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# Thermal Environments and Comfort Perception in Shophouse Dwellings of Ho Chi Minh City

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**Abstract:** This paper reports on a long-term investigation into the thermal environment and perceptions of comfort in dwellings located in Ho Chi Minh City. Of particular interest is the so-called 'shophouse' dwelling types prevalent in Vietnam and other SE Asian countries. Shophouses are narrow urban buildings used for business as well as living accommodation. A review of shophouses across the city determined three main types (traditional/new/row house) and four subgroups. Automated data recording systems were set up for longitudinal investigations (long-term recording of air temperature/humidity/movement) in four dwellings coupled with occupant questionnaires/interviews and shorter cross-sectional studies in additional buildings. The paper explains the techniques utilized to derive optimum data collection and some of the difficulties encountered. Summaries of the extensive data are presented noting for the warm season, typical indoor temperatures ranged from 29-35°C though the neutral temperature was 28.5°C (upper limit to the comfort range =31.5°C). The results are compared to previous comfort research findings. Due to the nature of the dwellings, an important environmental factor was considered to be air movement. Though there was a correlation between internal/external airspeed, indoor air movement rarely exceeded 0.2ms$^{-1}$. Design guidelines/suggestions for optimising comfort are made based on shophouse type.

**Keywords:** shophouses, thermal environment, perceptions, comfortable temperature, thermal preference.

## 1. Introduction

Most dwellings constructed in Vietnam use natural or mixed-mode ventilated mechanisms to support comfort for building occupants. Thus, the influences of the regional tropical climate along with climate change and urban heat island (UHI) impacts have exacerbated thermal discomfort. This is also linked to additional, perhaps excessive energy use for mechanical cooling systems in residential buildings during summer months, particularly in shophouse type dwellings. According to energy statistics in Vietnam, the energy consumption in households has taken an increasing and significant proportion of total energy use over the last decade and more: it was 22.4% in 2003; 31% in 2010; and 38% in 2014 (Duc, 2016). In addition, results of investigations of energy use in dwellings across the country by the Cimigo market research group show that householders living in shophouses used 69% of the total energy provision for all three housing types found in Vietnam: shophouse; villa; and apartment (Parkes, 2013). This marks the shophouse dwellings as a very important component of energy demand in Vietnam.

A review of international thermal comfort standards such as ASHRAE standard 55 and ISO7730, the comfort temperature and comfort zone for occupants indicated a lower value than studies of tolerance and adaptation in the tropics would suggest. This conclusion is supported by field studies of several researchers in SE Asia (Karyono, 2000) (Feriadi & Wong, 2004) (Djamila, et al., 2013). In this paper, the authors suggest that some review and revision can be carried out; they believe that the shortcomings of certain standards may be attributed to the modest number of thermal comfort studies conducted in naturally ventilated (NV) buildings in the tropical regions.

Although the number of attempts to study thermal comfort in equatorial climates has developed and expanded since 1950, research work in residential buildings has been somewhat limited. This could be responsible for a deviation in evaluation and conclusion of comfortable conditions for the occupants in warm climates (Djamila, et al., 2012). In addition, the national standards for the conditions of thermal comfort being implemented in Vietnam such as TXCDVN 306:2004 and TCVN 7438:2004 have been adopted and adapted from international standards. This also shows a lack of supporting evidence from empirical surveys and experiments in real-world local environments. Therefore, the authors here suggest that they do not fully reflect comfortable conditions and thermal perceptions of the Vietnamese.

The gaps in research of comfort set against balancing available energy supplies with demand for use for dwellings in Vietnam, especially shophouses, provided the motivation for the research reported in this paper. As a result of a comprehensive field survey including cross-sectional/longitudinal methods and occupant responses, this has been carried out for 'free-running' shophouse buildings in Ho Chi Minh City (HCMC). The specific focus of this paper is on the data from the cross-sectional studies, which has been analyzed to provide a better understanding of shophouse environments linked to the architecture across the city; and also the experience of the local people living in the warm conditions. The objectives of this study are to examine environmental performance in/around the buildings and to investigate comfort perception and preference expressed by the residents of naturally ventilated and hybrid conditioned shophouses in HCMC.

## 2. Climatic conditions in HCMC

HCMC (formerly Saigon) is the second largest city in the country and is located in the south-central part of Vietnam. The city is characterized by a tropical monsoon climate with the key features of high air temperature and high humidity across much of the year.

The average monthly maximum temperature and humidity lies between 31-35°C and 69-92% (IBST, 2009). There are two dominant monsoon seasons: south and southeast monsoon winds in dry months with a maximum airspeed of 4.5ms$^{-1}$; the west and southwest monsoon winds in the rainy months with the strongest wind reaching 5ms$^{-1}$. The urban expansion of the city, as well as the increasing ambient temperatures arising from global warming, are accelerating the vulnerability of the urban climate. The city's mean temperature has risen by 0.9-1.2°C since 1958; moreover, the extreme temperatures in summer can peak at 40°C, and an increase of 20% rainfall in the rainy season has been experienced (Thuc, et al., 2016). The climate changes and man-made modification result in unsatisfactory microclimatic conditions in and around buildings, and trends of increasing energy use by households to reduce discomfort.

## 3. 'Shophouse' dwellings in HCMC

In essence, the 'shophouse' dwellings in Vietnam are terraced houses; however, the features of vernacular culture, society, history, and architecture are catalysts that have formed this unique housing type, although variations are also found in other regions of SE Asia. It is a combination of both 'shop' for commercial/retail/work purposes normally found on the ground floor, and 'house' providing accommodation on the upper floors. An overarching view of the morphologies of shophouses shows they are diverse in size, configuration, style, and structure. However, having a long and narrow shape as a ‘tube’ is a principal characteristic of these dwellings.

Figure 1. Five shophouse types found in HCMC

Shophouses have typical dimensions ranging from 3-5m in width, 10-100m in length, and 1-5 floors in height; when originally planned/built (1850 onwards) they provided scope for use of natural daylight and ventilation. However, since the mid-20$^{th}$ century, pressures on urban space have led to significant changes. The studies in 2010 determined 20.1% of land in HCMC was completely covered by buildings, reducing natural light and ventilation options (Downes, et al., 2011). This, combined with urban heat island effects now, causes significant difficulties for the internal environments of shophouses. Energy availability issues and its cost means conditions in shophouses can reach and exceed the upper limits of acceptability and choices have to be made between energy-use and comfort.

Arising from a survey of land use conducted in HCMC between 2009 and 2014, a total of five shophouse typologies were identified: rudimentary (type 1), traditional (type 2), new (type 3), commercial (type 4), and row house (type 5) (Moon, et al., 2009). Examples of each type are shown in figure 1. The housing types 3 and 5 are the most dominant; type 2 buildings generally constructed between the 1850s and 1920s are special types found in certain places around the city. Figures 2 and 3 depict the most popular spatial layout of floor plans of a new shophouse in HCMC with the ground floor left for use as a shop. All family members live on the upper floors. The main spaces such as bedrooms and living room are organized close to the façade to allow penetration of natural light and air flow. The service rooms are located at the rear. The staircase is normally positioned in the middle as the main element not only to connect all the different spaces of a house but also to allow deeper access for daylight and natural ventilation through the house. On the top floor, the householders usually arrange a worship room, a small garden at the front, and a drying court at the back.

## 4. Research methods

A total of 59 households with 117 individual respondents were involved in a field study which took place in HCMC in the warm months of 2017. A summary of samples is listed and classified by shophouse type in Table 1. As previously mentioned, research was carried out to investigate comfort conditions of three main dwelling typologies: traditional house, new shophouse, and row house; these are selected because of their predominance in the city. The cooling mechanism used in most cases is a hybrid type with air-conditioners being operated at certain times of the day/month/year; just 3 of the houses were entirely cooled by natural ventilation. Room fans were also usually employed to provide air movement cooling.

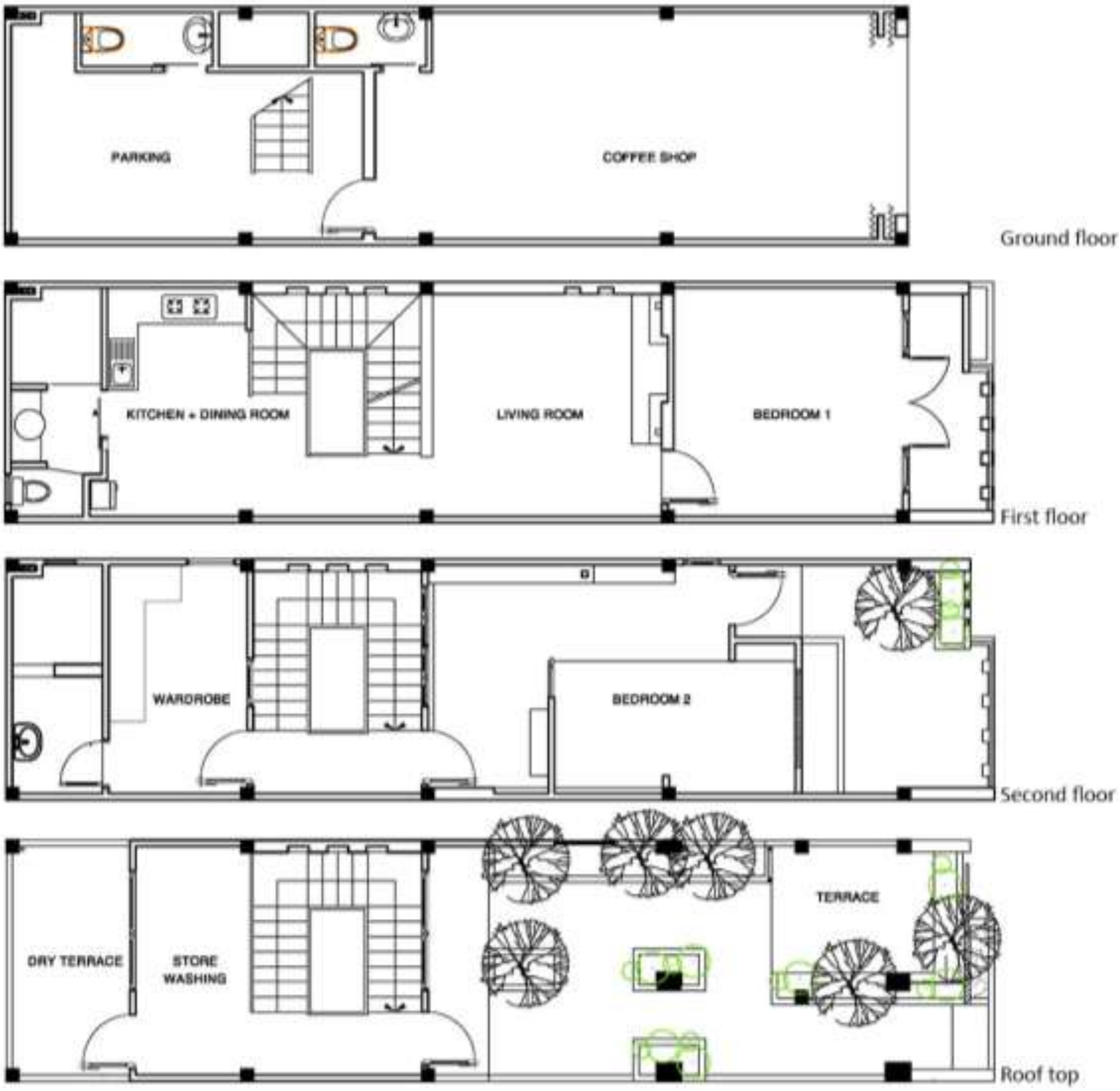



Figure 2. An example of a new shophouse in HCMC – No 6, Street No 41, District 4

Figure 3. Indoor environment of a shophouse at No 6, Street No 41, District 4

There were two survey types used for the field work including investigations of indoor and outdoor physical environment of buildings; and thermal comfort survey using questionnaires. All surveys were conducted in the natural conditions of the environment. It means that the options for mechanical ventilation were switched off. For the study of environmental conditions, both techniques of cross-sectional measurements and longitudinal recording were used. The variables of air temperature, humidity level, air velocity, and light level were measured room by room; the positions for measurement of wind flow and daylight were selected following 3D and 2D rectangular systems respectively. The instruments employed in the studies were tested and calibrated before use and were selected to give an optimum combination of reliability, accuracy and cost. Each spot measurement was made every 30 seconds. A total of 4 houses from 16 initially selected from the cross-sectional surveys were chosen for the installation of a more complete the data logging system which was responsible for recording the physical factors in and around the buildings for ten months.

Table 1. Sampling distribution

| Type | No of houses | No of subjects |
|---|---|---|
| Traditional house | 3 | 3 |
| New shophouse | 46 | 22 |
| Row house | 10 | 92 |
| | **59** | **117** |

For thermal comfort surveys, the questionnaires about sensation, acceptability, and preference of subjects to the thermal environment were administered for completion by the subjects. Meanwhile, at the same time measurements of the thermal environment were made. The occupants selected were chosen because they spent a minimum of 6 hours per day at home.

In previous field studies, the subjects were usually arranged in the same room for survey questioning and logging of measurements. However, in reality, spatial use of the dwelling means that people's daily activities are very flexibly located around their house. Therefore, obtaining responses of subjects should be carried out in different rooms where they are more naturally located instead of in the same room; this was the approach taken in this survey.

Before responding to the survey form, all participants were provided with briefing notes to explain the purpose and procedures. Each survey took about 15 minutes to fill in. The scales of ASHRAE Standard 2004 and McIntyre were applied; however, they were modified according to the condition of warm climate. The meters were located within a radius of 1m around the subjects. Depending on people' posture such as sedentary activity, standing or lying, the environmental data were collected at different heights – 0.1m, 0.6m, 1.1m, and 1.7m above the floor. The time to read values was 30 seconds after activation of the meter.

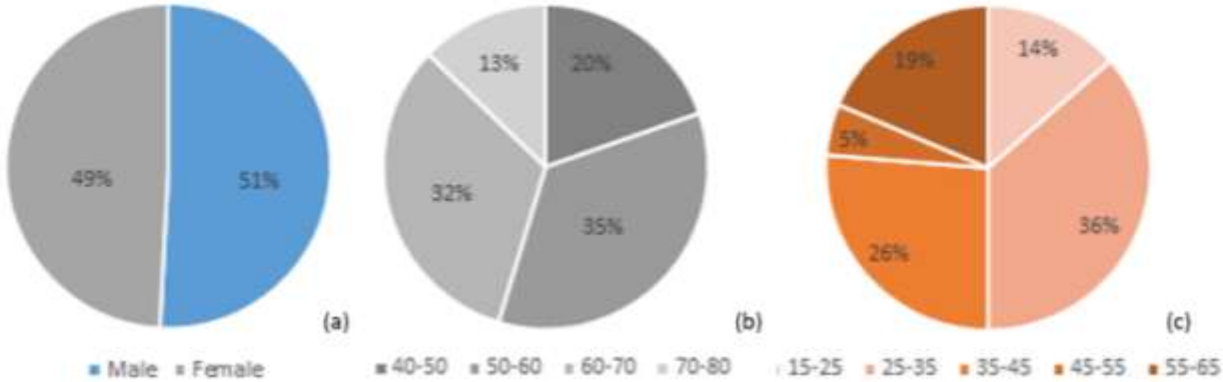



Figure 4. Summaries of personal parameters (a: gender, b: age, and c: weight (kg))

Respondents' parameters are shown in Figure 4 including gender, age, and weight. The range of their ages is between 15 and 65, and the health was self-reported as good for those chosen for the study. Most of them are in the age bands of 25-35 (26%) and 35-45 (36%). The ratio of male and female shares the same proportion. Furthermore, the major weights of the Vietnamese are in the ranges of 50-60kg (35%) and 60-70kg (32%).

## 5. Analysis and results of field study

### 5.1. Indoor and outdoor climate

The statistical summary of the 117 sets of records of climatic conditions in and around the buildings, whilst the occupants were being surveyed, is described in Table 2. Handheld instruments were used for measurements in occupied zones of the buildings. All indoor values were averagely calculated based on the measurements at three height levels above the floor while the outdoor parameters of temperature and humidity were recorded simultaneously at a single consistent height outside the building. The external airspeeds were also measured at three various heights in front of the buildings, and then generating the average numbers.

The indoor and outdoor air temperatures show the typically warm condition of the environment during summer months. The maximum inside and outside air temperature peaked at 34.6°C and 37.8°C respectively. The mean values of indoor air temperature ($T_a$), mean radiant temperature (MRT), and Operative Temperature ($T_{op}$) were similarly at 32°C. However, whilst the minimum temperature of the three variables was very alike, the maximum level of MRT was 1°C higher than the others. The standard deviation of three temperatures was almost the same. The hot conditions found in the indoor environment probably results from high solar loads, the low thermal mass, and weak natural ventilation in the shophouse dwellings in HCMC. The indoor operative temperature had a mean of 31.5°C and a maximum of 34.8°C (Figure 5).

Table 2. Summary of the indoor and outdoor climate

| | Indoor | | | | Outdoor | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Max. | Min. | Mean | SD | Max. | Min. |
| Air temperature (°C) | 31.9 | 1.18 | 34.6 | 29.1 | 32.8 | 1.74 | 37.8 | 29.5 |
| Relative humidity (%) | 61.9 | 7.29 | 76.9 | 44.9 | 59.5 | 8.30 | 79 | 41 |
| Mean radiant temperature (°C) | 32.0 | 1.35 | 35.5 | 29.0 | | | | |
| Operative temperature (°C) | 31.9 | 1.24 | 34.8 | 29.1 | | | | |
| Air velocity ($ms^{-1}$) | 0.14 | 0.10 | 0.55 | 0.01 | 0.32 | 0.22 | 1.0 | 0.07 |

Relative humidities indoors were not excessively high on hot days, with a mean of 61.9%, maximum of 76.9%, and a minimum of 44.9%. The outdoor environment had a mean humidity level of 59.5%. Air velocities were relatively low in the naturally cooled buildings, with a mean of 0.14$ms^{-1}$. In some cases, a more pleasant condition of air movement, in the range of 0.25 – 0.55$ms^{-1}$, was measured in spite of some very low flow external wind environments. The mean and maximum outdoor wind speeds were recorded at 0.32$ms^{-1}$ and 1.0$ms^{-1}$ respectively. During observations of the thermal condition in shophouses in HCMC, the occupants made use of different kinds of fans to create air movement including wall mounted, free-standing, and ceiling fans.

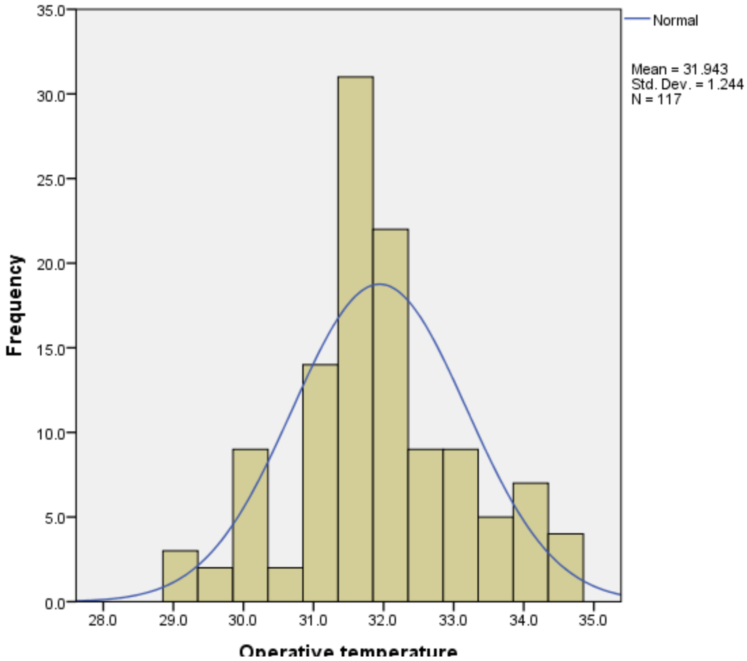


Figure 5. Distribution of operative temperature

**5.2. Thermal comfort responses**

In order to collect thermal responses of the subjects, the standard scales and questionnaires for the survey were translated into the Vietnamese language. All 117 subjects were asked for their thermal sensation to a seven-point ASHRAE scale (+3 – hot, +2 – warm, +1 – slightly warm, 0 – neutral, -1 – slightly cool, -2 – cool, and -3 – cold) under warm climate condition. Figure 6(a) indicates the highest percentage of thermal sensation votes (TSV) of approximate 50% occurred at +2 (warm). 45% of the subject votes fell into an acceptable range from -1 (slightly cool) to +1 (slightly warm) according to ASHRAE Standard 55, 2004, in which, 25% occupants felt comfortable at a mean operative temperature of 31.5°C. It is observed that 5% of people responded as having a too hot sensation at temperatures of 33 - 34°C – see Figure 6(b).

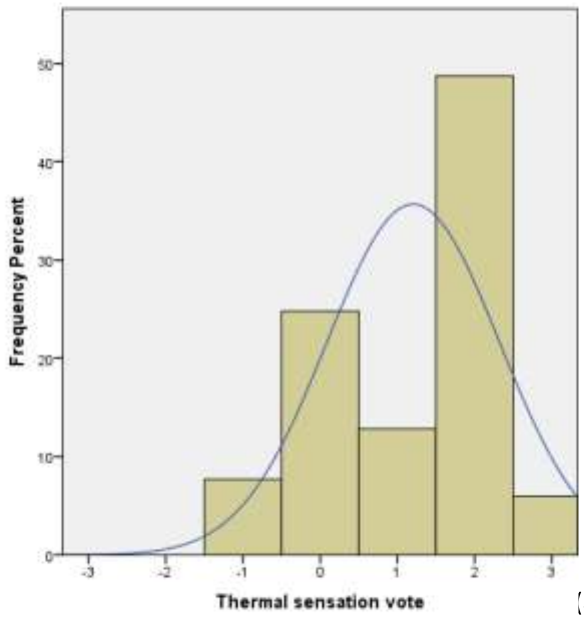
The linear regression analysis between two variables - indoor operative temperature and subjective vote found a quite strong relationship:

$TSV = 0.36\ T_{op} - 10.23$ (1)

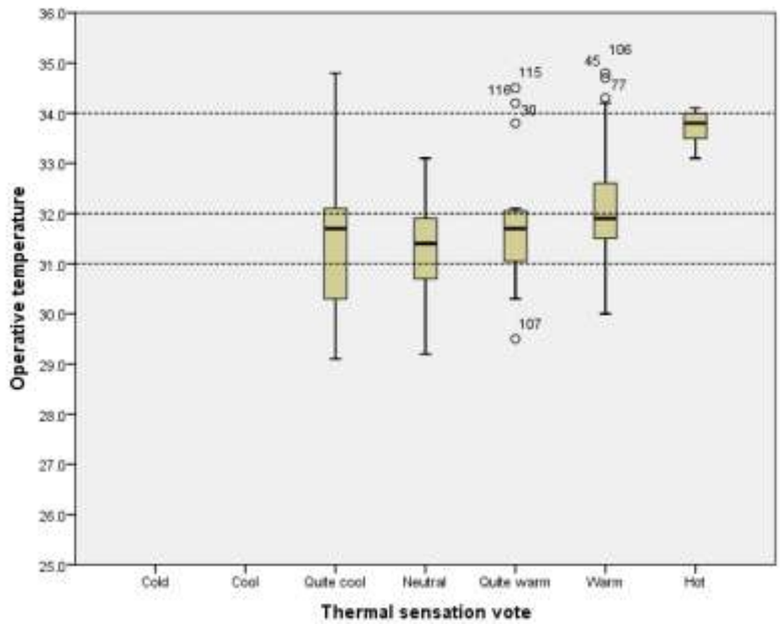
($R = 0.398$, $R^2 = 0.159$, Sig. =0.000, BCa 95% CI = [0.190, 0.519])

The neutral temperature was 28.5°C and the upper limit of comfort range in warm months was 31.5°C. The statistical value of R squared (0.398) is explained by the strong link to indoor operative temperature for the occupants' responses. In hot humid climates such as frequently occur in HCMC, people appear to tolerate a warmer condition than others at high and medium altitudes. The long-term acclimatisation and flexible behavioural adjustments of people to regional climate could provide a reason for the level of acceptability. And perhaps, these explain why subjects sensed neutral in spite of the observed temperatures of over 31.5°C.

Although the zone of acceptable temperatures for the naturally ventilated residences in warm months lies between approximately 28.5°C and 31.5°C, the environmental condition indoors cannot be considered as offering true thermal comfort. Approximate 65% observed data show indoor operative temperatures higher than the upper limit of the comfort zone.




(a)




(b)

Figure 6. Distribution of thermal sensation votes
(frequency of subjective responses – a, and relationship to operative temperature - b)

**5.3. Comparison with predicted mean vote (PMV) model**

Another histogram analysis of predicted comfort was carried out by computing the values of PMV results using the Center of the Built Environment (CBE) Berkeley, Thermal Comfort Tool. For comparison between the distribution of TSV and PMV, it should be noted that almost all calculations related to warm conditions lie outside of the acceptable thermal environment for comfort (-0.5<PMV<0.5) with 10% PPD (predicted percentage of dissatisfied). However, if predicted mean votes are normalised into a seven-point scale of TSV (-0.5 < PMV < 0.5 set as 0/neutral, 0.5 < PMV < 1.5 set as +1/slightly warm) etc, 80% of the results produced by the heat balance model are in “warmer than neutral” region (> +1) see Figure 8. There seems to be a discrepancy between the predicted votes and what might be otherwise expected from subjects located in a hot tropical climate.

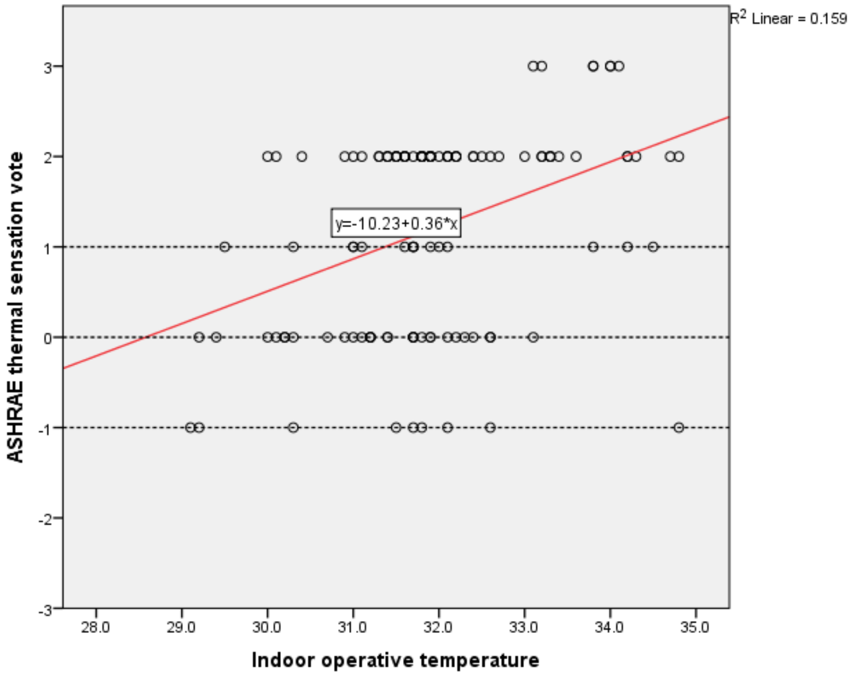



Figure 7. Linear regression of indoor operative temperature and ASHRAE sensation votes

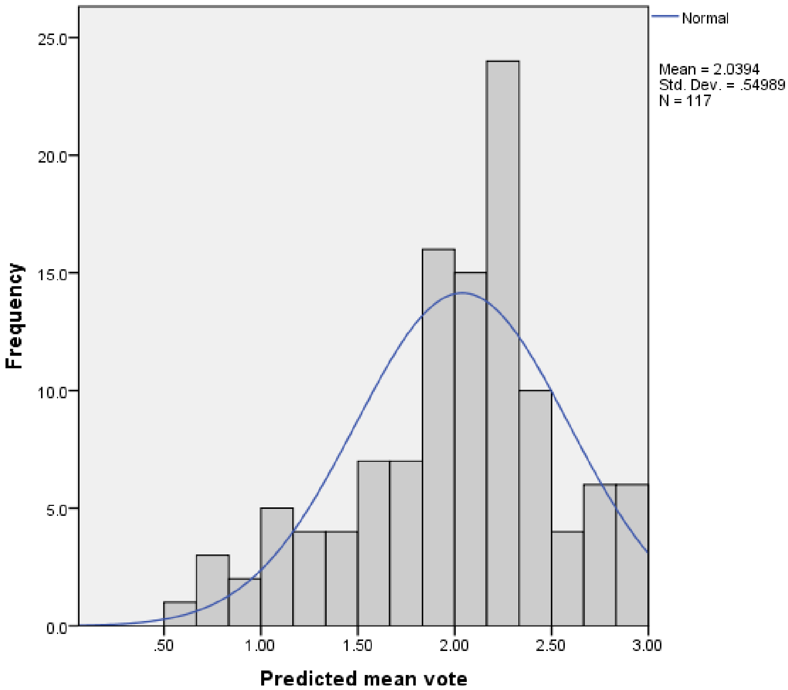



Figure 8. Correlation of operative temperature and PMV

Figure 9 introduces two linear regressions defined between the dependent variable (TSV) and independent variables as follows: effective temperature (a) and predicted mean votes (b). The correlation coefficient of both regressions shows the large effect of two variables: Ra = 0.440 and Rb = 0.430. In Figure 9(a), the intersection of the linear model and reference line at value 0 of TSV identifies the neutral temperature at 29.7°C Effective temperature (ET). This output is 1.2°C warmer than the comfort temperature estimated by $T_{op}$. The model generated from the linear analysis of TSV and ET is:

TSV = 0.4 ET – 11.89 (2)

In comparison between two equations (1) and (2), the difference between respective regression gradients and intercepts is significant.

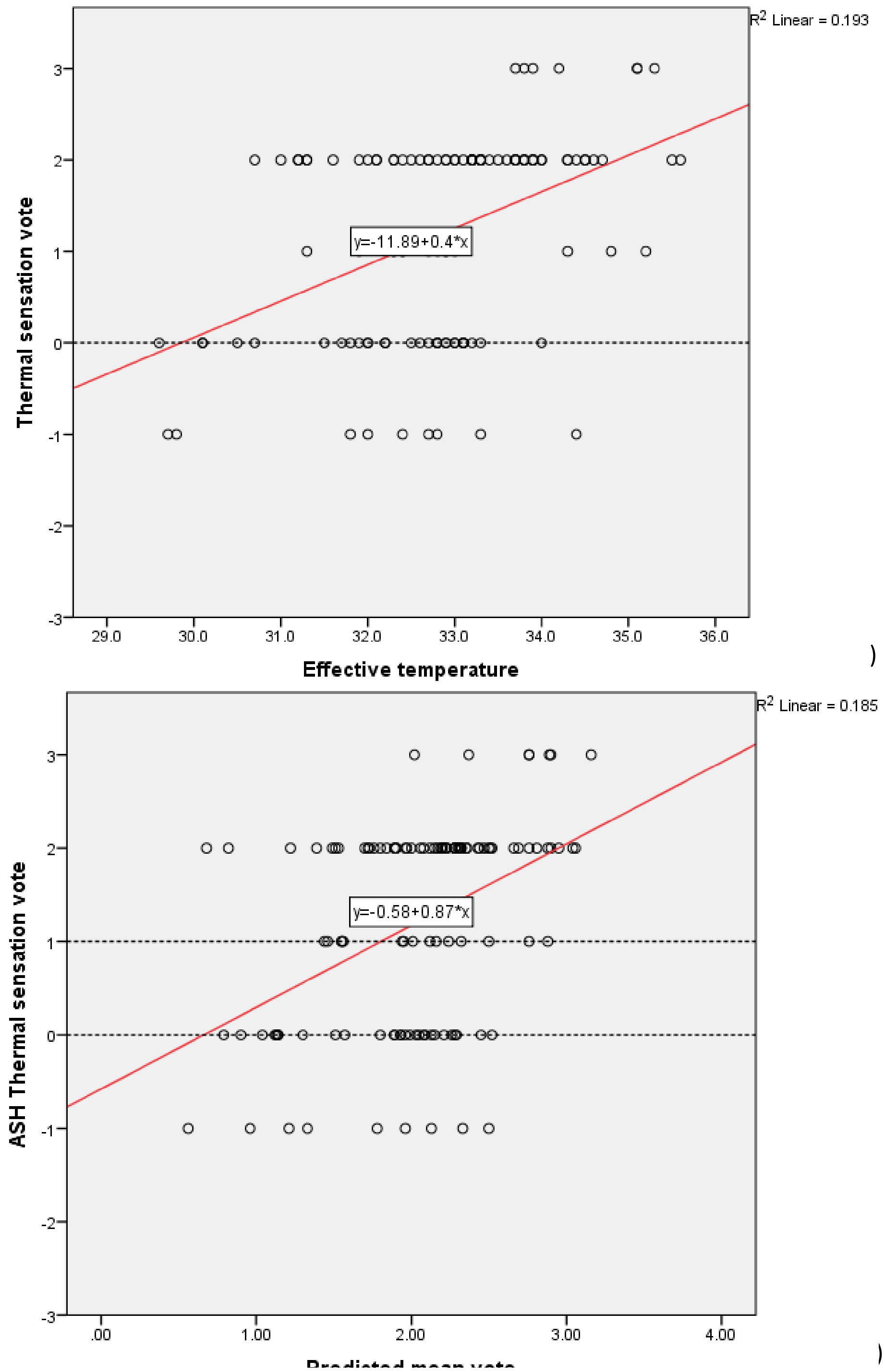



Figure 9. Correlation of effective temperature (a) and PMV (b) and thermal sensation votes

In Figure 9(b), over 90% of plots on the scatter chart are located in the warmer region; PMV > 1. The outputs of statistical analysis (R = 0.430, R square = 0.185, Sig. = 0.000, BCa 95% CI = [.524, 1.206]) illustrate an imbalance between using the two variables. In other words, the model of Fanger fails to predict the comfort temperature for the occupants. The equation indicates that when TSV is equal to 0 and +1, PMV has values of +0.7 and +1.8 respectively.

In the lower part of the chart (at the level of -1), the significant deviation in comfort prediction between two models can also be seen. Some subjects indicated that they felt slightly cool in the recorded observations; however, the prediction of the Fanger model indicates outcomes from ‘slightly warm’ to the ‘hot’ condition.

### 5.4. Thermal preference

The thermal preference votes utilised a seven-point scale (3 - hotter, 2 - warmer, 1 - little warmer, 0- no change, -1 - a little cooler, -2 - cooler, and -3 – colder) corresponding to thermal sensation scale to identify the preferred temperature of the subjects. The asymmetrical result showed over 95% occupants preferred a cooler condition during the summer season. Most of them voted for preferences of (little cooler) and (cooler) – see Figure 10. The number of these votes was approximately equivalent to the number of subjects who felt warm and hot under observed environmental condition.

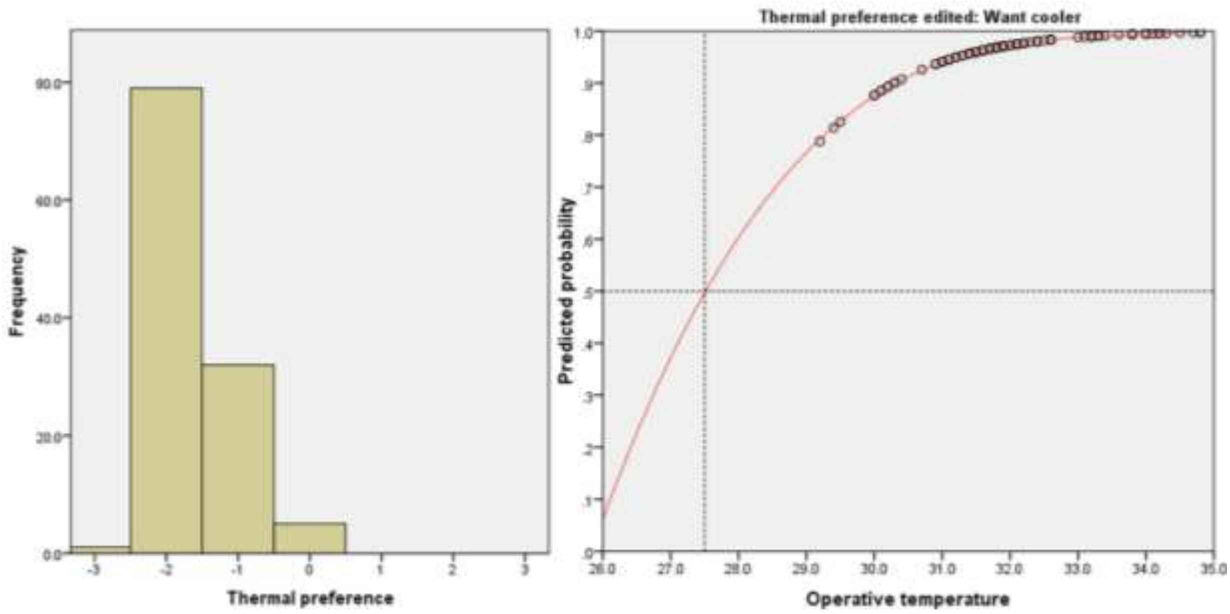



Figure 10. Analysis of thermal preference

A binary logistic analysis was run separately for the two groups of preference votes - “want to be cooler” (<0) and “no change” (=0). The preferred temperature was determined at the intersection of the regression and reference line at the probability of 50% as a neutral percentage of people who want to be cooler. Although the real data do not show completely on the lower part of the exponential line, outputs after analysing are significant in statistical terms (R square = 0.999, Sig. of Chi-square = 0.013, Wald statistic = 3.741 and its Sig. = 0.05, and Exp (B) = 2.243). The logistic analysis between preference vote of “want to be cooler” and operative temperature shows the subjects desire the cooler condition rather than the neutral temperature found. The preferred temperature is 27.5°C, which is 1°C lower than comfort temperature. In reality, the desirable environment for people is not easy to achieve in a real environment in Vietnam as the present, where the internal ambient temperatures experienced during the survey were much higher than what might be predicted as desirable.

### 5.5. Comparison with previous findings

The first comparison was carried out between the work described in this paper and previous studies on thermal comfort by researchers in Vietnam. Two research project reports found had examined the occupants' responses to their immediate environment but using different approaches. These were an experimental study of 40 respondents in an air controlled chamber built in Hanoi (Nguyen, et al., 2003) and field study which collected 1200 subjective responses in the University of Danang during summer months (Nguyen, 2013). It is possible that the neutral operative and effective temperatures defined by Nguyen in 2012 and in the study reported in this paper in 2017 are consistent with the comfort range found by Nguyen, et al. in 2003. However, in the comparison between the empirical study conducted in 2012 and this paper's findings from studies undertaken in 2017, the occupants of dwellings were found to have a neutral thermal sensation at 28.5°C $T_{op}$ or 29.8°C ET which is higher by 0.7°C $T_{op}$ / 2.7°C ET compared to the comfort temperature for the schools studied in Danang. Two possible conclusions are generated: firstly, the comfortable temperatures/range from the statistical analysis of subjective responses in the real environment are 4-5°C higher than the set point/range implemented in the national construction standards.; secondly, the differences in research results between 2012 and 2017 could be attributed to variations of climate and geographic location; and building type (Djamila, et al., 2012).

Table 3. Neutral temperatures and comfort ranges of the Vietnamese found in Vietnam

| | City | Year | Season | Building type | Cooling | Method | Neutral temperature (°C) | Comfort zone (°C) |
|---|---|---|---|---|---|---|---|---|
| Hung Dang | Ho Chi Minh City | 2017 | Warm | Residence | Natural | Field study | 28.5 (TOP), 29.8 (ET) | |
| Tuan Nguyen | Danang | 2012 | Warm | School | Natural | Field study | 27.9 (TOP), 27.1 (ET) | |
| Hang Nguyen | Hanoi | 2003 | Cold | | | Experiments | | 24 - 29 (Ta) |

The second comparison relates to studies on comfort for residential buildings over the wider tropics in SE Asia. Most researchers approached the issue by carrying out empirical studies and then they indicated that the observed thermal neutralities vary significantly over SE Asia.

The comfortable operative temperature calculated here from the equation (1) is 0.7°C lower than that determined by Henry (2000) in Jakarta, Indonesia and by 1.5°C compared to the work of Harimi (2007) in Kota Kinabalu, Malaysia. However, it is higher by 2.9°C $T_a$ compared to the work of Ballantyne (1967) in Port Moresby; by 1.5°C compared to N.H. Wong (2000) in Singapore; and by 0.5°C $T_a$ compared to Preechaya (2011) in Bangkok, Thailand.

The thermal neutrality in those studies is similar to the study presented here and also of deDear in 1990 for housing. It is noted that the neutral temperatures found in Singapore, Indonesia (1993), and Thailand were analysed from a combination of both dry and wet seasons. All results indicate that the observed thermal comfort in naturally ventilated buildings, particularly dwellings in hot humid climates, is divergent from the prediction of the PMV model and the implementation of international and local standards.

A review of the works of Henry Feriadi (2004) and de Dear (1994) found that the preferred temperatures for the occupants were at the intersection of two probit lines determined for two trends – "want to be cooler" and "want to be warmer". However, the observed data in HCMC show some variation; for instance, the subjects did not encounter conditions in which their preference would be "want to be warmer". Thus, the identification of preferred temperature in HCMC has to use a modification of the typical approach shown in Figure 10. The temperature thus determined to be preferred by occupants is 27.5°C which is 1.5°C and 4°C higher than those found in naturally ventilated houses in Jogjakarta, Indonesia (Feriadi & Wong, 2004) and in air controlled office buildings in Townsville, Australia (Dear & Fountain, 1994) respectively.

Table 4. Neutral temperatures of the subjects in NV residential buildings in the tropics

| | City | Country | Year | Building type | Method | Neutral temperature (°C) | Preferred temperature (°C) | Comfort zones (°C) |
|---|---|---|---|---|---|---|---|---|
| Ballantyne | Port Moresby | | 1967 | Residence | Field study | 25.6 (Ta) | | |
| | Port Moresby | | 1979 | | Climate chamber | 26.7 (Ta) | | |
| Richard deDear | Singapore | Singapore | 1990 | Residence | Field study | 28.5 (TOP) | | |
| Nuy Hien Wong | Singapore | Singapore | 2000 | Public housing | Field study | 26.9 (TOP) | | |
| Henry Feriadi | Jakarta | Indonesia | 2000-2001 | Residence | Field study | 29.2 (TOP) | 26.0 (TOP) | |
| Preechaya Rangsiraksa | Bangkok | Thailand | 2002-2003 | Residence + Office | Field study | 28 (Ta) | | 25.5 - 30.5 (Ta) |
| Harimi Djamila | Kota Kinabalu | Malaysia | 2007-2008 | Residence | Field study | 30.2 (Ta) | | |
| Hung Dang | Ho Chi Minh City | Vietnam | 2017 | Residence | Field study | 28.5 (TOP), 29.8 (ET) | 27.5 (TOP) | 31.5 (TOP)-upper limit |

The difference between the three sets of findings can be plausibly interpreted as arising from the following: firstly, the difference between cooling options within the samples: natural ventilation for houses in Vietnam and Indonesia; and mechanical cooling for offices in Australia. Many comprehensive studies around the world have indicated that the distinction between thermal subjective responses in air-conditioning and naturally ventilated buildings arises from the variable context of the environment, thermal experiences, and expectations of future thermal desire (Brager & de Dear, 1998). Therefore, in field experiments by de Dear and Fountain in 1994, the temperatures for neutrality and preference found in air conditioning offices are far lower than those found in free-running houses in HCMC. Secondly, for the observed data in Jogjakarta, they were collected in both rainy and sunny seasons. Under a cooler condition in wet months, the samples in a field study of Henry Feriadi showed a preference for warmer in the investigated environment. Consequently, the different characteristic of seasonal data affects divergence in the analytical result of two studies besides reasons of varying climate and demographics.

The authors here have attempted to reconcile some variations in data and analysis with those examples from similar studies and of similar environments in SE Asia, however, there are variations which could prove significant. In particular, it is important in the particular location of Vietnam to understand clearly what occupant sensations and expectations are likely to be as this has impacts on demand for and use of air conditioning systems.

## 6. Conclusion

The field study undertaken considered both architectural design typologies and also environmental conditions giving rise to comfort/discomfort sensations. These were conducted in the shophouses during warm months in HCMC. The conclusions as follows:

- The indoor and outdoor climatic conditions of the shophouse dwellings were not beneficial for thermal comfort of the occupants with hot air temperature, high solar loads, and low air movement. The thermal environment in buildings strongly correlated with changes in the surrounding climate.
- The neutral and preferred temperatures were found at 28.5°C and 27.5°C $T_{op}$ respectively; with the upper limit of comfort ranging up to 31.5°C. These findings show a level of variability compared to previous studies in Vietnam and other countries in SE Asia.

The authors suggest that the reasons result from variations of building type, climate, characteristic of data, and demographics. This would indicate a need for further study.

- For indoor thermal comfort, there is a significant divergence of thermal neutrality predicted from the observed data and heat balance model. The deviation of comfort temperature is 1.2°C $T_{op}$.
- The paper shows a knowledge gap in the study of comfortable environments for naturally ventilated and air-conditioned buildings in Vietnam, particularly lacking is information for naturally ventilated residences either from empirical or experimental approaches. The existing efforts in this research field are significant, but still very few in number.
- The comfort temperature/range determined by the field study are significantly different from those prescribed by local and international standards.
- The necessity for further field studies and analysis in cool season is evident in order to achieve a comprehensive set of results for thermal comfort for the occupants of residential buildings in HCMC.

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