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ASSESSMENT OF BIOTHERMAL CONDITIONS FOR URBAN TOURISM IN THE SELECTED EUROPEAN CITIES

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Abstract: Urban tourism has become very popular in the last years, so the crucial problem in bioclimatology is to elaborate proper methods for evaluation of climatic conditions in the cities, which are popular tourist destinations. This paper presents results of the assessment of biothermal conditions in Madrid, Stockholm and Warsaw. For this purpose biometeorological indices (*PST* and *UTCI*) based on human heat budget models as well as tourism climatic index *TCI* was used. The calendars of bioclimates' suitability for urban tourism in these cities were designed using *WSI* index. Applied research tools were appraised and recommendations for future evaluations of climate in terms of urban tourism were given.

Keywords: *urban tourism, thermal stress, human heat balance*

I. INTRODUCTION

In the last years urban tourism has become one of the most popular leisure and recreational activity. In the case of this type of tourism, cultural and social factors are the most important in deciding about holiday destination. However, information related to weather and climate is taken into consideration at the stage of choosing the best time for visiting specific city. Urban tourism, unlike 3S tourism or winter tourism, is not limited by very specific weather conditions. Nevertheless to satisfy tourists' needs, it should be perceived as beautiful and pleasant or at least as acceptable and not bothering while sightseeing. Thermal component is considered as the main factor determining the desirability of weather (de Freitas, 2001). Hence in connection with intensive development of urban tourism it is important to investigate biothermal conditions in those European

metropolises, that are popular tourist destinations, as well as to indicate the most favourable and the most adverse periods of the year for this type of leisure activity.

There are few methods to evaluate bioclimatic conditions for tourism and recreational purposes developed. Initially a common approach was to use simple indices that took into account only chosen meteorological elements to characterise intensity of both direct and indirect impacts of atmosphere on human body. Nowadays indices based on human heat budget are the most frequently applied for this kind of assessments. Some of them like *PET* (Physiological Equivalent Temperature) or *PMV* (Predicted Mean Vote) became very popular, although they were not originally designed for evaluating tourism climate.

For many years researches on ideal tourism-climate index were conducted. The most popular became *TCI* (Tourism Climatic Index) proposed by Mieczkowski (1985). Although *TCI* has some disadvantages and is criticized in biometeorological literature, it is widely applied because of two reasons: it uses easily accessible data and it is the only method that helps to evaluate climate for general tourism purpose. Although there are new indices (like *CIT* – Climate Index for Tourism), none of them was designed especially for assessing climate for the sake of urban tourism (Blazejczyk, Kunert 2011).

Weather information given to the tourists should be simple, synthetic and it should take into consideration various types of human physical activity. What is more, not only particular meteorological elements, but also the whole weather complex influences tourist's sensations and well-being. Blazejczyk (2005) designed *WSI* index (Weather Suitability Index), derived from the biothermal-meteorological weather classification, that enables to create weather suitability calendars for various types of activities undertaken during urban tourism.

The main objective of this project is to assess the bioclimatic conditions in three European capitals - Madrid, Stockholm and Warsaw, with the emphasis on their usefulness for urban tourism. In order to evaluate sensible climate, two biometeorological indices – *UTCI* (Universal Thermal Climate Index) and *PST* (Physiological Subjective Temperature) are applied. For the lack of special research methods, an attempt of application *TCI* in the assessment of thermal conditions for urban tourism will be made, as well as calendars of weather suitability for tourism in these cities would be worked out, to delimit the most favourable seasons during the year for urban tourism.

II. MATERIALS AND METHODS

Three European capitals: Madrid (Spain), Stockholm (Sweden) and Warsaw (Poland), representing different tourism regions were chosen to evaluate their bioclimatic potential for urban tourism. Long-term characteristics of

biothermal conditions in the selected cities covered a ten year period, from 2000 to 2009. *UTCI*, *PST*, *TCI* and *WSI* indices were calculated from daily meteorological data for 12:00 UTC from local synoptic weather stations (tab. 1). Presented results refer for midday hours, which are typical for the highest outdoor activity of tourists. While the data from airport weather stations is not representative for the whole areas of the cities (especially not for the central districts), we believe that use of standard observations enables regional and seasonal comparability of biothermal conditions in analysed cities.

Table 1 Characteristics of synoptic weather stations

Station full name	Geographical location	Elevation (m)
Madrid Barajas	40°27'59" N 3°33'20" W	609
Stockholm Bromma	59°21'02" N 17°56'59" E	14
Warsaw Okęcie	52°09'46" N 20°57'40" E	106

II.1 Indices used in the study

II.1.1 Physiological Subjective Temperature

PST (°C) is based on the MENEX_2005 human heat balance model (Blazejczyk 2006). It defines subjective thermal sensations of humans after 15-20 min exposition to ambient conditions while adaptation processes to maintain homeothermy take place. When calculating *PST* actual ambient conditions are expressed by mean radiant temperature under clothing (*iMrt*), as well as the intensity of heat exchange between human body and atmosphere (S_R) is taken into consideration. Detailed formulas may be found in Błażejczyk, Kunert (2011). The particular ranges of *PST* (°C) indicate various thermal sensations of man:

< -36.0ºC	- frosty	24.1 – 34.0	- warm
-36.0 – -16.0	- very cold	34.1 – 44.0	- hot
-16.1 – 4.0	- cold	44.1 – 54.0	- very hot
4.1 – 14.0	- cool	> 54.0	- sweltering
14.1 – 24.0	- comfortable		

PST values lower than 44.0ºC and higher than -16.0ºC are considered as tolerable and not inducing thermal discomfort.

II.1.2 Universal Thermal Climate Index

UTCI (°C) is a new index elaborated by international working group to assess thermal strain caused by environment. It is defined as the equivalent air temperature of the reference conditions, causing the same human physiological responses as in the actual thermal conditions. Therefore *UTCI* is the air temperature which would produce under reference conditions the same thermal strain as in the actual thermal environment (Bröde et al. 2011). It is based on Fiala multi-node model of human thermoregulation (Fiala et al. 2001) which is augmented with a clothing model. So far *UTCI* is the unique index that takes into account heat exchange between various body layers themselves and the atmosphere, as well as it is the only research considers intensity of physiological responses of an organism in specific thermal conditions. Based on physiological criteria *UTCI* values were divided into 10 heat stress categories (Blazejczyk et al. 2010):

< -40ºC- extreme cold stress
-40 to -27 - very strong cold stress
-27 to -13 - strong cold stress
-13 to 0 - moderate cold stress
0 to 9 - slight cold stress
9 to 26 - no thermal stress
26 to 32 - moderate heat stress
32 to 38 - strong heat stress
38 to 46 - very strong heat stress
> 46 - extreme heat stress.

UTCI values between 18 and 26°C may comply closely with the definition of the "thermal comfort zone".

II.2 Tourism Climatic Index

TCI is an index that not only takes into consideration thermal aspects of climate, but also includes other meteorological elements (like sunshine duration or precipitation) that may influence the quality of tourism and recreation (Mieczkowski 1985). It was developed to assess the climatic conditions for the purpose of 'average' tourism activity (i.e. sight-seeing and shopping). *TCI* bases on a standardized rating system of 5 sub-indices (*CId* - daytime comfort and *CIa* - daily comfort both derived from equivalent temperature, *R* - precipitation, *S* - sunshine, *W* - wind). The sub-indices are summed with following formula:

$$TCI = 2 \cdot (4 \cdot CId + CIa + 2 \cdot R + 2 \cdot S + W)$$

The greatest disadvantage of *TCI* is the fact, that although devised on previous research results and biometeorological literature, its rating system is definitely subjective (Scott, McBoyle 2001). *TCI* values were divided into 10 categories of usefulness for tourism:

90 – 100	- ideal	40 – 49	- marginal
80 – 89	- excellent	30 – 39	- unfavourable
70 – 79	- very good	20 – 29	- very unfavourable
60 – 69	- good	10 – 19	- extremely unfavourable
50 – 59	- acceptable	<10	- impossible

II.3 Weather Suitability Index *WSI* and the calendars of weather complexes' usefulness

Weather Suitability Index *WSI* is derived from the biothermal-meteorological weather classification of Blazejczyk (2005), that distinguish weather types basing on thermal sensations, radiative stimuli intensity, thermophysiological strain due to sultriness, thermal contrasts throughout the day and existence of rain and snow cover. Particual weather types may be calculated using BioKlima Software (http://www.igipz.pan.pl/Bioklima-zgik.html). *WSI* is a numerical measure which evaluates weather a given weather type is pleasant and enables maintenance of thermal balance of human organism. Final weather suitability for different types of tourism activities is defined on the basis *WSI* average values, where:

< 0.5	unfavourable weather
0.5 – 1.2	moderate favourable weather
1.2 – 2.0	favourable weather
≥ 2.0	very favourable weather.

III. RESULTS

III.1 Biothermal conditions in the selected cities

III.1.1 Madrid

In the analysed period mean decadal *UTCI* values at 12:00 UTC throughout the year vary in Madrid from 6°C at the end of December to about 34°C in the third decade of July, what corresponds with „slight cold stress" and „strong heat stress" categories, respectively (Fig. 1). However, in particular years those values remarkably diverge from long-term means. In the coldest days of January *UTCI* can fall sometimes to -24°C, what reflects „strong cold stress". Conversely in the summer from mid-June to the end of September on some days *UTCI* at midday

hours overreach 40°C, which indicates occurrence of "very strong heat stress". In the period 2000-2009 the highest *UTCI* value was 43°C (7th August 2005).

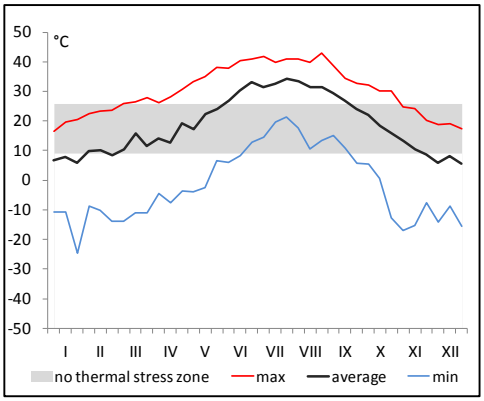

Fig. 1 Annual course of mean, maximum and minimum decadal UTCI values at 12:00 UTC in Madrid(2000-2009) with "no thermal stress zone" marked.

According to *UTCI* the main weather limitations for urban tourism in Madrid are related to heat strain and they occur in summer. The ideal conditions for outdoor activities, when in general "no thermal stress" is observed, fell on two periods – from late February to the beginning of June and from mid-September to mid-November, what in fact comes to more than half of the year.

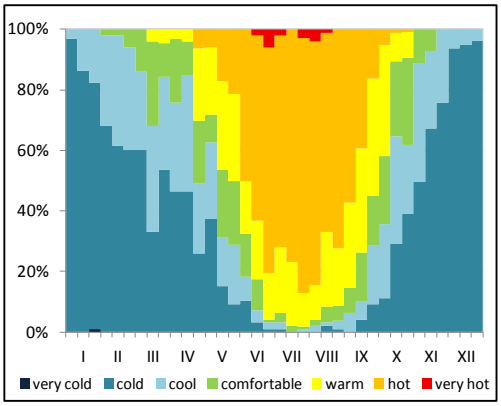

Fig. 2 The frequency of thermal sensation categories by PST at 12:00 UTC in Madrid (2000-2009)

According to *PST* most frequently in the winter, at 12:00 UTC, occur "cold" sensations (82.6%), while in the summer prevail thermal sensations of "hot" (70.1%) (Fig. 2). Surprisingly very rarely during the whole year occur comfortable weather conditions (10% cases). In terms of thermal comfort relatively the best time of the year for urban tourism in Madrid is in May, as well as at the end of September and October.

III.1.2 Stockholm

The amplitude of mean decadal *UTCI* values at 12:00 UTC in Stockholm is similar to the amplitude in Madrid, although the values of the index differ considerably. They vary throughout the year between -10.9°C at the end of December to 20.6°C at the end of July, what refers to heat stress categories from „moderate cold stress" to „no thermal stress" (Fig. 3).

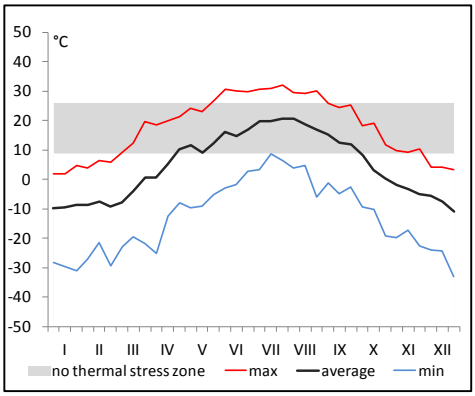

Fig. 3 Annual course of mean, maximum and minimum decadal UTCI values at 12:00 UTC in Stockholm (2000-2009) with "no thermal stress zone" marked.

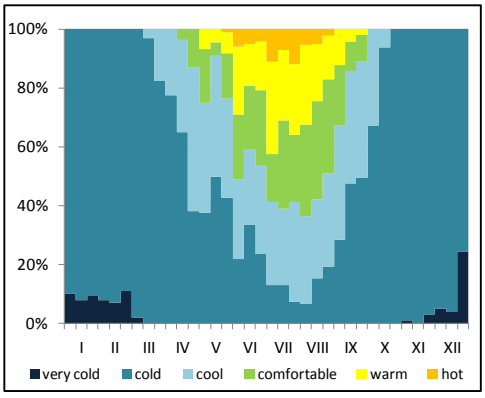

Fig. 4 The frequency of thermal sensation categories by PST at 12:00 UTC in Stockholm (2000-2009)

During the year, single situations of "strong heat stress" occur only in the end of July, while for the rest of summer season maximal values of *UTCI* do not exceed the range of "moderate heat stress". On the other hand, the minimal values at midday hours occur in the third decade of December (-32.8°C), indicating "very strong cold stress". Assuming that the most favourable conditions for urban tourism will be those not causing thermal stress in humans, the most preferable time to visit Stockholm is the period from the middle of April to the beginning of October.

Considering the whole year, the most frequent in Stockholm are "cold" thermal sensations (62.6%) (Fig. 4). They are observed in 90% of days in winter and in 17.3% in summer what signifies that biothermal conditions are in general unfavourable for tourists in this city in cold season. In summer in Stockholm perceptible weather conditions are variable. The most common thermal sensations are "cool" (28.8%) and "comfortable" (25.6%), but in June and August thermal sensation "warm" also occurs (22%).

III.1.3 Warsaw

Mean decadal *UTCI* values throughout the year oscillate in Warsaw between -13.5°C in the first decade of January to about 24°C in the third decade of July, what corresponds to „strong cold stress" and „no thermal stress" categories, respectively (Fig. 5).

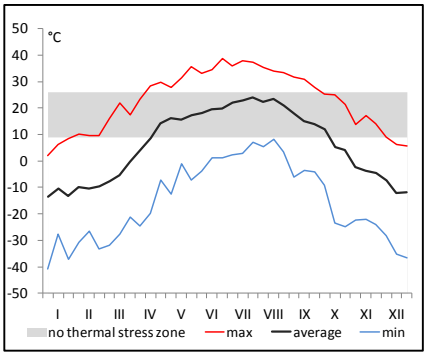

Fig. 5 Annual course of mean, maximum and minimum decadal UTCI values at 12:00 UTC in Warsaw(2000-2009) with "no thermal stress zone" marked.

In January *UTCI* sometimes falls even to -40°C, what reflects „very strong cold stress". Absolute minimum of *UTCI* in the analysed period was -45.6°C and was observed on 5th January 2008. Biothermal conditions in Warsaw in winter are in general unfavourable for tourists due to cold strain of variable intensity. In the same time from mid-June until the end of July on some days *UTCI* may overreach 37°C, which indicates occurrence of "strong heat stress" and sometimes in late July "very strong heat stress", which may be harmful to human organism while staying long outdoors without special protection.

The most favourable time of year for urban tourism in Warsaw, similarly like in Stockholm, is observed from the end of April to the beginning of October, when mean decadal *UTCI* values indicate "no thermal stress".

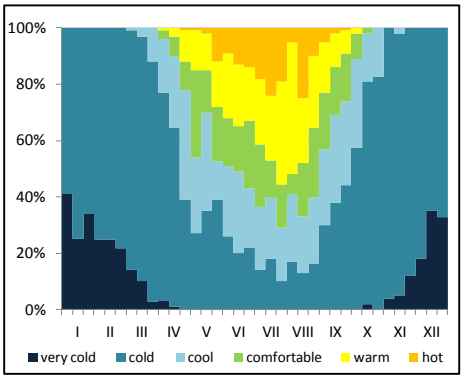

Fig. 6 The frequency of thermal sensation categories by PST at 12:00 UTC in Warsaw (2000-2009)

According to PST values, the most common thermal sensation in Warsaw, at 12:00 UTC during whole year, is "cold" (53.8%) (Fig. 6). What is worth mentioning, in winter the "very cold" sensations appear relatively often (28.9%). Moreover, in summer, thermal sensations changed a lot from year to year, but most frequently PST indicates "warm" thermal sensation. At the same time comfortable perceived climate in warm season appears in Warsaw in 15% days, which is 2,5 times more frequent than in Stockholm.

III.2. *TCI* application in the assessment of biothermal conditions for urban tourism

According to *TCI*, the best weather conditions for tourism in all three cities are observed during the summer (tab. 2). In Madrid from June to September bioclimate is ideal for tourism (*TCI* values above 90), while in Stockholm and Warsaw from June to August *TCI* values indicate very good and excellent climatic conditions, respectively. On the other hand, in Stockholm and Warsaw in the coolest season *TCI* values are relatively low, which suggests unfavourable conditions for tourism. Although these results are in accordance with general observations of biothermal conditions in Stockholm and Warsaw, they are doubtful in case of Madrid, where in the warmest season heat stress and hot thermal sensation occur very often. Underrating by *TCI* the coolest season of the year in Stockholm and Warsaw, in terms of urban tourism seems also inappropriate, because tourists can adapt to some degree to low temperature using suitable clothes. What is more, *TCI* does not take into consideration psychological factors (i.e. higher tolerance for weather fluctuations due to voluntary nature of exposition on outdoor conditions (Thorsson et al. 2004)), that distinguish tourists from the others.

Table 2 *TCI* monthly values in Madrid, Stockholm and Warsaw (2000-2009)

Month	Madrid	Stockholm	Warsaw
Jan	51	35	34
Feb	56	40	40
Mar	60	48	47
Apr	63	58	60
May	77	65	73
Jun	95	**71**	**83**
Jul	**96**	**77**	**83**
Aug	**96**	**72**	**82**
Sep	**91**	59	70
Oct	63	45	52
Nov	54	36	41
Dec	48	38	36

Above-mentioned results show that using *TCI* to assess biothermal conditions for urban tourism is not very advisable approach, mainly because this index gives to much value to warm and sunny weather, no matter how high and uncomfortable the temperature may be.

III.3 Calendar of weather suitability for urban tourism

In case of urban tourism, the most common form of spending time outdoors by tourists is walking, hence weather suitability for mild recreation seems to be the most important determinant. In Madrid meteorological conditions conducive to urban tourism occur from the second decade of September to the end of May, with a maximum in March and October, when the weather is very favourable for sightseeing in 66% and 60% of cases respectively (fig. 7). What is more, in the second decade of March prevail optimum conditions for each type of outdoor activity. The least favourable meteorological conditions for walking around the city are observed in the summer season, which is associated with the frequent occurrence of high air temperature and large thermal loads of the organism.

The highest suitability of weather for urban tourism in Stockholm falls on the warm season. Most favourable conditions for mild recreation occur in late April and May and from June to late August. The best time during the year to visit Stockholm is the first decade of June, when the average value of WSI reaches 2.35 and very favourable weather is present on 69% of the days. Due to the high cloudiness and low air temperature in winter and autumn, meteorological conditions from the second decade of October to the first decade of March are barely moderately favourable for sightseeing.

In Warsaw, conditions suitable for walking and exploring the city are observed from March to the end of October. The optimal weather to stay outdoors prevails from the second decade of April to the second decade of May and throughout September. What's more, the third decade of April is characterized by ideal weather conditions for all forms of recreation. In summer, meteorological conditions are not very suitable for urban tourism, due to the high variability of the weather during this period. Similarly as in Stockholm, unfavourable conditions for mild recreation are not observed in Warsaw during the year.

Month	Madrid			Stockholm			Warsaw		
	SB	**MR**	AR	SB	**MR**	AR	SB	**MR**	AR
Jan	0.69	1.55	2.60	0.00	0.64	2.26	0.00	0.74	2.44
	1.01	2.19	2.75	0.00	0.71	2.42	0.00	0.83	**2.66**
	0.92	2.05	2.67	0.00	0.72	2.37	0.00	0.71	2.28
Feb	1.29	1.90	2.41	0.00	0.77	2.33	0.00	0.74	2.26
	1.78	2.23	2.45	0.00	0.87	2.71	0.00	0.94	2.46
	1.25	1.93	2.07	0.00	0.79	2.48	0.00	1.02	2.42
Mar	1.77	2.30	2.32	0.00	0.94	2.40	0.12	1.20	2.48
	2.16	**2.48**	2.38	0.09	1.35	2.35	0.31	1.16	2.33

	1.74	2.18	2.30	0.64	1.99	**2.74**	0.73	1.58	2.36
	1.73	2.29	2.03	0.72	1.70	2.53	1.05	1.80	2.46
Apr	1.75	2.17	2.20	1.07	1.85	2.65	1.52	2.20	2.34
	1.95	1.95	1.68	1.46	2.15	2.71	**2.00**	**2.25**	2.21
	1.34	1.68	1.64	1.45	2.05	2.56	1.97	2.21	2.10
May	1.67	1.65	1.41	0.92	1.73	2.60	1.88	2.16	1.99
	1.56	1.61	1.36	1.11	1.80	2.20	1.61	1.94	1.89
	1.01	0.98	0.80	**1.80**	**2.35**	2.27	1.67	1.81	1.77
Jun	0.82	0.69	0.42	1.09	1.89	2.08	1.46	1.87	1.63
	0.78	0.41	0.14	1.18	2.02	2.12	1.50	1.87	1.72
	0.97	0.70	0.31	1.41	2.06	1.81	1.49	1.73	1.31
Jul	0.93	0.51	0.18	1.32	2.20	1.92	1.17	1.48	1.29
	0.71	0.44	0.19	1.18	2.19	1.92	1.34	1.58	1.26
	0.74	0.44	0.19	1.28	2.26	1.89	1.44	1.88	1.46
Aug	0.95	0.71	0.33	1.08	2.18	2.14	1.19	1.52	1.30
	0.91	0.59	0.31	1.20	2.18	2.24	1.70	1.83	1.61
	1.13	0.85	0.44	1.17	1.96	2.49	1.80	2.13	1.95
Sep	1.64	1.37	0.83	1.07	1.82	2.52	1.74	2.07	2.17
	1.72	1.82	1.34	1.22	1.96	2.64	1.79	2.14	2.38
	2.08	2.21	1.70	0.61	1.44	2.43	1.39	1.90	2.25
Oct	1.84	2.21	2.22	0.03	0.93	2.53	0.61	1.63	2.41
	1.70	2.04	1.97	0.00	0.79	2.17	0.42	1.40	2.44
	1.56	2.15	2.37	0.00	0.77	2.31	0.06	0.92	2.40
Nov	1.45	2.13	2.43	0.00	0.69	2.20	0.03	0.87	2.52
	1.13	1.89	2.56	0.00	0.58	2.03	0.00	0.78	2.43
	0.64	1.55	2.49	0.00	0.62	2.20	0.00	0.84	2.64
Dec	0.62	1.78	**2.80**	0.00	0.74	2.45	0.00	0.73	2.42
	0.51	1.55	2.53	0.00	0.64	2.27	0.00	0.75	2.49

SB – sunbathing
MR – mild recreation
AR – active recreation

Weather:

0 – 0.49	unfavourable
0.5 – 1.19	moderate
1.2 – 1.99	favourable
2.0 – 3.0	very favourable

Fig. 7 Calendar of weather suitability for various forms of recreation (on basis of 10-day averages of *WSI*) in Madrid, Stockholm and Warsaw (2000-2009)

IV. CONCLUSIONS

Every kind of tourism activity has specific requirements from the weather, so it would be very difficult to develop one universal index to assess climate for the purpose of tourism in general. This is probably the main reason why *TCI* is not suitable to evaluate biothermal conditions in terms of urban tourism, whereas its basis and usefulness categories would better suit the 3S tourism research.

However, biometeorological indices based on the human heat budget models are very useful for determining the most favourable and adverse seasons in

the year for tourism in the cities. They could be used in the tourism weather assessment research if provided with special usefulness scales, every time fitted to specific tourist activity. This approach would require further research on tourists' weather perception with reference to their preferences towards climatic conditions during different leisure activities.

Using *WSI* to create weather suitability calendar for urban tourism, reliable and easy to interpret results were obtained, that allowed to distinguish between various physical activity demands. Unfortunately this approach lacks information about adverse, unpleasant or even harmful to human organism meteorological conditions and ignores the risk of their occurrence in particular place.

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References

Blazejczyk K.: Biotermiczno-meteorologiczna klasyfikacja pogody jako narzędzie oceny warunków bioklimatycznych, in: Babinski Z. (ed.) Srodowisko przyrodnicze w badaniach geografii fizycznej, Promotio Geografica Bydgostiensia, 2, 89-127, 2005. [in Polish]

Blazejczyk K.: MENEX_2005 – the revised Version of Man-Environment Heat Exchange Model, 2006. www.igipz.pan.pl/geoekoklimat/ blaz/menex.htm (accessed 20 Aug 2012).

Blazejczyk K., Bröde P., Fiala D., Havenith G., Holmer I., Jendritzky G., Kampmann B., Kunert A.: Principles of the new Universal Thermal Climate Index (UTCI) and its application to bioclimatic research in European scale. *Miscellanea Geographica*, 14, 91-102, 2010.

Blazejczyk K., Kunert A.: Bioklimatyczne uwarunkowania rekreacji i turystyki w Polsce [Bioclimatic pronciples of recreation and tourism in Poland], 2-nd ed. *Monografie IGiPZ PAN*, 13, Warsaw, 2011. [in Polish]

Bröde P., Fiala D.,Błażejczyk K., Holmér I., Jendritzky G., Kampmann B., Tinz B., Havenith G,: Deriving the operational procedure for the Universal Thermal Climate Index (UTCI), *Int J Biometeorol, 56, 481-494,* 2011.

de Freitas C.R.: Theory, Concepts and Methods in Tourism Climate Research, in: *Proceedings of the First International Workshop on Climate, Tourism and Recreation*, 3-20, 2001.

Fiala D., Lomas K.J., Stohrer M.: Computer prediction of human termoregulatory and temperature responses to a wide range of environment al conditions, Int J Biometeorol, 45, 143-159, 2001.

Mieczkowski Z.: The Tourism Climatic Index: a method of evaluating world climates for tourism. *The Canadian Geographer*, 29(3), 220-233, 1985.

Thorsson S., Lindqvist M., Lindqvist S.,: Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. Int J Biometeorol, 48, 149-156, 2004.

BioKlima Sotware - http://www.igipz.pan.pl/Bioklima-zgik.html (accessed 20 Dec 2013).

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