PET Comfort Index Calibration using Decision Trees

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INTRODUCTION

This study is part of an inter-institutional umbrella project, Urban Climate, Urban Design and Global Climate Changes that aimed at analysing the response of the thermal comfort index, Physiological Equivalent Temperature (PET) (°C), for acclimatised residents in the tropical city of Salvador, Brazil, by associating PET (°C) intervals with voted thermal perception. PET defines its neutral condition based on equalized human heat balance. However, as people are adapted to different climatic conditions, classes of thermal perception, including the comfort zone will differ according to the local climate.

RESULTS

The field research interviewed 1,435 individuals, obtaining 1,002 valid questionnaires, after removing atypical observations for not fulfilling the required criteria or incomplete information.

Table 1 - Percentages of responses per PET interval defined by DT

PET (°C) ↓	Category → Node ↓	1 Hot	2 Warm	3 Slightly Warm	4 Comfortable	5 Slightly Cool
				(%)		
≤ 26.8	3	9.0	16.8	21.9	48.8	3.5
26.8 - 29.4	4	15.2	24.9	21.4	36.7	1.7
29.4 - 34.1	5	27.6	36.2	15.4	20.8	0.0
≥ 34.1	6	51.5	25.8	13.6	9.1	0.0

Table 2 - PET (°C) Index Calibration using DT

	Category	DT at 50%	DT at 30%
1	Hot	PET > 34.1 °C	> 34.1 °C
2	Warm	PET > 29.4 °C	29.4<PET≤34.1 °C
3	Slightly Warm	-	26.8<PET≤ 29.4 °C
4	Comfortable	PET < 29.4 °C	≤ 26.8 °C
5	Slightly Cool	-	-

MATERIALS AND METHOD

The methodology used involved carrying out meteorological measurements of air temperature and humidity, solar radiation, wind velocity and simultaneously interviewing acclimatised pedestrians about their thermal perception in open urban spaces. A statistically representative sample of the population included residents living in Salvador for more than a year and between 20 and 59 years old. Interviewees had to meet specific criteria, namely, they should usually work in a non-artificially conditioned environment, should spend more than 15 minutes outdoors, should not have ingested alcohol or cold, spicy or greasy food within an hour of the interview, and should be in good health, not in menopause or pregnant. In total 1,435 interviews were conducted in 2 consecutive days in each of the four seasons from 2009 to 2010, with measurements at 10 minute-intervals from 2:00 to 5:00 PM. The PET thermal comfort index (°C) was obtained using the PET model systematized by Rayman® application, v. 1.2 (RUTZ; MATZARAKIS; MAYER, 2000). By statistical analyses through the Classification and Regression Tree (CART) algorithm (SPSS 17.0), we related thermal perception to the measured variables. For each subject, we created a pair comprised of PET (°C) value and the thermal perception category using Fanger's seven-point scale categories: +3 (Hot); +2 (Warm); +1 (Slightly Warm); 0 (Comfortable); -1 (Slightly Cool); -2 (Cool) and -3 (Cold). Decision Tree - DT technique of exploratory data analysis was used to calibrate the PET index (°C).

Table 3 - PET Index Calibration from different studies: Brazil, Germany and China, in °C

Categories	1	2	3	4	5	6	7
Thermal Perception	Hot	Warm	Slightly Warm	Comfortable	Slightly Cool	Cool	Cold
Physiological Stress	Extreme positive stress	Strong positive stress	Moderate positive stress	No thermal stress	Moderate negative stress	Strong negative stress	Extreme negative stress
PMV	3	2	1	0	-1	-2	-3
Germany (KATZSCHNER, 2011)	> 42	38 - 41	29 - 34	18 - 28	13 - 17	< 13	
Hong Kong (KATZSCHNER, 2011)	> 45	35 - 45	30 - 35	12 -30	9 - 12	< 8	
Belo Horizonte (HIRASHIMA, 2010)	> 35.0	30.5 – 35.0	-	≤ 30.5	-	-	
Salvador (FÉ et al, 2007)	-	-	-	≤ 20.0	-	-	
Salvador (Authors)	≥ 34.1	29.4 - 34.1	26.8 -29.4 (inference)	≤ 26.8	-	-	

CONCLUSIONS

This study was aimed at calibrating the thermal comfort index PET (°C) for the population of Salvador, Brazil in urban areas by measuring environmental variables and interviewing pedestrians on thermal perception simultaneously.

Decision Tree statistical analyses identified PET sequenced and clear intervals. Interpreting DT results by 50% criterion gave inconclusive determinations for all but one category, "Hot". Applying a less restrictive criterion of 30% of responses to DT values, the study defined the categories, "Hot" (category 1), PET > 34.1 ºC, "Warm" (category 2), 29.4 < PET= 34.1 ºC and "Comfortable" (category 4), PET = 26.8 ºC. "Slightly Warm" (category 3) did not reach the 30% criterion of responses. Yet, the researchers defined this interval by inference (26.8 <PET = 29.4 ºC). Even the 30% criterion was not sufficient to determine the lower limit of "Comfortable", nor "Slightly Cool" (category 5) or the categories related to negative thermal stress. Nonetheless, the upper limit of "Comfortable" set at 26.8 °C indicates a significant result for Salvador due to predominance of positive thermal stress conditions throughout the year. In conclusion, this study proposes the PET index = 26.8 °C as the upper limit for the "Comfortable" category for the city of Salvador.

REFERENCES

ANDRADE, T.; KATZSCHNER, L. FREIRE, T.; NERY, J. A method to derive thermal comfort conditions for a tropical city. In: CONFERENCE ON PASSIVE AND LOW ENERGY ARCHITECTURE, 21., 2004,Eindhoven. *Plea2004: The 21th Conference on Passive and Low Energy Architecture*, v. 1. p. 19-22, 2004.
BARBETTA, Pedro Alberto. *Estatísticas aplicadas às Ciências Sociais*. Florianópolis. UFSC, 1994.
BREIMAN, L.; FRIEDMAN, JH; OLSHEN, R.A.; STONE, E. C. J. *Classification and Regression Trees*. California: Wadsworth International Group, 1984.
ASSIS, E.; NERY, J.; KATZSCHNER, L. *Projeto Urban Climate and Urban Design for Global Climate Changes, Brasil–Alemanha*. Belo Horizonte: UFMG; Salvador: UFBA; Kassel (Alemanha): UniKassel, 2007.
FANGER, P. *Thermal comfort: analysis and applications in environmental engineering*. Copenhagen: DanishTechnical Press, 1970.
FÉ, D.S.; ANDRADE, T.C.G.; SANTANA, M.J.A.; NERY, J.; FREIRE, T.M.M.; OLIVEIRA, I.B.Indices de Conforto Térmico: avaliação para clima quente e úmido. *Anais da Biblioteca Nacional*, v. 1. p. 697-706, 2007.
HIRASHIMA, S. Q. da S., *Calibração do Índice de Conforto Térmico Temperatura Fisiológica Equivalente (PET) para espaços abertos do município de Belo Horizonte*. 2003. 225 f. Dissertação de Mestrado. UFMG, Belo Horizonte, 2010.
HÖPPE, P. Heat balance modelling. *Experientia*, v. 49, p. 741-746, 1993.
HÖPPE, Peter R. The physiological equivalent temperature: a Universal Index for the biometeorological assessment of the thermal environment. *International Journal of Biometeorology*, n.43, p. 71-75, 1999.
INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE).*Brasil – Censo 2000*. Disponível em: <http://www.ibge.org.br/>. Acesso em:6 nov. 2009.
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. Ergonomics of the thermal environment: Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria: ISO 7 730. 3ª ed. Genebra, 2005.
KATZSCHNER, L. Urban climate: thermal comfort. urban planning. Salvador: Goethe-Institut Salvador, 15 fev 2011. Cópia eletrônica fornecida pelo autor (Palestra ministrada durante a 5ª Visita Técnica do Projeto Urban Climate and Urban Design for Global Climate Changes, em cumprimento ao EDITAL CNPq nº 004/2007).
MATZARAKIS, A.; AMELUNG, B. Physiologically equivalent temperature as indicator for impacts of climate change on thermal comfort of humans. In: THOMSON, M.C.; GARCIA-HERRERA R.; BENISTON, M. (Ed.). *Seasonal forecasts, climatic change and human health*. 2008. Netherlands: Springer Science; Business Media B.V., 2008. Chap. 9, p. 161-172.
RUTZ, F.; MATZARAKIS, A.; MAYER, H. *Rayman*, v.1/2, 2000. Disponível em: <http://www.mif.uni-freiburg.de/rayman/ >. Acesso em: 22 set. 2009.
SAFAVIAN, S.R.; LANDGREBE, D. A survey of Decision Tree Classifier Methodology.*Man ad Cybernetics*, v.21, p. 660-674, 1991.
SOUZA, Sandra. *Avaliação do desempenho térmico nos microclimas das praças*: Piedade e Visconde de Cayru. Salvador/BA.2010. 203 f.Dissertação (Mestrado em Engenharia Ambiental Urbana) - UFBA, Salvador, 2010.
WESTPHAL, C.; BLAXTON, T. *Data mining solutions*: methods and tools for solving real-word problems. New York: John Wiley& Sons, 1998.