Thermal Comfort and Building Energy Consumption in the Philippine Context

Mary Myla Andamon

School of Architecture, Landscape Architecture and Urban Design
The University of Adelaide, Adelaide, South Australia, Australia

ABSTRACT: This paper reports on the findings of the thermal comfort field study carried out in air conditioned offices in Makati City (Manila), Philippines and examines the role of non-thermal factors in comfort perception. The international comfort standard, *ANSI/ASHRAE Standard 55* is used extensively as a reference for comfort levels in the Philippines. The potential for energy conservation through stringent control of indoor temperatures underpin the examination of the applicability of the universal values of comfort temperatures recommended by international comfort standards. Comfort has become synonymous with the consumption of applied energy. As global concern about the environment increases (e.g. consumption of scarce energy resources), it is timely to look into the relationship between comfort practices in the built environment and building energy use. The responses of the Filipino office workers contradicted currently accepted thermal comfort theory and drew out questions on the behavioural variables that affect thermal comfort perception and preferences. The findings of this study suggest that the framework advocating the separation of the technical and social constructs of comfort, on which conventional approaches to thermal comfort are predicated, shape and maintain the associated behaviour (practices and conventions) towards comfort which have ill-considered consequences on energy use and consumption.

Keywords: thermal comfort, energy consumption, indoor environments

1. INTRODUCTION

People modify both their behaviour and environments to conform with societal expectations of thermal comfort. With the technologies of the modern world, dependence on mechanical systems in the built environment became the norm. Air conditioning technologies have transformed what is regarded as a 'normal' building in many different parts of the world that these play a critical role in providing expected comfortable thermal environments in modern buildings. Expectations of a comfortable environment are converging worldwide: hot environments are being cold while cold indoor environments are being heated [1].

It has long been recognized that the quality of indoor environments should not be improved at the expense of higher energy consumption. However, climatically controlled environments effect a dependence on the consumption of energy to make buildings habitable. Air conditioning design and operation closely follow the universally applied criteria of the thermal comfort standards [2, 3]. The potential for energy conservation through stringent control of indoor temperatures underpin the examination of the applicability and impact of comfort standards particularly in developing countries in the tropics.

This paper presents the general results of the thermal comfort study carried out in Makati City (Manila), Philippines. Like most countries in tropical Southeast Asia, air conditioning for cooling is most certainly pervasive in modern office buildings in the Philippines [4]. The findings of this study show that the office buildings operated within a narrow temperature range and had bandwidths of temperatures that correspond to the lower spectrum of the comfort criteria prescribed by the standards. The *ANSI/ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy* is used extensively as a reference for comfort levels [5].

2. OBJECTIVES AND METHODOLOGY

The primary objective of this research, using the Philippine office environment as a case study, is to examine the applicability of the universal values of comfort temperatures recommended by thermal comfort standards. Central to the study is the comfort field investigation, which involved both the monitoring of indoor climatic conditions of five air conditioned office buildings using laboratory-grade instrumentation and the subjective assessments solicited from 277 office workers by way of questionnaires and interviews.

The indoor environment monitoring equipment used in this (Class II) field investigation consisted of a globe thermometer, omni-directional anemometer, temperature and humidity probes. This instrumentation measured the physical quantities of air temperature, relative humidity, globe temperature and air velocity which described the conditions of the offices within the surveyed buildings.

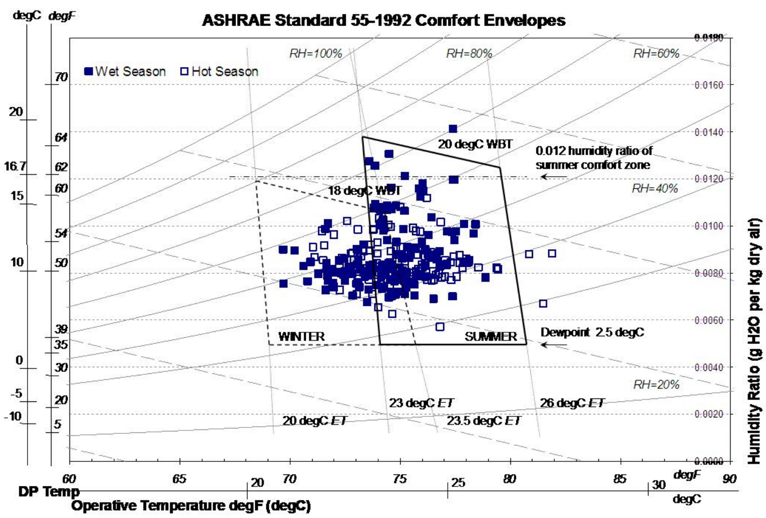
The survey questions on current environmental conditions administered to the office workers provided a 'snapshot' of how the occupants perceived their work environment which can be directly correlated to the physical data simultaneously measured. The survey likewise covered questions designed to elicit information to allow examination of the conceptual meaning of comfort and for greater analysis of the relationship between comfort and various psychological parameters.

3. PHILIPPINE THERMAL COMFORT STUDY

3.1 Indoor Climates and Occupant Comfort Perception

The objective physical measurements of the surveyed Philippine offices showed averages of indoor conditions (Fig. 1) that were within the standards' prescriptions for both the winter and summer comfort zones (20.0°C to 26.0°C), albeit these offices were found to have conditions on the cool side, with temperatures generally lower than the statutory limit of 23.0°C (summer comfort criteria). For all the buildings, air temperatures ranged from a minimum of 20.9°C to a maximum of 27.7°C with an average of 23.7°C.

Interestingly, the comfort perception of the low mean temperatures and temperature ranges found in the Philippine office buildings is one of acceptance and preference. With the central tendency of the comfort responses clustered around the cooler sensations, yet finding the conditions acceptable (Fig. 2), the thermal preference of the office workers in this study translate to a lower and narrower temperature range of 21.5°C to 24.5°C, at 80% acceptability, best described by the regression model, $Comfort/Acceptability = -6.913T^2 + 314.83T - 3486.9$ (r^2=0.79, F=10.97, p<.05), where T is the indoor temperature (Fig. 3). A significant number of office workers would feel uncomfortable at temperatures beyond 24.0°C to 24.5°C. The lower limit of the acceptability (preference) temperature range pushes the lower limit of the summer comfort criteria of 23.0°C to 26.0°C outward by 1.5K. Notably, the acceptability temperature range closely matches the winter design criteria of 20.0°C to 23.5°C.



*each symbol represents climatic values for a workstation visit

Figure 1: Distribution of Indoor Climatic Measurements on *ANSI/ASHRAE Standard 55-1992*

The responses of the office workers in this study contradicted currently accepted thermal comfort theory. The 'one-dimensional' classical thermal comfort theory has been to strictly provide and maintain a neutral state. Following this conventional analysis of thermal comfort, the responses of the office workers implied a thermal neutrality of 26.4°C and a comfort zone as defined by the standards over a broader temperature range (23.3°C to 29.5°C) than the summer design criteria (23.0°C to 26.0°C). This extends the upper limit of the summer comfort zone outward by as much as 3.5K. The implication of this analysis is that within the standard's definition of comfort zone, the limits of acceptability of indoor conditions can be defined wider than the prescription of the standards. This indicates that without sacrificing comfort, energy conservation opportunities can be adopted through the relaxation of the upper temperature limits.

However, a significant finding of this study is that office workers were comfortable and find acceptable (preferable) office conditions that are outside the summer comfort zone specifications of the *ANSI/ASHRAE Standard 55-1992*, specifically on the cooler side of the spectrum. The optimum temperature value that best describes the comfort temperature (preferred temperature, T_{Pref}) of the office workers is 22.2°C, derived from the regression model, $T_{Pref} = -0.183T + 4.054$ (r^2=0.85, F=55.32, p<.0005), where T is the indoor temperature.

For an office population who has been acclimatised to the outdoor hot humid climate, the subjects in this study preferred much lower temperatures than the recommended values of the comfort standards. The findings can be summarised as this – the measured temperatures found in the office environments are low, the subjects find these conditions in the main to be cool or cold and in general prefer this situation or wish to feel cooler. In comparison with the results of other comfort studies in the Southeast Asia region [6], where indoor conditions of air conditioned office buildings can be characterized as approximately similar in temperature range (22.8°C to 23.6°C), the thermal neutralities of the Southeast Asian subjects were found to be higher than 24.0°C, which agrees well with the recommended design values of the comfort standards. Equating the preferred temperature as the comfort value for the Philippine sample (22.2°C), the comfort temperature would be 2.0K to 2.4K lower than the comfort values found in the other studies in the region, indicating that there is a significant difference in the comfort conditions preferred by Filipino office workers in air conditioned environments.

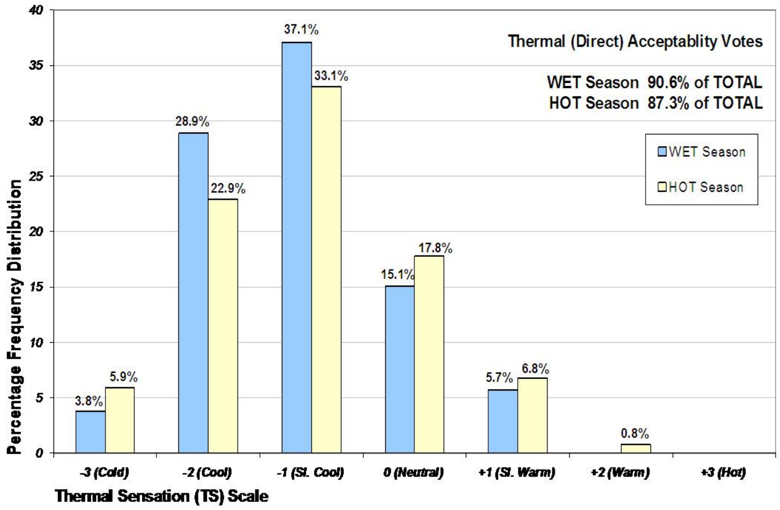
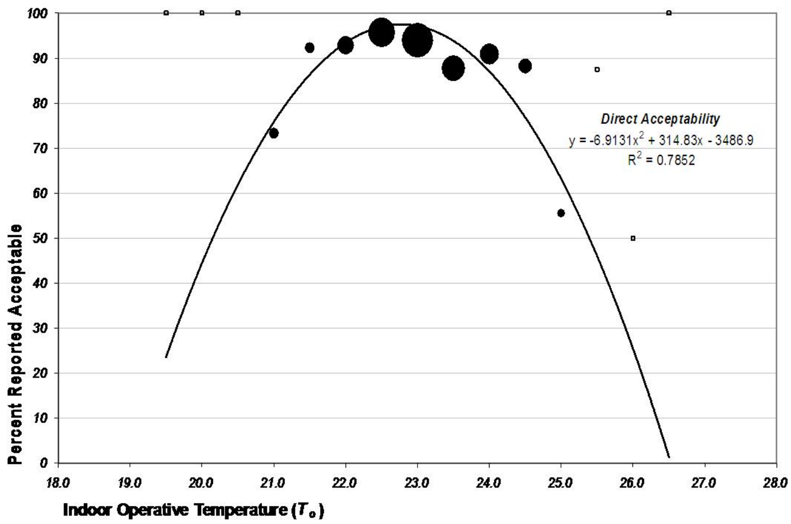


Figure 2: Crosstabulation of Thermal Sensation Votes versus Thermal Acceptability Votes



* area of each dot is proportional to the number of subjects in the sample

Figure 3: Acceptability of Indoor Thermal Conditions

The findings of lower temperature preferences in this field study were found to be not significantly different from the preferences of occupants of air conditioned offices in temperate climates, where the neutral temperature values closely approximate the preferred (acceptability) responses of the Filipino office workers. In Manila, where air conditioning in offices have become a norm, it would seem that indoor climatic expectations have been raised to the levels similar to those in Australia, the US and the UK [7]. Due to the amount of energy spent to achieve comfort conditions in air conditioned office buildings, the occupants' satisfaction with conditions beyond the limits of the standards, particularly the lower limit, can be a critical issue.

Nevertheless, as the data of this study suggest, the perception of indoor climates as observed seems not strictly determined by indoor thermal conditions and personal variables that affect physiological processes. It is suggested that comfort responses in climatically controlled environments may only be tangentially related to comfort standards and have much to do with cultural, social and contextual dimensions, which have only been regarded by the prevailing comfort paradigm as secondary factors. Thermal perceptions of and satisfaction with the indoor climate are indicated to be strongly influenced by non-thermal factors.

3.2 Impact of Psycho-Social and Contextual Factors on Comfort Perception

To extend the physical and thermal assessments of the office workers, a number of psycho-social and contextual issues were explored. The analyses of free-answer impressions have supplemented the data on occupant attitudes and beliefs pertaining to indoor thermal comfort conditions. Anecdotal and descriptive evidence on office preferences also indicated that the office workers would favour air conditioning in the workplace, which renders support for the analysed tendencies of preference for cooler conditions. Conceivably, the cooler indoor conditions observed in the office buildings apart from being a reflection of this office preference also augments it. It can be inferred from the free-answer responses that since climatically controlled buildings means cooler temperatures, this conduced a subliminal predilection for such conditions particularly in office environments. The free-answer beliefs about air conditioning use in the workplace indicated that it is tied up with ideas of modernity. The association of cool temperatures with modernity and consequently comfort, the indoor conditions found in the office buildings have conformed to the expectations of the office workers. The workplace expectations and office preferences overrode the sensitivity to and acceptance of the thermal conditions of office environments.

These responses of the Filipino office workers suggest that psycho-social parameters and contextual issues dominated the preference for indoor conditions and were largely influenced by the non-thermal factors of expectation, conventions and practices of comfort. This predisposition places an overwhelming demand for constantly cool indoor temperatures: the greater the cooling stimulates the need for more. Such dependence on air conditioning technology would promote increased reliance on energy-intensive systems. The background to explaining the findings, the impact of thermal perception, comfort preferences and expectations have had on social and cultural practices in the Philippines is beyond the scope of this paper and is discussed elsewhere [8].

4. COMFORT PRACTICES AND CONSUMPTION PATTERNS

The technical specification of comfort, informed by physiological “proof” of what people need, aligns with the interests and capabilities of the climate control industry. The notions of comfort have been defined by the engineering comfort models that assume human-building interactions to be straightforward physical relationships and these are firmly enshrined within design guidance for the built environment. This standardization of indoor climates which consequently shaped and maintained societal comfort practices and conventions has far reaching implications. More than its influence in the change in beliefs and expectations about comfort, the technological advancement in the management and control of indoor environments also naturalized its need in society.

The translation of the emphasis on the physical meaning of comfort in the built environment meant that concepts of comfort have become synonymous with the practices associated with the air conditioning technology [9]. Consequently, comfort progressed on as a commodity or a recognisable service deliverable by way of universally specified design guidelines and standards. The use of the quantitative thermal comfort criteria entrenched in the design standards has become a resolute basis of current comfort practices. The attraction of design standards and procedures is their utility, which reduces human comfort to an engineering problem that can be resolved by simple calculation [10]. The indoor criteria embodied in the standards for built environments moulded the concept of comfort as a uniform thermal condition – easily promoted, marketed and delivered to consumers. This physical definition of comfort became a legitimising rationale for consumption patterns as the specifications of comfort are driven by consumer expectations.

Cool comfort as a commodity dependent on the use of the energy intensive technology of air conditioning has become an aspect of everyday life with significant impacts on energy consumption. Insights on the anchoring of the escalation of the demand for comfort on the collective habits and practices (behaviour) of a society provided a better understanding of how the demand for the consumer good of ‘comfort’ relates to energy consumption. Understanding the latent factors that propel these comfort practices, likewise allows insights on the future of energy demand.

5. COMFORT STANDARDS AND BUILDING ENERGY CONSUMPTION

5.1 Comfort Temperature and Energy Use

The five surveyed office buildings exhibited relatively similar indoor climatic conditions (Fig. 1). To investigate and explore the impact of the observed temperature preferences of the Filipino office workers on building energy consumption, one of the surveyed office buildings, the Ayala Tower One (ATO), was further studied.

The energy use modelling of ATO Building provided energy calculations which were compared to actual energy figures and data made available by the building managers [11]. Although the building temperature design was set at 24.8°C, the actual indoor climatic measurements taken in the ATO offices indicated an average of 23.4°C T_o and workstations were observed to have modal temperatures of 22.6°C T_o. Using the energy calculations at 23°C as the base case, analysis of the results of the energy modelling of ATO building at the temperature settings of 20°C to 26°C indicate that raising the temperature setting from 23°C to 24°C would reduce the cooling energy consumption by

1.4% and total energy consumption by 0.6% once lights and other uses are taken into account (Fig. 4). At a temperature setting of 25°C, the reduction in cooling and total energy use would be 2.2% and 0.9%, respectively. Similarly, lowering the temperature setting to 22°C to correspond to the preferred temperature of 22.2°C showed an increase of 1.5% in air conditioning energy consumption and 0.6% in total energy consumption. The lower limit of the preferred temperature range at 21.5°C would result in increased annual cooling energy use by approximately 4.8% and 1.9% in total energy use.

Although in terms of energy consumption, the percentage reductions to illustrate the energy savings were not considerable, the monetary equivalent of the increase and reduction are quite significant (Table 1). The reduction of 1.4% in cooling energy use by raising the temperature settings from 23°C to 24°C is equivalent to an annual cost saving for the building of US$10,300 (or US$0.10/m^2 at ATO floor area of 105,685 m^2). At 25°C, the further reduction in cooling energy use by 2.2% is tantamount to an approximate cost saving of US$16,200 (US$0.15/m^2).

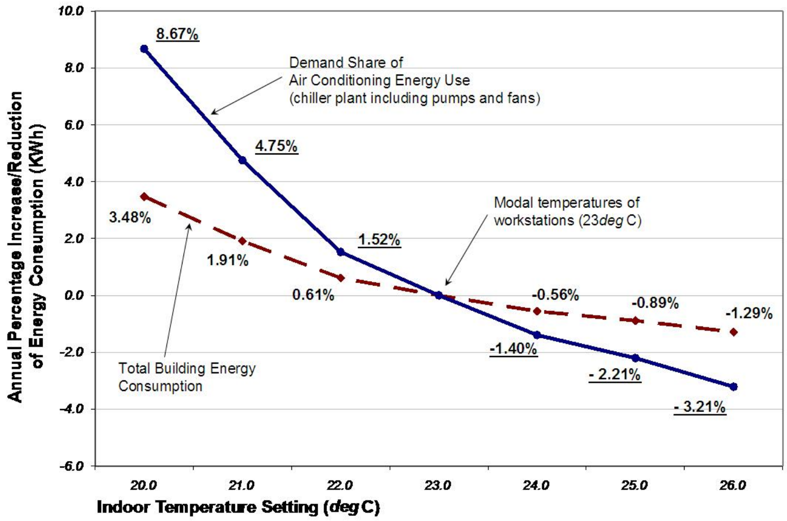


Figure 4: 2002 Energy Use Calculations for Ayala Tower One (ATO) Annual Increase/Reduction of Energy Consumption

Table 1: Ayala Tower One (ATO) – 2002 Air Conditioning Use and Consumption

Temp Setting	Cooling Energy Use (KWh)	Increase (+)/ Reduction (-) (KWh)	Value in US$*
22°C	6,502,000	+97,700	$11,300 (increased cost)
23°C	6,405,000	-	-
24°C	6,315,000	-89,500	$10,286.50 (savings)
25°C	6,263,000	-141,300	$16,300 (savings)

*Cost of electricity: US$0.115 (PhP 6.23)/KWh in 2002-2003 [11]. US$ exchange rate in 2003: US$1=PhP54.20 [12].

Conversely, the preferred temperature of 22.2°C would result in increased annual cooling energy consumption of approximately US$11,200. Although ATO figures do not correspond to the other four buildings in this study, for purposes of discussion and illustration, with all the five surveyed office buildings (approximate total floor area of 400,000 square metres) observed to be operating at similar temperature conditions and exhibiting the same modal temperatures, raising temperature settings by 1°C approximately equates to an annual cost saving of around US$40,000. Similarly, an increase of 2°C from 23°C could indicate a savings of around US$60,000. These figures do not seem substantial. However, with the further assumption that all other similar high-rise office buildings in Makati City (CBD), Philippines could exhibit relatively comparable indoor climatic conditions as with the surveyed buildings in this study, at the current number of 137 completed high-rise buildings [13] (again, notwithstanding building floor area, building design envelope and designed cooling capacity and using the average floor area of the five surveyed buildings at 80,000 square metres), the 1°C to 2°C increase in temperature settings could collectively effect cost savings of around US$1.1M to US$1.6M annually.

Viewed in the light of the poverty context, the annual cost savings due to the reduction of cooling energy consumption brought about by the adjustment in indoor temperature settings would mean that curbing energy consumption would have an effect on good economy as monetary resources could be channelled to projects geared toward the alleviation of poverty in the Philippines. In 2003, the poverty incidence in the country using the international poverty line of US$1 per day purchasing power parity (PPP) prices was 11.1%, higher than the average for Southeast Asia (5.8%) [12]. Further exploring the significance of the reduction of cooling energy use of Ayala Tower One as a result of the adjustments in the temperature settings indicate that using the international poverty line of US$1 per day at 2003 US$-PhpPeso currency exchange rates, the annual cost savings of approximately US$10,300 to US$16,300 for ATO would impact 6 to 9 Filipino families of 5 members who do not have one nominal US dollar per person per day (Table 2).

Table 2: Poverty Incidence in the Philippines and Ayala Tower One Air Conditioning Energy Use

Temp Setting	Annual Cost Savings in US$*	US$1-a- day International Poverty Line**	
		Population Headcount	No. of Families
23°-24°	$10,286.50	28	5.6
23°-25°	$16,300	45	8.9

*US$ exchange rate as published by the Central Bank of the Philippines in 2003: US$1=Php54.20 [12].
**Annual per capita $1 poverty threshold is US$365. With 5 as the average family size in the Philippines, annual $1 poverty threshold per family is US$1,825 [12].

Published figures indicate that in 2000, 45.4% of Filipino families or an estimated 6.9M poor families lived below the poverty line [12]. Thus, the loose translation of the potential reduction of cooling energy use (approximately US$1.1M to US$1.6M) effected by a 2-degree increase in temperature settings in approximately 137 high-rise office buildings in Makati-CBD would be its substantial contribution to the alleviation of poverty for almost 600 to 900 families.

6. CONCLUSION

The interdependence of people's preferences and associated choices has been brought into the discourse of economics and consequently, consumption. This interdependence has become a cornerstone in explaining societal behaviour. This study has further shown that the value system underlying behavioural patterns should be questioned as well as the social and technological conditions that support and maintain the existence of these patterns. The representation of the framework of the dynamic collective norms and practices of comfort with the technologies and services that engender and sustain it, indicated that it is not realistic to believe that the use of these energy intensive services be mitigated when at the same time, the existing consumption values and normal collective practices (ways-of-life) prevail.

As global concern about the environment increases, it is timely to look at the relationship between comfort practices and energy use in buildings. With air conditioning systems being sold and bought the world over, its technologies have transformed the building stock in the globally diverse climatic regimes. The universally applied engineering standards, predicated on a framework that advocates the separation of the technical and social constructs of comfort, which inform the control of indoor environments the world over have homogenized the definition of comfort and in turn affected individual and collective lifestyles. These lifestyles manifested in social conventions and practices and cultural expectations have become institutionalized that effect a demand for comfort and consequently impact scarce and diminishing energy resources.

REFERENCES

[1] Guy, S. and E. Shove, *A Sociology of Energy, Buildings and the Environment: Constructing Knowledge, Designing Practice*. Routledge Research Global Environmental Change. 2000, London: Routledge. 164.

[2] ASHRAE, *ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy*. 2004, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 26.

[3] ISO, *ISO 7730-1993: Moderate Thermal Environments - Determination of the PMV and PPD Indices and Specifications of Conditions for Thermal Comfort*. 1993, Geneva: International Organization for Standardization (ISO).

[4] Fowler, G.A., *Cubicle Culture: Kind of Blue: In Asia, Elite Offices Show Off With Icy Temperatures*, in *The Wall Street Journal*. 2005, Dow Jones & Company, Inc. p. B1.

[5] National Building Code of the Philippines, *National Building Code of the Philippines - Presidential Decree No. 1096 -1977*. 2000, Quezon City, Philippines: Philippine Law Gazette (Vicente B. Foz). 382.

[6] Karyono, T.H., *Thermal Comfort in the Tropical South East Asia Region.* Architectural Science Review, 1996. **39**(3): p. 135-139.

[7] de Dear, R.J., *A Global Database of Thermal Comfort Field Experiments.* ASHRAE Transactions, 1998. **104**(1B): p. 1141-1152.

[8] Andamon, M.M., T.J. Williamson, and V.I. Soebarto. *Perceptions and Expectations of Thermal Comfort in the Philippines*. in *Comfort and Energy Use in Buildings - Getting Them Right, Windsor 2006*. 2006. Cumberland Lodge, Windsor, UK: Network for Comfort and Energy Use in Buildings (NCEUB).

[9] Prins, G., *On Condis and Coolth.* Energy and Buildings, 1992. **18**(3-4): p. 251-258.

[10] Cooper, I., *Comfort Theory and Practice: Barriers to the Conservation of Energy by Building Occupants.* Applied Energy, 1982. **11**(4): p. 243-288.

[11] Ayala Property Management Corporation, *Ayala Tower One and Exchange Plaza Building Information*. 2002, Ayala Property Management Corporation (APMC): Makati City, Philippines. p. 15.

[12] Asian Development Bank, *Poverty in the Philippines: Income, Assets, and Access*, ed. K. Shelzig. 2005, Manila, Philippines: Asian Development Bank. 165.

[13] *Commercial Real Property of Asia*. 2005. Available: http://www.emporis.com (Accessed: 13 May 2005).