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Thermal Comfort of Non-Malaysian Residents at Different Levels of a Multi-Storey Residential Building in Malaysia

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Abstract:

Creating a thermally comfortable environment is one of the most important criteria to be considered when designing multi-storey residential buildings in Malaysia. These types of buildings are increasingly being occupied by non-Malaysian (Iranian) residents. However, there is a lack of information as to the actual thermal comfort conditions endured by their residents under natural ventilation.

This study seeks to establish the indoor climatic conditions at different levels of a naturally-ventilated multi-storey residential building during the month of April 2009, by comparing measured conditions to the thermal comfort sensation (Actual Thermal Sensation-ATS) of international occupants. Additionally, the compatibility of PMV application with ATS is also reviewed

The field measurement results indicate that residential units at higher levels tend to be more thermally comfortable compared to the lower units. However, these results differ from the ATS results in that the lower units were deemed more comfortable. Furthermore, it was found that the PMV scales cannot be directly applied to thermal comfort evaluation in countries with hot and humid conditions, such as Malaysia, even for non-locals.

Keywords:

Multi-storey Residential Building, Microclimate, Thermal Comfort, Predicted Mean Vote, Actual Mean Vote.

1. Introduction

As a developing country, Malaysia is facing problems to accommodate the urban population. The migration of rural population to cities caused the government and private agencies to build different kind of houses (Mohamad Ali 2003). Creating a thermally comfortable environment is one of the most important parameters, in addition to the residential type, to be considered when designing buildings,. However, in most cases thermal comfort has not been given due consideration.

Due to this lack of optimal design of buildings according to the energy efficient standards in different climates, especially tropical regions, there is a need for architects to find optimal ways for designing buildings (Feriadi et al. 2004). In fact, recent trends have shown a heavy usage of mechanical ventilation devices for effective distribution of air in securing thermal comfort in tropical countries. These days, because of the increase in usage of mechanical ventilation devices, it has been observed that energy consumption with the aim of achieving comfortable environment is getting higher and therefore costlier. As a result, most of the occupants prefer to use natural ventilation to reduce the running cost in buildings (Wong et al. 2002). In addition, in maritime countries such as Malaysia which are near the equator and have low evaporation rate, long hours of sunshine, high relative humidity and high overcast cloud cover, buildings should be designed to enable natural ventilation. Therefore, the efficient use of energy and the promotion of energy saving in designing new residential buildings and renovation of old buildings in tropical countries are crucial (Hatamipour et al, 2007).

In the past 50 years, some thermal comfort studies have been performed in humid tropical regions (Wong et al. 2002). Unsurprisingly, thermal responses from occupants recorded in different countries displayed disagreement with predictions by the PMV model (Becker et al. 2009). The PMV model seems to overestimate the sensation of warmth in non-air-conditioned buildings located in warm climates. Also, through most of the previous studies researchers proved that the predicted mean vote (PMV) model of thermal comfort has not agreed with the results of field studies in non air-conditioned buildings in different climates, including naturally ventilated buildings located in the tropical regions (Fanger and Toftum 2002).

Many researchers have compared the results of field surveys with the PMV model in different areas to find out whether the actual mean votes agree with the predicted mean votes (PMV) model in different climates (Wong et al. 2002).

Currently, there has been little discussion in the earlier studies on establishing a sufficient thermal comfort assessment for the domestic sectors, especially multi-storey domestic buildings in tropical countries like Malaysia. According to the literature review, most of the previous studies in relation to the thermal comfort in Malaysia have been conducted in low-cost housing, traditional Malay houses, terrace houses, and air-conditioned houses, however, only the one study by Dahlan (2008) involved multi-storey hostels in Malaysia. Correspondingly, bioclimatic design in Malaysian multi-storey domestic buildings has not been fully explored according to the occupants' comfort needs. Therefore, it is the intention of this study to fill this gap, by providing information of thermal comfort in this type of dwellings where the use of non-air conditioning is employed, focusing on non-Malaysian residents.

Hence, this could be possible by finding out the existing level of thermal sensation and thermal comfort of residents in such buildings. The need to establish comfort conditions necessary for the occupants then becomes the first line of inquiry of the current study which is intended to investigate the thermal comfort conditions and also to be the first to examine thermal comfort in a Malaysian naturally ventilated multi-storey domestic building occupied by non-Malaysians.

The first objective of this study is to evaluate the indoor thermal comfort conditions at different levels of a naturally-ventilated multi-storey residential building in Malaysia using the PMV model, through the measurement of microclimatic factors.

The second objective is to establish the thermal comfort sensation (actual thermal sensation) of the non-Malaysian residents (in this case, Iranians) at different levels of the same building**.** The final objective is to investigate the compatibility of the PMV scale of thermal comfort with the thermal sensation of the occupants.

2. Research Methodology

Since the focus of the study is on indoor climate and thermal comfort in multi-storey residential buildings in Malaysia, an empirical research method has been used. It involves two steps, namely objective and subjective measurements. These measurements were conducted in a multi-storey residential building located in the East Lake complex from the15th to 20th of April, 2009. The three units under study were located in the third, sixth, and tenth floors of this multi-storey residential building. Moreover, all the units had the same orientation and were all naturally - ventilated (Figure 1).

Figure 1: Locations of the three units at different levels

2.1 Objective Measurements

The first method is field work measurements of all the relevant thermal comfort variables. The thermal comfort level of the indoor environment was measured inside three units, each from a different level, from the 15th April to 20th of April, 2009. The month of April was chosen because according to the Malaysian Meteorological Department (MMD) report (2009), generally, most places in the country had higher than average temperature in the months of April and May (www.met.gov.my).

For the purpose of the measurements, a physical quantities measurement instrument, namely the Universiti Kebangsaan Malaysia (UKM) Thermal Comfort Multi-station (TCM) logger was used. This logger is able to measure all four environmental variables (air velocity, relative humidity, dry bulb temperature and globe bulb temperature). In addition, HOBO loggers were used during the field measurement for the purpose of double checking the climate data. For every residential unit, one HOBO logger was placed outside and inside the living room starting from the 12th until the 26th of April, 2009. The measurements were taken by the HOBO loggers at every 10 minute interval to record the respective air temperatures and relative humidity of both the outdoor and the indoor environments.

The UKM TCM logger was installed in the living room of each apartment. This is due to the fact that the majority of the residents spend most of their time in the areas of their living and dining rooms for their daily activities (watching TV, eating, socializing with mates and maybe studying). In contrast to the many HOBO loggers, only one UKM TCM data logger was available throughout the field measurement, therefore each unit had the logger for the time period of two days only during the 15th until the 20th of April, 2009. The measurements ran every 10 minutes from 6.00 pm till 10:00 pm. This timing was chosen because all the residents were present in their units at that period. At the end of each measurement in a unit, the data were saved accordingly, and the UKM TCM logger was transferred to the next unit for installation (Figure 2).

In this study, the metabolic rate is set to be 60 W/m^2 (Seated relaxed) whereas the Clo-value (thermal resistance) is set to be 0.4 clo where the residents were wearing underwear, normal trousers, and T-shirt.
At the end of each monitoring by the UKM TCM logger the data were downloaded by the PC software for the purpose of data acquisition. In order to analyze them, the output file was then exported to a Microsoft Excel 2007 spreadsheet. The measurement assessment is mainly concerned with the variation of PMV during the evening period. To calculate the PMV equation, an online program "PMV 2008 ver 1.0, Ingvar Holmer" was used (www.Ingvar Holmer.com).

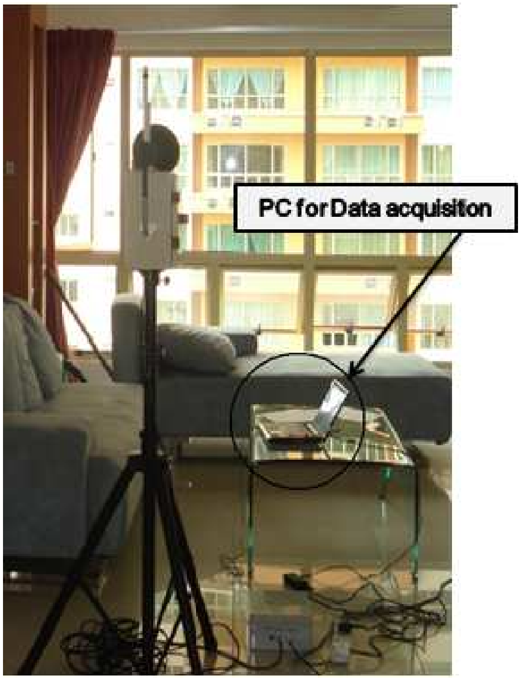

Figure 2: View of the living room, TCM logger and the computer used for Data acquisition

2.2 Subjective Measurements

To complement the results obtained by environmental monitoring, the method of field survey of the occupants' responses to simple questionnaires was used. The questionnaires along with the environmental monitoring process were simultaneously carried out among the occupants of the three specified units.
The assessment of the thermal environment in the aforementioned naturally ventilated multi-storey residential building was based on the occupants' votes on thermal sensation and comfort perception estimated by the Preference Scale (Mclntyre scale) and ASHRAE Scale.
Each specified housing unit was occupied by about 3 to 4 persons and all of the residents were international Iranian students. Residents must have been living in their respective residential units for at least three months to be chosen as participants in the survey. At least two individuals from each of the three units were selected to answer the questionnaires. In the survey method, the occupants were randomly chosen from both genders in the age range of approximately 20 to 45 years old.
The residents provided answers to the questionnaires two times during each of the two monitoring days. The first one was at 6.00 pm and the second at 10.00 pm. This timing was chosen because all the residents were present in their units at those periods. For the sake of having more accurate responses (ISO 7730 Standard), all the respondents must

have been in seated positions for at least 30 minutes before the time of answering the questions. In total, there were 32 residents, who responded to the questionnaires from the 15th to the 20th of April, 2009. Out of all the respondents, 11 of them were residents of the three units that were monitored simultaneously. The remaining 21 respondents, did not have their units monitored, however their units were in the same orientation as the monitored units. Each of the low, middle and high levels had respondents from both monitored and non-monitored units. All the respondents, from either monitored or non-monitored units, answered the surveys two times a day, at the same time periods, during the evening. Altogether, because each respondent provided answers four times (two times during each of the two days), there were 128 responses collected.

To assess the thermal sensation, a seven-point ASHRAE scale was provided in the questionnaire form. The scale consists of the following: cold (-3); cool (-2); slightly cool (-1); neutral (0); slightly warm (+1); warm (+2) and hot (+3). Throughout this study, subjects' responses are referred to as 'Actual Thermal Sensation Vote'. The Preference scale is useful for subjective assessment of comfort and focuses on the issue of thermal preference, introduced by McIntyre (1978). This scale identifies the thermal conditions people prefer to be in rather than the exact sensation they are experiencing. The neutral vote is categorised as 'no change' whilst the other two are 'want cooler' and 'want warmer'. At last, according to the statistical analysis of the mean comparison of paired samples t-test, the assessment of the objectives was performed by the SPSS Program version15.00.

3. Results and analysis

3.1 Evaluation of Thermal Comfort

In accordance to the first objective, the summary of the field measurement results conducted during the 15th to20th of April, in the three different levels' units of a naturally-ventilated multi-storey residential building is presented in Table 1.

Table 1: Summary of indoor Thermal Comfort measurements, outdoor climatic parameters and Neutral Temperatures during the 15th-20th of April 2009

Units' position	Thermal Comfort parameters (Mean Values)				PMV	Outside Climatic parameters (Mean Values)		Neutral Temp. (°C)
	Temp. (°C)	RH (%)	Air Velocity (m/s)	Globe Temp. (°C)	Mean Values	Temp. (˚C)	RH (%)	Mean Values
3rd	30.40	59	0.05	29.80	+1.46	29.10	66	26.50
6th	29.80	62.5	0.13	29.40	+ 1.21	28.60	67	26.80
10th	30.60	61	0.38	30.40	+ 1.43	30.30	66	27.00

3.2 Data Analysis Based on Simulation with Reference to the ISO 7730

The thermal comfort range was taken to be the conditions when the PMV has the values between -1 and +1, based on ISO 7730-94. Thermal comfort study of the units in different levels of the naturally-ventilated multi-storey building showed that in most of conditions, PMV values for the specified units do not fall within this range. By comparing the results, PMV range in the unit which is located in the 6^{th} floor is the lowest as its mean shows (+ 1.21), followed by the 10^{th} floor (+ 1.43) and the 3^{rd} floor (+ 1.46). While the main climatic elements affecting building process and thermal comfort level (PMV) are solar radiation, air temperature, humidity, wind, and rainfall (Koenigsberger et al. 1980; Markus and Morris 1980; Givoni 1976), solar radiation is the most important element among all, as it includes the amount of heat transferred to the buildings and residents (Peng Chen 2002; Griffiths 1976; Battan 1974; Trewartha 1968).

From the data analysis, the 6^{th} floor has the lowest mean temperature (29.80˚C) followed by the 3^{rd} floor (30.40˚C) which in turn is followed by 10^{th} floor (30.60˚C). Therefore, it is evident that the resulting values are not within the comfort range, as stated by ASHRAE 55, during the evening hours (6.00 until 10.00 PM).

Air temperature variation values have a close relationship with the solar radiation absorption from the sun. As façade design of the building is the same for all levels in terms of shading, materials and glazing, findings revealed that the 6^{th} floor unit is more comfortable, because the unit is located in the middle level and thus is not exposed to the solar radiation as much as the highest level (10^{th} floor). Moreover, the mean temperature value (29.8˚C) in the 6^{th} floor is the lowest compared with the 10^{th} (30.6˚C) and the 3^{rd} floor (30.4˚C) units' mean temperature value.

Although the mean temperature value in the 3^{rd} floor (30.4˚C) is less than that of the 10^{th} floor (30.6˚C), its PMV is higher. The reason is that the 3^{rd} floor unit, as the lowest level, has less wind speed variations (0.05m/s) compared to the 10th floor wind speed variations (0.38m/s).Thus, it renders the 10th floor to have a lower mean value of PMV than the 3rd floor. Some studies (Rohles et al. 1982, Scheatzle et al. 1989, and Fountain 1991) have implied that the extent of comfort zone could be reached in high air temperatures by increasing the air movement more than the expectation of international standards (ASHRAE 55-2004). This shows that as the height increases, the wind speed variations increase as well to affect thermal comfort.

3.3 Discussion With Respect to Neutral Temperature

In this study, the neutrality temperature for naturally-ventilated buildings in Malaysia was predicted by using the Auliciems' equation. According to the literature, the studies of Daghigh et al. (2009) in a naturally-ventilated office and Dahlan et al. (2008) in naturally-ventilated multi-storey hostels, both utilized the Auliciems' equation in the Malaysia region . Subjects' thermal neutrality was predicted using the calculation adopted from the optimum thermal comfort, $T_{n,}$ model for naturally ventilated buildings. The Auliciem model (1982) estimated $T_{n,}$ using the following equation: $T_n = 17.6 + 0.31T_o$ where T_n is the comfort temperature and T_o is the mean of the outdoor dry bulb temperature. Then the range of temperature around T_n corresponding to 90% thermal acceptability is defined (Table 2).

This percentage of acceptability is applied as a function of operative temperature in order to produce a 90% acceptable comfort zone.

Numerous climate chamber and field studies have been conducted in hot and humid South East Asian countries and the surrounding regions since the 1930s. In all studies, the proposed neutral temperatures are higher than the 24.5ºC recommended by

ASHRAE Standards 55. For the indoor design conditions, the comfort range for all studies have higher maximum values, some at 4 degC higher than the recommended range (23ºC to 26ºC) for air-conditioned buildings. For naturally-ventilated buildings, the neutrality temperatures of 26.1ºC and 27.4ºC have been recommended for Malaysia (Abdul Rahman and Kannan 1997, Sabarinah and Ahmad 2006). In this study, the neutrality temperatures for the units of the three levels are between 26.5ºC and 27.0 ºC. It is also possible to state that the three units located in different levels, have almost acceptable amount of neutrality temperatures (26.5˚C for the 3rd floor, 26.8˚C for the 6th floor and 27.0˚C for the 10th floor unit) in terms of thermal conditions.
Based on Auliciems equation (1982), for 90% acceptability of thermal comfort, the suggested value is Tn ± 2.5 ˚C and for 80% acceptability the suggested value is Tn ± 3.5 ˚C. In order of the levels' heights, by adding ± 2.5˚C to these values for 90% acceptability, the comfort zone is between 24˚C and 29˚C in the 3rd floor unit, between 24.30˚C and 29.30˚C in the 6th floor unit and between 24.50˚C and 29.50˚C in the 10th floor unit (Table 2).

Table 2: Outside Climatic parameters, Neutral Temperatures (Mean Values)

		Outside Climatic parameters (Mean Values)		Neutral Temperature (°C)				
					90%Accept.		80%Accept.	
Units Position	**Date**	**Air Temp (°C)**	**Humidity (%)**	**Neutral Temp. (°C)**	**Tn- 2.5**	**Tn + 2.5**	**Tn- 3.5**	**Tn+ 3.5**
3th Floor	19-20 April	29.10	65.77	26.50	24	29	23	30
6th Floor	15-16 April	28.60	66.64	26.80	24.30	29.3	23.3	30.3
10th Floor	17-18 April	30.30	66.33	27	24.50	29.5	23.5	30.5

3.4 Discussion of the Subjective Measurements

This assessment involved 32 respondents' real vote, from all units (monitored and non-monitored units) who answered the surveys two times a day (at 6.30 pm and 10.00 pm during the 15th until the 20th of April). The analysis results of the respondents' votes from each of the three different levels' (low, middle, high) units according to the preference scale is shown in Table 3. This scale identifies the thermal conditions people prefer to be in rather than the exact sensation they are experiencing.
Among the three levels, the low levels' units are the ones with the highest number of residents (62.5%) who expressed a neutral vote (no change). In this regard, the low level's units are followed by the high and the middle levels' units with 47.23% and 25% of residents expressing a neutral vote respectively.

Table 3: Relative frequency of ASHRAE Thermal votes: Analysis of Votes on ASHRAE scale in different levels

Thermal Preference	Low levels (19th & 20th April)		Middle levels (15th & 16th April)		High Levels (17th & 18th April)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Want Cooler	15	37.5	39	75	19	52.77
Want No change	25	62.5	13	25	17	47.23
Total	40	100%	52	100%	36	100%

3.5 Discussion of Thermal Comfrot range and Actual Thermal Sensation's Comparison

Based on the subjective survey results, it was the low level unit that was shown to be the most thermally comfortable, followed by the high and middle levels units respectively.

However, this result is different from what was obtained through the field objective measurements. Based on the PMV results it was found that the middle level unit was the most thermally comfortable unit, followed by the high and low level units respectively. This variation in the results of the study is attributed to the relative humidity variations which have the lowest value (59%) in the lowest level unit (3rd level) followed by the high (10th floor) and middle level (6th floor) units (61% and 62.5%) correspondingly. In other words, as the relative humidity increases, the range of thermal comfort sensation gets narrower, which translates in an increased thermal discomfort.

This is supported by the literature. Nicol (2004) states, "it is generally assumed that in hot conditions where loss of metabolic heat by convection and radiation decrease and the bulk of heat losses are via evaporation, increased humidity will increase discomfort". Furthermore, Nicol (2004) concludes in his study that in humid climates or in conditions in which the relative humidity is high, temperatures that are about 1˚C lower may be required by people to remain comfortable, but the main consequence of higher humidity (or water vapor pressure) is that it has the effect of reducing the width of the comfort zone. Besides, for the purpose of discovering whether PMV and actual thermal sensation are compatible, the following analysis is presented.

The calculated PMV in the three different levels' units (3rd, 6th and 10th floor) of the naturally ventilated multi-storey residential building indicated that the three specified units have a mean value of around +1.37 for PMV in most of the conditions.

According to the results which were obtained from the survey, in monitored and non-monitored units, the mean value for the thermal comfort vote is 1.0397. Results obtained from the survey show that in most conditions thermal vote centred around 1.0 (slightly warm) and by equating the central three categories of ASHRAE scale with the notion of acceptability, some of the occupants are assumed to be satisfied with thermal conditions in their units, while the calculated PMV indicated that the indoor conditions of the units almost more than slightly warm in most conditions. This means that by making a comparison between PMV and the actual thermal

sensation vote it is found that the PMV predicted warmer thermal conditions than the real thermal comfort sensations of specified residents.
The statistical analysis of the mean comparison of paired samples t-test (SPSS Program) is also performed, in order to find the compatibility of the PMV scale of thermal comfort with the thermal sensation of the Iranian residents.
The results showed that the PMV scale of thermal comfort and the thermal sensation of these Iranian residents do not have enough compatibility.

4. Conclusion

In the current study, the neutrality temperatures for the three units located in different levels of the naturally ventilated multi-storey residential building have almost, in terms of thermal condition, acceptable amounts that are between 26.50 º C and 27 º C, falling within the neutrality temperatures range as predicted by Abdul Rahman and Kannan (1997), Sabarinah, Ahmad (2006) and Daghigh, Sopian and Moshtagh (2009).
This study has revealed that according to the field measurements, in terms of the levels' height, the middle floor unit (6^{th} floor) was more comfortable, followed by the highest (10^{th} floor) and the lowest (3^{rd} floor) levels' units. One factor which has an important effect on PMV and comfort range is air temperature. The middle level unit which has the lowest mean value of PMV (+1.21) among the units had the lowest mean temperature value (29.8˚C) which is almost near the comfort range mentioned by Sapian et al. (2001).
In contrast to the field measurements, the subjective survey's results demonstrated that it was the low level unit that was the most thermally comfortable unit, followed by the high and middle level units respectively. This difference in results is attributed to the relative humidity variations.
As a result, based on the study's outcomes, the PMV prediction of thermal comfort at different levels of the naturally-ventilated multi-storey residential building was warmer than the real thermal comfort desired by the occupants.
This result is consistent with the research conclusion which was obtained by Dahlan et al. (2008) regarding two high-rise university hostels located in Universiti Malaya, Petaling Jaya (HH1) and Universiti Putra Malaysia, Seradng (HH2) from May 12 to June 19 in 2007. An explanation for these results could have roots in the "Adaptive Theory" which suggests that people are not passively receptive of their thermal environment (de Dear and Braer 2002) and (Zhang et al. 2007). It could be understood that similar to literature results which mentioned the Malaysians' acclimatization to higher temperature, the residents of the current study, who were non-Malaysians, also acclimatized to the higher temperatures but not as much as the locals.
This difference in results means that the PMV model of thermal comfort needs to be modified in order to have an appropriate thermal index model that represents the real thermal comfort conditions in real life situations.
To sum up, the PMV formula, when it is used to predict people's mean comfort votes in their everyday situations, can be inaccurate to a high degree, especially in warm environments. PMV has the capability of being greatly modified, especially in hot and humid regions, so that the validity of its predictions improves (Humphreys and Nicol, 2002).

References:

- Auliciems, A. "Towards a psycho-physiological model of thermal perception." *Int J Biometeorol, 25,* 1981: 109−122.
- ASHRAE Standard 55-2004, (2004), Thermal Environmental Conditions for Human Occupancy. (ANSI Approved).
- Daghigh, Roonak, Kamaruzzaman Sopian, and Jalil Moshtagh (2009) , Thermal Comfort in Naturally Ventilated Office Under Varied Opening Arrangements: Objective and Subjective Approach. European Journal of Scientific Research, pp 260-276.
- Dahlan, N.D, P.J Jones, D.K Alexander, E Salleh, and D Dixon (2008), Field Measurement and Subjects' Votes Assessment on Thermal Comfort in High-rise Hostels in Malaysia. Indoor and Built Environment, pp 334-345.
- de Dear, RJ, and GS Braer (2002), Thermal Comfort in Naturally ventilated buildings: Revisions to ASHRAE Standard 55. Energy Buildings, Vol.34, No.6, pp 549–561.
- Fanger, P.O, and Jorn Toftum (2002), Extension of PMV model to non-air-conditioned buildings in warm climates. Energy and Buildings, pp 533-536.
- Feriadi, Henry, and Nyuk Hien Wong (2004), Thermal comfort for naturally ventilated houses in Indonesia. Energy and Buildings, pp 614-626.
- Fountain, M.E. (1991), Laboratory studies of the effect of air movement on thermal comfort: a comparison and discussion of methods. ASHRAE Trasactions Vol. 97, pp 863-863.
- Humphreys, M.A., and J.F. Nicol (2002), The validity of ISO-PMV for predicting comfort votes in every-day thermal environments. Energy and Buildings, Vol. 34, No. 6, pp 667–684.
- Nicol, Fergus (2004), Adaptive thermal comfort standards in the hot–humid tropics. Energy and Buildings Vol. 36 , pp 628–637.
- Records of Meteorological Data (2009), Malaysian Metrological Department: Petaling Jaya Station, Kuala Lumpur.
- Rohles, F., and S. and Jones B. Konz (1982), Ceiling fans as extenders of the summer comfort envelope. ASHRAE Transactions, Vol. 89, Part 1, pp 245-263.
- Sabarinah, S.H, and Ahmad (2006), Thermal Comfort and Building Performance of Naturally Ventilated Apartment Building in the Kelang valley: A Simulation Study. Proceedings of the Energy in buildings(sustainable symbiosis) Seminar. pp 115-132.
- Scheatzle, D., and H. and Yellot J Wu. (1989), Extending the summer comfort envelope with ceiling fans in hot, arid climates. ASHRAE Transactions, Vol. 95, Part 1.

- Wong, N.H, H Feriadi, P.Y Lim, K.W Tham, C Sekhar, and CheongK.W (2002), Thermal comfort evaluation of naturally ventilated public housing in Singapore. Building and Environment,Vol. 37, pp 1267–1277.
- Zhang, G, C Zheng, Yang W, Q Zhang, and DJ Moschandreas (2007), Thermal comfort investigation of naturally ventilated classrooms in a subtropical region. Indoor Built Environ ,Vol. 16, No.2, pp 148–158.