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FIELD ASSESSMENT OF THERMAL COMFORT PERFORMANCE IN LECTURERS' ROOM

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Abstract:
A comfort level of a person is a subjective substance and has been one of the most important elements in achieving maximum productivity. To obtain the current state of comfort among lecturers in one of higher learning institutions in Malaysia, a questionnaire survey and measurements were conducted in the lecturers' room in the Faculty of Architecture, Planning and Surveying (FSPU) in Universiti Teknologi MARA Perak. The questions were designed based on ASHRAE 7-point scale and previous literature reviews. Measurements were conducted in 33 lecturers' room by using Delta Ohm and Grey Globe, along with the distribution of the questionnaire. The main objective of this study is to determine the level of comfort from the lecturers' point of view during their hours in the office by comparing the Predicted Mean Vote (PMV), Percentage of Predicted Dissatisfied (PPD) counted as the objective measurement, and TSV (Thermal Sensation Vote) which is the subjective measurement. Since the office rooms are situated in a mechanically conditioned building, the supposedly comfort temperature is 24°C.

Keywords: Thermal Comfort; Predicted Mean Vote; Percentage of Predicted Dissatisfaction; Office Building; Thermal Comfort Vote

1.0 INTRODUCTION

Thermal comfort can be defined as "the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation." When people have a thermal discomfort, instead of being comfortable, they will feel uncomfortable instead, for example, it may be either too hot or too cold for them; but the temperature is not the only factor that affects their thermal comfort. There are factors that affect a person's thermal comfort, which are environmental factors and individual factors. The examples of the environmental factors are air temperature, air velocity, relative humidity, and mean radiant temperature. Meanwhile, for individual factors, there are metabolic rate and clothing insulation.

As comfort has its own limitations and constraints, a study showsthat occupants would usually equip their office with fans; this indicates the discomfort that revolves around the person which may be caused by the air conditioning system that does not work to their liking. This is shown in a study conducted by Huizenga et al. (2006). The result of the study shows that the highest voted poll for occupants' satisfaction scores is 42 %; whereas 39% expressed their dissatisfaction and the rest, i.e. 19% of the occupants, are neither satisfied or dissatisfied (neutral). Pivac and Nizetic (2017) stated that thermal discomfort often affects health and productivity which could likely lead to a syndrome that is familiarly known around people who stay inside a building, i.e. "sick building syndrome" (SBS) or "building related illness" (BRI). Therefore, the appropriate temperature for the lecturers' room should be studied in every aspect. It is the aim of this study to propose ways of improving the thermal comfort level in the lecturers' office to give satisfying comfort to the respondents by assessing the methods mentioned.

2.0 LITERATURE REVIEW

Previous studies of a similar nature had been carried out in air-conditioned rooms or offices with comparable conditions. According to Teli et al. (2012), the PMV predictions usually differ from the thermal sensation vote whereby it may be higher. For most studies, the thermal sensation vote indicates warmer surroundings. The thermal sensitivity might also diverge for each person according to an individual's higher metabolic rate per kg body weight (Teli et al. 2012). By looking at ASHRAE information, it is stated that for thermal sensation vote (TSV), the acceptable range of the scale is -1, 0, 1 (Zhao et al., 2017). According to Zhao et al. (2017), the comfort temperature to be in a refrigeration condition is between 24°C to 26°C. It was also said that the occupants use mechanical devices to control and improve the indoor thermal environment. For summer season clothing where the temperature might be about 32°C to 35°C, the usual clothing level of clothing (clo) is 0.5 and the indoor temperature is set to 22°C to 24°C for a relative humidity of 65% to achieve thermal comfort (Caetano et al., 2017). For the idea of the "expectation model", thermal comfort can be considered as achieved when the indoor environment condition tallies with the respondents' expectations.

As for the air movement, according to ASHRAE (2013), the recommended air velocity should be about 0.15 m/s where the air temperature should be 24°C to achieve the satisfying level of comfort. Fountain & Arens (1993) explained that movement of air might perhaps offer a needed cooling in the unwanted warm conditions which would probably affect the workers, but it may also create a draught. Air movement may be liked and perceived by the occupants as it gives out freshness to the room but may at the same time annoy some of the occupants. Experiencing the movement of air, when the speed and velocity are at a high speed, will bring many possible consequences, rangingfrom a pleasant sense of coolness, all the way down to an unpleasant sense of coldness. These ranges will dependon the air temperature, mean radiant temperature, humidity, clothing, metabolic rates and how the occupants prefer them better.

As for the humidity aspects, relative humidity (RH) might sound like having a lot of advantages towards the air circulations and thermal comfort of the occupants, but according to CCOHS (2018), if the relative humidity (RH) is at its higher rate levels which is more than 60% than it should be, it can lead to the growth of mould and mildew, and not only that, bacteria, dust mites, and fungi will grow well under the moist and humid conditions when the relative humidity of the room is at more than 60%. Meanwhile, low relative humidity (RH) of less than 30% could lead to diseases, where the occupants in the building might get infections, eye irritations or stuffy nose, as spreading of viruses are faster in a low relative humidity. The occupants in the room that has no air-conditioning system or where the weather conditions outdoor affect the thermal environment indoors, will find it hard to cool themselves down when they are feeling uncomfortable with the heat as the relative humidity can reach up to 70% in that situation. It means that the suitable and desirable relative humidity (RH) for a room is not less than 30% and not more than 60%; and they will varyaccording to the climates and to what they find acceptable.

3.0 METHODOLOGY

3.1 Survey Method

The respondents who participated in answering the questionnaire were the lecturers from Block A of Faculty of Architecture Planning and Surveying. So, to narrow down the numbers of respondents, there are only 33 questionnaires were distributed out to every level in Block A. The answers will be represented by a method called 7-point thermal sensation scale that comprises of the following:

+3 Hot	+2 Warm	+1 Slightly Warm	0 Neutral	-1 slightly cool	-2 Cool	-3 Cold

3.2 Measurement Method

The measurement method used can be classified as a Class II protocol. According to Gail & Richard (1998), class II is a protocol that uses field experiments that includethe physical environmental elements or variables (ta, tg, v, rh, clo, met). These variables are important to calculate the heat balance and the measurement of PPD and PMV. Not only physical measurement was taken but the questionnaires were also structured at the same time. The equipment used during the measurement method of the thermal comfort level were the Delta Ohm Model HD 32.2 (Photo 1 a), and HOBO Data Logger (Photo 1 b). The parameters for these equipments are the temperature, the relative humidityand the air velocity or the wind speed. For the HOBO Data Logger, a K-type wire was used to connect it with the data logger and on top of the sensor of the K-Type wire, a table tennis ball with a diameter of 40mm, covered in Flat Epoxy Paint in the shade Dove Grey, was placed. For Delta Ohm and HOBO Data Logger, thirty-three (33) respondents were involved, with the equipment left in their office for a day. The selection of rooms was chosen at random according to the availability of the lecturers as long as every selected lecturer's room is from both side of the front and back of the building on every level. The measurement was taken from 7:00 am – 6:00 am which was about 13 hours of continuous measurement in every room This is also the office hours for the lecturers; furthermore, the centralized air-conditioning system starts functioning at 7:00 am and is automatically off at 7:00 pm. The equipment is placed in the middle of the room near the lecturers' sitting area, at the height of 1.5m from the floor level which is equivalent to the sitting position. The measurement was taken in 33 different lecturers' rooms that uses the centralized air-conditioning system. The interval for the measurement taken will be every 5 minutes of an interval (for 13 hours logging). All the data collected were then transferred to excel through its own software. Delta Ohm Model 32.2 uses Delta Ohm software, whereas HOBO Data Logger uses HOBO Software.

(a) (b)

Figure 1. a) Delta Ohm Model 32.2 b) 40mm gray painted table tennis with K-type thermocouple with Hobo data logger

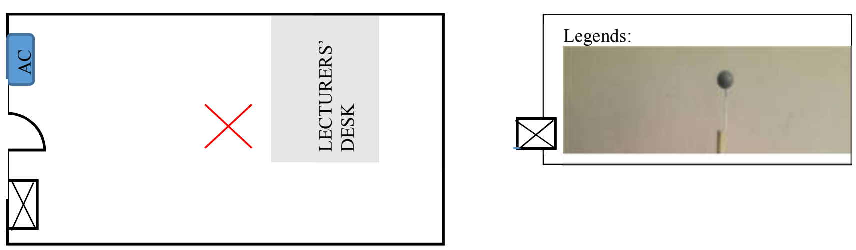

Figure 2 Equipment layout in lecturers' room

3.3 Case Study

3.3.1 Description of Field Case Study

For the case study, the selected building that met the criteria and suitable for the case study is Block A of Faculty of Architecture, Planning and Surveying in Shah Alam, Selangor. The involvement of the case study will be at three (3) different levels which are, level 1, level 2 and level 3. First and foremost, Block A is one of the blocks located in Faculty of Architecture, Planning and Surveying which is one of the faculties in MARA University of Technology which is situated in Shah Alam. The total area of level 1 and level 2 is about 18,033.4 m², whereas 9016.7 m² is the total area for each level. That is about 327.88 m length and 27.5 m width. The calculated areas include the area of the toiletsand the staircase area. Each of the lecturers' office is measured with an area of 93.47 m² that adds up between 7.63 m² length and 12.25 m² width. The front rows of the lecturers' room on every level are the ones that is facing the road and is exposed to direct sunlight, meanwhile, the back rows of lecturers' room are the ones that face Block B in FSPU building which is not directly exposed to sunlight.

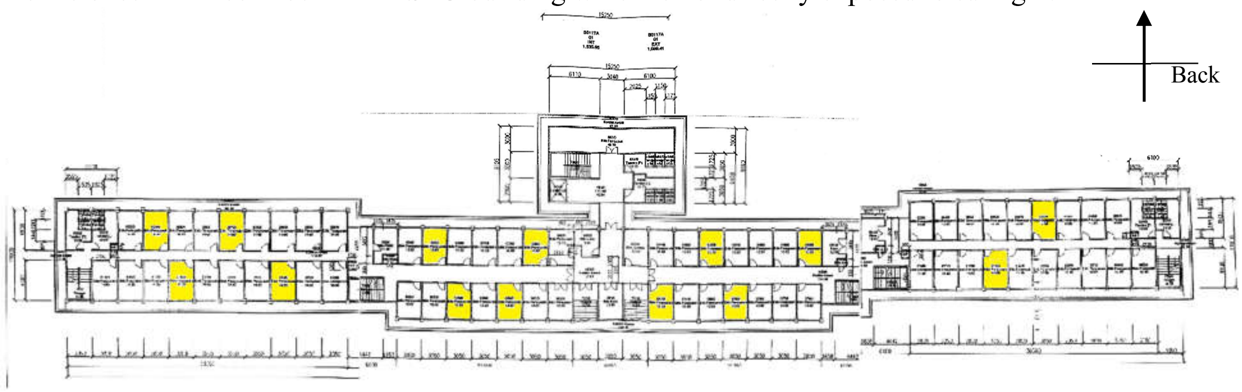

Figure 3: Layout plan on level 1

Figure 4: Layout plan on level 2

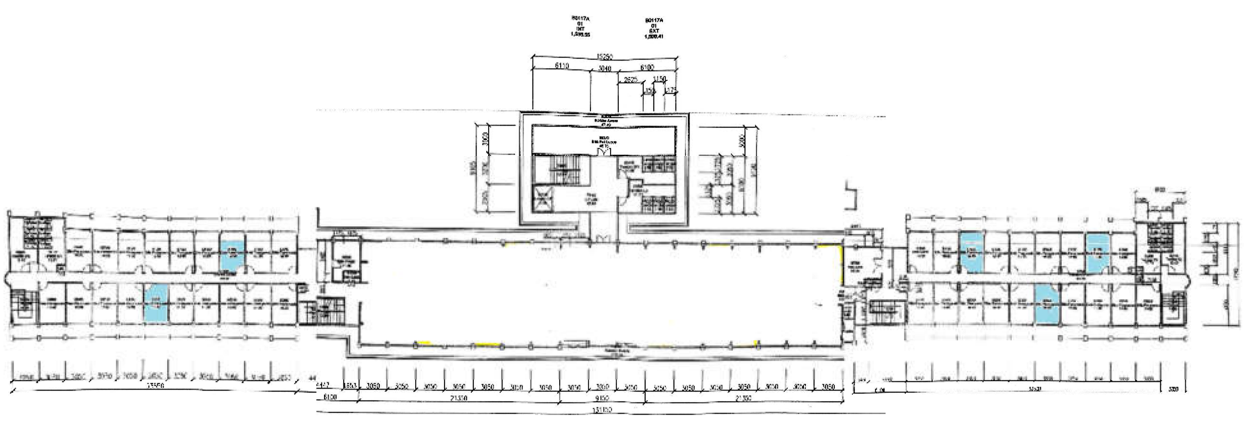

Figure 5: Layout plan for level 3

3.3.2 HVAC System Description

For the HVAC system in the lecturers' offices, they are conditioned by a variable air volume (VAV) mechanical system that provides an automatic zoning system and chiller based cooling. So basically, the system used is a centralised air-conditioning system. The automatic zoning system is a system where it operates with one system only. The ductwork in this system, which is the auto-zoning system is equipped with a series of thermostatically controlled dampers that standardise the air flow to each zone,i.e. to each room or office.

4.0 RESULTS AND DISCUSION

4.1 Field Measurement Data

Figure 6 shows that the highest percentage of thermal comfort vote (TCV) is neutral at 30.3% which means that the respondents are neither comfortable nor uncomfortable which could be due due to the weather during the time the survey was taken. And then followed by slightly uncomfortable at 27% as tthe respondents might be feeling too warm or experiencing uncomfortable draught in the room. The next chart is Thermal Sensation Vote (TSV) where a mojority of the respondents, i.e.33%, were feeling both slightly warm and cold, not only due to the difference in the weather condition during the measurement but also due to an individual's preference towards their desired temperature which depends on the individual factor of a person i.e. metabolic rate and clothing insulation. The source of discomfort might affect the thermal comfort of a person which can be in many forms as shown in the above chart; a majority of the respondents agree that their source of discomfort comes from an insufficient cooling system. That must be due improper maintenance of the air-conditioning system and the age factor. Draught might not be the main concern here because majority of the respondents are comfortable with the orientation and the velocity of the draught. The highest percentage is 24% where a total of 8 respondents voted comfortable.

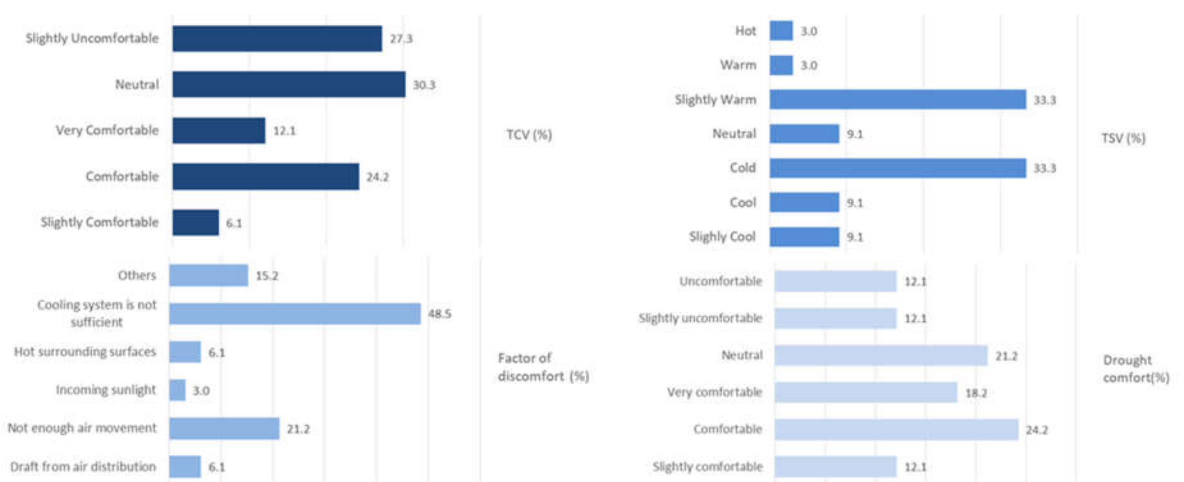

Figure 6: TSV, TCV, and Factor of discomfort and Draught Comfort

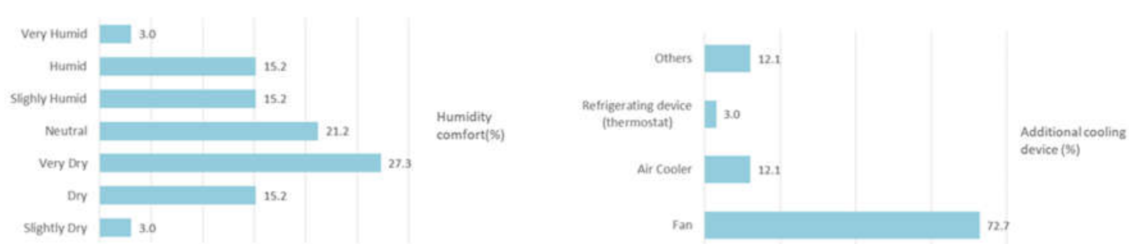

Figure 7: Humidity comfort and additional cooling devices

Humidity is very important in order to avoid our body from sweating as it means the temperature is hot or not suitable. For this survey, the highest percentage of respondents at 27% feel that their offices are dry. Supposedly, if the sensation is warm, the humidity feeling should be high in terms of humidity level. But when the respondents voted for dry, it must be due to the usage of their cooling devices, such as fans. Having cooling devices in the office indicates that they are not satisfied with the temperature of the environment inside. The most used cooling device is the fan which conquered 72% of the vote and the least used cooling device is the refrigerating devices.

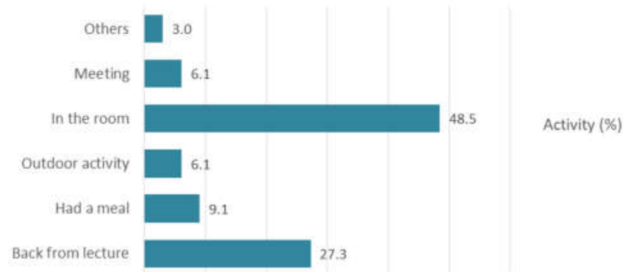

Figure 8 Activity before answering the questionnaire

Figure 8 above reveals what the respondents were doing 5 to 10 minutes before they answered the questionnaire. This type of question is important as it will be the reason of why the person feels slightly different from other people. While answering this questionnaire, most of the respondents were in their room doing their work. The respondents who were sitting in the office might feel slightly cooler than the ones who just got back from lecture, meetings, etc. as they would have to walk all the way to their office.

Figure 9 below shows the measured average outdoor data, indoor data and the summary of the air temperature (°C), Mean Radiant Temperature (°C) and the Relative Humidity (%) during the collection of survey responses respectively. The average temperature occurred within these 6 days is between 26°C to 29°C even though the highest temperature recorded was 31°C.Compared to the average outdoor temperature in most days, the actual high temperature of 34°C, the difference between indoor and outdoor temperature was 5°C to 8°C. It might differ due to the orientation of the room as some rooms are located directly facing the sunlight and some are not. The mean radiant temperature did not contrast much from the air temperature due to the facilities that they used were considered as less high heat generating equipment. Meanwhile, the relative humidity (RH) is mostly above 60% for most rooms,which is probably due to the efficiency of the air-conditioning system. This shows the humidity level is not at its best as it exceeds 60%.

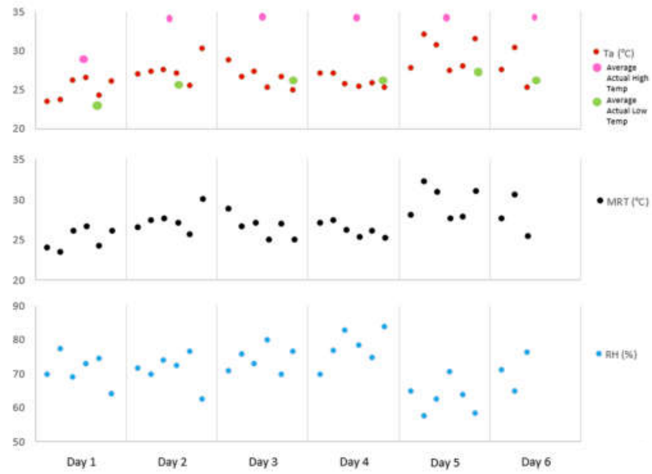

Figure 9 Measured indoor and outdoor data for air temperature, MRT and RH

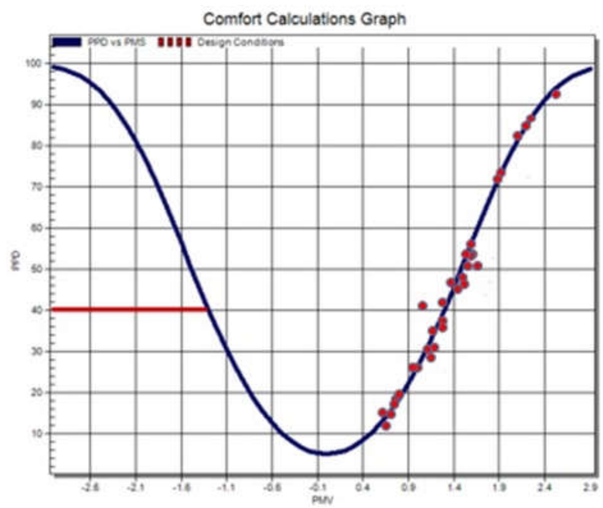

Figure 10: Predicted Mean Vote (PMV) vs. Predicted Percentage of Dissatisfaction (PPD)

The graph above point out the PMV against PPD. The respondents PPD value are mostly high which is above the acceptable range of 10%. There are a lot of respondents at the range of 30% to 60% which is considered very high. Some of the respondents' PPD are higher than it is supposed to be which is in the range of 80% to 95%. This might be due to their malfunctioned air-conditioning system or due to the individual factors such as the metabolic rate and clothing insulation.

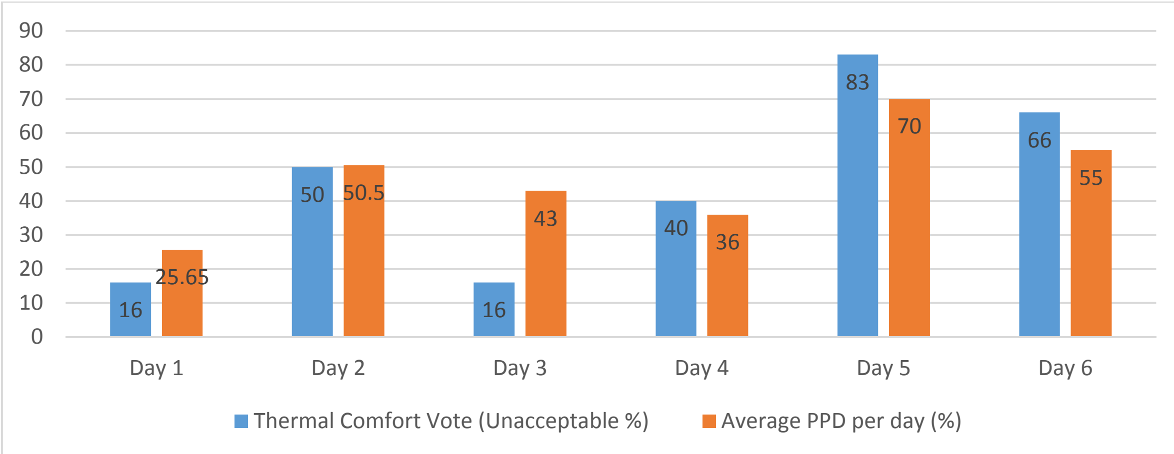

Figure 11: Thermal Dissatisfaction

Figure above shows the graph of daily unaccetable percentage of thermal comfort vote f according to the questionnaire and average Predicted Percentage of Dissatisfaction according to the measurement taken. The unacceptance level of TCV is mostly higher than the average PPD, TCV shows that the respondents have higher tolerance towards cool sensation as they are not satisfied with the comfort in the room. For day 1 and day 3, the percentage of unacceptable is lower than the otherswhich be might due to the outdoor weather conditions; either it was slightly raining or cloudy during the survey or clear and sunny during other days.

5.0 CONCLUSION

In this study, it was proven that the comfort satisfaction level of the respondents is low based on the survey and the measurement made. In general, the dissatisfaction level is high towards the current condition of their room because of the insufficient cooling system that involves the centralised air-conditioning system. The acceptable range for PMV is basically at the range of -0.5 to +0.5; meanwhile, PPDshould not be below 10% to ensure that the occupants inside the room will be satisfied with the condition of the room as this will indirectly keep them healthy and motivated to work. As we are aware, the acceptable temperature for an office is supposedly 24°C -25°C but unfortunately it only occurs when it is raining which suggests that the air-conditioning system is not efficient.

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