Identification of Ideal Thermal Settings for Administration Office on Hot-Humid Climate

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Abstract. Thermal conditions in Administration Room, Department of Architecture, Universitas Indonesia were taken as case studies to understand the ideal thermal settings for occupants in the administration office with hot-humid climate. The investigation aims to visualize the indoor environmental quality of the office room in terms of temperature and humidity and obtain the perceptions of occupants regarding their satisfaction toward the evaluation of thermal comfort for office space. On-site measurements of air temperature and relative humidity for objective data, as well as questionnaire for subjective data, were applied to obtain occupants' responses on the thermal quality of the office. The correlation between objective and subjective data that shows the thermal comfort level influenced the working environment. The study found that most of the time, the occupants of the room feel slightly cold rather than satisfied with their thermal environment settings. The data further show that the comfortable temperature this Administration room around 26-28°C and RH from about 50-60%.

1. Introduction
Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55) [1]. Based on the above definition, comfort is a state of mind, not a state of condition. The definition of thermal comfort is talks about the status of mind or satisfaction that influenced by physical, physiological, and other factors. The perception of thermal sensations is different for each person. Besides, thermal comfort is a state that each person will judge the environment to be neither warm or too cold. In other words, there are no absolute standards for thermal comfort itself, as people live in a various range of climates of the world. In 1962, Macpherson defined the following six factors as those affecting thermal sensation: four physical variables (air temperature, air velocity, relative humidity, mean radiant temperature), and two personal variables (clothing insulation and activity level, i.e., metabolic rate) [2]. Temperature is a measurement to show the degree of hotness, or sensible heat or cold in a body or place. High temperature can increase sweat production in the shape of an individual, which creates body heat and wetness sensation.

On the other hand, air velocity made a freshness and comfort of individuals in any room space. Relative humidity is the amount of moisture in the air compared to what the air can hold at that temperature. Thermal comfort of people affected by relative humidity, especially when the vapor liberated that creates a sense of discomfort. That because the body produces the sweat glands that leak onto the skin, which evaporates and draws away heat. The rate at which this evaporation takes place is determined in part by the ambient humidity. If the air is arid, the sweat evaporates quickly and easily.
If the weather is very humid, sweat evaporates slowly and cause sense too hot and have sticky sweat. However, the feeling of comfortable or not varies from one individual to another because of variations of physical activity, age, and clothing. Thus, the effect of thermal comfort in the building is very important because it influences how human development their physical and physiological. In this regard, discussion about what constitutes thermal comfort in the administration room as a working space, how thermal comfort can be measured, and what are the factors inherent to people, their behavior, and its immediate environment that can modify associated with temperature and humidity. The intention is to provide the evidence and suggest a practical solution that should give protection.

2. Contents

2.1. Thermal Comfort in Office Space with Hot-Humid Climate
Macpherson (1962) defined six factors that affect thermal sensation: two personal variables (clothing insulation and activity level, i.e., metabolic rate), and four physical variables (air temperature, air velocity, relative humidity, mean radiant temperature) [2]. The ASHRAE (2013) further determined several human metabolic rates based on activities performed in which office activities are said to produce heat ranging from 1.0 Met on light activities like reading, to 2.1 Mets on heavier activities like lifting/packing [1].

Thermal comfort is very much dependent on the insulating effect of clothing on the wearer. When someone is wearing too much clothing or PPE (personal protective equipment), it may cause of a heat stress even if the environment is not considered warm or hot. For other countries with four seasons, if clothing provides not enough insulation, the wearer may be at risk from cold injuries such as frostbite or hypothermia in cold conditions. Clothing is both a potential cause of thermal discomfort as well as a control for it as the human body adapts to the climate in which it works—adding more layers of clothing if the body felt cold or remove layers of clothing if the body felt warm. It is important to identify how the clothing contributes to thermal comfort or discomfort.

Meanwhile, about the metabolic rate, the more physical work, a person does, the more heat the body will produce. The more heat the body produces, the more heat needs to be lost so the body won't overheat. The impact of metabolic rate on thermal comfort is critical. A person's physical characteristics should always be borne in mind when considering their thermal comfort. They have to examine some factors; their size and weight, age, fitness level, and sex can all have an impact on how they feel, even if other factors such as air temperature, humidity, and air velocity are all constant.

Lechner (2015) explained the four physical variables as thermal conditions of the environment. First, temperature is a measurement to show the degree of hotness or sensible heat or cold in a body or place. High temperatures can increase the sweat production in the body heat and wetness sensation, which affected by heat loss mostly through the means of convection. Next, relative humidity (RH) thermal comfort of people affected by relative humidity, especially when the vapor liberated that creates a sense of discomfort. That because the body produces the sweat glands that leak onto the skin, which evaporates and draws away heat. The rate at which this evaporation takes place determined in part by the ambient humidity. If the air is very dry, the sweat evaporates quickly and easily. If the air is very humid, sweat evaporates slowly and cause sense too hot and has a sticky sweat. In hot and humid tropical climate like in Indonesia, high humidity is often considered an issue because the humidity makes it hard for the human body to release heat through evaporation [6]. The relation between air temperature and RH can be presented in a psychrometric chart. It shows the level of thermal comfort that someone may experience considering these two factors. The other two environmental factors are air movement and Mean Radiant Temperature [3].

2.2. Case Study and Research Method
The area of Universitas Indonesia, Depok, lies at a hot-humid tropical area with two weather conditions annually: the rainy season from November to May, and the dry season from June to November [7]. The case study took place in Administration Office, Department of Architecture, where the working hours
start at 8.00-16.00 WIB on weekdays with lunch breaks around 12.00-13.00 WIB daily. The windows and doors of the office are almost always closed. Thus, natural ventilation barely exists, and the cooling system was regulated mostly by the use of air conditioner.

Research methods include inventory, on-site measurements, and questionnaires to obtain a comprehensive data of the respondents' thermal sensation within the office. Inventory of items were done to put in consideration of the possible heat sources. On-site measurements of air temperature and relative humidity using Temp/RH data logger installed in three different areas: one outside of the office and two inside (as seen in figure 1) as a basic evaluation of the thermal condition in office. Measurements were conducted on August 21st-23th, 2019, and the data was recorded hourly from 8.00-16.00 WIB.

![Figure 1. Administration Office Layout](image1)

Figure 1. Administration Office Layout

Questionnaires were distributed to respondents of three staff of administration as users of the space, to make an inquiry to the office workers about the perception towards the thermal condition in their office. The respondents, through the questionnaire, were asked to give a score towards thermal satisfaction they feel at a certain time. The scores are ranged from -2 (very cold sensation) to 2 (very warm sensation). These scores were then averaged to determine the average satisfaction towards a certain thermal setting, as seen in figure 2.

![Figure 2. Ranges of satisfaction based on average of scoring from questionnaire](image2)

Figure 2. Ranges of satisfaction based on average of scoring from questionnaire

The second survey was done within the rainy season, from October 15th to October 17th, to see if the respondents have a different thermal sensation.

2.3. Discussion

Table 1 and 2 shows the collected data from each hour of the survey time. The data includes on-site measurements of the average air temperature and relative humidity inside and outside of the office. It also measured the average thermal sensation of the respondents of the questionnaire. The psychrometric chart (Figures 3 and 4) was used to identify the relation of air temperature and relative humidity to human comfort. The Givoni Bioclimatic chart helped show how the average human would feel regarding thermal comfort in the same condition [8].
From the first survey, it was found that all of the air temperature and relative humidity inside the office space was within the range of the Givoni Bioclimatic chart comfort zone. It was in line with survey results, which show that scoring ranges from -0.83 to 0.50. Hence, neither of the respondents ever feel much too warm nor too cold.

However, it was also found that the satisfied zone has a smaller area compared to the slightly cold zone, and mostly overlaps with it. It was in line with the fact that most of the time, the respondents feel slightly cold rather than perfectly satisfied. An anomaly was found on August 22nd, at 13.00 WIB, where the correspondents on average said that it felt slightly warm while, in reality, the air temperature and relative humidity is lower than the satisfied zone, which should cause the feeling of slightly cold instead. The possibility was it caused by the activity that was done during the lunch break, which may result in the rise of human metabolic rate and cause discomfort [2][3].

The second survey was conducted in the rainy season, where rain did fall for some time. However, the rain fell at night time, so it did not directly affect the respondents' thermal condition. Even so, the

Table 1. On-Site Measurements and Questionnaire Results

| Time  | Air Temp (°C) | RH (%) | Air Temp (°C) | RH (%) | Average Thermal Satisfaction |
|-------|---------------|--------|---------------|--------|-----------------------------|
| 09:00 | 25.85         | 58.24  | 25.50         | 47.60  | -0.83 Slightly Cold         |
| 10:00 | 26.50         | 53.88  | 25.30         | 44.30  | -0.83 Slightly Cold         |
| 11:00 | 27.36         | 48.85  | 25.00         | 41.50  | -0.17 Satisfied             |
| 12:00 | 27.71         | 50.30  | 24.40         | 47.00  | 0.17 Satisfied              |
| 13:00 | 27.60         | 53.00  | 24.60         | 46.20  | -0.83 Slightly Cold         |
| 14:00 | 27.84         | 48.10  | 24.40         | 45.50  | -0.53 Slightly Cold         |
| 15:00 | 28.18         | 51.85  | 24.30         | 51.50  | -0.17 Satisfied             |
| 16:00 | 29.38         | 54.28  | 24.30         | 51.70  | -0.17 Satisfied             |

Figure 3. Thermal comfort analysis through Psychrometric Chart
weather throughout the day was cloudy in those three days of experiment, so the respondents felt colder than the usual (Table 2). The air conditioner inside the room was set at 25°C for all times.

Table 2. Second On-Site Measurements and Questionnaire Results

| Time       | Average Indoor Thermal Condition | Average Outdoor Thermal Condition | Average Thermal Satisfaction | Satisfaction Level |
|------------|----------------------------------|----------------------------------|-----------------------------|--------------------|
| Day        | Hour | Avg. Temp. (°C) | RH (%) | Avg. Temp. (°C) | RH (%) | Avg. Temp. (°C) | RH (%) | Avg. Score |
| 10/10      | 9:00 | 25.26            | 66.78   | 29.76           | 69.68   | 25.76            | 66.78   | -1.00       | Slightly Cold |
| 10:00      | 27.14 | 61.08   | 29.82   | 64.86   | -0.86   | Slightly Cold |
| 11:00      | 29.14 | 64.09   | 27.97   | 71.24   | -0.86   | Slightly Cold |
| 12:00      | 25.69 | 62.44   | 29.37   | 67.68   | -0.86   | Slightly Cold |
| 13:00      | 28.70 | 65.33   | 28.54   | 65.18   | -0.86   | Slightly Cold |
| 14:00      | 28.57 | 57.85   | 29.07   | 80.85   | -0.86   | Slightly Cold |
| 15:00      | 29.34 | 58.71   | 29.38   | 70.81   | -0.86   | Slightly Cold |
| 16:00      | 28.07 | 62.98   | 29.36   | 72.74   | -0.86   | Slightly Cold |
| 15/10      | 9:00 | 25.07            | 66.63   | 37.55   | 68.71   | -1.00       | Slightly Cold |
| 10:00      | 26.03 | 66.53   | 37.63   | 61.80   | -1.00   | Slightly Cold |
| 11:00      | 26.07 | 65.58   | 29.68   | 66.58   | -1.00   | Slightly Cold |
| 12:00      | 26.48 | 64.67   | 29.82   | 69.56   | -1.00   | Slightly Cold |
| 13:00      | 29.42 | 58.94   | 29.38   | 70.81   | -1.00   | Slightly Cold |
| 14:00      | 26.06 | 66.30   | 29.32   | 62.21   | -1.00   | Slightly Cold |
| 15:00      | 25.65 | 66.89   | 29.57   | 70.58   | 0.00    | Satisfied |
| 16:00      | 25.70 | 57.87   | 29.54   | 70.07   | -1.00   | Slightly Cold |
| 16/10      | 9:00 | 24.65            | 68.42   | 29.07   | 66.24   | -1.00       | Slightly Cold |
| 10:00      | 24.61 | 68.76   | 28.60   | 78.13   | -1.00   | Slightly Cold |
| 11:00      | 24.74 | 68.07   | 27.08   | 60.46   | -0.86   | Slightly Cold |
| 12:00      | 25.37 | 66.07   | 29.92   | 73.78   | 0.00    | Satisfied |
| 13:00      | 24.64 | 65.54   | 28.37   | 74.13   | 0.00    | Satisfied |
| 14:00      | 24.81 | 66.20   | 28.92   | 72.11   | -0.86   | Slightly Cold |
| 15:00      | 24.15 | 64.49   | 29.28   | 71.61   | -0.86   | Slightly Cold |
| 16:00      | 24.50 | 65.54   | 28.51   | 68.68   | -0.86   | Slightly Cold |

It was found that almost all of the air temperature and relative humidity inside the office space was still within the range of the Givoni Bioclimatic chart comfort zone, shifting slightly to the left side. It is in line with survey results, which show that scoring ranges from 0 to -2, indicating that most of the respondents feel slightly cold at most times and never too warm.

It was also found that the satisfied zone still has a smaller area compared to the slightly cold zone, and mostly overlaps with it. That was in line with the fact that most of the time, the respondents feel slightly cold rather than perfectly satisfied. An anomaly was found on October 14th at 8.00 WIB and October 15th at 9.00 WIB, where the correspondents on average said that it felt too cold while in reality, the air temperature and relative humidity is higher than the satisfied zone which should cause the feeling of warmer instead. It possibly caused by the activity that was done before they enter the office space, which is assumed to be lighter activities compared to what they do within the office for the rest of the day [2][3].

Figure 4. Second Thermal comfort analysis through Psychrometric Chart
3. Conclusion
Based on the research, in a room without natural ventilation like such a case, air conditioner (AC) plays a vital role in creating the ideal thermal setting for office space, especially in a hot, humid climate condition like Indonesia. Although there are several heat sources other than the sun (like the lights), they did not seem to have a significant effect on the overall room temperature [9].

This research was able to prove that there are no absolute standards for thermal comfort as the psychrometric chart shows that the satisfaction level differs in different conditions even when every thermal setting is still within the range of the predetermined comfort zone. More so, there were moments of anomalies where the respondent felt warmer or colder inside the room, whereas the on-site measurements shows that they should have felt otherwise.

This research did not take into detail of what each respondent's activities, metabolic rate, and thermal barriers are. Hence, the authors were unable to prove in detail of how personal factors affect human perception towards a room's thermal setting. However, from the literature reviews and conducted surveys, it can be concluded that a person's thermal comfort is affected by his/her activities, metabolic rate, and clothing. The AC here only functioning as a tool to help someone to find his/her thermal comfort.

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