

Original Research Paper

Determination of Thermal Comfort for Social Impact Assessment: Case Study in Kota Damansara, Selangor, Malaysia

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Abstract: This study determined the thermal comfort of outdoor recreational park in Kota Damansara, Malaysia. Predicted Mean Vote (PMV) index, Predicted Percentage of Dissatisfied (PPD) and Thermal Sensation Vote (TSV) were applied in order to determine thermal comfort in the study area. Comparison and establishment of relationship were done between PMV and Predicted Percentage of Dissatisfied (PPD) to demographic factors and affecting factors among visitors of public parks in Kota Damansara. Based on the research analysis, the thermal comfort ranges in urban recreational park of Kota Damansara was within the comfort zone and satisfactory to its users. The comfort level of both public parks by using PMV and TSV was +1.5 and 0 while PPD was 56.70%. The result of this study showed that comfort zone of respondents shifted towards the right of TSV curve. Compact human settlement in the city exacerbated the development of housing to meet the demand, thus affected the amount of green areas available in study area. The results from the research could be useful for landscape's architect, urban planner and engineers to create a sustainable development in Malaysia or all over the world.

Keywords: Environmental Impact Assessment, Urban Planning, Thermal Comfort

Introduction

Population increment in the world obviously causes more emerging technologies to cope with human living standard. Urban is a place where human have vast jobs opportunities contributing to high productivity, luxurious lifestyle and massive network of transportation, unfortunately, accompanied by urban heat island. Urban heat island greatly affecting urban in a way that the heat trapped in building blocks of the city will lead to warmer temperature compared to rural areas outside the city. Compact human settlement in the city allows more room for development of housing to meet the demand that in turn impacted amount of green areas available. Options for human comfort in warm climate and limited space in urban areas include green belt policy (NE, 2010) or assessment of thermal comfort.

Thermal comfort can be defined as condition of mind that expresses satisfaction with the thermal environment

(ANSI/ASHRAE Standard 55, 2010). When an occupant of a building generates heat and is allowed to dissipate into surrounding environment, thermal comfort of the individual is maintained. If the environment conditions is depriving for the individual, health effects such as heat stroke and heat exhaustion may occur (Curriero *et al.*, 2002). Thermal sensation is defined as a conscious experience resulting from exposure to a group of variables making up the thermal environment (ASHRAE, 1981). Thus, standard of thermal comfort is needed for assessing human comfort. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) established Standard 55 which titled 'Thermal Environmental Conditions for Human Occupancy' in year 1992. The main purpose of the standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space

(ANSI/ASHRAE Standard 55, 2010). It includes four environmental factors and two personal factors namely humidity, temperature, thermal radiation, air velocity activity and clothing. Development of this standard is useful for landscape's architect, urban planner and engineers to promote sustainable development dealing with global warming. Apart from developing energy efficiency building such as green building, many deaths occurred during winter time can also be prevented with proper housing conditions.

Outdoor Thermal Comfort

Solar radiation from outdoor environment clearly gives an effect on thermal comfort of a subject. Hodder and Parsons (2007) studied the relationship between thermal comfort and exposure of solar radiation. The experiment conducted in an environmental chamber with monitored environmental conditions such as air temperature, mean radiant temperature, relative humidity and air velocity. Three designs of experiment was conducted to determine effect of radiation intensity, effect of spectral content of radiation and effect of glazing type respectively. By applying International Organization of Standardization (ISO) thermal sensation scale, a linear relationship was established between level of stimulated solar radiation and thermal sensation rating. Apart from ratings, supporting evidence proving solar radiation for determination of thermal comfort is the mean skin temperature measurements.

Multiple logistics regression can also relate the environmental parameters and personal parameters along with preferences votes (Oliveira and Andrade, 2007). Bioclimatic comfort is assessed in a leisure area and results reflect possibility to identify preferences of subject in outdoor environment conditions, even with the influential personal characteristics such as gender and age. Other than that, an indoor model was applied to outdoor conditions but with careful steps due to the large gap of indoor and outdoor environments conditions. Subjects performing moderate to vigorous physical activities had been modeled using Comfort Formula (COMFA) outdoor thermal comfort model (Kenny *et al.*, 2009). Outdoor thermal comfort model is based on heat and moisture flux of one's body's energy with its environment. However, it's a disadvantage when the model act to over- or underestimated the heat and moisture exchange as much as 6% of total cases. Sensitivity analysis is recommended to determine changes of each COMFA model inputs that will affect its outputs. Inputs can be air temperature, Controlled Room Temperature (CRT), metabolic activity or relative humidity.

Another popular index that had been utilized to measure outdoor comfort range is Physiological Equivalent Temperature (PET). Along with daily climatic data collected for the past 11 years, amount of rainfall and days

count with rain can dramatically affect PET values, thus affecting thermal comfort (Kenny *et al.*, 2009). This is due to the reason that climate in the study area are very prone to heat-related ailments. PET values were categorized into grades according to level of physiological stress. Chen and Ng (2012) summarized the application of models and indicators that are widely used and some discussion on evaluating behavioral aspects of outdoor thermal comfort. Outdoor thermal comfort assessment can be categorized into two types which are steady-state assessment and non-steady-state assessment methods.

Steady-state assessment linked human thermal sensation with microclimatic conditions. PMV indices developed by Fanger (1982) are widely utilized on measuring thermal response based on seven-point scale which is +3 = hot, +2 = warm, +1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool, -3 = cold. PMV indices often combined with PPD. Few other steady-state models are PET (Mayer and Hoppe, 1987), which is based on Munich Energy-balance Model for Individual (MEMI), Index of Thermal Stress (ITS) (Givoni *et al.*, 2003), COMFA outdoor thermal comfort model (Kenny *et al.*, 2009) and Outdoor Standard Effective Temperature (OUTSET) (De Dear and Brager, 2002).

For non-steady-state model such as Pierce Two Node Model, it could possibly portray dynamic and detailed study however there are no internationally accepted non steady-state indices (Hoppe, 2002). Skin temperature that is needed as an input appear to be a drawback of this assessment method as it is not feasible and practical in outdoor cases. Nikolopoulou *et al.* (2004) extensively studied thermal comfort of outdoor spaces using field surveys and environmental monitoring data. Thermal comfort responses are determined by relationship of subjective thermal responses with microclimatic parameters and building models. Data of microclimatic parameters to build a model can be acquired from local meteorological stations. Actual Sensation Vote (ASV) has been employed and the results are correlated with microclimatic parameters. There are weak correlations between these two ASV and microclimatic parameters simply indicate that one parameter is insufficient for thermal comfort assessment. Besides that, ASV is also compared to PMV and only 59% of PMV falls within comfort proves that solely physiological approach is unsatisfactory to identify outdoor thermal comfort conditions. Trial to develop model using multiple linear and stepwise regression found to be significant for all microclimatic parameters except for Relative Humidity (RH). Adding correction factors to model developed could be useful for urban designers to fully utilize outdoor open spaces in urban.

Apart from using various models for assessing thermal comfort, calibration is often needed to accurately reflect the results based on field studies conducted. Monteiro and Alucci (2006) had provided calibration for widely used

outdoor thermal comfort assessment as much as 20 predictive models which some are from Givoni *et al.* (2003; Nikolopoulou *et al.*, 2004; Jendritzky, 1991). Calibration of the models would be used to assess outdoor thermal comfort in Grande Sao Paulo, Brazil. Methodologies involved two approaches which were field research and simulation and calibration of those models. Microclimatic variables measurements and questionnaires were conducted in summer and winter. All the models summed up to 32 types of indexes and are computationally processed whereby the results were compared to conducted field researches that will provide calibration value for the models. To establish the calibration values, three criteria were developed as below:

- 1st criterion: Correlation of model parameter and results of thermal sensation responses
- 2nd criterion: Correlation of index and results of thermal sensation responses
- 3rd criterion: Percentage of correct predictions

Range limits for all indexes were changed to obtain maximum percentage of correct predictions and maximum correlation between model parameters or indexes with results of thermal sensation responses. In conclusion, models with high possibility of predicting thermal sensation responses are considered by having good correlation of 1st criterion due to high potential to accurately predict thermal sensations after the calibration of these models.

Many researches had focused on quantitative approach in discussing outdoor thermal comfort conditions. In a research done by Nikolopoulou and Steemers (2003), psychological adaptation was implemented into her research linked to thermal sensation. Naturalness, expectations, experience on short and long term, time of exposure, perceived control are psychological adaptations issue where its relative weight need to be addressed and understanding of its interconnections. Adaptation of humans towards outdoor thermal comfort was suggested when the Actual Percentage of Dissatisfied (APD) were very different from theoretical PPD. The term naturalness is describe as an environment without artificiality whereby it is the main concern of this research because this factor is not influenced by any other factors however as an integral part in psychologically influencing user's perception on thermal comfort endurance to wide changes of environment. Parameters which are taken into consideration are experience and perceived control. Users experiences in a city of natural and built environments whether indoor or outdoor could affect their thermal sensation. Some environments of shady areas, breeze exposure and access to sun can be controlled and this also will drive user's perceptions on thermal comfort. Nikolopoulou and Steemers (2003)

emphasizes that psychological adaptation need to be taken into account on urban planning along with basis physical model to increase usage of outdoor space.

Gomez-Apeitia *et al.* (2011) had also researched on comparison of outdoor and indoor thermal comfort temperatures. The method they employed was different with most of the research by imparting Averages for Thermal Sensation Intervals (ATSI). As it named, intervals from data obtained will be used to calculate mean and standard deviation and subsequently draw regression line. From the results of his research, he found that human may achieve higher tolerance of indoor temperatures than outdoor in winter. This is due to the need to conceal body temperature when indoor temperature is hot and human body is acclimatize to the environment which the comfort temperature range is larger. In contrast, during summer, the comfort ranges decreases. Respondents' houses made of concretes and cement absorb and retain heat well making indoor temperature higher than outside. In turn, the respondents had adjusted to their expectations.

Kantor and Unger (2010) studied the outdoor thermal comfort conditions in an urban park in inner city of Szeged (South-East Hungary). In commons, the methodology involves calculation of PET derived from in situ meteorological data. Another special feature included in this research was application of Geographical Information System (ArcView). Human observations method clearly gives information on personal characteristics and the pattern of movement in the urban park. With the aid of ArcView GIS 3.3, data collected are processed and area usage maps were created. Field study was only conducted in spring and autumn for the period of study of 2 years (2008-2009). Thermal comfort conditions are estimated using data available from nearest meteorological station. Additional subjective information was gathered through social surveys and unobstructed observations. Mapping of study area was also done to accurately illustrate buildings and trees along with surface covers. Weather conditions was also observed and classified into overcast, partly cloudy and clear. Data digitization in ArcView allows convenient data interpretation such as queries on any respondents and grouping them into any combinations. The research showed that human physical adaptation make them extend the time spent on outdoors and reduced clothing values. The number of respondent increases when the environment conditions are considered thermally stressed and it is explained by research of Nikolopoulou and Steemers (2003).

Monteiro and Alucci (2009) addressed the presence of vegetation impacting outdoor thermal comfort in urban spaces in Sao Paulo, Brazil. Two major comparison of study area were chosen whereby the first area was fully shaded by trees and another area shaded by processed materials. Measurements and

questionnaires survey was also set up in three targeted conditions namely under open sky, shaded by trees and under a processed cover. Significant differences of thermal sensations can be observed in summer compared to winter which the result was quite similar. Under shaded trees, thermal sensation conditions are more likely to be neutral than open sky. Apart from that, respondents' thermal sensations are cooler under shaded trees than under processed materials. The differences in thermal conditions could be insignificant in morning but it gets more significant when the day reach afternoon.

Zambrano *et al.* (2006) addresses evaluations of outdoor thermal comfort of Rio de Janeiro. As in practice, Fanger's model that are widely used considering environmental and individual parameters (PMV and PPD). An acceptable thermal condition as suggested by ISO 7730 is to have less than 10% of PPD. Thermal comfort analysis was done by using ASV and prediction of comfort had been done through PMV and PPD. At last, two results from the study will be compared. 40 questionnaires are done in 4 different points in a square which was located under shades, sunny area, partial shade area and fully shaded with vegetation respectively. Results of point 2 (sunny area) happens to have unsatisfactory percentage although overall results showed high level of satisfaction (77%). However, prediction of comfort using PMV and PPD found that there are higher PPD ranges from 31-100% whilst in observed results, there are only high satisfaction percentage. They expecting the results would be contrasted due to the fact that respondents had already adapted to heat. In conclusion, dissatisfaction of respondents arose because of several factors such as presence of solar radiation, surface temperature of materials and presence of ground cover of vegetation which are aligned with obtained environmental parameters measurements. Methods employed by PMV and PPD reflect the need of changing the urban space. Despite of the dissatisfaction of respondents in the study area, the comfort conditions of the space are considerable due to the climatic conditions of Rio de Janeiro. In months of cold climate, the sunny areas can be a dynamic space.

Malaysia's Geography and Climate

Malaysia is situated along the equatorial and located in southeast of Asia. The climate is tropical with annual

southwest (April to October) and northeast (October to February) monsoon wind. The terrain ranges from coastal plains to rising hills and mountains. Average annual population growth rate in 2010 is reported as much as 1.6% which makes up 28.3 million people living in Malaysia (DSM, 2010). Selangor appeared to be the most populous state by reporting 5.46 million people and urban growth rate had increased to 71.0% since 2000. High level of urbanization can be observed in Federal Territory of Kuala Lumpur and Putrajaya. Selangor has about 91.4% urbanization level. This indicates that Selangor is experiencing rapid growth of its economy where the population centralized in this state. The first 6 months of 2012 had attracted foreign investment on projects amounted up to RM 3.4 billion.

The challenge of the urbanization is to meet people's need. Low cost housing project that had been proposed becomes a conflict with raw material prices such as cement. Current slow development of housing causes houses price to hike when it fail to meet population demand. Only 87.2% of house ownership reported in Selangor compared to other states which had 93.4 and 93.3% for Kelantan and Kedah respectively (PGM, 2012). Alternative to the issue raised is the proposal of energy-efficient buildings by Real Estate and Housing Developers' Association Malaysia (REHDA). Total 26% of global greenhouse emissions come from energy supply needed to generate electricity while land use, land use change and forestry contribute to 17%.

Microclimatic Parameters (February)

During the month of research (February 2013), Malaysia is at the edge of northeast monsoon season which will usually end in March. Monthly rainfall is above average and raining often occurs in the evening. Approximately 9-22 days of rainfall occurred in peninsular states which include Selangor. Lowland areas recorded temperature ranges from 25.6-28.7°C (MMD, 2013).

In this research, air temperature, relative humidity, wind speed and solar radiation were measured. For both public parks, survey conducted in morning starts at 7-10 am and 5-7 pm in afternoon. However, calculation of Mean Radiant Temperature (MRT) is needed to calculate PMV. It can be measured using globe thermometer and become an input for MRT calculation. To avoid tedious calculation of MRT, data from secondary source was used which is shown in Table 1.

Table 1. Meteorological parameters

Parameters	Minimum	Maximum	Mean ± standard error	Standard deviation
Ambient Temperature, °C	24.4	32.2	28.5±0.1	1.8
Relative Humidity, %	52.0	96.0	70.8±0.6	9.9
Air Velocity, ms ⁻¹	0.0	3.1	1.3±0.0	0.8
Physiological Equivalent Temperature, °C	20.8	39.7	26.9±0.2	3.3
Mean Radiant Temperature, °C	24.5	50.5	33.3±0.3	4.9

Source: (Nasir *et al.*, 2012)

Background of Study Area

Kota Damansara Township was chosen as a study area. It is located in the sub district of Sungai Buloh in Petaling Jaya, Selangor Malaysia. It is a 4,000-acre (16 km²) developing township with upcoming Sungai Buloh-Kajang Line. Recreational parks in Kota Damansara were chosen as the study area to assess outdoor thermal comfort. Recreational park extensively serves its user originate from surrounding or even those who came further than the nearby area. Two large parks were chosen for the assessment which was Lake Garden at section 6 (coordinate- 3.157, 101.579) and RimbaRiang Recreational Park at section 9 (coordinate- 3.180, 101.583) (Fig. 1). These two parks were frequently visited in morning and afternoon. The Lake Garden was surrounded by semi-detached houses and the lake was extended to another zone of housing area. The available exercises facilities and benches are limited but the trees are considerably dense to shade the path walk. There are a number of entrances into the park from 2 different housing areas. Parking lot is available in the main entrance near to where the survey will be conducted. RimbaRiang Recreational Park has more promising facilities such as public toilets, sitting area with roof, children playground and exercises equipment. There are numerous trees but all the trees had not fully grown up where the height is about 2-3 meters tall. The surface covers of the entrance are concrete with small bushes and flowers around the sitting area where the survey is conducted.

Methodology

Questionnaire Survey

A total of 30 questionnaire surveys had been conducted in 2 different places with 15 surveys each. The questionnaire was designed based on three sections. Section A consists of demographic information of respondents such as age, gender, occupation, religion, race, nationality and income. Section B refers to visitor's house and visiting frequency, while Section C refers to the environmental parameters such as soft-scape and hardscape of recreational parks. The time frame and frequency visiting at the park was also noted. The seven point ASHRAE thermal sensation scale are:

- + 3 = Hot
- + 2 = Warm
- + 1 = Slightly Warm
- 0 = Neutral
- -1 = Slightly Cool
- -2 = Cool

- -3 = Cold

The respondents were also asked to rate their current thermal sensation using the ASHRAE thermal sensation scale for determination of TSV. Clothing type and activity can be observed and noted. Hence, the range of value clothing would be calculated to be compared with PMV. The survey questions include how they scale the affecting factors of perceiving thermal comfort such as lighting intensity, wind velocity, air temperature and presence of hardscapes. The scale used was semantic scales with 5 intervals (best, good, average, bad and worst).

Respondents Information

Table 2 showed the respondents information for this study. Majority of respondents fall into age ranges from 21-30 as much as 43.30% followed by 20% of respondents within range of age 31-40. The percentage for respondent's age ranges from 10-20 and 61-70 are same which was 10.00% or 3 person count. For the age range of 41-50, respondents participated was 16.70%. Respondent's gender for female and male is 15 for both. Out of 30 respondents, Malay appear to be the majority with 66.70% followed by Chinese, Indian and others with percentages of 23.30, 6.70 and 3.30% respectively. Thus, religion was expected to portray similar trend as ethnic composition. 66.70% of respondents belong to Islam while 6.70% of respondents belong to Christian. The other two religions were Buddha and Hindu with percentage of 16.70 and 10.00% respectively.

Only Malaysian was involved in the survey with sum of 30 local people. Occupations of respondents can be categorized into seven division named professionals, non-professionals, retired, housewives, students and self-employed. 43.30% of respondents belong to professionals which require special skill in their job. Students and nonprofessional comprise 16.70% of the total respondents. Retiree and housewives have the same percentage which were 10.00% and the least respondents involve in the survey with 3.30% is self-employed. The income ranges can be divided into 7 categories where the largest percentages of respondents is as much as 43.30% falls into income range <RM 2,000 while the least percentage of respondents is from income range of <RM 11,000 and <RM 20,000 with only 3.30%. About 23.30% of the total respondents have income range <RM 5,000 followed by income range <RM 8,000 with 16.70%. Degree qualification seems to be significant in the survey having 36.70% or 11 respondents. Then, it is followed by 23.30% for secondary level, 20.00% for diploma, 13.30% for SPM level and 6.70% for STPM level.

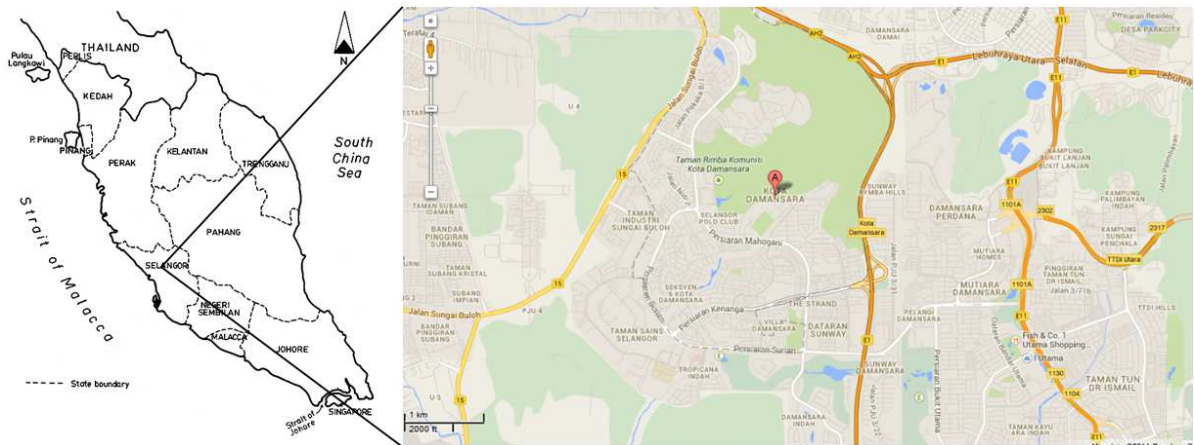


Fig. 1. The location of Kota Damansara, Selangor in Peninsular Malaysia (Source: Edited from FAO, 2014; Google Maps, 2014)

Table 2. Respondents information in study area

	Range/Category	Frequency	Percent
Age	10-20	3	10.0
	21-30	13	43.3
	31-40	6	20.0
	41-50	5	16.7
	61-70	3	10.0
Gender	Male	15	50.0
	Female	15	50.0
Ethnicity	Malay	20	66.7
	Indian	2	6.7
	Chinese	7	23.3
	Others	1	3.3
Religion	Islam	20	66.7
	Christian	2	6.7
	Buddhist	5	16.7
	Hindu	3	10.0
Nationality	Malaysian	30	100.0
Occupation	Professional	13	43.3
	Non-Professional	5	16.7
	Retired	3	10.0
	Housewife	3	10.0
	Student	5	16.7
	Self-Employed	1	3.3
Income	<Rm 2,000	13	43.3
	<Rm 5,000	7	23.3
	<Rm 8,000	5	16.7
	<Rm 11,000	1	3.3
	<Rm 20,000	1	3.3
Qualifications	Others	3	10.0
	Secondary	7	23.3
	Spm	4	13.3
	Stpm	2	6.7
	Diploma	6	20.0
Total	Degree	11	36.7
		30	100.0

Predicted Mean Vote and Predicted Percentage Dissatisfied Theory

According to ANSI/ASHRAE Standard 55 (2010) prediction of thermal comfort by using steady-state energy balance will determine PMV index. The equation is developed by Fanger (1970) as below:

$$PMV = [0.303 \exp(-0.036M) + 0.028]L \quad (1)$$

Where:

M = Rate of metabolic heat production, W/m²
 L = Thermal load on the body, defined as the difference between internal heat production and heat loss to the actual environment for a person hypothetically

Value of M can be estimated from activity level of a person by using Table 3. The equation for L is the differences between right and left side equation as follows:

$$\begin{aligned} M - W = & 3.96 \times 10^{-8} f_{cl} [(t_{cl} + 273)^4 - (t_r + 273)^4] \\ & + f_{cl} h_c (t_{cl} - t_a) + 3.05 [5.73 - 0.007(M - W) - p_a] \\ & + 0.42 [(M - W) - 58.15] \\ & + 0.0173M (5.87 - p_a) \\ & + 0.0014M (34 - t_a) \end{aligned} \quad (2)$$

Where:

M = Rate of metabolic heat production, W/m²
 W = Rate of mechanical work accomplished, W/m²
 f_{cl} = Clothing area factor Acl/AD, dimensionless
 t_{cl} = Clothing temperature, °C
 t_r = Mean radiant temperature, °C
 h_c = Convective heat transfer coefficient, W/m²/°C
 t_a = Air temperature, °C
 p_a = Partial water vapour pressure in air, kPa

As a part of the energy balance equation, the clothing temperature, t_{cl} , was calculated by iteration as:

$$\begin{aligned} t_{cl} = & 35.7 - 0.028(M - W) \\ & - R_{cl} \{39.6 \times 10^{-9} f_{cl} [(t_{cl} + 273)^4 - (t_r + 273)^4] \\ & + f_{cl} h_c (t_{cl} - t_a)\} \end{aligned} \quad (3)$$

To find clothing area factor Acl/AD, dimensionless, f_{cls} , the following equation is used:

$$\begin{aligned} f_{cl} = & 1.0 + 0.2I_{cl} \text{ when, } I_{cl} < 0.5clo \\ \text{or, } = & 1.05 + 0.1I_{cl} \text{ when, } I_{cl} > 0.5clo \end{aligned} \quad (4)$$

Table 3. Typical metabolic heat generation for various activities

	W/m ²	met ^a
Resting		
Sleeping	40	0.7
Reclining	45	0.8
Seated, quiet	60	1.0
Standing, relaxed	70	1.2
Walking (on level surface)		
3.2 km/h (0.9 m/s)	115	2.0
4.3 km/h (1.2 m/s)	150	2.6
6.4 km/h (1.8 m/s)	220	3.8
Office Activities		
Reading, seated	55	1.0
Writing	60	1.0
Typing	65	1.1
Filing, seated	70	1.2
Filing, standing	80	1.4
Walking about	100	1.7
Lifting/packing	120	2.1
Driving/flying		
Car	60-115	1.0-2.0
Aircraft, routine	70	1.2
Aircraft, instrument landing	105	1.8
Aircraft, combat	140	2.4
Heavy vehicle	185	3.2

Source: (ASHRAE, 2001)

Heat transfer took place in each individual was either free convection or forced convection. Therefore, convective heat transfer coefficient, h_c , will be determined as follows:

$$\begin{aligned} h_c = & 2.38(t_{cl} - t_a)^{0.25} \quad 2.38(t_{cl} - t_a)^{0.25} > 12.1(V^{0.5}) \\ \text{or, } = & 12.1(V^{0.5}) \quad 2.38(t_{cl} - t_a)^{0.25} < 12.1(V^{0.5}) \end{aligned} \quad (5)$$

According to Harvey and Huang (2007) the partial water vapour pressure in air, p_a , is the product of saturated vapour pressure and relative humidity given by:

$$p_a = p_{sat} x t_a x RH \quad (6)$$

Where:

p_{sat} = Saturation vapour pressure, kPa
 RH = Relative humidity, %

To find p_{sat} , Antoine's formula is utilized:

$$p_{sat} = 0.1333 \exp(18.6686 - 4030.183 / t_a + 235) \quad (7)$$

After PMV index were estimated, another method employed to relate PMV was estimation of PPD. Fanger (1982) established the relationship as:

$$PPD = 100 - 95 \exp[-(0.03353PMV^4 + 0.2179PMV^2)] \quad (8)$$

The graph for PMV-PPD model will reflect the percentage of dissatisfied of 5% at PMV = 0

Data Analysis

In order to calculate PMV with the data available, repetitive calculation for 30 data were collected. Visual Basic for Application (VBA) in Excel is appropriate for the PMV determination. By recording macro in VBA and stored in module, specific effect will take in workbook according to the formula that had been inserted into macro. Macro acts as storage for formula and a template for input of environment parameters and personal parameters. PMV can be calculated by inserting the input into its respective column. Statistical Package for Social Sciences (SPSS Version 20) will be used to analyze the data collected. This software was suitable for researcher to gather and analyze the data digitally. Trends, charts and formula can effectively illustrate data outcome in a few clicks which was very convenient for the user. Data collected were used to establish PMV and PPD. Hypothesis was derived from the results along with other analyzed data. Demographic data was compared to PMV using Chi square test of independence to observe its significance. Results of affecting factors are also compared to PMV. The comparison generate links or relationship of affecting factors and demographic with PMV or PPD.

Reliability of Dependent Variables

Cronbach's alpha coefficient as an indicator for reliability of dependent variable was tested using SPSS. When the result of test had internal consistency with the alpha value above 0.70 it signify that the scale used acceptable. For this research, the dependent variables

were tested for reliability and showed value above 0.70 and is deemed acceptable.

There is limitation for ranges of input in PMV model for metabolic rates, clothing, air temperature, mean radiant temperature and air velocity (Havenith *et al.*, 2002). Recommended and ranges used in this study is tabulated in Table 4. The value used in this study had exceeded the recommended ranges and the results depicts out of range for PMV from -3 to +5.

Results of Predicted Mean Vote and Percentage of Dissatisfied of Public Park

Microclimatic parameters were measured in morning and afternoon in recreationalpark, Kota Damansara. The average for environment parameters measurement is shown in Table 5. Secondary data is used to substitute unavailability of measurement of environment parameters in recreational park for PMV calculation. As for recreationalpark, although there are measurements made, mean radiant temperature requires globe temperature and thus, secondary data is also used.

Predicted Mean Vote of Recreational Parks

Thermal Sensation Vote (TSV) is the expression of respondents regarding their comfort level during survey according to ASHRAE 7 point scale. 80% of respondents believed that from -2 to +2 are their comfort range (Fig. 2). The wide range of comfort zone could be due to wider tolerance towards understanding of lack of control towards variation of outdoor environment parameters. The PMV estimation by using steady-state energy balance model involved input such as air temperature, relative humidity, wind speed, mean radiant temperature, clothing value and activity level.

Table 4. Comparison of PMV range with actual study

Parameters	Recommended ranges	Range used in this study
Metabolic rates (met)	0.8-4.0	1.0-3.8
Clothing (clo)	0.0-2.0	0.29-0.72
Air temperature (°C)	10.0-30.0	24.4-32.2
Mean radiant temperature (°C)	10.0-40.0	24.5-50.5
Air velocity (m/s)	0.0-1.0	0.0-0.31

Table 5. Microclimatic measurement of recreational parks

Date	Recreational parks							
	Morning/Afternoon		Relative humidity (%)		Wind speed (m/s)		Solar radiation (Lux)	
	Air temperature (°C)							
16/2/2013	27.8	30.0	76.2	60.8	0.0	*3.1	164.0	500.0
17/2/2013	28.6	29.8	70.7	63.5	0.0	*3.1	164.0	486.0
23/2/2013	27.4	29.5	71.9	62.0	0.0	*3.1	55.0	924.0
24/2/2013	28.2	29.4	67.9	72.3	0.0	*3.1	150.0	1969.0
Average	28.0	29.7	71.7	64.7	0.0	*3.1	133.0	970.0
Standard deviation	0.5	0.3	3.5	5.2	0.0	0.0	52.6	696.5

*secondary data from (Nasir *et al.*, 2012)

Table 6. Chi-square test for Predicted Mean Vote (PMV) with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	75.986	72	0.351
Length of staying	33.432	36	0.591
Comfort status	78.095	72	0.291
Length of time staying in park	18.095	18	0.449
Frequency of visiting park	96.500	72	*0.029
Section C			
Air quality	62.381	54	0.203
Temperature	72.364	54	*0.048
Lighting	73.068	72	0.443
Wind	68.500	54	0.089
Landscape setting	78.808	72	0.272
User-friendly	74.615	54	*0.033
Odour	54.917	54	0.440
Accessibilities	47.542	54	0.720
Tree's density	52.976	72	0.955

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Table 7. The choice of clothing worn by respondents in public parks of Kota Damansara

Garment descriptions	Clo value
Men's brief, t-shirt, ankle length athletic socks, walking shorts	0.29
Men's brief, short sleeved, knit sport shirt, ankle length athletic socks, walking shorts	0.38
Men's brief, short sleeved, knit sport shirt, slippers, walking shorts	0.39
Men's brief, t-shirt, ankle length athletic socks, sweatpants bra, panties, T-shirt, Sweatpants, ankle length athletic socks	0.44
Men's brief, t-shirt, slippers, sweatpants	0.45
Men's brief, short sleeved, knit sport shirt, sweatpants, ankle length athletic socks	0.53
Bra, panties, straight trousers (thick), long sleeve sweaters (thin), sandals	0.59
Bra, panties, ankle length athletic socks, sweatpants, long sleeve sweaters (thin)	0.61
Bra, panties, ankle-length athletic socks, sweatpants, long sleeved (thin)	0.70
Bra, panties, ankle length athletic socks, long sleeved flannel shirt, sweatpants	0.70
Bra, panties, ankle length athletic socks, sweatpants, long sleeve sweaters (thick)	0.72

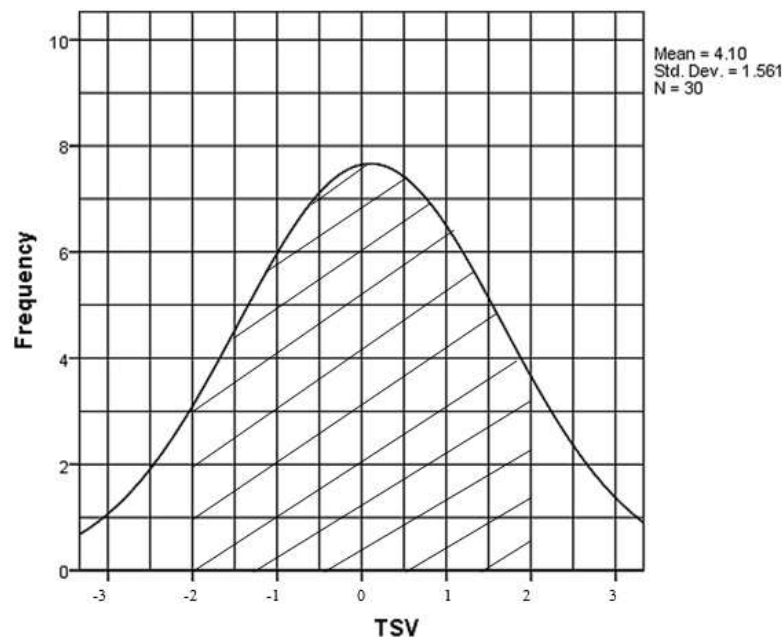


Fig. 2. Thermal Sensation Vote (TSV) of recreational parks in Kota Damansara

The results of calculation for PMV in recreational park showed 80% of respondents were in comfort zone at -0.06 to +2.69. The distribution is slightly deviating from Thermal Sensation Vote (TSV). The deviation from TSV is expected to occur in tropical climate due to physiological acclimatization of people to the temperature in hot and humid climate $\chi^2(54) = 72.364, n = 30, p = 0.048$. This can be explained by (Kantor and Unger, 2010) where human may tolerate outdoor environment which made them extend the time of visiting the park and adjust the clothing worn.

In this study, the respondents may choose to visit the park often instead of extending the time due to satisfaction of thermal sensation in the park $\chi^2(72) = 96.500, n = 30, p = 0.029$. The Chi-square test of independence for Predicted Mean Vote (PMV) with dependent variables was shown on Table 6. Majority of respondents wear clothing value of approximately 0.47 clo. Clothing worn in outdoor recreational park ranges from 0.29 to 0.72 clo was affecting the PMV curve to deviate from TSV (Table 7). With the choice of clothing worn by majority of respondents, PMV depicts that they will feel slightly warm to warm which would probably place them in discomfort zone.

TSV results had shown otherwise where majority of respondents are in their comfort zone by expressing their comfort level as neutral. The user-friendly features in the park is associated with PMV in the way that respondents may psychologically feel that park are more user defined $\chi^2(54) = 74.615, n = 30, p = 0.033$.

Predicted Mean Vote and Predicted Percentage of Dissatisfied of Recreational Park in Kota Damansara

PMV values were plotted against PPD value from calculation using Excel (Fig. 3). From the trend observed, the shaded region represents dissatisfied percentage of

respondents. The results is not consistent with PMV which theoretically when PMV value approaches -0.06, PPD would show only 5.10% of dissatisfaction. Comparing to PMV value earlier, +1.5 is the optimum value (slightly warm to warm) where majority of respondents are comfortable. They are satisfied with the warm conditions surrounding the recreational park. However, the PPD value at +1.6 had shown that 56.70% respondents are dissatisfied with their comfort level.

Demographic Information with the Crosstab Analysis

Chi-square method was employed to test on the association between variables in contingency tables (Investopedia US, 2013). The alpha was determined to be 0.05 generally in social science. This method requires one independent variable and one dependent variable. The significant association will be determined if the answer for Pearson Chi-square have lower value than alpha ($\alpha = 0.05$).

Age Factor

Age factor as an independent variable were tested using chi-square test for independence against dependent variables for type of dwelling, length of inhabiting the house, current comfort status, length of time staying in the park and frequency of visiting the park along with next section of questionnaire which consists of air quality, temperature, lighting, wind, landscape setting, user-friendly, odor, accessibilities and tree's density. The results were tabulated as in Table 8. The test failed to indicate a significant difference, for all of the dependent variables except for tree's density in public park, $\chi^2(16) = 28.137, n = 30, p = 0.030$ (an alpha level of 0.05 was adopted for this and all subsequent statistical tests). The association could be due to different sensitivity levels of age groups towards tree's density.

Table 8. Chi-square test of independence for age with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	16.096	16	0.446
Length of staying	12.634	8	0.125
Comfort status	20.596	16	0.195
Length of time staying in park	4.933	4	0.294
Frequency of visiting park	17.046	16	0.383
Section C			
Air quality	11.929	12	0.451
Temperature	10.835	12	0.543
Lighting	22.617	16	0.124
Wind	16.646	12	0.163
Landscape setting	17.271	16	0.368
User-friendly	13.179	12	0.356
Odor	14.929	12	0.245
Accessibilities	18.942	12	0.090
Tree's density	28.137	16	*0.030

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant.

Table 9. Chi-square test of independence for gender with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	2.353	4	0.671
Length of staying	0.533	2	0.766
Comfort status	7.825	4	0.098
Length of time staying in park	1.429	1	0.232
Frequency of visiting park	3.300	4	0.509
Section C			
Air quality	1.143	3	0.767
Temperature	5.273	3	0.153
Lighting	3.091	4	0.543
Wind	2.400	3	0.494
Landscape setting	3.292	4	0.510
User-friendly	4.154	3	0.245
Odour	2.844	3	0.416
Accessibilities	0.234	3	0.972
Tree's density	1.778	4	0.777

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

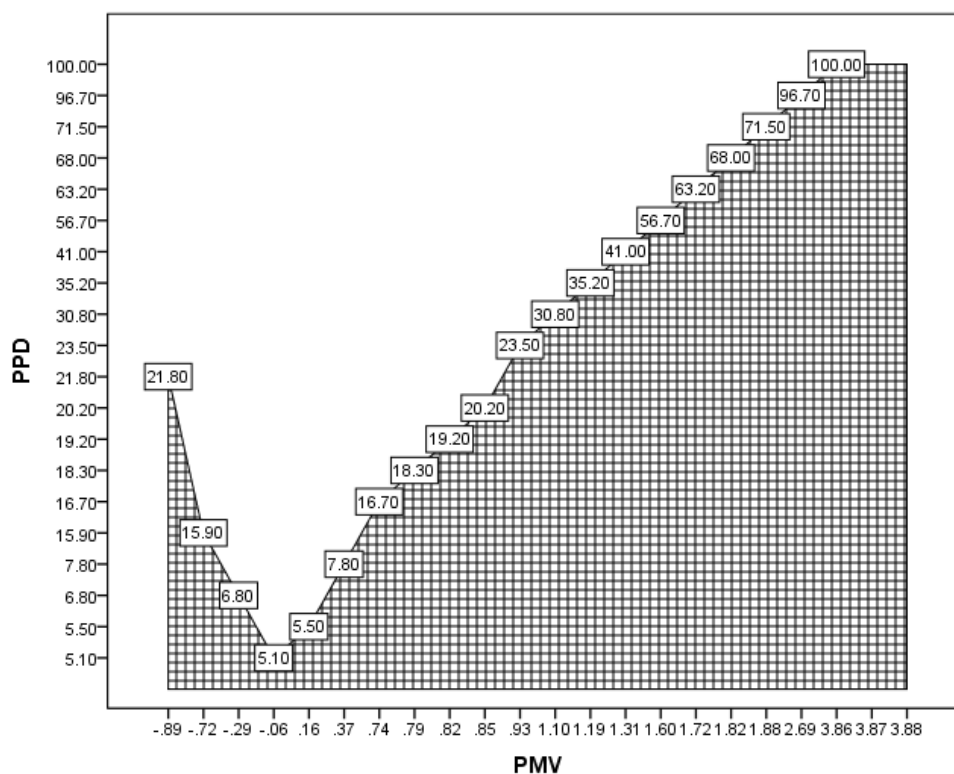


Fig. 3. The Predicted Percentage of Dissatisfied (PPD) for visitors of Recreational Parks in Kota Damansara

Gender Factor

There are no significant association for recreational park between gender and type of dwelling, length of staying, comfort status, length of time staying in the park and frequency of visiting park as none of the reported asymp. sig. is less than $\alpha = 0.05$ (Table 9). The similar result was shown for Section C which includes association of gender with environment parameters such

as air quality, temperature, lighting, wind, landscape settings, odor, accessibilities and tree's density.

Ethnicity Factor

Ethnicity was tested for its association for the same dependent variables. The result was tabulated in Table 10. There are no significant association between ethnicity and type of dwelling, length of staying, comfort status and frequency to visit recreational park as none of

the reported asymp. sig. is less than $\alpha = 0.05$. However, length of staying showed a significant difference with ethnicity $\chi^2(6) = 13.342, n = 30, p = 0.038$. The culture of spending time in park with fishing activities and relaxing with friends and family of certain ethnicity could be a possible reason of relating to time spent in the park. The other dependent variables for section C are also insignificant.

Religion Factor

Religion was tested for its association for the same dependent variables. The result was tabulated in Table 11. There are no significant association between religion and type of dwelling, length of staying, comfort status and length of time staying in the park as none of the reported asymp. sig. is less than $\alpha = 0.05$. Frequency of visiting park have strong relation to religion in this case χ^2

(12) = 28.625, $n = 30, p = 0.004$. Since the park was located near to mosque, it was possible to say that majority of visitors in the park is Muslim. There are also other dependent variables showed same significance difference such as accessibilities $\chi^2(9) = 17.995, n = 30, p = 0.03$ and tree's density $\chi^2(12) = 21.440, n = 30, p = 0.044$.

Occupation Factor

Occupations were tested for chi-square of independent to observe its significance of differences with other dependent variables (Table 12). The only dependent variable that passed the chi-square test is lighting for recreational park. It showed significant difference when associated with occupations $\chi^2(20) = 32.012, n = 30, p = 0.043$. The reason behind this association could be different demand on artificial lighting in the park due to different exposure.

Table 10. Chi-Square test of independence for ethnicity with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	17.948	12	0.117
Length of staying	13.342	6	*0.038
Comfort status	12.133	12	0.435
Length of time staying in park	1.871	3	0.600
Frequency of visiting park	19.843	12	0.070
Section C			
Air quality	4.254	9	0.894
Temperature	7.691	9	0.566
Lighting	12.672	12	0.393
Wind	5.164	9	0.820
Landscape setting	4.935	12	0.960
User-friendly	10.264	9	0.330
Odour	7.737	9	0.561
Accessibilities	14.714	9	0.099
Tree's density	9.934	12	0.622

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Table 11. Chi-Square Test of Independence for Religion with Dependent Variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	16.584	12	0.166
Length of staying	9.795	6	0.134
Comfort status	12.845	12	0.380
Length of time staying in park	1.349	3	0.717
Frequency of visiting park	28.625	12	**0.004
Section C			
Air quality	3.776	9	0.926
Temperature	9.473	9	0.395
Lighting	13.409	12	0.340
Wind	2.817	9	0.971
Landscape setting	5.269	12	0.948
User-friendly	8.718	9	0.464
Odor	6.294	9	0.710
Accessibilities	17.995	9	*0.035
Tree's density	21.440	12	*0.044

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Table 12. Chi-Square Test of Independence for Occupation with Dependent Variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	22.023	20	0.339
Length of staying	7.644	10	0.664
Comfort status	22.389	20	0.320
Length of time staying in park	4.115	5	0.533
Frequency of visiting park	23.777	20	0.252
Section C			
Air quality	17.239	15	0.305
Temperature	8.818	15	0.887
Lighting	32.012	20	*0.043
Wind	10.328	15	0.799
Landscape setting	14.776	20	0.789
User-friendly	6.213	15	0.976
Odor	9.202	15	0.867
Accessibilities	17.421	15	0.294
Tree's density	15.463	20	0.749

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Table 13. Chi-square test of independence for income with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	20.479	20	0.428
Length of staying	12.360	10	0.262
Comfort status	15.358	20	0.756
Length of time staying in park	7.017	5	0.219
Frequency of visiting park	20.570	20	0.423
Section C			
Air quality	10.239	15	0.804
Temperature	33.503	15	**0.004
Lighting	14.835	20	0.786
Wind	14.249	15	0.507
Landscape setting	15.762	20	0.731
User-friendly	11.883	15	0.688
Odour	18.632	15	0.231
Accessibilities	14.190	15	0.511
Tree's density	18.375	20	0.563

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Table 14. Chi-square test of independence for qualifications with dependent variables

Dependent variables	Value	df	Asymp. Sig. (2-sided)
Section B			
Type of dwelling	18.393	16	0.301
Length of staying	6.266	8	0.617
Comfort status	14.980	16	0.526
Length of time staying in park	5.608	4	0.230
Frequency of visiting park	20.985	16	0.179
Section C			
Air quality	11.767	12	0.465
Temperature	6.292	12	0.901
Lighting	21.836	16	0.149
Wind	10.594	12	0.564
Landscape setting	16.425	16	0.424
User-friendly	22.101	12	*0.036
Odor	11.253	12	0.507
Accessibilities	12.276	12	0.424
Tree's density	9.225	16	0.904

* denotes value that is lesser than $\alpha = 0.05$; **denotes value that is lesser than $\alpha = 0.05$ and strongly significant

Household Income Factor

Household income as an independent variable was analysed for chi square test of independence and the results had shown in Table 13. Strong association between lighting and income can be observed $\chi^2(15) = 33.503$, $n = 30$, $p = 0.004$. This result is consistent with occupation therefore it confirms the differences in demand of each range of income.

Qualifications Factor

The relationship of qualifications with other dependent variables was tested. The result was depicted in Table 14. User-friendly seems to be related to qualifications in public park $\chi^2(12) = 22.101$, $n = 30$, $p = 0.036$. There are no other dependent variables that are associated with qualifications.

Conclusion

The thermal comfort ranges in urban recreational park of Kota Damansara is within the comfort zone and satisfactory to its users. The comfort level of both recreational parks by using PMV and TSV is +1.5 and 0 while PPD is 56.70%. This study showed that comfort zone of respondents shifted towards the right of TSV curve. As stated by Fanger (1982), PMV-PPD model will reflect the percentage of dissatisfied of 5% at PMV = 0. Hence, for this research, PMV at -0.06 (nearest to 0) showed 5.10% of PPD. The outcome for this study could be different from European countries which experiences climate differences compare to tropical climate in Malaysia. A better physiological adaptation was developed due to exposure of hot and humid tropical climate.

Significant association can be found between PMV with frequency of visiting park, air temperature and user-friendly function. Other association that were also prominent in this research were age with tree's density, ethnicity with length of staying, religion with frequency of visiting the park, accessibilities and tree's density, occupation with lighting, income with temperature, qualifications with user-friendly. Further research was encouraged to accurately predict thermal sensation of local environments along with psychological factors and other possible affecting factors. Establishment of precise thermal comfort studies could aid in developing towards greener development to meet population demand and better lifestyle or reduced occupational risks.

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Author's Contributions

Nor Hanisah Mohd Hashim: Participated in all field investigation and data analysis; contributed to the manuscript writing.

Kok Weng Tan: Data analysis and contributed to the manuscript writing.

Yvonne Ling: Participated in all field investigation and data analysis.

Ethics

It is declared that there are no ethical issues that may arise in the present study.

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