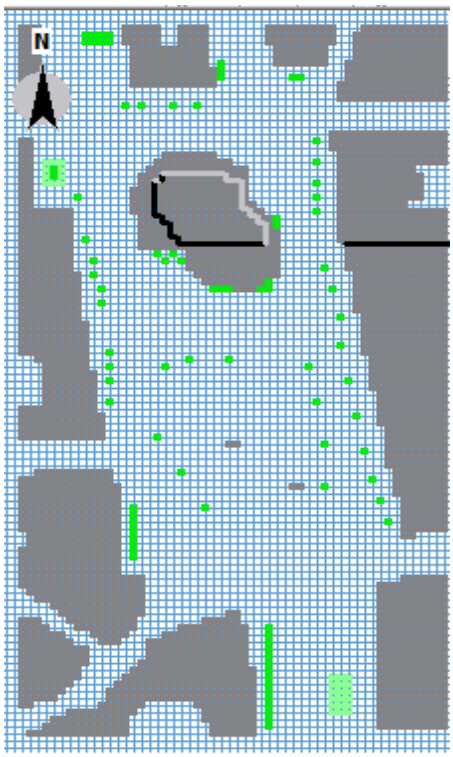
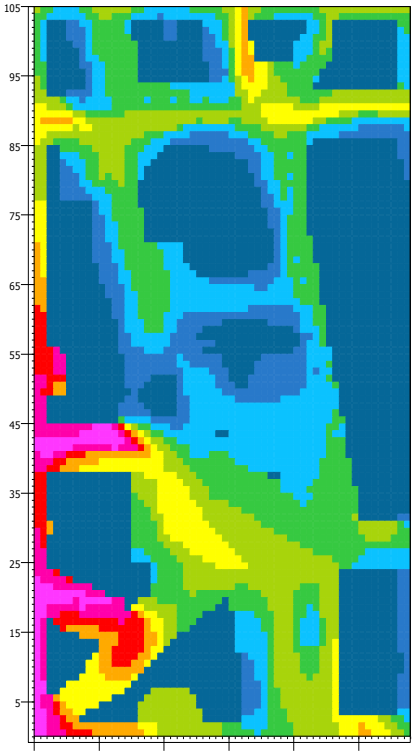
PTE-MIK MARCEL BREUER DOCTORAL SCHOOL

Ph.D. THESIS BOOKLET OF THEORIES-2019

Pécsi Tudományegyetem
Műszaki és Informatikai Kar
Breuer Marcell
Doktori Iskola

EVALUATING AND ENHANCING OUTDOOR THERMAL PERFORMANCE IN MODERATELY WARM-WET CLIMATE ZONE





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1. Research problem context

Without an understanding of the urban microclimate measures and their parameters and how landscape elements will affect them, designers are at risk of creating urban landscapes, which will perform poorly or even have a negative impact on the microclimate. Landscape architects and urban planners do not integrate the accumulated knowledge of climatology into applicable planning guidelines and tools as a way to improve the microclimate of the outdoor built environment. Nevertheless, most researches are published in scientific literature and are not accessible to the majority of landscape designers and planners. Moreover, the design implications of the results are rarely extracted in a usable form. Therefore, developing a landscape and urban design strategies for outdoor environment in moderately warm-wet climate zone based on bioclimatic principals in order to provide landscape architects with design guidelines that can evaluate as well as improve the microclimate and conserve energy is essential.

2. The research main aim and objectives

The main target of this research is investigating the possibility of enhancing the outdoor thermal comfort in central European city of Pecs in summer. **In simple words is to determine how designers could modify climatic conditions in urban spaces for thermal comfort and develop a better understanding of the relationship between outdoor thermal comfort, urban design, and microclimate in an attempt to improve the pedestrians 'thermal perception. However**, to achieve this aim, the following objectives were derived:

1-Quantitively and qualitatively evaluating the outdoor thermal performance in Pecs city

2-Formulating design measures that could enhance the outdoor thermal performance

3-Quantifying the effect of different design measures that could possibly enhance the outdoor thermal performance

4-Providing the designers and decision makers with a comprehensive framework for use in evaluating or predicting the effect of different design measures and their parameters in enhancing the outdoor microclimate.

3. New Scientific Results

None of the available literature and studies attempted to test thoroughly all the weather parameters and design measures at central European public space of Pecs-city at any of their studies, since this field of study still very limited in Hungary as well as in central European countries. This gap in the body of knowledge was identified and was bridged in this research.

3.1 1st Theory

Introducing a comprehensive classification for the design measures and their parameters that have an impact on outdoor thermal comfort performance to building design system that can help in central European countries. I have comprehensively classified and categorized design measures and their parameters. However, the measures are grouped under three levels; the macro-level, the intermediate-level as well as the micro-level. Nonetheless, I have also classified the design measures and their parameters that are believed to have a positive impact on urban thermal comfort in this particular study. Moreover, a list of possible measures for enhancing outdoor thermal performance was formulated *see Fig.1*.

Design level	Design measures	To be studied parameter
Macro	Street design orientation	0, 45, 90, 135,180,225,270,315.
	Canyon geometry	-H/W 0.65 -H/W 1 -H/W 1.5
Intermediate	Softscape (Vegetation, waterbody)	-Plantation 1-Grass (12%,17%,25%,) 2- Hedge dense (2m) (12%,17%,25%,) 3- Dense district crown (10m) (12%,17%,25%,) -Water (6%9%)
		-Green roofs 50%,100% of roof surface -Green walls 50%,100% of wall surface
	Hardscape (albedo)	-Paving Albedo, red stone , and pavement Concrete
Micro	Building envelope Heat Transmission	Walls & roofs (with and without insulation) (with and without insulation)
	Roof shape	Pitched, Flat

Fig.1. The proposed measures and their parameters for applying to enhancement process

3.2 2nd Theory *(Paper I)*

A new subjective-objective assessment approach of outdoor thermal sensation has been employed to measure the predicted mean vote, air temperature, humidity, wind speed, as well as solar radiation. In an attempt at understanding the voters' thermal sensation as shown in Fig.2.
I have found that:

- In general, the outdoor thermal sensation is uncomfortable almost two-thirds of the Participants felt uncomfortable.
- On average **14:00 PM** was recorded the highest very hot *(rate 4).*
- Plantation and water body have a profound effect on outdoor thermal comfort.
- The simulation results proved ENVI-met's great reliability in predicting outdoor thermal comfort when compared against questioner's results *see Fig.3.*

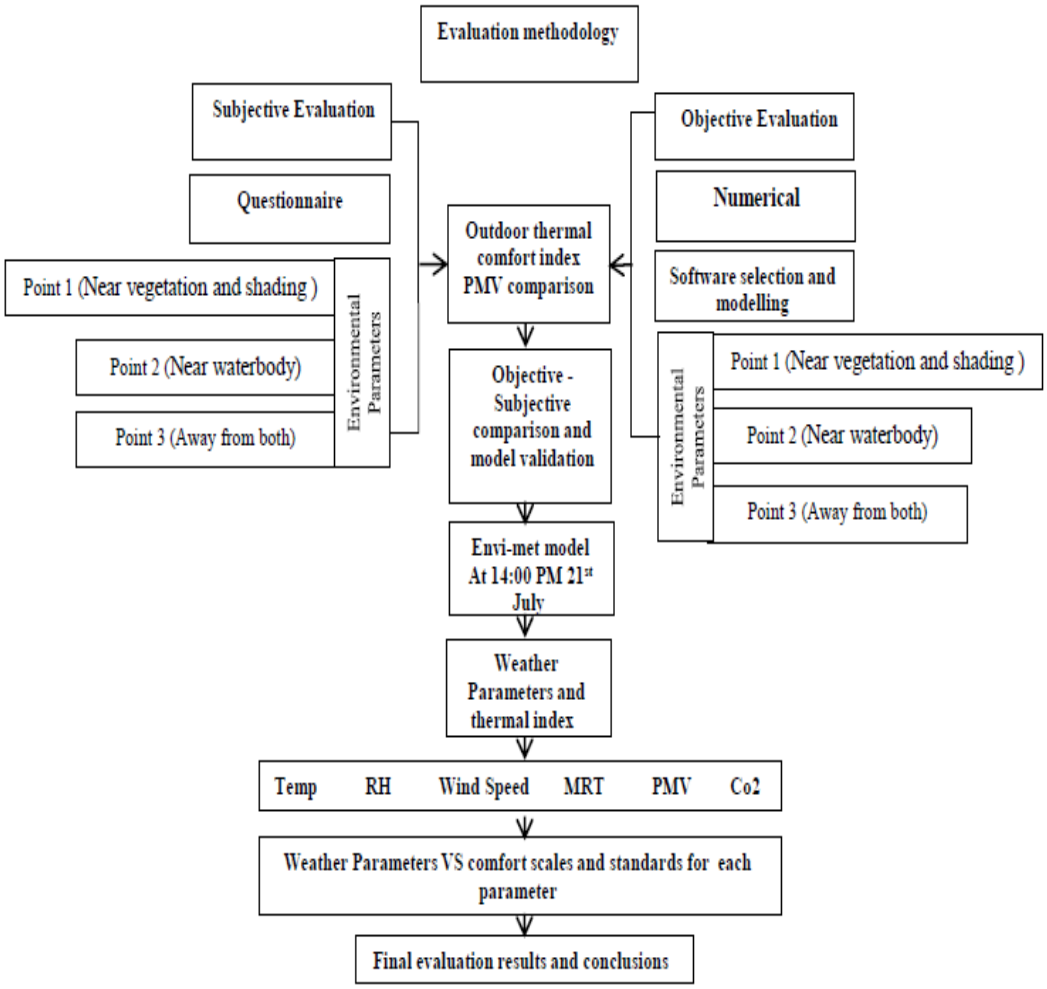

Fig.2. The subjective-objective assessment approach

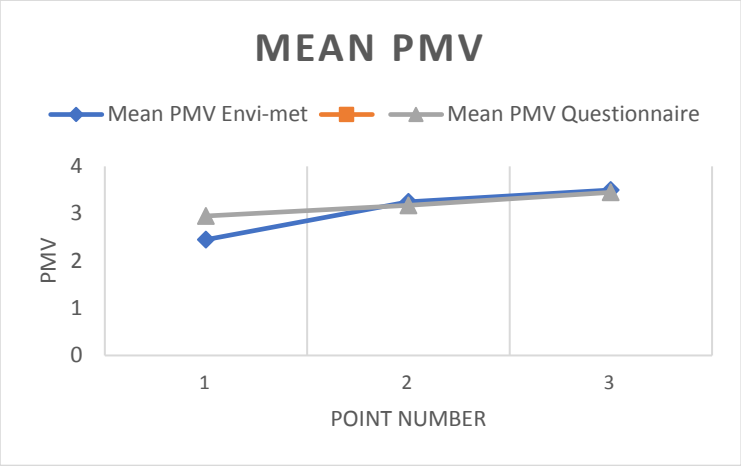

Fig.3. The mean PMV measured at Széchenyi square in comparison with the mean PMV value output from simulated cases.

3.3 3rd Theory *(Paper II)*

There are several microclimate simulation codes with different levels of complexity and response to different variables. An approach for choosing and investigating the capabilities of the CFD (Computational Fluid Dynamics) tools serving the scope of research was implemented, comparing the features and capabilities of the programs in three main categories *as shown in Fig.4.* I found that among several microclimate simulation tools ENVI-met is capable of predicting and simulating the thermal comfort indices (PMV, PET, MRT and PDD), meteorological parameters (airspeed, wind direction, air temperature, relative humidity, global solar radiation) as well as most of the design strategies in outdoor spaces. Therefor ENVI-met has been chosen as the most suitable tool among the eight tools.

Choosing criteria	RayMan	Envi-met	ANSYS	Autodesk® CFD
General criteria				
User Interface	Friendly	Friendly	Extremely complex	Friendly
Reliability & accuracy	High	High	Very high	High
Cost	Free	Low	Very high	Free
Operating system	Windows	Windows	Windows and MAC	Windows
Compatibility	Low	Moderate	High	Very high

Visualization and graphics	Moderate	High	High	High
Comfort Prediction index	PET	PMV	-	-

Fig.4. Detailed comparison of CFD software serving the scope of research

Note: for a complete list I would refer you to take a look at the manuscript (57-61) pages.

To enhance outdoor thermal performance in the study site

3.4 4th Theory *(Paper III), (Paper IV)*

Quantifying the effectiveness of the design measures on urban thermal performance at a central European public space. I have proved that street orientation, canyon geometry, plantation-area ratio, water-area ratio, green roofs, green walls, as well as the pavement materials have a significant impact on the outdoor thermal performance. However, roof shape and building heat transmission have negligible impact on the urban thermal comfort in this particular study area.

Case name	TA	RH	WS	PMV	MRT	CO2
Original base case (OBC)	304.8	34.2	1.4	5.2	353	358
Street orientation (315)	303	35.5	1.5	4.8	353	357
H/W=0.65	304	35.3	1.55	5.1	353	358
Dense district crown (10m) 25%	304	34.5	1.45	5.1	353	354
9% water	304.5	36.7	1.4	4.8	346	357
Green roofs 100%	304	35	1.4	5	353	357
Green walls 100%	304	37	1.5	5	351	355
Pavement concrete	304.8	34.2	1.4	5.1	347	358

Fig.5. Parameters that have a significant impact on outdoor thermal comfort

5.5 5th Theory *(Paper III), (Paper IV)*

Introducing practical environmental treatments for urban thermal design. I have established that applying the selected measures and their parameters to the study site has significantly improved the air temperature, relative humidity, as well as the MRT by *2.3k, 2.8%, and 8k* respectively. I have also found that the proper street design (orientation and canyon geometry) can accelerate the air velocity and mitigate the air temperature in the summertime which could affect the outdoor thermal satisfaction as well.

Case name	TA (K)	RH (%)	WS (m/s)	PMV	MRT (K)	Co2 (PMM)
Original base case (OBC)	304.8	34.2	1.4	5.2	353	358
Final enhanced case (FEC)	302.5	37	1.6	4.6	345	354
The difference	2.3	-2.8	-0.2	0.6	8	4

Fig.6. The results comparison between the final enhanced case and the original base case

5.6 6th Theory *(Paper I), (Paper II), (Paper III), (Paper IV)*

I have provided the designers and decision makers with a comprehensive approach for use in evaluating and predicting the effect of different design measures and their parameters in modifying the outdoor microclimate that can be seen in Fig.1 to Fig.4.

Scope and limitations

The research is focused on the effect of different design measures and parameters at different urban levels on improving the outdoor thermal. This work is concerned with alleviating heat stress during the extended summer period in a moderately warm-wet climate zone. Although some of the findings may be generalized, the conclusions of the study are not necessarily valid throughout moderately warm-wet climate groups, since there are climatic and considerable variations between different cities in terms of size, planning principles, proximity to the sea, and topography, etc. Moreover, visual and acoustical comfort performance are not investigated here.

The following relevant papers to the thesis topics:

I. Numerical evaluation of outdoor thermal comfort and weather parameters in summertime at Széchenyi square, Pollack Periodica Journal, University of PÉCS, Hungary. Vol. 14, 2019

II. An overview of microclimate tools for predicting the thermal comfort, meteorological parameters and design strategies in outdoor spaces, Pollack Periodica Journal, University of Pecs, Hungary. Vol. 14, 2019

III. Impact of street canyon geometry on outdoor thermal comfort and weather parameters in PÉCS, Pollack Periodica Journal, University of Pecs, Hungary. Vol. 14, 2019

IV. Water body effects on microclimate in summertime: a case study from PÉCS, Pollack Periodica Journal, University of Pecs, Hungary. Vol. 14, 2019