Thermal Comfort Of The Outdoor Transition Space In the Dean's Office Building

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Abstract. The increase in the transmission of the COVID-19 disease, creating an effort to prevent transmission by controlling total of space users in the Dean's Office Building, University of Bengkulu to avoid overcrowding users of space in buildings. The control has an impact on the increasing number of space users in the transition space of outdoor (terraces, hallways, corridors) in the eight Dean's Office Buildings. The thermal comfort of the outdoor transition space needs to be considered because the post-pandemic adaptation behavior causes the change in the function of the transition area as buffer between outdoor and indoor spaces, is currently becoming a waiting room for entering buildings with uncertain waiting times. In addition, University of Bengkulu is located in coastal area with air temperatures during the day between 30 °C - 34 °C and wind speed ranging from 0-2,2 m/s. The purpose of this research is to determine the perception of thermal comfort of space users in the transition space, Dean's Office Building, University of Bengkulu. Measurement data in the form of air temperature, air humidity, and wind speed at the peak of the dry month were carried out at 08.00-16.00 for 10 working days and interview data on the perception of thermal comfort of space users. Interview and measurement data will be inputted on the Ray-man measuring instrument to obtain the PET, PMV, SET values.

1. Introduction

In the city of Bengkulu, there are 13 campuses spread across several urban villages. One of the campuses is Bengkulu University which has a unique geographic location, a campus which is about 500 meters from the beach. Geographical location in the coastal area is important because the climate is influenced by the characteristics of certain geographic locations [1] The micro climate problem that arises in coastal areas is the wind speed that is quite high. Studies that have been conducted in Makassar City prove that the macro climate cannot be intervened, but the level of wind speed that blows can affect the temperature and humidity levels as well as the temperature of solar radiation which can improve the microclimate environment by paying attention to the direction of the wind. In this study, it was found that the campus which is closest to the beach in the dry season has the highest wind speed (0.45 m / sec) higher than the campus which is located in the city center and the farthest distance from the beach. However, the average wind speed is higher in the rainy season (0.59 m / sec) than in the dry season [2]. Wind speed has the potential to improve the microclimate and thermal comfort of the outdoor space. Campus is a formal educational environment that accommodates various student activities with the existence of outside campus spaces having an important role. The outer space is generally protected by
a roof and appears in the form of a terrace or veranda which acts as a receiving zone and an intermediate zone between the outer and inner spaces [3]. The outer space transition area in the Dean's Office Building at Bengkulu University in the form of a terrace is enclosed by physical elements in the form of a building wall on one side, shaded / roofed, has no walls on three sides, and functions as a transition area for ease and effectiveness of access in creating continuity between the building and outdoor. The outer transitional areas such as terraces, atria, hallways, and corridors are those that have the function of supporting space and connecting physically between the outer and inner spaces [4]. Which protects the space from outside views as a form of privacy and movement control [5]. Buildings that provide space to support human activities require comfort [6] so that the creation of a comfortable situation for the activity actors inside must be able to be fulfilled by an outside space [7]. The outdoor space which has thermal comfort indicates that it can increase outdoor activity and physical mental health [8].

During the pandemic, the spread of the novel coronavirus disease 2019 (covid-19), which was found in the first case in Wuhan City, China at the end of 2019, caused serious public health problems globally [9]. To break the chain of covid-19 transmission at the University of Bengkulu, efforts to prevent the transmission of covid-19 were carried out by implementing a system of sharing work time for education personnel to control the number and density of space users in the Dean Office Building of Bengkulu University. So that during the pandemic period with the adaptation of new habits, the transition area becomes a temporary waiting room due to restrictions on the number of space users allowed to enter the building. This has an impact on the transition area in each Dean's Office Building experiencing changes in function and an increase in the number of space users. The increased user space density can create uncomfortable thermal conditions when the air temperature exceeds 30 °C. Another study in the city park area in Banjarbaru indicated that wind speed, daily air temperature and the average humidity of the microclimate affect the comfort felt by its users [10]. The conditions and thermal sensations felt by users according to ASHRAE (American Society of Heating Air Conditioning Engineer Refrigerating) are determined into six parameters, namely air temperature (Ta), relative humidity (RH), wind speed (v), average radiation temperature (Tmrt), activities (W), and clothes (Clo). These thermal conditions create human perceptions which are very closely related to aspects of the human person [11]. Aspects of the human person that determine thermal sensation such as physiological factors such as age, sex and things related to human metabolism [12].

Evaluation studies regarding thermal comfort in buildings in coastal areas have been carried out on stage dwellings in coastal areas using measurement methods and analysis of manual PMV thermal comfort index formulations showing thermal conditions for 12 hours in two different rooms in hot and somewhat hot conditions. There is a bias between the results of the calculation of the PMV value and the thermal response of the respondent due to the wind speed factor [13]. Another study regarding the comfort of the outer space area of the campus area by measuring survey methods at a specified point and mapping the area using the Geographic Information System (GIS) shows that the percentage of thermal conditions in the Unsrat Manado campus area is dominated by a bit hot because it is related to the percentage of land cover area ratio, high buildings, wall and window materials [7]. Outdoor comfort is carried out in the corridor of the ITB campus by measuring and being analyzed using the Rayman model and the perception of 50 respondents randomly on thermal conditions shows that the PET value in a comfortable state, the SET value is in a neutral state but has a different PMV value from the preference results of male respondents. male and female [14]. The difference in preferences between boys and girls is because girls have a higher index of attention than boys to climate change which affects the condition of comfort [15].

2. The Content of the Extended Abstract
To find out the perception and sensation of thermal comfort in the transitional area of the outer space of the Dean's Office Building, Bengkulu University, which is located in a coastal area in a hot-humid tropical climate, this study conducted the results of interviews with room users and measurement results on air temperature variables (Ta). Relative humidity (RH), wind speed (v), average radiation temperature (Tmrt) into the Rayman 1.2 calculation model. The use of the Rayman 1.2 model as a tool
that calculates the PMV, PET, and SET indices. The PMV value index obtained to determine a person's sensation in certain activities is related to the difference between internal heat production and heat loss to the environment [16].

The analysis focuses on knowing the perceptions and sensations of thermal comfort of space users (in this case students) in the transitional area of the outer space of the Bengkulu University Dean's Office Building, which is located in a coastal area in a hot-humid tropical climate during the Covid-19 pandemic phase. The perceptions and sensations of thermal comfort studied were used to evaluate thermal comfort in response to changes in the function of the post-COVID-19 phase transition space. This thermal comfort evaluation calculation model is expected to be a study in designing a green campus environment that is suitable for the academic community of Bengkulu University in a sustainable manner in the post-pandemic period.

2.1. Study Area
Bengkulu City is geographically located between 3 ° 45' - 3 ° 59' south latitude and 102 ° 14' - 102 ° 22' east longitude in the coastal area. Bengkulu City does not have an area more than 30 kilometers from the seaside. This position causes the air to be relatively hot with the air temperature being relatively the same throughout the year. The maximum temperature ranges from 29 °C - 30 °C each month and the minimum air temperature ranges from 23 °C with humidity ranging from 81% - 91% and the maximum wind speed range is at 14-19 knots. Monthly rainfall ranges from 200-600 mm with the number of rainy days every month between 10-21 days. Bengkulu City is classified as climate type A (Wet Tropical) with 10 wet months starting from October to July. The dry season occurs from May to October and from December to January there will be heavy rains.

The location of this research is in Bengkulu University, Bengkulu City, Indonesia. Bengkulu University is located in Bengkulu City located at 3 ° 45'35.19 "S 102 ° 16'20.66" E is an area of higher education covering an area of 81.19 hectares which is located in a lowland area about 500 meters from the shore of the Indian Ocean so that the wind blows from the sea is firmer than the midtown area which is densely built and is thought to have an influence on the microclimate of the campus area. As much as 60% of the campus area is covered by vegetation and green land. The campus area is dominated by buildings 2-3 floors. Transition area The Dean's Office Building underwent a change in function during the covid-19 pandemic and experienced an increase in the number of space users which had an impact on the density of space users in the transition area. This triggers the discomfort of moving as well as thermal comfort in the transition area. Moreover, the outdoor temperature conditions around the Dean's Office Building range from 30 °C - 34 °C.

Figure 1 (a) Bengkulu Province Region; (b) Bengkulu City, (c) University of Bengkulu

2.2. Field measurements in the study area
The purpose of this study was to determine the perception and sensation of thermal comfort in the transitional area outside the Bengkulu University Dean's Office Building during the dry season. The variables measured are air temperature (Ta), relative humidity (RH), and wind speed (v). Measurements were made during the peak of the dry season with clear sky conditions on 24 August 2020-28 August 2020 in four measurement locations at (1) the Faculty of Economics and Business is
at 3° 45'42.31" S 102° 16'08.31" E (2) Faculty Law is at 3° 45'43.03" S 102° 16'17.11" E (3) Faculty Agriculture is at 3° 45'34.53" S 102° 16'08.86" E (4) Faculty of Mathematics and Natural Sciences is 3° 45' 21.72" S 102° 16'29.42" E and 17 August 2020 - 21 August 2020 in four measurement locations at (1) the Faculty of Engineering is 3° 45'30.82" S 102° 16'35.97" E (2) Faculty of Medicine and Health Sciences is at 3° 45'18.79" S 102° 16'40.97" E (3) The Teaching and Education Faculty is at 3° 45'27.66" S 102° 16'30.63" E (4) Faculty of Social and Social Sciences politics is at 3° 45'33.09" S 102° 16'27.19" E. In addition to field measurements, data collection in this study was conducted by interviewing 240 respondents to synchronize the variable value measurement data. The start and end times of the interview were recorded. In general, respondents spend five-ten minutes completing the interview. The sample size used is as many as respondents.

2.3. Overview of the reviewed Meteorological measurements and instrumentation
The Rayman model was developed to calculate long and short waves of radiation flux affecting the human body. The Rayman model can be run by inputting climate data measurements such as air temperature, humidity, activity, and human body mass index [17]. To obtain microclimate data in the dean building area, direct measurements are needed in the dean building transition room. The data collection was carried out in each dean building on 23 August 2020 until 31 August 2020. This is because August is the time of the highest position of the sun, especially in the city of Bengkulu, so it affects the quality of data on air temperature and humidity. Measurements are made on work activities in the dean building from 08.00 WIB to 16.00 WIB.

2.4. Research Method
The method used in this study is a quantitative method, namely by conducting an observation approach in the research area to obtain thermal comfort in the transition room in the dean building. The data collected consists of secondary data and primary data. Secondary data is obtained by measuring, interviewing and documentation. Primary data consists of location measurement data in the form of air temperature data (Ta) taken using a thermometer, air humidity (Rh) and wind speed (v) using an anemometer.
Collecting data using the method of distributing questionnaires by conducting interviews with 240 respondents. The questions asked in the questionnaire consisted of (1) gender, (2) age, (3) height, (4) weight, (5) types of clothing, (6) types of activities in the dean building area, (7) duration of activities, and (8) temperature perception of the room. The results of this data were then processed using the Rayman Model to obtain the PMV, PET, and SET values. Secondary data were obtained by conducting a survey in the Bengkulu University area in the form of documentation of the atmosphere of the dean building, and collecting literature studies of scientific journals. The Rayman model was developed to calculate long and short waves of radiation flux affecting the human body. The Rayman model can be run by inputting climate data measurements such as air temperature, humidity, activity, and human body mass index.

2.5. Results and data analysis

To determine the values of PMV (Predicted Mean Vote), PET (Physiological Equivalent Temperature), and SET (Standard Effective Temperature), microclimate data is needed which is obtained by measuring on site. Then the results of climate data are combined with respondent data consisting of the type of activity, the type of clothing worn and the respondent's physical condition. All of these data are then processed using the Rayman Model to obtain PMV, PET, and SET. This data is then divided based on the comfort type category for each existing standard.

SET (Standard Effective Temperature) is a standard index of comfort based on the psychological level of a person's body against the thermals in a room which is influenced by the type of clothing worn as well as conditions of air temperature, humidity, and wind speed. SET scale can be seen in the following table 1.

| Grade of physiological stress | ASHRAE (PMV) | Fanger (PMV) | Rohles & Nevins (PMV) | Gagge's DISC (PMV) | SET (°C) |
|------------------------------|--------------|--------------|----------------------|--------------------|---------|
| Painful                      | +5           | +5           | +5                   | >37.5              |         |
| Very Hot                     | +4           | +4           |                      |                    |         |
| Hot                          | 7            | +3           | +3                   | 34.5 - 37.5        |         |
| Warm                         | 6            | +2           | +2                   | 30.0 - 34.5        |         |
| Slightly warm                | 5            | +1           | +1                   | 25.6 - 30.0        |         |
| Neutral                      | 4            | 0            | 0                    | 0.5                | 22.2 - 25.6 |
PMV (Predicted Mean Vote) is an index developed to determine the physiological value of the human body's thermal exchange against its external environment. The PMV value in a person is determined from their activities related to the thermal load on the body. PET (Physiological Equivalent Temperature) is the physiological equivalent of a person's body in balancing body temperature against an environment, both indoor and outdoor. The PMV and PET scales in terms of the perceived psychological load can be seen in the following table 2.

| Grade of physiological stress | ASHRAE | Fanger (PMV) | Rohles & Nevins | Gagge's DISC | SET (°C) |
|-------------------------------|--------|-------------|----------------|-------------|---------|
| Slightly cool                 | 3      | -1          | -1             | -1          | 17.5 - 22.2 |
| Cool                          | 2      | -2          | -2             | -2          | 14.5 - 17.5 |
| Cold                          | 1      | -3          | -3             | -3          | 10.00 - 14.5 |
| Very cold                     |        |             | -4             | -4          |         |

### Table 2 Thermal Sensation Scale. PMV Index, and PPD

| PMV (°C) | PET (°C) | Thermal Sensation | Grade of physiological stress |
|----------|----------|-------------------|--------------------------------|
| -3.5     | 4        | Very cold         | Extreme cold stress           |
| -2.5     | 8        | Cold              | Strong cold stress            |
| -1.5     | 13       | Cold              | Moderate cold stress          |
| -0.5     | 18       | Slightly cool     | Slight cold stress            |
| 0.5      | 23       | Comfortable       | No thermal stress             |
| 1.5      | 29       | Slightly warm     | Moderate heat stress          |
| 2.5      | 35       | Warm              | Strong heat stress            |
| 3.5      | 41       | Hot               | Extreme heat stress           |

### 2.6. Discussion

Based on data released by the Task Force for the Acceleration of COVID-19 in Bengkulu Province on 31 August 2020, it was stated that Bengkulu City was in a moderate risk status with 254 confirmed cases recorded [18]. Studies conducted by [19] showed that the function of social distancing and the effectiveness of ventilation in preventing transmission of covid-19 indoors using the Wells-Riley model shows that through social distance 1.60 - 3.00 m (safe social distance in the possibility of transmission of exhaled aerosols while speaking) and ventilation adequate can increase the effectiveness of preventing the transmission of covid-19. If these two things are done then halved the space density will be reduced and significantly reduce the infection rate by 20-40% during the first 30 minutes. Measurement of conditions of air temperature, humidity and wind speed is carried out from 09.30 WIB to 12.00 WIB. The measurement results show the average value of air temperature (Ta) 30.68 °C, the average value of air humidity (Rh) 64.50% and the average wind speed (v) 0.73%. The types of activities that the respondent did before conducting the interview were sitting, walking, standing, walking leisurely, and walking fast.
The types of clothing used by the respondents consisted of 5 types, namely, 1.13, 1.19, 1.27, 1.29, and 1.76. Based on survey data, female respondents tended to wear types of clothing types 1.13 and 1.29. Then for the average male respondent using 1.19 types of clothing.

The results of respondent data obtained from the questionnaire consisted of 168 female respondents and 72 male respondents from 8 (eight) Faculties at Bengkulu University. The number of respondents in the dean building of the Faculty of Economics and Business, consisting of 24 female respondents, showed an average Tmrt (°C) of 21.56, an average PMV value of 0.42, an average PET value (°C) of 26.98, and an average SET value. (°C) 23.04. For male respondents consisting of 6 respondents, showing an average value of Tmrt (°C) 19.82, an average PMV value of 1.47, an average PET value (°C) of 25.43, and an average SET (°C) value of 24.30. In the dean building, the Faculty of Law consists of 24 female respondents who show an average Tmrt (°C) of 21.58, an average PMV value of 1.19, an average PET value (°C) of 26.84, and an average SET value (°C) 23.86. For male respondents consisting of 6 respondents, showing an average value of Tmrt (°C) 20.03, an average value of PMV 1.43, an average value of PET (°C) 25.47, and an average value of SET (°C) 23.53.

Figure 4 Respondent data based on activity

Figure 5 Respondent data based on clothing

Figure 6 a). Rayman's calculation results at the Faculty of Economics and Business, and b). Rayman's calculation results at the Faculty of Law
The number of respondents in the dean building of the Faculty of Agriculture, consisting of 17 female respondents, showed an average Tmrt (°C) of 21.82, an average PMV value of 1.55, an average PET value (°C) of 27.12, and an average SET value (°C) 24.51. For male respondents consisting of 13 respondents, showing an average value of Tmrt (°C) 20.79, an average value of PMV 2.03, an average value of PET (°C) 25.85, and an average value of SET (°C) 21.03. In the dean building of the Faculty of Mathematics and Natural Sciences, 26 female respondents showed an average Tmrt (°C) of 21.51, an average PMV value of 1.57, an average PET value (°C) of 26.90, and an average SET value. (°C) 24.37. For male respondents consisting of 4 respondents, showing an average value of Tmrt (°C) 23.68, an average value of PMV 2.03, an average value of PET (°C) 28.65, and an average value of SET (°C) 25.10.

![Graph](image1)

Figure 7  a). Rayman's calculation results at the Faculty of Agriculture and b). Rayman's calculation results at the Faculty of Mathematics and Natural Sciences

The number of respondents in the dean building of the Faculty of Social and Political Sciences consisted of 21 female respondents showing an average Tmrt (°C) of 21.85, an average PMV value of 1.62, an average PET value (°C) of 27.29, and an average value of average SET (°C) 24.68. For male respondents consisted of 9 respondents, showing an average value of Tmrt (°C) 21.17, an average PMV value of 1.68, an average PET value (°C) of 26.52, and an average SET (°C) value of 24.27. In the dean building of the Faculty of Medicine and Health Sciences, 23 female respondents showed an average Tmrt (°C) of 21.47, an average PMV value of 1.41, an average PET value (°C) of 26.75, and an average SET value ( °C) 24.32. For male respondents consisting of 7 respondents, showing an average value of Tmrt (°C) 23.17, an average value of PMV 2.04, an average value of PET (°C) 28.89, and an average value of SET (°C) 26.10.

![Graph](image2)

Figure 8  a). Rayman's calculation results at the Faculty of Social and Political Sciences and b). Rayman's calculation results at the Faculty of Medicine and Health Sciences
The number of respondents in the dean building of Faculty of Teacher Training and Education consists of 22 female respondents showing an average Tmrt (°C) of 21.29, an average PMV value of 1.45, an average PET value (°C) of 26.60, and an average value SET (°C) 23.91. For male respondents consisted of 8 respondents, showing an average value of Tmrt (°C) 21.56, an average value of PMV 1.75, an average value of PET (°C) 27.04, and an average value of SET (°C) 24.09. In the Dean building, the Faculty of Engineering consists of 11 female respondents who show an average Tmrt (°C) of 22.55, an average PMV value of 1.72, an average PET value (°C) of 27.96, and an average SET value (°C) 25.39. The male respondents consisted of 19 respondents, showing an average Tmrt (°C) of 20.85, an average PMV value of 1.58, an average PET (°C) value of 26.13, and an average SET (°C) value of 23.86.

Based on the results of the data processing above and associated with SET and PET data with an average SET value of 23.72 °C and PET 26.53 °C, female respondents were categorized as having a neutral state and did not feel thermal stress. This is also the case with the condition of male respondents, the average value of SET 24.16 °C and PET 26.98 °C. The average thermal comfort for male respondents leads to a slightly warm feeling, while the female respondents approach a feeling of warmth. This is because the majority of female respondents wear the hijab, so the value of clothing is quite high. The variation in the value of thermal stress on the respondent's body is also influenced by the user's ability to choose an area in the transition space in the dean building in carrying out activities that allow respondents to interact with the environment around the building. [20].

Figure 9 a). Rayman's calculation results at the Faculty of Teacher Training and Education and b). Rayman's calculation results at the Faculty of Engineering

Figure 10 Rayman's calculation results at the Bengkulu University
3. Conclusion
The environmental conditions of the Bengkulu University microclimate are influenced by the coastal area which has relatively warm temperatures. Based on this condition along with the different environmental conditions of each dean building, SET and PET for men and women tend to be neutral and quite warm. SET and PET values are influenced by the type of clothing worn, the activities carried out by the respondent and the relatively warm environmental conditions of the Dean. Especially the type of women's clothing worn by the majority uses the hijab, thereby increasing the thermal value received by the body. The transitional room conditions in each dean building have a variety of atmosphere. This is influenced by the position of the transition space towards the orientation of the sun as well as the natural and artificial environmental conditions that exist around the dean building.

The data obtained from the Rayman model can show the quality of the transitional space in the dean building to the occupants in the quantitative category. This data is supported by direct measurements of the microclimate conditions in the Bengkulu University area as well as conducting interviews with respondents regarding the respondents' views of the thermal conditions in the transitional room of the dean building.

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