raised the number of visitors to a great extent.

3.2.1. Subjective method – Human monitoring

Human monitoring was carried out every Tuesday, Wednesday and Thursday (except 1st May as a holiday) from 12 to 15 p.m. People were cumulatively counted in half hour periods, their positions marked on a map (see on Fig. 3), and some personal features were also noted. The recorded subjective parameters include 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) and the clothing insulation. The insulation of clothes is often measured with the unit 'clo', where 1 clo (= 0.155 m^2KW^{-1}) corresponds to a person wearing a typical business suit and 0 clo means a naked body. Since the observations were carried out in spring, the following three clo-categories were created: (1) under 0.5 clo e.g. short and T-shirt, (2) 0.5-1 clo e.g. trousers and light pullover and (3) above 1 clo e.g. additional jacket or thick vest.

From 15th April attendance was recorded also every ten minutes on the whole and, if it was possible, according to whether the visitors stayed in the sun or in the shade. Since the aim was to study the recreational aspects of the area usage according to the thermal conditions, only those people became subject to our investigations who lingered on the site for a relatively longer time. People who either worked or only passed through the area were not included in the examination.

3.2.2. Objective method – Environmental monitoring

For the objective thermal comfort assessment of outdoor (urban) areas such thermophysiologically based indices are mainly recommended which were developed directly for the outdoor conditions (e.g. the Physiologically Equivalent Temperature – PET). We have chosen, however, the expressive Predicted Mean Vote – PMV, which was developed originally for indoor situations and only later was transferred to outdoor conditions, due to this index is easy to interpret. Furthermore, the case study was carried out in springtime when extreme index values ordinary were not expected.

The PMV values were calculated from the ten-minute averages of air temperature, relative humidity, wind velocity and global radiation. Temperature and humidity data have been obtained by a stationary QLC 50 automatic station which is situated in the investigated green space near the University building (Fig. 3). Since global radiation and wind speed was measured on the top of the University building (Fig. 3), wind speed data had to be reduced to the reference height of 1.1 m (the average height of an adult's gravitation centre) according to the following formula (Kuttler 1998):

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

where v_h is the wind speed (ms^{-1}) at the height of h (m), α 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 the densely built-up inner city.

The index calculations took place with the help of the radiation and bioclimate model RayMan developed according to Guideline 3787 of the German Engineering Society (Gulyás et al. 2006). Two main cases of index calculations have to be distinguished: without or with environmental morphology. The first one represents the situation if the subject would stay on a plain surface with no horizon limitations, i.e. there would not be any radiation-modifying obstacles. This set of data was used to characterize the thermal conditions of the measurement days. In the second case all buildings, deciduous and coniferous trees were taken into account with their radiation properties (albedo and emissivity), which modify the radiation fluxes. This way the thermal characterization of some selected points in the area was carried out, in order to compare them on the score of their thermal conditions. The calculations were taken in all cases on a 'standard European subject', a 35 years old, sedentary man in light clothing (0.9 clo), 1.75 m high and weighing 75 kg.

4. RESULTS AND DISCUSSION

4.1. Thermal comfort conditions of the measurement days

The subjects' distribution according to gender showed that there were roughly twice as many females as males; furthermore the majority (more than 90%) rated to the 'young' age category. They were very likely to students of the University of Szeged and came to the area to hang out between their lectures.

According to Fig. 4 a persistent warming could be perceived in the measuring period, though the frequency distribution of the PMV categories reveal the versatility of the thermal comfort conditions in spring. The rainy days, 4th April and 23rd May for example, entailed the deteri-oration of the circumstances in terms of the common negative PMV values, meaning high proba-bility of discomfort due to cold sensation. At the same time 29th April proved the warmest day in the fourth month, because of the high global radiation values due to cloudless conditions. Strong heat stress indicated by high PMV values occurred only in the last measurement week.

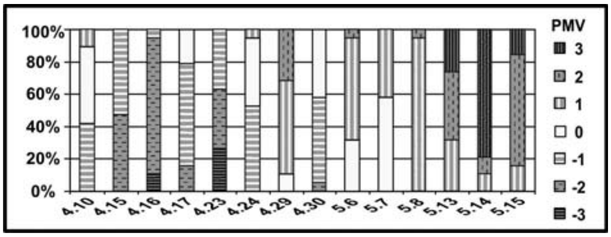

Fig. 4 Thermal conditions of the measurement days between 12 to 3 p.m. in terms of the frequency distribution of the individual PMV categories

4.2. Attendance according to the thermal comfort conditions

The attendance is going to be discussed in accordance with the thermal conditions first taking the detailed dataset resulting from the ten-minute human and environmental monitoring. Plotting the number of visitors as a function of the PMV values at the given moment positive correlation can be seen between the two measures (Fig. 5). While in the case of cold-cool categories the attendance converges to zero, it shows greater numbers and a remarkable scatter by the slightly warm, warm and hot categories. It is worth to mention that the average attendance rises suddenly in days with conditions significantly warmer than on the previous ones, presumably due to the absence of the former cloudy weather conditions. The days of 17th and 29th April and 7th May offer excellent illustrations for this phenomenon (Table 1).

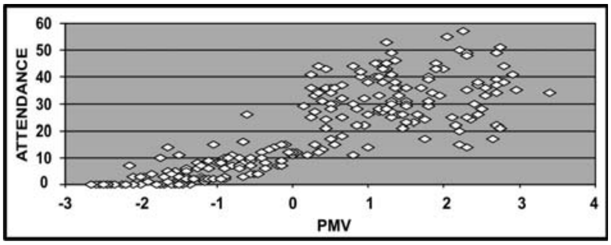

Fig. 5 Attendance of the study area as a function of the thermal comfort conditions

Table 1 Daily mean attendance for the measuring period 12 to 3 p.m. calculated from the ten-minutes data

Date	15 Apr	16 Apr	17 Apr	23 Apr	24 Apr	29 Apr	30 Apr	06 May	07 May	08 May	13 May	14 May	15 May
Mean attendance	3	3	11	1	9	31	6	22	34	36	37	38	28

Although the observed thermal conditions on 13th and 14th May were principally stressful considering the high frequencies of the PMV values 2 and 3, the most visitors were found on these days. Such a high attendance in spite of these physiologically harmful circumstances can been explained by the mechanisms of physical and psychological acclimation. Due to the area design, people had the chance to choose that ‘sub-area’ which offers the most favourable micro-bioclimatic conditions, so in the case of strong solar radiation visitors can move, for example, to the shaded morphological step. Fig. 6/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. 6/B), additionally the generally dominant passive forms of activity (i.e. sitting, lying or standing) become even more common, while the walking or playing subjects completely disappear (Fig. 6/C). It is worthy to note that the proportion of male subjects slightly decreases with the warmer conditions (Fig. 6/D).

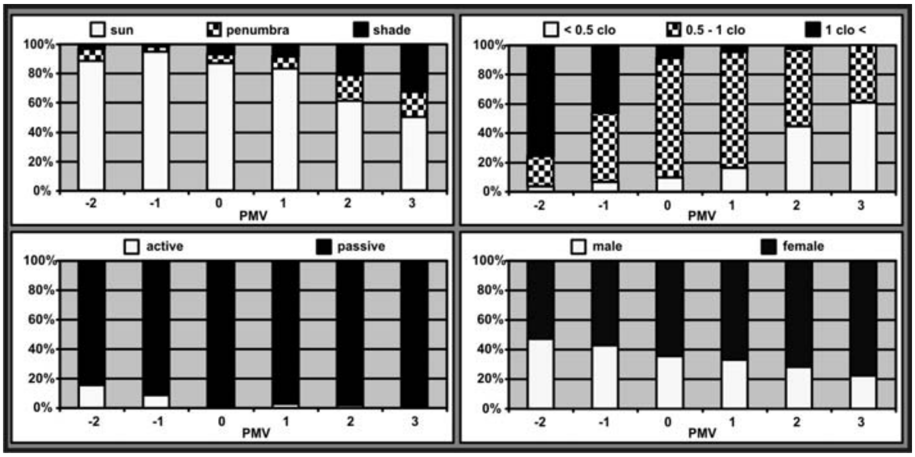

Fig. 6 The visitors’ position (A), clothing (B), form of activity (C) and gender (D) according to the observed PMV categories

Even in the case of warm and hot thermal conditions a fair number of visitors stayed in the sun (see Fig. 6/A), which adverts the high importance of the psychological factors affecting human thermal comfort. This means a large number of subjects came to the green area to enjoy the stimulating effects of sunshine, to become refreshed and fill up both physically and psychically. Some of them even took a sunbath by lying on the grass. According to international experts of the topic (Nikolopoulou and Steemers 2003, Thorsson et al. 2004), people who expose themselves voluntarily to given thermal conditions, those who can leave when they wish as well as those who have the choice to select from various microclimatic opportunities within the place, become more tolerant to the thermal environment and stay longer despite even the physiologically stressful conditions.

There are two important facts to mention. Besides the friendly design, the accessibility of the area also affects 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 relatively long time did not occur.

4.3. Spatial pattern of the attendance

In the next stage of this investigation some sectors of the area will be compared according to their usage and their thermal characteristics which is expressed in terms of PMV calculated by using the measured air temperature and humidity, the reduced (to 1.1 m) wind velocity and the obstacles-modified radiation values. The latter were simulated by means of the RayMan model from the measured global radiation data according to the method described in section 3.2 as 'PMV calculation with environmental morphology'. First of all the comparison of the 10 benches – as evident sitting places – was performed, the analysis of other sub-places with considerably different morphology (e.g. grassy area, upper and lower parts of the morphological step as well as the northwestern side of the area shaded by old trees) will be the next stage of the analysis.

The thermal characteristics of the benches expressed in terms of category-frequencies of PMV values reveal only small differences, as 17-20% of all cases fell into the comfortable (-0.5 < PMV < 0.5), 25-40% into the warm discomfort (0.5 < PMV) and 41-54% into the cold discomfort (PMV < -0.5) category (Fig. 7). The warm-hot categories occurred most frequently in the cases of the 10th and 1st benches, while the 6th proved the coolest one. Extreme values were very rare in all cases, so the effects of large thermal differences influencing significantly the spatial distribution of the visitors sitting on the benches could not be analysed. The situation presumably would be very different if the radiation (consequently the thermal sensation) modifying effects of trees and bushes around the benches would be pronounced. The 2nd bench had the highest mean attendance with 88.1% whilst the 9th had only 56%. Generally the eastern benches (1st to 6th) had more visitors than the westerns, supposedly due to undergrads (forming the largest proportion of visitors) who, arriving mainly from the eastern side, began taking a seat from this direction.

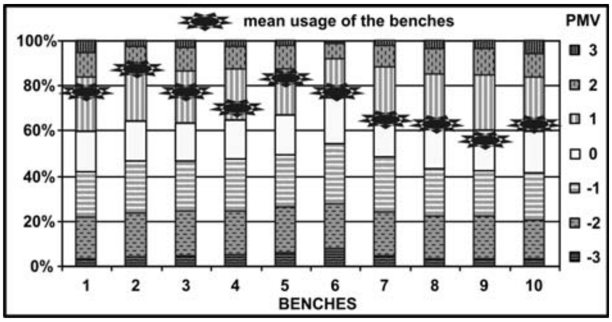

Fig. 7 Thermal conditions and the mean usage of the benches of the site

5. CONCLUSIONS

This study investigated the attendance of a green area in the central region of Szeged under various thermal conditions by means of human and environmental monitoring. The change of the visitors' personal characteristics and reactions (e.g. decreased amount of clothing, moving into the shaded sub-areas, as well as the lower activity level) with the warming thermal environment unequivocally exemplify the mechanisms of the physical acclimation serving the extension of staying outdoors. The relatively high attendance in the sun despite the too warm conditions and strong direct radiation emphasize the importance of psychological agents influencing subjective thermal comfort. The selected study area is an excellent example of how an aesthetical green area with appropriate design in the densely built up city centre could enhance the citizens' time staying in an outdoor environment. Besides accessibility the success of this place is due to the fact that it enables both physical and psychological acclimation by offering various microclimatic opportunities of which the most appropriate can selected as a function of the actual weather conditions.

The investigations will be extended both in temporal and in spatial manner (observation of squares, parks, playgrounds etc) in order to obtain an increasing amount of information on the usage of outdoor public spaces in urban environments. The results will be applied for our long-term aim, namely to propose design strategies for urban planning which can benefit the thermal comfort conditions in cities. The significance of the topic is obvious, as the social life, efficiency, well-being and health of citizens are positively influenced by human thermal comfort, so by obtaining and maintaining comfortable conditions urban life quality will be enhanced.

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