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Proposed Model of Neutral Temperature Equation for Adaptive Thermal Comfort in Student Flats Units in the Tropics

Samsuddin[1,*], Ramli Rahim[2], Baharuddin Hamzah[2], Rosady Mulyadi[2]

[1]Department of Architecture, Faculty of Engineering, Hasanuddin University, Indonesia
[2]Laboratory of Building Science and Technology, Department of Architecture, Faculty of Engineering, Hasanuddin University, Indonesia

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Abstract   Thermal comfort of residential rental flats is one of the problems from the ventilation aspect considering that the planning of flats is based on natural ventilation. This article is intended to formulate an alternative to the neutral temperature equation from the equation proposed by Humphrey, Auliciem, de Dear, Nicol, and Roaf with day and night measurement times. Measurements were carried out for three weeks in a student rental apartment building, Hasanuddin University Faculty of Engineering in Bontomarannu, Gowa Regency, which has 5 floors with 104 rooms. Measurements were made with 2,577 respondents during the day, and 2,043 at night. During the day, with an operating temperature between 29.2°C to 31.0°C, the neutral temperature (T_n) obtained from the PMV model is 27.6°C (T_o). This figure is lower than the actual choice of the TSV scale and the TCV scale, which were 30.3°C (T_o) and 29.7°C (T_o), respectively. At night, with an operating temperature between 27.7°C to 29.5°C, the neutral temperature (T_n) obtained from the PMV model is 26.2°C (T_o). Meanwhile, the neutral temperature obtained from the respondents' actual choices (TSV and TCV) were 28.8°C (T_o) and 28.2°C (T_o), respectively. The neutral temperature equations presented in the Humphrey, Auliciem, de Dear, Nicol, and Roaf equations show a lower thermal coefficient than the corrected thermal coefficient and the elaboration of the equations carried out in this study, both from daytime measurements and from night

measurements.

Keywords   Neutral Temperature Equation, Thermal Comfort, Daytime, Nighttime

1. Introduction

Thermal comfort is defined as a "state of mind expressing satisfaction with the thermal environment" as described in ASHRAE [1]. Thermal comfort plays a very strategic role in building design, because most or about 80% of the time people's activities are done indoors [2]. From the aspect of energy use, Perez-Lombard stated that 70% of energy use in buildings is allocated for air conditioning and artificial lighting. Therefore, buildings need to be designed to respond to climatic conditions while maintaining the comfort of the occupants [3].

The level of productivity and physical endurance (health) of humans is in a certain zone, while outside this zone human productivity and physical endurance decrease. This zone is related to comfort, where according to reports from various studies it is different between groups of people who live in different climatic locations. The British have a comfort zone of 15°C to 20°C while the humans who live in the United States achieve comfort levels between 19.5°C and 26.7°C, while those who live in the

tropics achieve a comfortable level in the temperature. 23.4°C to 29.4°C, all at humidity conditions between 30 to 70% [4].

Thermal comfort research in the tropics is important given that there is a significant increase in the mean annual temperature. Harimi [5] explained that when the climate data for the Kota Kinabalu area were analyzed, it was found that the trend of maximum outdoor temperature increase per decade was around 0.4°C with an average outdoor temperature increase of 0.3°C. The maximum outdoor temperature appears to be increasing faster than the average value.

Human thermal comfort sensation depends partly on his activity and clothing and partly on four environmental variables: air temperature, average emission temperature, air velocity, and humidity. Fanger [6] introduces a comfort equation forming all the combinations of the six factors mentioned above that will provide thermal comfort to humans. The convenience equation does not include time of day as a variable, but assumes that the comfort criterion is constant throughout the day. Fanger [7] in the study of thermal comfort conditions during simulated normal working days at the office and found no significant difference in the preferred ambient temperature during the 'morning and evening hours. Likewise with research conducted in 1974 by Fanger [8] who carried out investigations into thermal comfort in the morning (09.00-12.00) and in the evening (19.00-22.00) which did not found significant differences in the preferred ambient temperature at these two times.

Various studies on thermal comfort in the tropics have been carried out, including in Indonesia [9,10], Malaysia [11], and Singapore [12]. Most of the thermal comfort studies in the tropics are carried out with a heat balance model using the Predicted Mean Vote (PMV). In 1970 Fanger developed the PMV model which was later adopted by ASHRAE as the ASHRAE 55 standard [13]. The PMV model is calculated using six variables, namely air temperature, relative humidity, mean radian temperature (MRT), air velocity, clothing index, and the metabolic rate of the respondent's activity. A number of studies of thermal comfort in the tropics mentioned above found the neutral temperature predicted by PMV to be significantly lower than that of the respondents using the respondent's choice of thermal sensation (TSV). Several studies conducted by Hamzah [10,14] found that the students' neutral temperature was at 23.0°C (PMV) and 29.0°C (TSV). Karyono also found this difference in numbers [15] which revealed that the ISO-7730 and ASHRAE 55-56 standards were about 1-3°C lower than the comfortable temperature required by respondents in tropical regions such as Indonesia. Such conditions will have implications for wasteful energy use and complaints of discomfort due to low room temperature.

The general condition of rental apartment units built in Indonesia, including Makassar City, is a residential building that is mostly subsidized or assisted with technical requirements that direct the use of a building ventilation system with natural ventilation [16]. With thermal conditions tinged with temperatures varying from 28°C in the morning to 33°C in the afternoon [14]. This temperature range is outside the comfort zone by Indonesian local standards [17] and ASHRAE standards [1]. However, a number of studies of thermal comfort in Makassar City found that despite the hot temperature, more than 80% of respondents chose a "comfortable" area and more than 80% of students received a "hot" thermal environment. Adaptation activities that are usually carried out by respondents in order to adjust their thermal comfort needs with the temperature conditions in the room, including the use of fans, changes in activities, clothes, opening and closing windows, hanging fans and so on. Roaf et al. [18] suggested that there are three categories of thermal comfort adaptation activities, namely physiological, behavioral, and psychological. Of the three adaptation activities, behavioral adaptation is the most common way for people to adjust their thermal comfort.

Another thermal comfort concept is the adaptive thermal comfort model developed by Humphrey [19] based on thermal comfort data collected from 1935 to 1975. This concept is specially formulated to predict thermal comfort in naturally ventilated buildings located in tropical areas with hot thermal environments. The concept is put forward in the form of linear regression between neutral temperature (Tn) and average outside temperature (Tout) as follows:

$$T_n = 11{,}9 + 0{,}534 T_{out} \qquad (1)$$

The equation is then revised to improve the accuracy of the equation as follows [20]:

$$T_n = 13{,}2 + 0{,}534 T_{out} \qquad (2)$$

This equation was further refined in 1988 by formulating the following equation [20]:

$$T_n = 13.5 + 0.546 T_{out} \qquad (3)$$

Auliciems [21] develop a neutral temperature formula by stating the following equation:

$$T_n = 9.22 + 0.48 Ta + 0.14 T_{out} \qquad (4)$$

Auliciems dan de Dear [22] propose another equation with the following formula:

$$T_n = 17.6 + 0.31 T_{out} \qquad (5)$$

Nicol dan Roaf [23] suggests a different equation by proposing the following formula:

$$T_n = 17 + 0.38 T_{out} \qquad (6)$$

A number of equations mentioned above are based on research on thermal comfort conducted in Indonesia [14], showing a neutral temperature below the neutral temperature figure based on actual measurements with the TSV model, both for general building functions, and for residential buildings with effective day and night activities. Therefore, this study aims to analyze the neutral

temperature equation above based on tropical climatic conditions characterized by relatively high temperature and humidity.

2. Research Method

Measurements were made in student apartment units which are five-story buildings. Measurements were carried out every day in twelve rooms spread over five floors simultaneously. This is intended to obtain thermal conditions which represent the general thermal conditions of buildings. The downside of this measurement is that it doesn't specifically differentiate between thermal conditions on different floors.

The proposed neutral temperature equation is obtained by changing the existing equation constants according to the actual value of the internal temperature measurement results against the thermal conditions at the research location, both during the day and at night.

2.1. Data Collection

The data used as the object of study consists of four data components including: outdoor temperature data for the period 2014-2019, outdoor temperature data for the period of October 2020, objective data measurement results, and subjective data measurement results.

2.1.1. Outdoor Temperature Data for the Period 2014-2019

Data on temperature and relative humidity for outdoor space on a 6-year scale for the period 2014-2019 obtained from the weather monitoring tool Vaisala Type WXT520 which is equipped with data loggers Type CR800 series 2 which automatically stores data for a 24 hour period, RTU (Remote Terminal Unit), which is part of the AWS (Automatic Weather Stations) device on the campus data station of the Faculty of Engineering, Unhas Gowa.

2.1.2. Outdoor Temperature Data for the Period of October 2020

Temperature and relative humidity data for the out space for the period of October 2020 were obtained from the Vaisala Type WXT520 weather monitor. This data is obtained from the same instrument to measure 6-year scale data for the 2014-2019 period.

2.1.3. Objective Data Measurement Results

The results of objective data measurements are carried out to collect thermal environmental conditions and clothing data of respondents. The main instrument used in this study was the Thermal Comfort Multi Logger (LSI TC) from LSI-Lastem, Italy. LSI TC consists of three sensors that collect and record in one data logger. Tiga sensor termasuk psikometrik portabel probe (BSU102), which is used to record temperature and humidity relative humidity data. The second sensor is a Globe Thermometric Probe (BST131) which is used to record the temperature of the globe. The third sensor is a wet-bulb temperature probe (BSU121) for recording the wet-bulb temperature. Apart from LSI TC, another instrument used is Hobo Loggers which records measurements of the thermal environment in space. This tool was developed and manufactured by Onset in the United States. Two types of loggers Hobo are used in this study, namely the standard Hobo which records air temperature and relative humidity, and the Hobo logger with an external sensor that records air velocity in the room. This instrument (LSI TC), 2 hobo loggers with external sensors, and 3 standard hobo units are spread out in 6 rooms simultaneously on the same floor level with a continuous data recording period of 24 hours with the number of days that have been arranged. The sensor is installed at a height of approximately 1 meter above the floor level [12]. Respondent clothing data is an integral part of the questionnaire.

2.1.4. Subjective Data Measurement

Subjective measurements were carried out to record respondents' responses using a questionnaire instrument developed and modified based on the questionnaire used by Wong and Khoo [12]. The questionnaire used contains seven questions. Four questions are related to the thermal aspect, namely thermal sensation, thermal comfort, thermal preference and acceptance, the fifth and sixth questions concern air velocity, and the seventh question concerns indoor humidity. Question about TSV cover the seven ASHRAE scales consisting of cold (-3), cool (-2), slightly cool (-1), neutral (0), slightly warm (+1), warm (+2), and hot (+3). Questions about the TCV covering the seven Bedford scale consist of: much too cool (-3), too cool (-2), comfortable cool (-1), comfortable (0), comfortable warm (+1), too warm (+2), and much too warm (+3). This subjective measurement was carried out by taking two times scales, namely during the day between 10:00-15:40 and evening between 18:00-21:40 hours. This is done considering the function of the building as a function of housing.

Annual temperature conditions for the period 2014-2019 show the temperature conditions measured by day and night where there is a significant difference between the average daytime and night temperatures of 2.0°C. The maximum daytime temperature was recorded at 29.5°C in 2016 and the minimum temperature was 28.8°C in 2019. The maximum nighttime temperature was recorded at 30.5°C in 2017 and the minimum temperature was 24.9°C in 2015. Average air temperature during the day recorded in the 2014-2019 measurement period it was higher than the average air temperature measured in the 1968-2003 period [5].

2.2. Data Processing and Analysis

Data processing and analysis were carried out using

spreadsheet software and statistical packages which were used to calculate the maximum value, minimum value, and average value as the basis for describing the PMV, TSV, and TCV charts. The PMV of each respondent was calculated using data from four environmental variables and two personal variables. Four environmental variables include air temperature, average radiant temperature, relative air velocity, and relative humidity. Two personal variables include data on clothing and metabolic rate. The PMV value of respondents was determined using the PMV calculator developed by Farina [24] based on ASHRAE standard 55 [1]. Linear regression of PMV, TSV, and TCV was performed using SPSS statistical analysis (statistical package for social science) to show the distribution of respondents' actual voices to operating temperature (To). Data validity and reliability tests are carried out prior to data processing in order to ensure data normality.

2.3. Research Samples

The survey and objective data measurement were carried out for three weeks (21 days) in the Rusunawa building, Bontomarannu Engineering Faculty, Gowa Regency. This building is a 5-storey building with 104 rooms divided into 16 rooms on the ground floor and 22 rooms on the 2,3,4, and 5 floors. Measurements are carried out 24 hours a day to obtain temperature data that represents daytime and night considering the function of the building as a residential unit. The characteristics of the day and night measurement samples are described in Table 1 and Table 2 below.

Table 1.   Characteristics of Sample Based on Survey During the Daytime

No.	Date of Survey	Floor Level	Number of Rooms	Number of Respondents
1	1 October 2020	1	9	108
2	2 October 2020	1	9	128
3	3 October 2020	1	12	133
4	4 October 2020	1	12	128
5	5 October 2020	2	12	88
6	6 October 2020	2	12	127
7	7 October 2020	2	12	134
8	8 October 2020	2	12	97
9	9 October 2020	2	12	133
10	10 October 2020	3	12	126
11	11 October 2020	3	12	134
12	12 October 2020	3	12	134
13	13 October 2020	3	12	134
14	14 October 2020	4	12	134
15	15 October 2020	4	12	127
16	16 October 2020	4	12	127
17	17 October 2020	4	12	107
18	18 October 2020	5	12	133
19	19 October 2020	5	12	100
20	20 October 2020	5	12	124
21	21 October 2020	5	12	121
Total			246	2,577

Table 2. Sample Characteristics Based on Survey at Nighttime

No.	Date of Survey	Floor Level	Number of Rooms	Number of Respondents
1	1 October 2020	1	9	84
2	2 October 2020	1	9	101
3	3 October 2020	1	12	106
4	4 October 2020	1	12	85
5	5 October 2020	2	12	71
6	6 October 2020	2	12	106
7	7 October 2020	2	12	107
8	8 October 2020	2	12	102
9	9 October 2020	2	12	101
10	10 October 2020	3	12	74
11	11 October 2020	3	12	100
12	12 October 2020	3	12	107
13	13 October 2020	3	12	106
14	14 October 2020	4	12	107
15	15 October 2020	4	12	106
16	16 October 2020	4	12	100
17	17 October 2020	4	12	101
18	18 October 2020	5	12	98
19	19 October 2020	5	12	106
20	20 October 2020	5	12	80
21	21 October 2020	5	12	95
Total			246	2,043

3. Result and Discussion

3.1. Outdoor and Indoor Microclimate Conditions

Outdoor microclimate condition data is data obtained from the weather monitoring tool Vaisala which is located at the top of the campus building of the Bontomarannu Faculty of Engineering, Gowa Regency. Average outdoor temperature the room recorded in October during the day is 29.6°C with a maximum temperature of 30.9°C and a minimum temperature of 27.3°C. While the average temperature at night is 26.4°C, the maximum temperature is 28.0°C and the minimum temperature is 22.7°C.

Data on indoor microclimate conditions from day and night measurements that are recorded during the measurement can be seen in Table 3. This table shows that the average indoor air temperature during the day is 31.6°C with the maximum and minimum temperatures respectively 32.3°C and 30.6°C. Air temperature conditions indicate relatively high temperature conditions in the room. The average temperature recorded during the day and night is higher than the local Indonesian thermal comfort standards [17] and ASHRAE international standards [1]. The average relative humidity during the day and night was 71.78% and 74.05%, respectively. As with temperature, the relative humidity conditions are well above Indonesia's thermal comfort standards [17].

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Table 3. The Average Indoor Thermal Environment

Date of survey	Afternoon Operational Temperature (°C)	Afternoon MRT (°C)	Afternoon Indoor Temperature			Night Operational Temperature (°C)	Night MRT (°C)	Night Indoor Temperature			Relative Humidity (Afternoon)			Relative Humidity (Night)		
			Average (°C)	Max (°C)	Min (°C)			Average (°C)	Max (°C)	Min (°C)	Average %	Max %	Min %	Average %	Max %	Min %
1 October 2020	30.8	29.6	32.0	33.3	28.7	29.3	29.0	29.6	30.9	26.5	79.66	85.13	69.10	81.32	89.55	70.53
2 October 2020	30.8	29.5	32.1	33.4	28.8	29.3	28.9	29.7	31.0	26.6	75.58	84.11	68.59	77.02	84.80	67.12
3 October 2020	30.2	28.7	31.7	33.0	28.4	28.7	28.4	29.0	30.1	25.8	70.99	78.22	61.97	73.41	80.78	62.94
4 October 2020	30.0	28.7	31.3	32.8	28.2	28.6	28.2	28.9	30.2	25.9	70.73	77.76	61.95	72.57	80.12	62.78
5 October 2020	31.0	29.7	32.3	33.7	29.0	29.5	29.0	29.9	31.3	26.9	80.36	85.50	75.02	81.78	90.45	70.89
6 October 2020	30.3	28.8	31.8	33.1	28.5	28.8	28.4	29.2	30.4	26.2	71.26	79.29	62.37	73.57	81.16	63.78
7 October 2020	30.4	29.0	31.8	33.2	28.6	29.0	28.4	29.5	30.7	26.4	71.54	79.45	62.99	74.14	81.76	64.23
8 October 2020	29.4	28.0	30.8	32.1	27.7	28.0	27.2	28.7	30.1	25.8	68.24	74.11	58.24	70.59	76.89	61.22
9 October 2020	30.7	29.3	32.1	33.5	28.8	29.2	28.5	29.9	31.3	26.7	74.34	82.82	65.31	76.28	83.23	66.78
10 October 2020	30.5	29.1	31.9	33.2	28.6	29.0	28.5	29.5	30.8	26.5	72.03	82.78	64.97	75.17	82.54	65.21
11 October 2020	29.9	28.5	31.3	32.7	28.2	28.4	27.9	29.0	30.1	25.8	70.22	77.07	61.90	72.28	79.69	62.68
12 October 2020	30.7	29.5	31.9	33.4	28.7	29.2	28.7	29.8	31.2	26.7	75.25	83.14	67.52	76.93	83.90	66.80
13 October 2020	30.5	29.0	32.0	33.3	28.7	29.0	28.5	29.5	30.8	26.5	71.98	82.08	63.93	74.36	81.99	64.45
14 October 2020	29.5	28.0	31.0	32.3	27.9	28.1	27.4	28.7	30.1	25.8	68.51	74.36	58.34	70.94	78.32	61.53
15 October 2020	29.9	28.3	31.5	32.9	28.3	28.4	27.9	29.0	30.1	25.9	69.71	75.57	61.76	72.21	79.53	62.66
16 October 2020	30.5	29.1	31.9	33.3	28.6	29.0	28.5	29.5	30.8	26.5	71.99	82.55	64.72	74.65	82.12	64.57
17 October 2020	30.5	29.1	31.9	33.3	28.7	29.0	28.5	29.6	30.9	26.4	73.71	82.80	65.00	75.70	82.64	65.58
18 October 2020	29.4	27.9	30.9	32.2	27.7	27.9	27.2	28.6	30.0	25.6	67.30	73.97	54.04	69.67	76.89	60.54
19 October 2020	29.8	28.1	31.5	32.8	28.2	28.3	27.7	28.9	30.2	25.9	69.39	75.47	58.75	71.59	78.98	62.00
20 October 2020	29.2	27.8	30.6	32.0	27.6	27.7	27.1	28.3	29.6	25.4	65.98	73.10	42.62	69.50	76.65	60.29
21 October 2020	29.7	28.1	31.3	32.6	28.1	28.2	27.4	29.0	30.2	26.0	68.51	75.27	58.39	71.46	78.78	61.88
Average	30.2	28.8	31.6	33.0	28.4	28.7	28.2	29.2	30.5	26.2	71.78	79.26	62.26	74.05	81.47	64.21
Max	31.0	29.7	32.3	33.7	29.0	29.5	29.0	29.9	31.3	26.9	80.36	85.50	75.02	81.78	90.45	70.89
Min	29.2	27.8	30.6	32.0	27.6	27.7	27.1	28.3	29.6	25.4	65.98	73.10	42.62	69.50	76.65	60.29

3.2. Respondents' Responses to the Thermal Environment based on Thermal Balance

Respondents' responses to the thermal environment inside the building during the day and night can be seen in table 4. During the day on the TSV scale, 31.04% chose a neutral area (0), 27.01% chose a slightly cool (-1), 10.36% chose cool (-2), 1.59% chose cold (-3), 19.17% chose slightly warm (+1), 7.53% chose warm (+2), and 3.30% chose hot (+3). On the TCV scale, 40.55% chose comfortable (0), 12.03% chose comfortable cool (-1), 5.28% chose too cool (-2), 0.31% chose much too cool (-3), 24.13% chose comfortable warm (+ 1), 6.69% chose too warm (+2), and 1.49% chose much too warm (+3). Table 5 provides an overview of the respondents' responses to the thermal environment inside the building at night. On the TSV scale, 30.79% chose a neutral area (0), 26.97% chose slightly cool (-1), 10.38% chose cool (-2), 1.52% chose cold (-3), 19.24% preferred slightly warm (+1), 7.54% chose warm (+2), and 3.57% chose hot (+3). On the TCV scale, 40.63% chose comfortable (0), 11.89% chose comfortable cool (-1), 5.34% chose too cool (-2), 0.29% chose much too cool (-3), 32.35% chose comfortable warm (+1), 6.85% chose too warm (+2), and 2.68% much too warm (+3).

The data presented Figure 1 contain the percentage of respondents 'choice of thermal sensation, thermal comfort and prediction of the average choice of respondents during the day, which can be explained that the average prediction of respondents' choices is relatively different from the TSV scale and the TCV scale. In the prediction model (PMV), there are 75.28% of respondents predicted to choose hot areas (+2 and +3), 24.72% of respondents predicted to choose the middle area (-1, 0, and +1). If you compare the predictions of respondents who choose in the middle area (-1, 0, and +1) with the respondents' choices on the TSV and TCV scales figures 77.22% and 85.06%, It can be explained that the predicted figures in the PMV model against the options in the middle region (-1, 0, and +1) are much lower than on the TSV and TCV scales. Likewise, the predictions of respondents who chose a slightly cool area (-1) on the TSV scale were 27.01% and a comfortable cool area (-1) on the TCV scale was 12.03% compared to 0% in the PMV model, and respondents who chose a slightly warm area (+1) on the TSV scale as much as 19.17% and 32.48% of respondents chose a warm comfortable area (+1) on the TCV scale which is also compared to 24.72% in the PMV model.
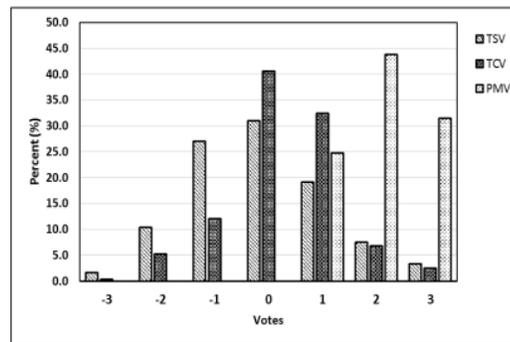

Figure 1. The Percentage of Thermal Sensation Votes, Thermal Comfort Vote, and the Predicted Mean Vote During the Day

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Table 4. Distribution of Respondents' Choice of TSV and TCV During the Day

Date of survey	TSV (Thermal Sensation Vote)							TCV (Thermal Comfort Vote)						
	cold	cool	slightly cool	neutral	slightly warm	warm	hot	much too cool	too cool	comfortable cool	comfortable	comfortable warm	too warm	much too warm
	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
1 October 2020	0	6	23	37	27	11	4	0	2	6	46	45	8	3
2 October 2020	0	8	31	45	32	8	4	0	5	23	49	37	8	1
3 October 2020	0	6	29	46	33	13	6	0	9	6	58	51	8	6
4 October 2020	0	16	44	42	18	8	0	0	10	6	67	39	6	1
5 October 2020	0	3	16	25	23	12	9	0	0	0	0	26	28	29
6 October 2020	0	6	28	38	31	18	6	0	5	4	55	55	6	2
7 October 2020	0	4	21	43	40	19	7	0	5	3	57	54	12	2
8 October 2020	0	7	36	30	15	3	6	0	6	6	34	40	8	3
9 October 2020	7	28	43	33	16	3	3	0	3	23	62	33	11	2
10 October 2020	6	25	42	33	15	4	1	0	2	26	63	26	11	0
11 October 2020	0	17	46	42	18	8	3	0	3	31	56	34	8	2
12 October 2020	0	14	37	42	31	8	2	0	7	26	54	38	6	2
13 October 2020	0	6	28	45	34	13	8	0	7	5	58	52	7	4
14 October 2020	0	7	29	43	32	17	6	0	8	5	60	52	7	2
15 October 2020	0	9	41	45	20	8	4	0	7	5	55	50	8	3
16 October 2020	0	8	35	50	23	8	3	0	2	5	50	57	9	3
17 October 2020	0	12	32	37	18	6	2	0	10	22	41	25	7	2
18 October 2020	0	8	27	40	32	18	8	0	7	5	53	60	9	1
19 October 2020	5	22	33	25	12	3	0	8	22	42	22	6	0	0
20 October 2020	17	35	37	23	8	2	2	0	9	36	56	26	0	0
21 October 2020	6	20	38	36	16	4	1	0	7	25	49	31	9	0
Number of choices	41	267	696	800	494	194	85	8	136	310	1045	837	176	65
Percentage of choices	1.59	10.36	27.01	31.04	19.17	7.53	3.30	0.31	5.28	12.03	40.55	32.48	6.83	2.52
Amount of data							2577							2577
Percentage of total							100							100

Figure 2 contains data on the percentage of respondents' choice of thermal sensation, thermal comfort and the predicted average choice of respondents at night. This data shows that in the PMV model, there are 75.38% of respondents predicted to choose hot areas (+2 and +3), 24.62% of respondents predicted to choose the middle area (-1, 0, and +1). When comparing the predictions of respondents who chose in the middle area (-1, 0, and +1) with the choice of respondents on the TSV and TCV scales at 77.00% and 84.87%, it can be explained that the numbers predicted in the PMV model to the choices in the middle area (-1, 0, and +1) are much lower than the TSV and TCV scales. Likewise, the predictions of respondents who chose a slightly cool area (-1) on the TSV scale were 26.97% and a comfortable cool area (-1) on the TCV scale was 11.89% versus 0% on the PMV model, and respondents who chose a slightly warm area (+1) on the TSV scale were 19.24% and 32.35% of respondents chose a warm comfortable area (+1) on the TCV scale which was also compared to 24.62% in the PMV model. Based on the data elaborated in Figure 2 and Figure 3, it can then be explained that the results of research on thermal comfort were carried out in several regions such as Indonesia [9,10], Malaysia [11], and Singapore [12] find relatively the same phenomenon. Therefore, the PMV model can be said to be an irrelevant model to be applied in thermal comfort research, especially in naturally ventilated buildings in tropical areas such as Indonesia.
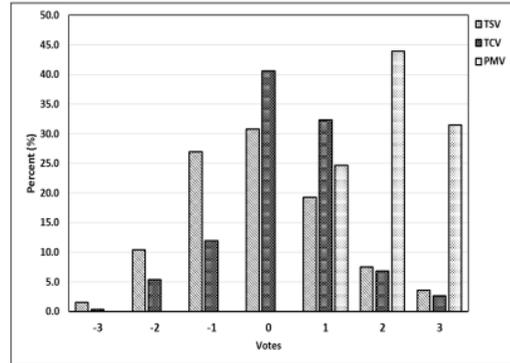
Figure 2. The Percentage of Thermal Sensation Votes, Thermal Comfort Vote, and the Predicted Mean Vote During the Evening

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Table 5. Distribution of Nightly Respondents' Choice of TSV and TCV

Date of survey	TSV (Thermal Sensation Vote)							TCV (Thermal Comfort Vote)						
	cold −3	cool −2	slightly cool −1	neutral 0	slightly warm 1	warm 2	hot 3	much too cool −3	too cool −2	comfortable cool −1	comfortable 0	comfortable warm 1	too warm 2	much too warm 3
1 October 2020	0	4	18	29	21	8	4	0	1	4	37	35	2	3
2 October 2020	0	5	22	30	25	14	5	0	4	4	44	43	6	1
3 October 2020	0	4	22	35	27	11	7	0	6	4	46	42	5	1
4 October 2020	0	9	25	29	15	5	2	0	8	17	33	19	5	4
5 October 2020	0	2	12	20	19	10	8	0	0	0	0	21	23	26
6 October 2020	0	3	16	34	32	15	6	0	4	3	46	42	10	2
7 October 2020	0	7	22	31	26	14	7	0	5	4	42	47	7	0
8 October 2020	5	20	33	27	12	4	1	0	1	21	50	20	8	0
9 October 2020	0	7	27	39	19	6	3	0	2	4	40	46	7	3
10 October 2020	0	5	28	23	11	2	5	0	4	4	27	31	6	2
11 October 2020	0	6	25	35	25	6	3	0	4	18	39	29	6	4
12 October 2020	0	5	23	37	26	11	5	0	8	4	46	41	7	1
13 October 2020	0	5	23	34	26	13	5	0	7	4	47	41	6	1
14 October 2020	5	23	34	26	13	3	3	0	2	18	50	26	9	1
15 October 2020	0	11	30	33	24	7	1	0	6	20	43	31	5	2
16 October 2020	0	12	34	33	15	6	0	0	8	4	53	31	4	0
17 October 2020	0	10	32	35	15	6	3	0	5	4	43	39	6	3
18 October 2020	13	28	30	18	7	1	1	0	8	29	44	20	0	0
19 October 2020	0	13	37	33	14	6	3	0	2	24	45	27	7	1
20 October 2020	4	17	27	20	9	3	0	6	18	34	17	5	0	0
21 October 2020	4	16	31	28	12	3	1	0	6	19	38	25	7	0
Number of choices	31	212	551	629	393	154	73	6	109	243	830	661	140	54
Percentage of choices	1.52	10.38	26.97	30.79	19.24	7.54	3.57	0.29	5.34	11.89	40.63	32.35	6.85	2.64
Amount of data							2043							2043
Percentage of total							100							100.00

Figures 3, 4, and 5 show the scatter plots and linear regression of the operating temperature (To) against the predicted PMV, TSV, and TCV during the day. With operating temperatures ranging from 29.2°C to 31.0°C, the neutral temperature (Tn) obtained from the PMV model is 27.6°C (To). This predicted neutral temperature is lower than the actual choice of the TSV scale and the TCV scale which are 30.3°C (To) and 29.7°C (To), respectively. Figures 6, 7, and 8 are scatter plots and linear regression of operating temperature (To) against predicted PMV, TSV, and TCV at night. With operating temperatures ranging from 27.7°C to 29.5°C, the neutral temperature (Tn) obtained from the PMV model is 26.2°C (To). As with the linear regression results during the day, the predicted neutral temperature is also lower than the actual choice of the TSV scale and the TCV scale which are 28.8°C (To) and 28.2°C (To), respectively.

The neutral temperature (Tn) obtained from the relationship between the actual choice (TSV and TCV) and the operational temperature (To) between day and night shows a significantly different number. On the TSV scale there is a neutral temperature difference between day and night of 1.5°C. On the TCV scale there is a neutral temperature difference of 3.5°C. Meanwhile, there is a neutral temperature difference predicted on the PMV scale between day and night of 1.4°C.

$$PMV = 0.8213Top - 22.696$$
$$R^2 = 0.301$$

Intersection point:
PMV => 27.6342
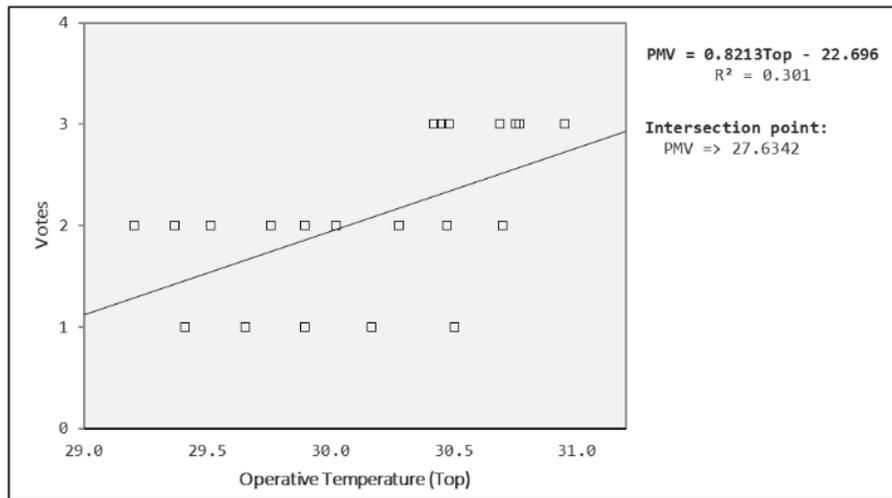
Figure 3. The Scatterplots and the Linier Regressions of the Operative Temperature (To) Versus the PMV During the Day

$$TSV = 0.7276Top - 22.023$$
$$R^2 = 0.0818$$

Intersection point:
TSV => 30.2680
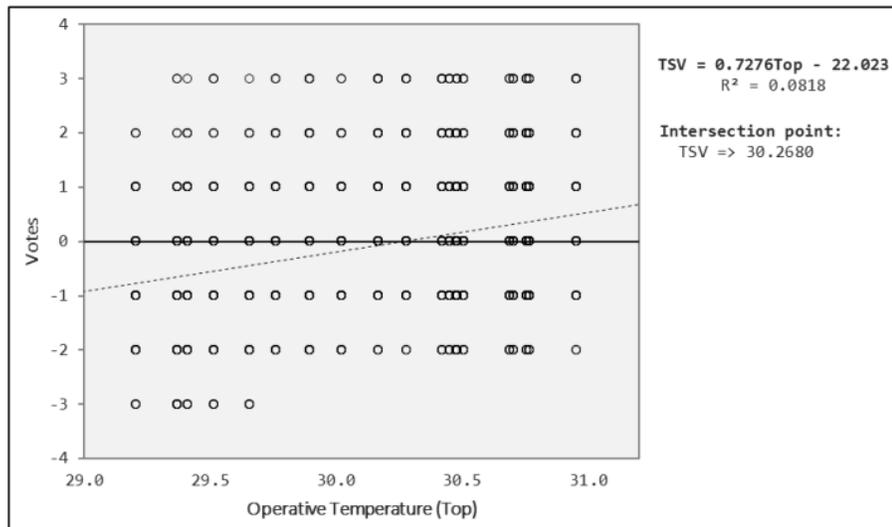
Figure 4. The Scatterplots and the Linier Regressions of the Operative Temperature (To) Versus the TSV During the Day
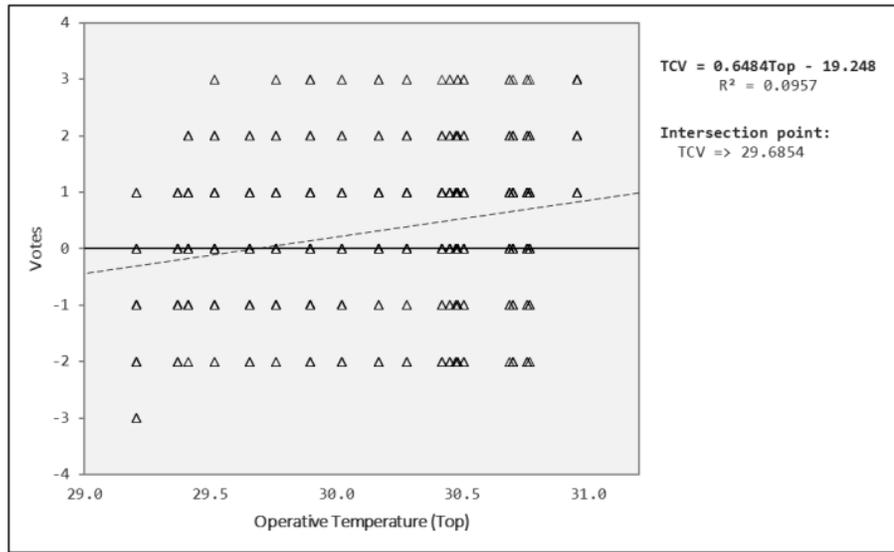
Figure 5. The Scatterplots and the Linier Regressions of the Operative Temperature (T_o) Versus the TCV During the Day
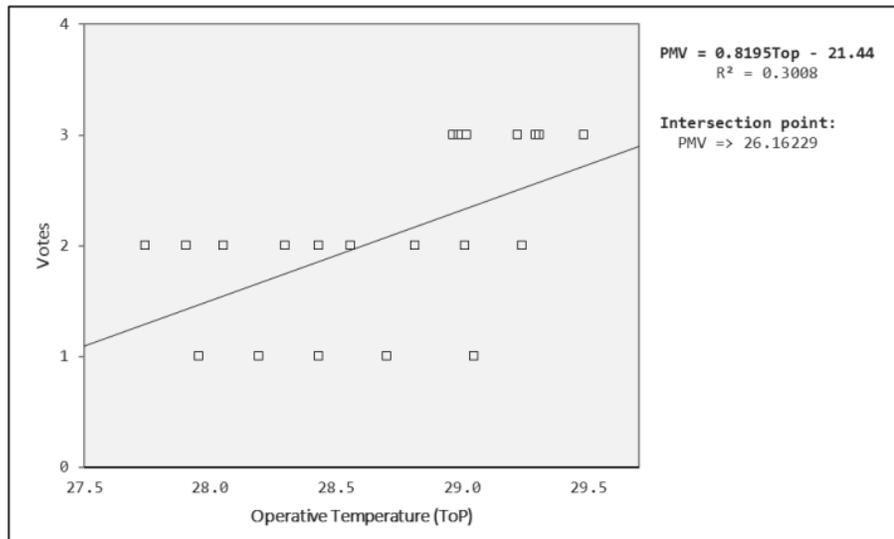
Figure 6. The Scatterplots and the Linier Regressions of the perative Temperature (T_o) Versus the PMV During the Evening
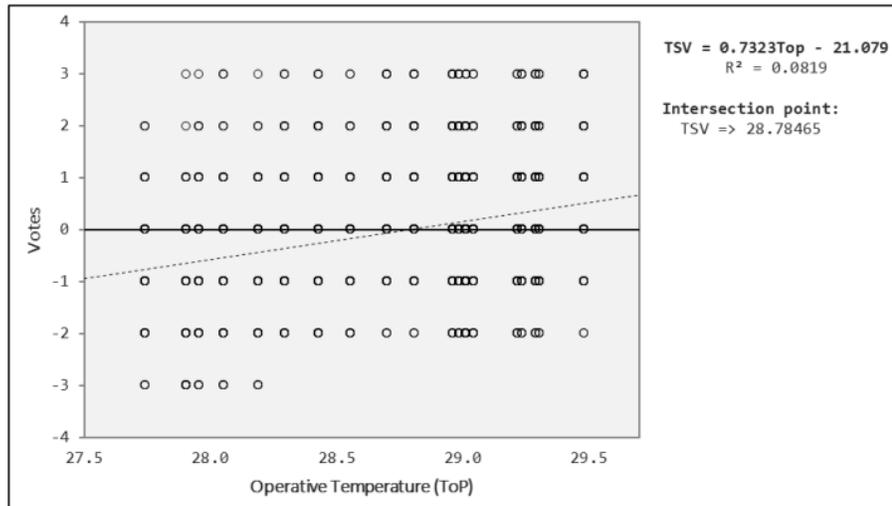
Figure 7. The Scatterplots and the Linier Regressions of the perative Temperature (T_o) Versus the TSV During the Evening
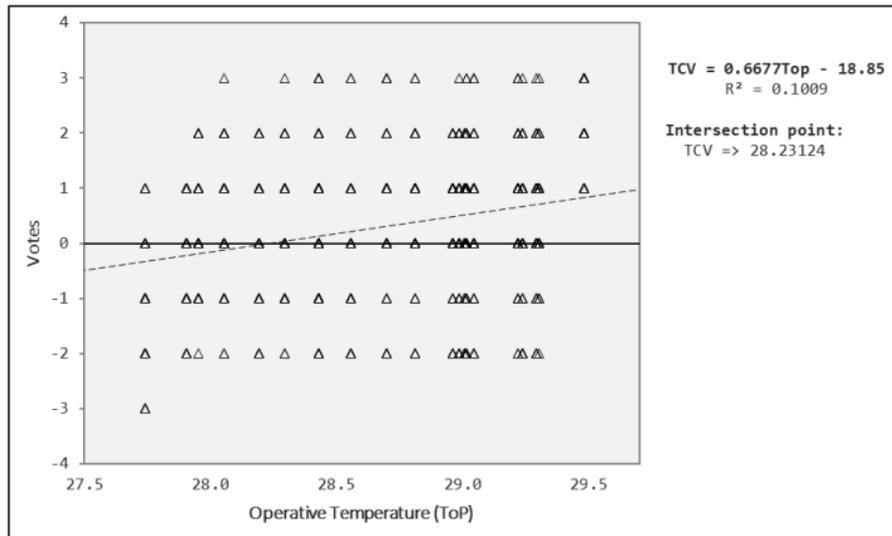
Figure 8. The Scatterplots and the Linier Regressions of the perative Temperature (T_o) Versus the TCV During the Evening

3.3. Respondent/Occupant Adaptive Activities

Adaptive activities carried out by respondents / residents in responding to thermal conditions in the room during the day or at night are by setting windows to a wide open position, opening doors, using paper fans, using battery-powered mechanical fans, and some rooms using electric fans. The use of air conditioning in the room was not found because the flats management policy did not allow the use of air conditioning due to considerations of limited electrical resources on campus. Other adaptive activities carried out by residents are leaving the room and joining a study room where the occupants are relatively better because of the sufficient number of window openings.

3.4. Elaboration of Equations on Neutral Temperature Measurement Results

The neutral temperature equations which are the object of study in this study are the six neutral temperature equations proposed by Humphrey, Auliciem, Auliciem and de Dear, Nicol and Roaf, respectively, as described in equation (1-6) above. With an actual neutral temperature of 12.3°C (TSV), an average outdoor temperature of 29.6 °C, an average indoor temperature of 31.6 °C, then the average neutral temperature of the 6 equations with respect to daylight measurement results the day is as follows:

1. The Humphrey's Equation   (1) : 27.7°C
2. The Humphrey's Equation   (2) : 29.0°C
3. The Humphrey's Equation   (3) : 29.7°C
4. The Auliciem's Equation   (4) : 28.5°C
5. Auliciem dan de Dear's Equation (5) : 26.8°C
6. Nicol dan Roaf's Equation   (6) : 28.2°C

Next, on th equation (1): $T_n=11,9+ 0,534T_{out}$, if 11.9 assumed to be the thermal constant (x), then the value of x = 14.5. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 14.5 + 0.534\ T_{out} \tag{7}$$

Equation (2) will be the same as the result of the elaboration of equation (1) because the multiplier for the outdoor temperature (T_{out}) is the same.

Furthermore, for equation (3): $T_n = 13.5 + 0.546T_{out}$, if 13.5 is assumed to be the thermal constant (x), then the value of x = 14.1. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 14.1 + 0.546\ T_{out} \tag{8}$$

Regarding equation (4): $T_n = 9.22 + 0.48T_a + 0.14T_{out}$, if 9.22 is assumed to be the thermal constant (x), then the value of x = 10.99. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 10.99 + 0.48T_a + 0.14T_{out} \tag{9}$$

Regarding equation (5): $T_n=17.6+0.31T_{out}$, if 17.6 is considered as the thermal constant (x), then the value of x=21.23. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 21.23 + 0.31T_{out} \tag{10}$$

Regarding equation (6): $T_n = 17 + 0.38T_{out}$, if 17 is assumed to be the thermal constant (x), then the value of x=21.23. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 19.06 + 0.38T_{out} \tag{11}$$

With the actual measured neutral temperature (TSV) of 28.8 °C, an average outdoor temperature of 26.4 °C and an average indoor temperature of 29.2 °C at night, the mean neutral temperature is obtained based on each equation as following:

1. The Humphrey's Equation   (1) : 26.0°C
2. The Humphrey's Equation   (2) : 27.3°C
3. The Humphrey's Equation   (3) : 27.9°C
4. The Auliciem's Equation   (4) : 26.9°C
5. Auliciem and de Dear's Equation (5) : 25.8°C
6. Nicol and Roaf's Equation   (6) : 27.0°C

Furthermore, for equation (1): $T_n=11.9+0.534T_{out}$, if 11.9 is assumed to be the thermal constant (x), then the value of x=14.7. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 14.7 + 0.534\ T_{out} \tag{12}$$

Furthermore, for equation (3): $T_n=13.5+0.546T_{out}$, if 13.5 is assumed to be the thermal constant (x), then the value of x=14.4. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 14.4 + 0.546\ T_{out} \tag{13}$$

Regarding equation (4): $T_n=9.22+0.48T_a+0.14T_{out}$, if 9.22 is assumed to be the thermal constant (x), then the value of x=11.9. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 11.09 + 0.48T_a + 0.14T_{out} \tag{14}$$

Regarding equation (5): $T_n = 17.6 + 0.31T_{out}$, if 17.6 is considered as the thermal constant (x), then the value of x=20.7. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 20.7 + 0.31T_{out} \tag{15}$$

Regarding equation (6): $T_n=17+0.38T_{out}$, if 17 is assumed to be the thermal constant (x), then the value of x=18.77. Thus, the neutral temperature equation corresponding to the actual measurement results is:

$$T_n = 18.77 + 0.38T_{out} \tag{16}$$

Furthermore, the comparison of the neutral temperature values for each of 24 equations of the day and night measurement results can be seen in Table 6 below:

Table 6. Comparison of The Neutral Temperature Value of Each Equation from the Day and Night Measurement Results

Neutral Temperature Equation Model	Neutral Temperature Equation	The Proposed Value of the Daytime Neutral Temperature Equation Constant	The Proposed Value of the Nighttime Neutral Temperature Equation Constant
The Humphrey's Equation Model (eq.1)	$T_n=11,9+0,534T_{out}$	$T_n=27.7\ °C$	$T_n=26.0\ °C$
The Humphrey's Equation Model (eq.2)	$T_n=13,2+0,534T_{out}$	$T_n=29.0\ °C$	$T_n=27.3\ °C$
The Humphrey's Equation Model (eq.3)	$T_n=13.5+0.546\ T_{out}$	$T_n=29.7\ °C$	$T_n=27.9\ °C$
The Auliciem's Equation Model (eq. 4)	$T_n=9.22+0.48T_a+0.14T_{out}$	$T_n=28.5\ °C$	$T_n=26.9\ °C$
The Auliciem & de Dears's Equation Model (eq. 5)	$T_n=17.6+0.31T_{out}$	$T_n=26.8\ °C$	$T_n=25.8\ °C$
The Nicol & Roafs's Equation Model (eq. 6)	$T_n=17.0+0.38T_{out}$	$T_n=28.2\ °C$	$T_n=27.0\ °C$

The data presented in table 6 above shows that the constant value of equation (3) from the daytime measurement results is the value closest to the thermal comfort figure based on the TSV scale measurement (30.3^{o}C). Likewise, the results of night measurements where equation (3) is the closest value to the TSV scale neutral temperature (28.8^{o}C). Furthermore, the proposed neutral temperature equation from daytime calculations is shown in Figure 9, while the proposed neutral temperature equation from nighttime calculations is shown in Figure 10.
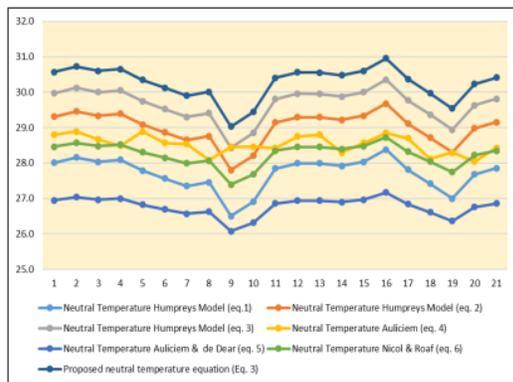
Figure 9. Proposed Neutral Temperature Equation for Daytime Measurement Results (eq. 3)
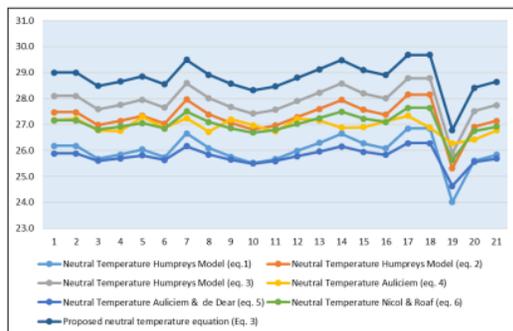
Figure 10. Proposed Neutral Temperature Equation for Nighttime Measurement Results (eq. 3)

4. Conclusions

Based on the analysis of the research, it can be concluded that the PMV model used to measure the level of thermal comfort in the tropics, especially in the research location, cannot produce real thermal comfort figures which are marked by a significant difference between the PMV measurement results and the respondents' actual choices (TSV and TCV). There is a difference significant between the neutral temperature predicted by PMV both in the daytime measurement and the nighttime measurement.

In the daytime measurement with operating temperatures ranging from 29.2°C to 31.0°C, the neutral temperature (T_n) obtained from the PMV model is 27.6°C (T_o). This predicted neutral temperature is lower than the actual choice of the TSV scale and the TCV scale which are 30.3°C (T_o) and 29.7°C (T_o), respectively. At night measurements, with an operating temperature ranging from 27.7°C to 29.5°C, the neutral temperature (T_n) obtained from the PMV model is 26.2°C (To). As with the daytime measurement, the neutral temperature obtained from the respondents' actual choice (TSV and TCV) was 28.8°C (T_o) and 28.2°C (T_o), respectively. The neutral temperature equations presented in the Humphrey, Auliciem, de Dear, Nicol, and Roaf equations (equations 1-6) have a thermal constant that is relatively lower than the thermal constant of the actual measurement results carried out in this study, both from the results of daytime measurements, as well as from the results of night measurements. Therefore, this study proposes an alternative neutral equation suitable for tropical areas.

Acknowledgments

REFERENCES

[1] Paliaga G, Schoen LJ, Alspach PF, Arens EA, Aynsley RM, Bean R, et al. Thermal environmental conditions for human occupancy. ASHRAE Stand. 2013;8400(STANDARD 55):1–44. https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_55_2013.

[2] Zhao R, Sun S, Ding R, Conditioning strategies of indoor thermal environment in warm climates, Energy and Buildings, Vol. 36, No. 12, pp. 1281-1286, 2004. DOI: 10.13189/ujer.2020.080849.

[3] Perez L, A review on buildings energy consumption information, Vol. 40, No. 3, pp. 394-398, 2008. DOI: 10.1016/j.enbuild.2007.03.007

[4] Olgyay V. Design with climate: Bioclimatic approach to architectural regionalism: New and expanded edition. Design with Climate: Bioclimatic Approach to Architectural Regionalism: New and Expanded Edition. New Jersey: Princeton University Press; 2015. 1–190 p.

[5] Harimi D, Ming CC, Kumaresan S, A Conceptual review on residential thermal comfort in the humid tropics, International Journal of Engineering Innovation & Research,

Vol. 1, No. 6, pp. 539 - 544, 2012. https://www.researchgate.net/profile/Harimi_Djamila/publi cation/282292620_A_Conceptual_Review_on_Residential_ Thermal_Comfort_in_the_Humid_Tropics/links/560abe9b0 8ae840a08d66b45/A-Conceptual-Review-on-Residential-T hermal-Comfort-in-the-Humid-Tropics.pdf

[6] Fanger P, Calculation of thermal comfort - introduction of a basic comfort equation, ASHRAE Transactions, Vol. 73, 1967.

[7] Fanger PO, Hojbjerre J, Thomsen JOB, Man's preferred ambient temperature during the day, ARCHSCIPHYSIOL, 1973

[8] Fanger PO, Östberg O, McK. Nicholl AG, Breum NO, Jerking E, Thermal Comfort Conditions During Day and Night, European Journal of Applied Physiology and Occupational Physiology, Vol. 33, No. 4, pp. 255-263, 1974. DOI: 10.1007/BF00430233

[9] Karyono TH, Heryanto S, Faridah I, Air Conditioning and the neutral temperature of the Indonesian University Students, Architectural Science Review, Vol. 58, No. 2, pp. 174-183, 2015. DOI: 10.1080/00038628.2014.1002828

[10] Hamzah B, Gou Z, Mulyadi R, Amin S, Thermal comfort analyses of secondary school students in the tropics, Buildings, Vol. 8, No. 4, pp. 1 - 19, 2018. DOI: 10.3390/buildings8040056

[11] Zaki SA, Damiati SA, Rijal HB, Hagishima A, Abd Razak A, Adaptive thermal comfort in university clasrooms in Malaysia and Japan, Building and Environment, Vol. 122, pp. 294 - 306, DOI: 10.1016/j.buildenv.2017.06.016

[12] Wong NH, Khoo SS, Thermal comfort in classrooms in the tropics, Energy and Buildings, Vol. 35, No. 4, pp. 337 - 351, 2003. DOI: 10.1016/S0378-7788(02)00109-3

[13] Eddy J, Alspach PF, Arens EA, Aynsley RM, Bean R, Hartman TB, et al, Thermal environmental conditions for human occupancy, ASHRAE Standard 55, 2017. https://www.ashrae.org/technical-resources/bookstore/stand ard-55-thermal-environmental-conditions-for-human-occup ancy

[14] Hamzah B, Mulyadi R, Amin S, Kusno A, Adaptive thermal comfort of naturally ventilated classrooms of elementary schools in the tropics, IOP Conference Series: Earth and Environmental Science, Vol. 402, 2019. DOI:

10.1088/1755-1315/402/1/012021

[15] 37 yono TH, Kenyamanan termal dan penghematan energi: Teori dan realisasi dalam desain arsitektur (Thermal comfort and energy saving: Theory and realization in architectural design), 2010. https://www.researchgate.net/publication/30 5188224%5Cnkenyamanan.

[16] RI. KP. Permen PU Republik Indonesia No. 5 Tahun 2007 Tentang Persyaratan Teknis Rumah Susun (Minister of Public Works of the Republic of Indonesia No. 5 of 2007 concerning Technical Requirements for Flats). 2007.

[17] 1 SN (Badan Standarisasi Nasional), Tata Cara Perancangan Sistem Ventilasi dan Pengkondisian Udara pada Bangunan Gedung (The Procedure of Designing Ventilation and Air Conditioning Systems in Buildings), pp. 1-55, 2001. http://staffnew.uny.ac.id/upload/132100514/pendidikan/per encanaan-pendingin.pdf

[18] Roaf S, Nicol F, Humphreys M, Tuohy P, Boerstra A, Twentieth century standards for thermal comfort: Promoting high energy buildings, Architectural Science Review, Vol. 53, No. 1, pp. 65-77, 2010. DOI: 10.3763/asre.2009.0111

[19] Humphreys MA. Bioengineering, thermal physiology and comfort. Cena, K, Clark JA, editor. Elseiver Scientific Publishing Company; 1981.

[20] Humphreys MA, Nicol JF, Outdoor temperature and indoor 3 ermal comfort: raising the precision of the relationship for the 1998 ASHRAE database of field studies. ASHRAE Transactions 2000;106(February).

[21] Raja IA, Nicol F, A technique for recordinga and analysis of postural changes associated with thermal comfort, Applied Ergonomics, Vol. 28, No. 3, pp. 221-225, 1997. DOI: 10.1016/S0003-6870(96)00036-1

[22] Auliciems A, De Dear R, Airconditioning in Australia I - human thermal factors, Architectural Science Review, Vol. 29, No. 3, pp. 67-75, 1986. DOI: 10.1080/00038628.1988.9 697267

[23] Nicol F, Roaf S, Pioneering new indoor temperature standars: The Pakistan Project, Energy and Buildings, Vol. 23, No. 3, pp. 169-74, 1996. DOI: 10.1016/0378-7788(95)00941-8

[24] Farina A, PMV Calculator [Internet], 2015. http://www.angelofarina.it/Public/Fisica-Tecnica-Ambienta le-%0A2015/Lez-04-05/PMV_cal_tanabe6.xls

SAMSUDDIN-ARTIKEL_UTAMA-CEA20-14822562_1.pdf

and in the evening", International Journal of Biometeorology, 1974
Publication

5   "Sustainable Houses and Living in the Hot-Humid Climates of Asia", Springer Science and Business Media LLC, 2018   1 %
Publication

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7   Yong Li, Shibin Geng, Xiaosong Zhang, Hua Zhang. "Study of thermal comfort in underground construction based on field measurements and questionnaires in China", Building and Environment, 2017   1 %
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8   P. O. Fanger, O. �stberg, A. G. McK. Nicholl, N. O. Breum, E. Jerking. "Thermal comfort conditions during day and night", European Journal of Applied Physiology and Occupational Physiology, 1974   <1 %
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9   Shahin Heidari, Steve Sharples. "A comparative analysis of short-term and long-   <1 %

term thermal comfort surveys in Iran", Energy and Buildings, 2002
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10   the Warm Front Study Group. "A field study of thermal comfort in low-income dwellings in England before and after energy efficient refurbishment", Building and Environment, 200906
Publication

<1 %

11   Baharuddin Hamzah, Muhammad Taufik Ishak, Syarif Beddu, Mohammad Yoenus Osman. "Thermal comfort analyses of naturally ventilated university classrooms", Structural Survey, 2016
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16 M.-J. Cheng. "Field Experiments on Thermal Comfort Requirements for Campus Dormitories in Taiwan", Indoor and Built Environment, 06/01/2008
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18 Samar Thapa, Ajay Kumar Bansal, Goutam Kumar Panda, Madhavi Indraganti. "Adaptive Thermal Comfort in the different buildings of Darjeeling Hills in eastern India – effect of

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difference in elevation", Energy and Buildings, 2018
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19 Springer Atmospheric Sciences, 2013.
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20 R Mulyadi, B Hamzah, M T Ishak, Y R F Taufik.   <1 %
    "Adaptive Thermal Comfort of Elementary
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    Publication

21 Yang, Xiufeng, Ke Zhong, Yanming Kang, and   <1 %
    Tianyin Tao. "Numerical investigation on the
    airflow characteristics and thermal comfort in
    buoyancy-driven natural ventilation rooms",
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    Publication

22 Charles Munonye, Yingchun Ji. "Evaluating the   <1 %
    perception of thermal environment in
    naturally ventilated schools in a warm and
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    Engineering Research and Technology, 2020
    Publication

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    Mulyadi, N Jamala, R Anggraeni. "Coconut
    Leaf Midribs as an Acoustical Panel –
    Feasibility Study through Impedance Tube

Method", IOP Conference Series: Materials Science and Engineering, 2020
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24 Arifuddin. "Cultural and Needs–based Housing Development Case Study: The Bugis Community in Makassar City", Procedia - Social and Behavioral Sciences, 2016
Publication

<1 %

25 Basaria Talarosha, Prasasto Satwiko, Dwira Nirfalini Aulia. " Air temperature and CO concentration in naturally ventilated classrooms in hot and humid tropical climate ", IOP Conference Series: Earth and Environmental Science, 2020
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