Objective and Subjective Assessments of Thermal Comfort in Hot-Humid Region

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. *Abstract:* - This study examines the Predicted Mean Vote (PMV) and Thermal Sensation Vote (TSV) in a university hospital in Malaysia. To comparing predicted and actual mean vote, the objective and subjective measurements are performed simultaneously. The facility department of Hospital University Kebangsaan Malaysia (HUKM) is the field study chosen for this survey. From 110 data set in subjective measurement and objective part it is found that people in hot humid region like Malaysia are adapted to warm weather since in this study the value of TSV was always less than the value of PMV in seven point ASHRAE scale .Furthermore it is found a significant correlation between actual mean vote and predicted mean vote while R^2=0.950. In addition it is revealed that neutral temperature in this field study (hot- humid region) is higher than expected by standards. The discrepancy between them is 1.6 °C.

Key-Words: -Thermal comfort, objective measurement, subjective survey, predicted mean vote, thermal sensation vote

1 Introduction

Hospital is one of the most critical buildings in thermal comfort issue since studies show thermal comfort can affect on patient healing presses and also on their length of staying [1]. Furthermore the proper thermal condition can increase productivity of nurses, decrease their absenteeism and improve their wellbeing [2], [3].

In other hand hospitals are 24 hour 7days in a week operation, therefore taking the right decisions in this field in addition of improving the indoor environment also can help significantly to enhance the energy saving and furthermore in reduction of carbon emission in environment [4].

According ISO 7730 [5], ASHRAE standards [6] and Fanger theory there are 6 variable that affect on thermal comfort. These 6 factors are divided by 2: environmental factors and personal factors. The environmental factors (i.e. air temperature, relative humidity, globe temperature and air velocity) are measured and the two personal factors (i.e. clothing insulations value (CLO) and metabolic rate (MET)) should be estimated [7].

There are some studies that show the thermal preference and thermal sensation for people in all climates are not the same and it is influenced by factors such as acclimatize and adaption [8].

This study is performed in hot-humid climate to examine the Predicted Mean Vote (PMV) according Fanger theory by objective measurement and Thermal sensation Vote (TSV) according subjective survey.

2 Methodologies
2.1 Field study description

This study is conducted in Hospital University Kebangsaan Malaysia (HUKM) located in Cheras-Malaysia and facility department in west part of HUKM is chosen for objective and subjective

measurement. Fig.1 taken from Google earth shows the general view of HUKM and facility department.

Fig. 1: General view of field study (facility department of HUKM)

For evaluating the thermal comfort in Facility department it is divided by 5 thermal zones since the activity and thermal condition in these zones were different. Facility department is a 3 story air conditioning building which includes Lobby, Kindergarten and Catering area in first floor, Praying room and Office in second floor. Maximum occupants are about 250. Fig.2 depicts the location of 5 thermal zones in this building.
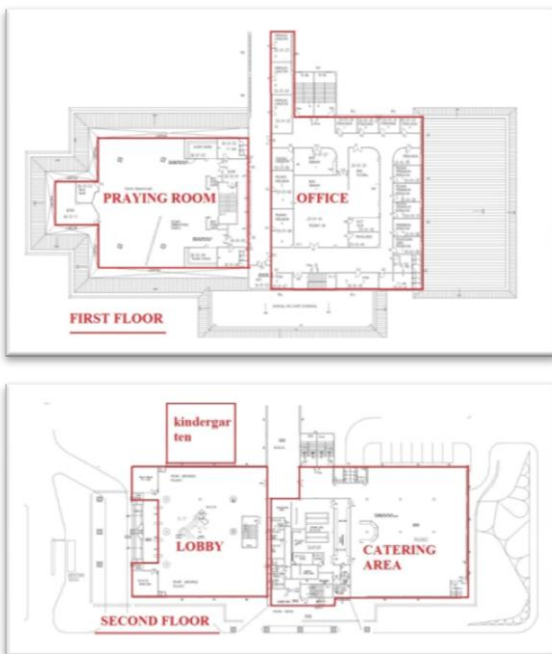

Fig. 2: location of 5 thermal zones in facility department of HUKM

In objective part of this study "Thermal comfort" is used for recording the environmental variable. This instrument can measure and record ambient temperature, globe temperature, relative humidity, air velocity, lux level, sound and CO_2.

In subjective part a questionnaire was prepared and this survey took place with a 110 sample size simultaneously with the objective measurement in May and June 2011.

The dominant gender and age distribution are presented in Table 1 and Table 2 respectively.

Table 1: Gender distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**male**	27	24.5	24.5	24.5
	female	83	75.5	75.5	100.0
	Total	110	100.0	100.0	

Table 2: Age distribution

		sex		
		male	female	Total
range age	<20	2	4	6
	20<x<30	10	56	66
	30<x<40	9	14	23
	>40	6	9	15
Total		27	83	110

3 Results and Discussion
3.1 objective measurements

According Fanger equation for calculating PMV, four environmental variables (i.e. ambient temperature, mean radiant temperature, relative humidity and air velocity) should be measured by device and two personal variable (i.e. clothing insulation value and metabolic rate) should be estimated according standards [9].

Table 3 shows the value of Clothing insulation value (CLO) and Metabolic rate (MET) for each thermal zone.

Table 3: Estimated value of CLO and MET

Thermal zones	lobby	office	Praying room	Kinderga rten	Catering area
CLO	0.6	0.6	0.7	0.6	0.6
MET	1.5	1.2	1.4	1.2	2

Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) are calculated for each thermal zone as it is shown in Table 4.

Table 4: Calculated values according Fanger theory

Thermal zones	lobby	office	Praying room	Kinder garten	Catering area
OP	28.83	25.35	26.35	22.10	27.25
PMV	+1.5	+0.1	+0.8	-1.5	+1.5
PPD%	48.4	5.1	17.2	52.9	48.2

Operative temperature (OP), predictive mean value (PMV), predicted percentage of dissatisfied (PPD).

3.1 Subjective measurement

110 hospital staff participated in this survey and filled out the questionnaire about thermal sensation. By SPSS analysis the value of actual mean vote is determined in every 5 thermal zones. They are presented in Table 5.

Table 5: TSV and PMV in 5 thermal zones

Thermal zones	lobby	office	Praying room	Kinder garten	Catering area
TSV	+1.08	-0.90	-0.27	-2.06	+0.61
PMV	+1.5	+0.1	+0.8	-1.5	+1.5

Predictive mean value (PMV), Thermal sensation Vote (TSV)

As it is shown in Table 5, in all thermal zones the value of actual mean vote (TSV) is less than the predicted mean vote (PMV) in seven point ASHRAE scale. In addition by analyzing the regression liner between TSV and PMV a significant relation was found while $R^2 = 0.950$ (Fig. 3)
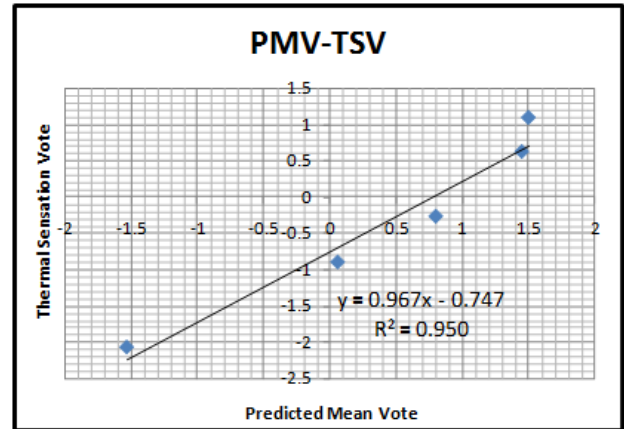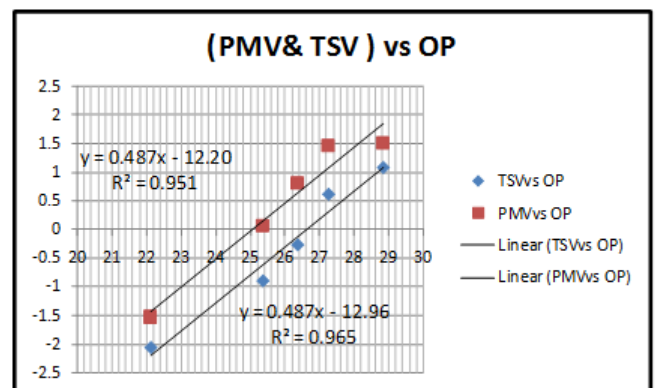

Fig. 3: Regression liner between predicted mean vote and thermal sensation vote

From above result it is inferred that in hot-humid climate people are acclimated to warm weather and they can tolerate warm weather more than people in other climate. In addition it is found their neutral temperature is higher than others. This finding is in agreement with a study conducted in Taiwan by Hwang and et al in 2009 [8].

By analyzing the regression liner between operative temperature and TSV and PMV it is revealed that thermal neutrality in this field study according subjective measurement is 26.6 °C while according the objective measurement is 25 °C. (Fig. 4)

Operative temperature (OP), predictive mean value (PMV), Thermal sensation Vote (TSV)

Fig. 4: Regression liner between operative temperature and PMV&TSV

4 Conclusions

For evaluating the thermal comfort in field study both objective and subjective measurement are performed. The facility department of Hospital University Kebangsaan Malaysia (HUKM) is selected as case study. The findings of this study are listed below:

- By comparing Predicted Mean Vote (PMV) according objective measurement and Thermal Sensation Vote (TSV) according subjective survey it is found the value of TSV is less than PMV in all cases. This finding is in agreement with adaptive theory that believes people in hot- humid region are adapted to warm weather and can tolerate this condition more than people in other climate.
In addition by analyzing the regression liner between PMV and TSV the strong relation is found while R^2 is equal 0.95.

- By analyzing the regression liner between operative temperature and both PMV and TSV it is found in this field study the neutral temperature for people in hot-humid region is higher than expected by standards.
According Fanger theory thermal neutrality in this field study is 25 °C while according the actual people vote it is 26.6 °C.

- For future studies it is recommended to find the desire temperature for people in hot-humid region by more evaluating on occupants' actual mean vote.

References:
[1] Ruey-Lung Hwanga, Tzu-Ping Linb, Ming-Jen Chengc, Jui-Hung Chiena-patient thermal comfort requirement for hospital environment in Taiwan-*Building and Environment* 42 (2007) 2980–2987.

[2] Roberto z.Freire, Gustavo H. C. Oliveira, Nathan Mendes Cheng, Jui-Hung Chien. Predictive controllers for thermal comfort optimization and energy saving. *Energy and Buildings*, Volume 40, Issue 7, 2008, Pages 1353-1365.

[3] Olesen, B. W. "International standards and ergonomics of the thermal environment." *Journal of applied ergonomic* "Volume 26, Issue 4, August 1995, Pages 293-302.

[4] SatishKumar, Ardeshir Mahdavi, Integrating thermal comfort "eld data analysis in a case-based Building simulation environment, *Building and Environment* 36 (2001) 711–720.

[5] *ISO7730*: Moderate thermal environments– determination of the PMV and PPD indices
And specification of the conditions for thermal comfort (2004).

[6] *ASHRAE*. ASHRAE Standard 55: Thermal environmental conditions for human occupancy. American Society of Heating, Refrigerating and Air-conditioning Engineers (2004).

[7] Guoqiang Zhanga Cong Zhenga Wei Yanga Quan Zhanga Demetrios J. Moschandreasa,b Thermal Comfort Investigation of Naturally Ventilated Classrooms in a Subtropical Region ,*Indoor and Built Environment* April 2007 vol. 16 no. 2 148-158.

[8] Ruey-Lung Hwang , Ming-Jen Cheng , Tzu-Ping Lin , Ming-Chin Ho .Thermal perceptions, general adaptation methods and occupant's idea about the trade-off between thermal comfort and energy saving in hot–humid regions .*Building and Environment* 44 (2009) 1128–1134.

[9] Fatemeh Azizpour, S. Moghimi, C. h. Lim, S. Mat, A. Zaharim, K. Sopian. Thermal comfort assessment in large scale hospital: case study in Malaysia. *Proceeding GEMESED'11 Proceedings of the 4th WSEAS international conference on Energy and development - environment - biomedicine* (2011)171-174.