

# The Perception of Thermal Comfort in Malaysia Public Low-Cost Housing

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## ABSTRACT

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*In Malaysia, the thermal comfort of low-cost high-rise housing has not been widely given a significant emphasis in the qualitative study despite its increasing scale and significance in the urban areas. Occupant's perception and adaptive behaviour are important to achieve the level of satisfaction in terms of a comfortable living environment. This paper assesses the occupants' perception and behaviour in a low-cost high-rise housing development that has been argued with various problems which have a considerable impact on lifestyle. Understanding of comfort as social and cultural behaviour, rather than an engineering approach. This research shows the results of a pilot study that utilized a qualitative strategy for analysing thermal comfort, rather than using the standard thermal comfort research methodologies. The building of study, in the category of low-cost high rise residential located at the urban context of Kuala Lumpur housing area, which is mainly natural ventilated with a versatile adaptive possibility available for the occupants. The outcomes signify the adaptive behaviour that enhances or limit the thermal comfort-related varieties. The results from the pilot study direct for more extensive research and comparison with previous qualitative studies.*

**Keywords:** *Thermal comfort, Qualitative study, Occupant perception, Adaptive behaviour, Housing*

## INTRODUCTION

The attempt to enhance the factors of low-cost housing design in Malaysia is still deserted and overlooked. The underlying factors are due to the low-price value, neglecting the occupant's needs and wants that contribute to the satisfaction of a comfortable and healthy living environment (Muhammad & Rohaslinda, 2017; Ismail et al., 2017). A dwelling can be characterized as a human habitat, providing cover, shelter, and security for individuals and households (Rapoport, 1980). Adebayo (2013) noted that the design of a shelter is a crucial aspect of a building. Low-cost housing is a type of housing whereby the complete expense of housing is being evaluated at a moderate and affordable range to those occupants with low salaries. In Malaysia, regular low-cost housing is an effort that is initiated generally by the public and private divisions. Generally, low-cost housing is described as the sufficient and fitting housing units of which this initiative is in accordance with minimum or at least standard complying with the code of practice exceptionally made for low-cost houses (Sirat et al., 1999). The housing requirement is generally specified in the National Standard for One & Two Storey Low-Cost Housing under CIS 1:1998 and the National Standard for Flats Low-Cost Housing under CIS 2:1998 (Ismail, 2003).

Meanwhile, the thermal condition of indoor space is an essential element of the indoor environmental quality component that is closely related and influenced by climate conditions. Recently, the phenomenon of climatic changes has affected the human environment adversely. The behaviour and activities of occupants are closely related to the effects of global warming, due to the increase of building energy usage and increased emission of carbon (Ismail et al., 2012). Malaysia has situated nearby the equator which has a hot and humid climate environment. Malaysia's greatest

climatic influences in buildings are intense solar radiation and high air temperature (Al-Tamimi & Syed, 2011). Apart from these elements of climate, partial air movement with high relative humidity has considerably affected the indoor thermal comfort of occupants in the building. There is a lot of study in engineering-based and quantitative survey approach studies have been performed (Sadeghi et al., 2020; Cao & Deng, 2018; Yu et al., 2017). However, less study can be found that having a concentration on occupants' perception and behaviour conducted throughout the experienced-based approach. Therefore, this paper focuses on identifying the thermal comfort perception and adaptive behaviour of occupants who are living in the low-cost high residential building of PPR development by using an unstructured interview approach as the research method.

## LITERATURE REVIEW

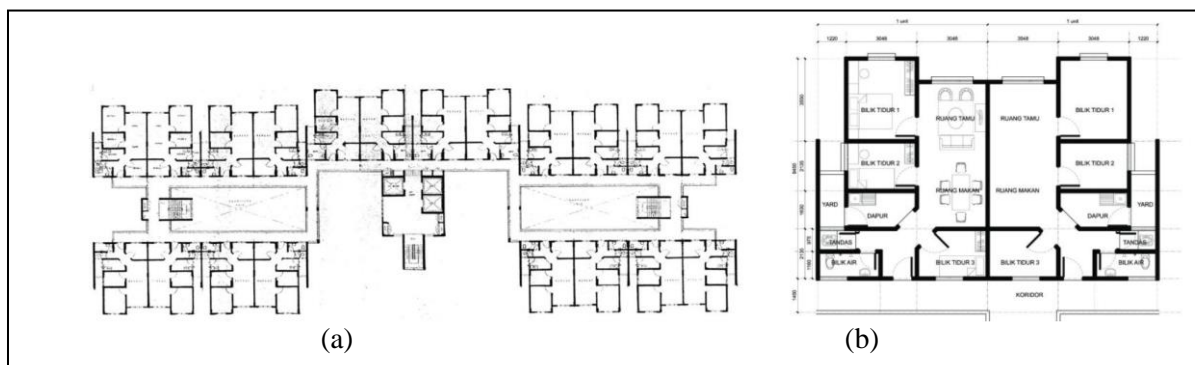
### Defining Low-Cost Housing and 'Program Perumahan Rakyat, PPR'

Low-cost housing is a type of housing whereby the total cost of housing is being priced at a reasonable range to those dwellers with low earnings. In Malaysia, a few approaches had been implemented in entire Malaysia concerning low-cost housing. One of the policies that were enacted was the "Zero Squatter by 2005" policy (Goh & Yahaya, 2011). In executing this initiative, these low-cost housings are known as the Peoples' Housing Programme (Program Perumahan Rakyat, PPR) to provide reasonable and satisfactory affordable housing for squatters to be relocated in major towns and urban communities. In Chapter 21, Ninth Malaysian Plan noted that in these PPR plans, 37,241 were built as low-cost houses, completed and leased to those qualified, and in contrast of this total, 24,654 units or 72.29 percent were built in Kuala Lumpur, and the rest of 12,587 units in other major towns throughout the country (The Ninth Malaysian Plan 2006-2010). In order to solve the slum housing and fulfilling the demands of the people with low income around Kuala Lumpur, the solution was to build PPR housing. The main objective of these housing is to improve the economic growth and resettlement of squatters. The PPR housings are for the low-income people with a household income of below RM2,500, prioritising on the family.

### Climate and Thermal Comfort in Urban High-Rise Buildings

Malaysia is a country with a tropical climate, exposed to great sunlight exposure periodically with the hot-humid setting of yearly median reading is 26.4°C including everyday moderate maximal reading at 34°C along with the everyday moderate minimal reading of 23°C (Al-Tamimi & Syed, 2011). The constant heating is different to those of dry and hot regions due to influences of soaring humidity levels including a variety of everyday thermal types (Haase & Amato, 2009). The two crucial aspects; high thermal levels of air and precipitation influences satisfaction including the well-being of users staying under the roof not considering effective cross air circulation (Sookchaiya et al., 2010). Consequently, differences in the energy level of the location further escalate atmospheric thermal levels specifically of the urban built environment in comparison to developing or underdeveloped locations.

The thermal comfort of humans is directly related to several elements, for instance, air temperature and movement, layers of clothing worn, and behavioural activities which include the human body itself (Thomas, 2006; Mora & Bean, 2018). Malaysia's urbanization has an adverse impact on environmental problems. Thermal comfort plays a significant effect on the efficiency and fulfilment of housing inhabitants (Great Britain Health and Safety Executive Staff, 1999). Goh and Yahaya (2011) studied the design quality of the existing PPR schemes based on different aspects including the location, the safety of the house, type of house, and structure of the house. The research showed that low-cost residents are generally contented with the current condition of current PPR designs even though there are imperfections in the configuration. Figure 1 (a) and (b) show the repetitive and typical layout of PPR high-rise schemes, respectively that have been built throughout Malaysia.



**Figure 1:** (a) Typical Level Layout Plans for the 18-storey PPR Low-Cost Flat (Source: Goh & Yahaya, 2011); (b) Typical PPR Housing Unit - Floor Plans (Source: Goh & Yahaya, 2011)

## Occupants Perception and Behaviour Affecting Thermal Comfort

Thermal comfort is characterized as "that state of mind which expresses fulfilment with the thermal condition". As indicated by this interpretation, satisfaction is an emotional feeling. Considering ASHRAE's interpretation on thermal comfort, stated that 80% of stationary or somewhat energetic people discovered that the surroundings are adequate in thermal. According to Mohit and Azim (2012), the appropriate housing design should provide sufficient current and future needs such as light, which affects the indoor environment which is adjustable by the occupant. Concerning climatic conditions, it drives many people to experience adequate comfort at room temperature, but still, it might vary depending on the activity, behaviour, attire, and humidity (Djamila et al., 2014). Interventions originated from unfavourable thermal comfort could impact the inhabitants feeling unpleasant regardless of whether the condition of rooms has enhanced, for example, using modifications towards air circulation openings, or shifting a person into appropriate thermal surroundings. When the room feels excessively warm and unseasonably chilly for a period without interventions, the perspective of inhabitants towards thermal comfort possibly end up weighted.

## Site Planning, Orientation and Ventilation in High Rise Buildings

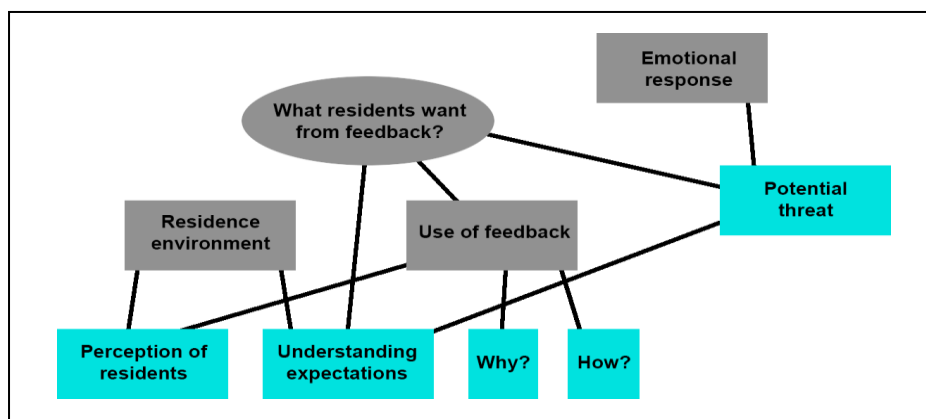
Thermal insulation is usually prioritised above the usual air movement in site planning and orientation of the building. The form of the buildings and connectivity of roads in the most newer residential expansion locations are lacking in concern of hot and humid weather in their schemes (Givoni, 1997). In Malaysia's urban areas, the air movement circulation is usually inconsistent due to the surrounding context influences and monsoon seasons (Ismail & Yoo, 2018). A common practice for good orientation of housing is preventing the building envelope that has great coverage of windows directing towards west and east. In restricted locations like the west to east longitudinal facing direction might not be possible, where an answer to this might call for different structural forms. For this situation, solar barriers preferred might contrast depending on its building orientation. Housings have an essential priority to give an indoor including external condition appropriate for household behaviours. For building passive strategy and sensitivity of housing planning, it is largely affected by the sensitivity of the location settings. Meanwhile, ventilation distributes outside air into the building or space and circulates the indoor air inside of a building or space. Generally, building ventilation is to circulate fresh air for the occupants, dispersing and expelling pollutants in the building. (Awbi, 2017).

## METHODOLOGY

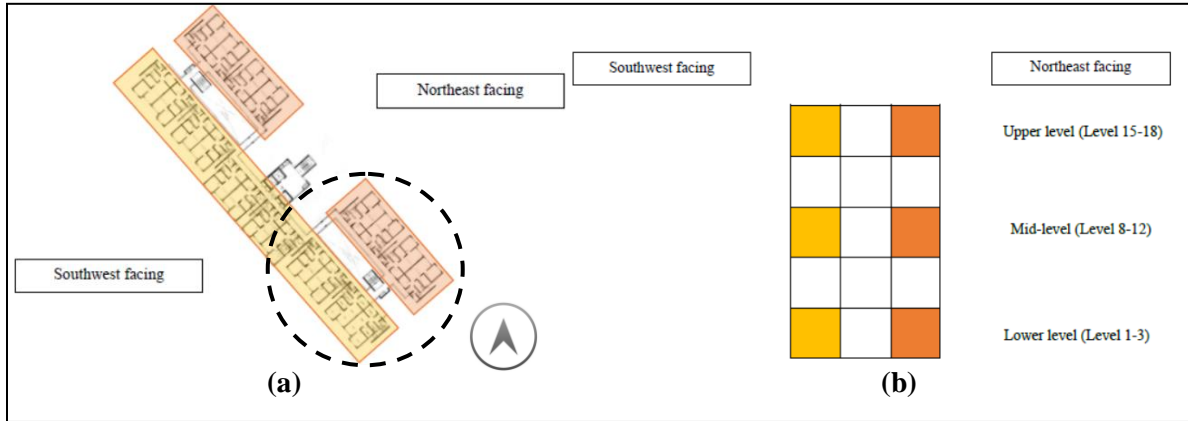
This research is conducted by a face-to-face unstructured interview with respondents by using the qualitative technique in a residential area of PPR Kampung Baru Air Panas. PPR Kampung Baru Air Panas, which consists of 8 blocks of 18-storey high-rise buildings, built-in repetition. However, Block A was selected due to its accessibility, high exposure to external elements, and orientation that does not implicate the tropical context.

The qualitative technique indicated in Figure 2 is used as perception and to observe for clues, emerging inquiries, including behaviour of the immediate context. The selection of the respondents was done by the systematic random sampling technique, where most of the respondents usually pass by the main lobby by using a lift or staircase. The interview themes revolve around the emotional response of feelings, desire, satisfaction, comparison with others and the perceived effectiveness of the development. Behavioural questions are to explore problems that revolve in adaptive opportunity, personal esteem framework, concerned hazard, and desires on living conditions in the residential unit. These questions were asked regarding observation and practiced adaptive actions, discussions, establish information, and analysis. At long last, conventional, and unconventional decree that governs actions to be analysed. Each interview could range from 10 to 20 minutes, recorded using an audio recorder including manually written to note main points.

Figure 3 (a) and (b) show the diagrammatic layout and section for the research to be carried out. A small number of six (6) participants living within the site were selected to acquire the data for low (level 1-3), middle (level 8-12), and high (level 15-18) levels of the block facing northeast and southwest. Each meeting is meant for concluding an initially determined scope of factors, and yet are generally not scripted, to urge respondents in expressing their experience in discussion with originality. The questions were designed to avoid direct themes, such as hot, cold, and comfort; instead, all the topics should emerge based on reactions also those that are generally respondents that volunteers. As the research is a pilot study, the small number of participants is a deliberate choice, and the generalizability of the results in terms of prior knowledge on the part of the participants is not considered a critical issue.



**Figure 2:** Methodology framework used in this study



**Figure 3:** Layout and section of the low-cost of the 18-storey PPR apartment at PPR Kampung Baru Air Panas at Block A; (a) standard level layout scheme and (b) diagrammatic section.

## RESULTS AND DISCUSSIONS

### Building Orientation and Thermal Comfort Perception

The building orientation and position are associated with the periodic change of solar path including unpredictable breeze movements. Well-designed building positioning optimises sustainability of energy in spaces, thriving the building into liveable and performance efficient. In this study, the interviews are carried out based on their apartment orientation which is divided into three (3) sections (lower, mid, high), allowing participants to express their perception towards the thermal comfort as shown in Table 1.

Based on the interviews and Table 1, the participants of lower and mid-levels facing the northeast side appear to be having thermal discomfort during the morning, whereas the higher levels experience thermal discomfort throughout the day. In addition, the participant from the lower levels was interviewed the same for both southwest and northeast. It appears that the participant felt thermal discomfort in the afternoon where direct sunlight heats the southwest side. Around the evening, the direct sunlight seems to be filtered by the trees for the lower levels but does not seem to help, but the participant was led to additional mechanical ventilation for thermal comfort. From the findings, the conclusion that can be drawn down in this study is the PPR high residential buildings still need a lot of improvement, especially in the thermal comfort aspects.

**Table 1: Perception and Behaviour on Thermal Comfort based on Building Orientation**

Northeast	Low	<i>During hot day. Like morning until afternoon. 11am until 3pm. Maybe because of my apartment unit position, when comes to afternoon, the sunlight doesn't directly penetrate my apartment, but morning. Evening. Because of sunset and my unit surrounded by grass area, also got wind blows in.</i>
	Mid	<i>Yes, I do, especially when it is hot in the morning, other than that it is okay. I think this side is better, because it is shaded in the afternoon, but the downside is that over here if the cars or motorcycles accelerate, it is very noisy. Sometimes late at night it wakes me up.</i>
	High	<i>Yes. When it is hot, most of the time I do sweat especially in the afternoon, that's why I ended getting a few fans to blow around. My unit is exposed to sunlight in the morning, but then throughout the afternoon, I can still feel hot. Sometimes at night I can be sweating even if the fans are on.</i>
Southwest	Low	<i>Yes, usually in the afternoon. The sun directly shines onto my apartment throughout the afternoon, but around evening, the trees helped cover some sunlight. The weather nowadays getting hotter, I ended up using A/C as well, fans are not enough. I think the other side of the block is better because the morning sun is not as hot as the afternoon sun. ...during the morning and night. It is cooler in the house.</i>
	Mid	<i>Yes sometimes. Because it is hot and stuffy. I sometimes turn on the A/C if it is too hot and cannot stand it. ...sometimes the house can get so hot, especially in the afternoon. The other side is better, the afternoon sun here is so hot throughout the day, I ended up putting on curtains and some plants. I think during the night until morning. It is cool, especially in the morning. But in the afternoon, it is hot. But the corridor area is cool.</i>
	High	<i>Yes. In the afternoon, it is very hot. I live near the roof area; throughout the day it is very hot. This side is good, sometimes can be very windy. Of course, in the afternoon it can get quite hot and stuffy.</i>

## Daylighting

The controlled entry of lighting, known as Daylighting, is of external radiation, open exposure radiation, including dispersed lighting to space in achieving lower energy usage, and artificial lighting. The adaptive behaviour of occupants towards daylighting plays an important role in thermal comfort as artificial lighting contributes to a certain amount of heat that radiates the internal space, while the exposure of daylight contributes to direct and indirect heating.

Based on Table 2, participants mainly use artificial lighting during the night and early in the morning time when there is not enough daylighting for their daily activities. It appears that their behavioural activities are affected by daylighting, where the use of artificial lighting is only necessary when there are daily activities. Switching on artificial lighting is not necessary as daylighting is sufficient for both northeast and southwest facing, which could lead to thermal discomfort due to direct and indirect heat exposure throughout the day. Nonetheless, a lot of people are unaware of newer technologies that could minimise the amount of heat waste and reduce carbon emissions, while providing good and sufficient lighting, such as, LED lighting, which provides many advantages for the environment.

From the analysis, appropriate solar barriers could help compromise daylighting, indoor thermal comfort including external conditions appropriate for household adaptive behaviours. For better effectiveness rates of these sun shading devices, they should be done in conjunction with proper building orientation, use of lightweight materials, effective cross-ventilation internally and they must be incorporated in the design as early as possible.

**Table 2: Perception and Behaviour on Daylighting**

<b>Northeast</b>	<b>Low</b>	<i>...during night-time. Because during daytime there is sufficient daylight inside my apartment, so it is not necessary to switch on the light.</i>
	<b>Mid</b>	<i>...not the whole day. Usually at night or early in the morning. Sometimes when it is dark, I will turn on when it is raining or cloudy, it is quite dark in the house. But not all day long.</i>
	<b>High</b>	<i>Yes, I turn on the table lamp because I need to do my work, but the other lights I close. I only turn it off at night when I'm going to sleep.</i>
<b>Southwest</b>	<b>Low</b>	<i>...only at night. We closed it before going to sleep. Early in the morning I will turn it on when I am preparing for my husband to go to work. In the afternoon doing house chores I usually closed it. It is bright enough for me, I think.</i>
	<b>Mid</b>	<i>...I usually turn them on early in the morning, and in the evening night-time. Throughout the afternoon I'm okay, not necessarily need to open.</i>
	<b>High</b>	<i>...I only turn it on in the morning preparing breakfast for my husband and children to school. I close the lights when the afternoon comes.</i>

## Passive and Active Ventilations

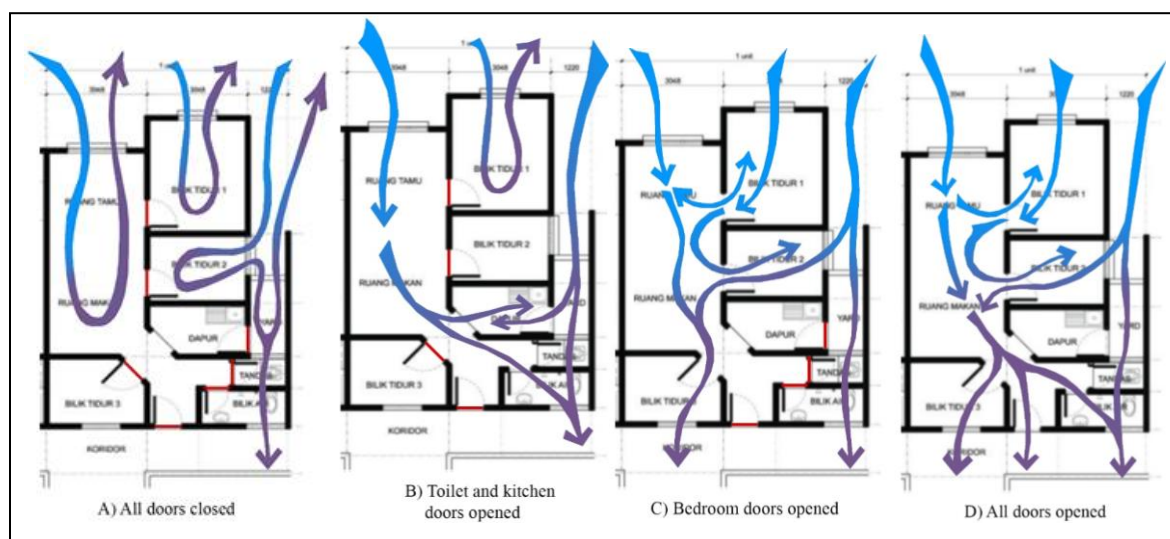
By analysis, the air movement within the unit is not effective due to the behavioural patterns of utilising openings that are originally provided by the standard low-cost PPR apartment unit configuration, mainly windows and doors. The participants do not seem to utilise effective cross-ventilation that requires both windows and doors to be opened.

**Table 3: Perception and Behaviour on Doors and Windows.**

<b>Northeast</b>	<b>Low</b>	<i>I open all the time is because of the mosquito net. If I didn't install the mosquito net, I won't be opening it. Due to safety I would say. My apartment is hot, but what I can open is window, not the main door. ...not as windy compared to the upper floors. I think the trees somewhat block the wind.</i>
	<b>Mid</b>	<i>...I open my windows for air to come in, if not it is going to be stuffy. But around night-time I will close the window or just open slightly to avoid insects... ...I usually close the door. Sometimes there are cats around the area, they come in and dump in front. Other than that, is because of security reasons.</i>
	<b>High</b>	<i>...the house can be stuffy and hot. I usually open the windows throughout the day. ...winds blow into my house when I open the windows, it is cooling... ...I usually close the door. I don't want people to look inside or break in.</i>
<b>Southwest</b>	<b>Low</b>	<i>...usually during the day when it is hot. I will close it during the night, sometimes insects fly inside... ...I don't want people to look into my house. I prefer not to open the door. I feel insecure.</i>
	<b>Mid</b>	<i>Yes, I usually open the windows if it is not hot. When it is hot, I would close the windows and open the A/C. ...I don't open the door. Because I don't want people to break in. So, I would rather have it locked.</i>
	<b>High</b>	<i>Yes, I open my windows most of the time when I am not using the A/C. So that the air circulates the house, if not it can be quite hot and stuffy. ...I don't like to open the door and let people see inside my house. I feel more secure when the door is closed.</i>

Table 3 shows the perception and behaviour of occupants in using the doors and windows provided by the PPR scheme. Thermal comfort is compromised when the windows are closed to prevent insects from intruding. All participants from all levels prefer to close the door for safety, security, and privacy, rather than opening the door for effective cross-ventilation coupled with opened windows. As cross ventilation is compromised, this causes the participants to feel a certain thermal discomfort which is a leading factor that participants felt hot and stuffy. By analysis, the air

movement within the unit is not effective. Each window and door if opened, provides natural cross ventilation, thus allowing winds to cross from the exterior façade of the PPR block facing northeast and southwest to cross into the internal air-wells shared by both sides. The effectiveness of cross ventilation depends on the openings of windows and doors.



**Figure 4:** Diagrammatic Cross Ventilation through Doors and Windows.

Figure 4 shows the diagrammatic patterns of cross ventilation through different scenarios of behavioural patterns by the occupants, where all windows are opened, and doors to be manipulated. By analysis, all participants prefer to have the main door closed, allowing a simulation to be studied. Scenario (A) indicates that when all doors are closed, cross ventilation only happens at the yard to the toilet, ineffective to ventilate the unit spaces. Scenario (B) shows that once the kitchen and toilet doors are opened, winds are able to cross ventilate through the living, dining, kitchen, yard, and toilet, but do not effectively ventilate through the staggered openings. Scenario (C) illustrates that when bedroom doors are all opened excluding the toilet and kitchen, the unit could cross ventilate thoroughly in the unit, but the most effective cross-ventilation would be a scenario (D) when all doors are opened, the unit is completely cross-ventilated

From the finding related to safety, privacy, and insect intrusion compromises the usage of windows and doors as openings, there were various factors that affect the perception and behaviour of the occupants' satisfaction of thermal comfort. There are various aspects that may contribute to improving natural ventilation. In consequence, natural ventilation itself is insufficient to provide a good thermal environment for the indoor spaces as it includes the relative humidity and temperature of the air itself. Besides that, the cooling process for humans is not only dependent on the air temperature as it also includes sensible heat cooling which is related to the behavioural activities held in the spaces.

Furthermore, air conditioning is the process of removing heat and moisture from the interior of an occupied space to improve the comfort of occupants by adjusting to agreeable thermal comfort. By analysis, as to indicate in Table 4, all the participants prefer A/C in their units to counter thermal discomfort and to cool their apartment unit especially when the weather is hot. Some of the participants have already installed the A/C units, and some of them have not. The concern for the participants was mainly due to the increase in electricity bills which could greatly affect their lifestyle, therefore compromising thermal comfort. Nevertheless, the finding of Emmerich (2006) is proven correct as using purely natural ventilation is insufficient to maintain acceptable thermal comfort. In naturally ventilated building, Aflaki et al. (2016) has also proven that mechanical ventilation such as ceiling fan, stand fans are inefficient to accomplish indoor cooling. From these findings, the air conditioner was the reason that occupants prefer to achieve thermal comfort. In environments where



natural ventilation elements are believed to be inadequate, using hybrid ventilation where supplemental mechanical ventilation such as air conditioner along with natural elements could offer a compromise.

**Table 4: Preference of Occupants using Air-conditioner.**

<b>Northeast</b>	<b>Low</b>	<i>Yes. Because sometimes it is too hot. I wanted to have but I worry about my electricity bill.</i>
	<b>Med</b>	<i>I think it is needed when the weather is hot. The time that I feel hot is during the morning to afternoon...</i>
	<b>High</b>	<i>...it is needed because it is hot. My unit is exposed to sunlight in the morning, but then throughout the afternoon, I can still feel hot. Sometimes at night I can be sweating even if the fans are on.</i>
<b>Southwest</b>	<b>Low</b>	<i>Yes of course. Sometimes it gets so hot in the house I feel like just going to a shopping mall.</i>
	<b>Med</b>	<i>Yes, because sometimes the house can get so hot especially in the afternoon. But I turn it on for a while then when it is cooled down, I turn it off and open the fan.</i>
	<b>High</b>	<i>I think during the night until morning. It is cool especially in the morning. But in the afternoon, it is hot. But the corridor area is cool. Sometimes I turn on the A/C because I want to cool down the room.</i>
		<i>Yes definitely, that is why I bought the A/C. The weather is so hot, the house is so hot. Sometimes I feel like turning on the A/C the whole day, but I can't, it would be too expensive later.</i>

## Other Contributing Factors

Domestic or home appliances are items that run on electricity and supports house activities for instance heating food, ironing, washing, and refrigeration. These items contribute to thermal discomfort indirectly when using it. The participants were asked about additional appliances besides the basic ones, and yet, it seems that the participants have indicated that they use additional appliances that contribute towards the thermal discomfort which is inevitable for their daily use.

In addition, having more occupants could lead to increase in room temperature due to body heat, thus contributing to thermal discomfort for the inhabitants. It appears that the participants are at optimal occupancy for the apartment units, not more than four occupants in a unit. The activities that are held by these people seem to be normal, nothing extraordinary in their daily activities. From the findings, participants engage in normal activities in the house such as cooking, while gatherings and other activities are minimal which does not entirely affect the thermal comfort. Therefore, the number of occupants and activities are may not the main contributing factor that leads to thermal discomfort.

## CONCLUSIONS

In conclusion, the analysis of the selected building, the current occupants of the PPR residential unit are experiencing thermal discomfort. This study recommends that the PPR low-cost residential building scheme should integrate sun shading devices (balcony latch at living area window), provision of air-conditioning system in the design process to avoid random installation during post-occupancy, and building orientation of different structural forms facing east and west to improve the thermal comfort quality and providing a healthy indoor environment of buildings. Different building locations and site contexts may require different methods in providing good thermal conditions, thus provide opportunities for researches and studies in this field. Further investigations and analysis are pursuing intensively.

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