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Analysis of the Comparison Between Residents' Perception and Field Measurement of Visual and Thermal Comfort (Case Study: Student Dormitory Building)

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ABSTRACT

As public buildings, student dormitories must be comfortable as they host most of the students' lives and activities. A space's visual and thermal comfort significantly impacts the occupants' activities and productivity. Indicators for assessing the building comfort level include visual, thermal, and noise comfort in spaces or buildings. This paper presents the results study of the building's visual and thermal comfort measurement and the occupants' perception toward comfort. This paper also presents the comparison between that measurement and the occupants' perceptions. This research employs a mixed-methods approach consisting of qualitative methods (occupants' perception questionnaire) and quantitative methods (field measurements of lighting levels, air temperature, and humidity). Data were collected through questionnaires distributed to dormitory residents and field measurements using an Environmental Meter 4 in 1 to measure natural and artificial lighting levels, air temperature, and humidity. The data obtained were analyzed and then presented in a descriptive format. Based on residents' perceptions, the findings indicate that the overall visual and thermal comfort in the dormitory building falls within a good category. The field measurements on natural lighting, air temperature, and humidity show that the student dormitory building meets the established comfort standards. However, the artificial lighting of staircases and corridors doesn't meet the standards due to many non-functioning lights and low lumen levels. Overall, the lighting, temperature, and humidity conditions in the dormitory building are influenced by building design, orientation, surrounding environment, and occupants' behavior. To enhance comfort and health for residents, improvements in artificial lighting systems, enhancement of natural ventilation, and education on the importance of good air circulation are necessary.

1. Introduction

The student dormitory building serves as a place for students to study, socialize with other residents, and build character. Additionally, the building meets basic needs by protecting from rain and sun while ensuring the privacy of its occupants [1]. The performance of the building, which must meet reliability requirements, is crucial to ensure it functions properly. The criteria for building reliability include safety, health, comfort, and convenience [2]. Indicators for assessing the building comfort level include visual and thermal comfort within the space or building. Visual comfort refers to adequate lighting levels that help individuals see objects clearly and comfortably [3]. In Indonesia, visual comfort is regulated by SNI 6197 of 2020 concerning Energy Conservation in Lighting Systems. Thermal comfort refers to how an individual expresses their satisfaction with the surrounding environmental temperature [4]. In Indonesia, thermal comfort is determined based on SNI 03-6572 of 2001 regarding the Procedure for Ventilation and Air Conditioning Systems in Buildings. Thermal comfort is critical because it concerns a comfortable room temperature [5].

Failure to meet visual and thermal comfort requirements can disrupt activities, productivity, and health of occupants [6][7][8][9][10][11]. Lighting too bright or dim can cause eye strain, headaches, and reduced productivity [12]. The effects of a room being too hot or cold can lead

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to health and psychological issues for the occupants [13]. Health problems arising from sweltering conditions include heat cramps, heat exhaustion, heat stroke, and heat rash. Health issues in icy conditions include chilblains, trench foot, and frostbite [14][15].

Considering that visual and thermal comfort significantly affect health, efforts to achieve these comfort standards in buildings are essential [16]. Furthermore, almost all adults spend 90% of their time indoors [17]. Despite this, many building occupants consider their environment comfortable yet still experience health problems. This issue is exacerbated by the occupants' lack of awareness regarding the building's visual and thermal comfort standards [18].

Given this background, it is important to understand the relationship between visual and thermal comfort levels and the occupants' perceptions. However, there has been no research addressing this issue. Therefore, this study aims to determine the visual and thermal comfort of the male student dormitory buildings at Gadjah Mada University (UGM) based on the occupants' perceptions and measurements of the building itself and then compare these to understand the relationship between the levels of visual and thermal comfort and the occupants' perceptions. This research is conducted in one of UGM's male student dormitory buildings. The function of the student dormitory is chosen as a case study because students are assumed to represent an educated segment of society.

The selected dormitory for the study is the male student dormitory with the highest occupancy capacity, exclusively housing students from various regions attending Gadjah Mada University. It has been operational since October 2016. The dormitory consists of two physically separate but similarly designed buildings (Twin Buildings). Each building has five floors. The total number of rooms in the two buildings is 184. Each room is occupied by two students, providing a total bed capacity of 368. The roads around the dormitory are quite busy as they provide access to nearby schools and campuses. The dormitory has several facilities, including a lobby, study room, prayer room, canteen, bedrooms, en-suite bathrooms, shared kitchen, Wi-Fi area, and 24-hour security. Additionally, each room is furnished with bunk beds, study tables and chairs, and wardrobes.

2. Research Methods

This research employs a mixed-methods approach consisting of qualitative (occupant perception questionnaires) and quantitative (measurements of lighting levels, air temperature, and humidity) methods. The qualitative method allows researchers to understand the occupants' perceptions of the conditions experienced while living in the student dormitory. The quantitative method is used to determine the dormitory building's field measurement results against the standards applicable in Indonesia. These two results are then compared and discussed.

2.1 Location of Research

The research was conducted at one of the male student dormitory buildings of Gadjah Mada University (UGM) Residence. The layout of the Student Dormitory can be seen in Figure 1. As previously mentioned, the dormitory consists of two buildings (Twin Buildings), denoted in Figure 1 as A for the south building and B for the north building.

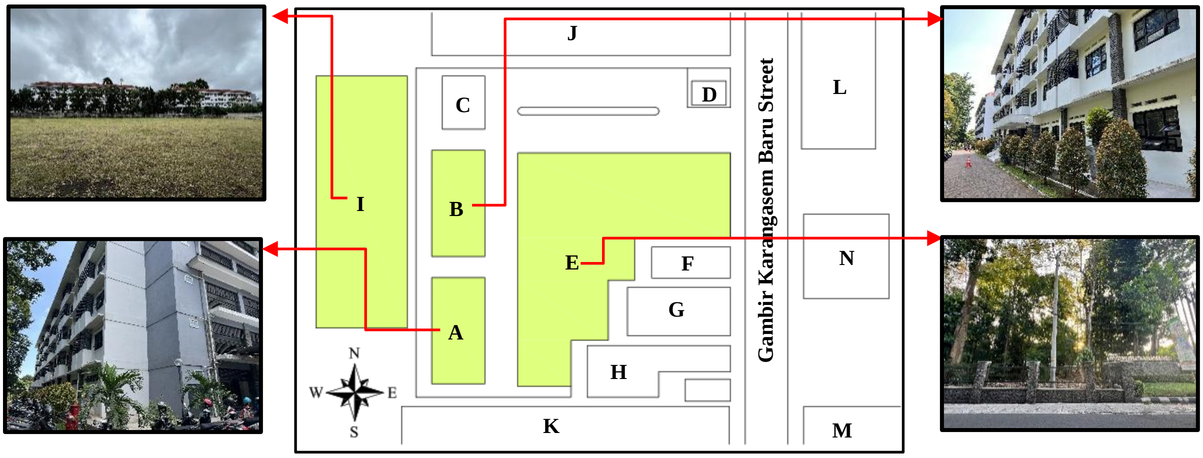
Each building consists of 5 floors. The student dormitory buildings are oriented east-west, thereby directly receiving solar radiation. However, on the eastern side of the buildings, there is a green open space planted with trees whose average height can reach the height of the dormitory buildings. On the western side, there is a football field. On the northern and southern sides, there are non-story buildings.

2.2 Type of Data

This research uses both primary and secondary data. Primary data includes occupant perception questionnaires, field observations, and measurements of the dormitory buildings. Secondary data consists of shop drawing documents of the student dormitory and the dormitory profile data. The profile data is taken from the UGM Residence website (https://residence.ugm.ac.id).

2.3 Research Variables

The assessment of occupant perceptions and measurements of visual and thermal comfort levels in the dormitory buildings consists of two indicators and four sub-indicators. These indicators and sub-indicators are determined based on the Indonesian National Standards (SNI), as shown in Table 1. The assessment of occupant perceptions is conducted using questionnaires



Description :

A = Student Dormitory Building A (TB 1)
B = Student Dormitory Building B (TB 2)
C = Ground Water Tank
D = Security Guard Post
E = Green Open Space
F = Shop
G = Silviculture Lab, Faculty of Forestry, UGM
H = Nursery, Faculty of Forestry, UGM
I = Football Field
J = Wood Management Unit
K = Shopping Area
L = Shopping Area
M = Shopping Area
N = Hotel

Figure 1. Site layout of the student dormitory building.

Table 1. Visual and thermal comfort indicators and sub-indicators of building.

Indicators	Sub-indicators	Standard
Visual comfort	Natural lighting	SNI 03-6197 : 2020
	Artificial lighting	SNI 03-6197 : 2020
Thermal comfort	Temperature	SNI 03-6572 : 2001
	Humidity	SNI 03-6572 : 2001

2.4 Data Collection Technique - Questioner

Questionnaires were distributed to dormitory occupants who stayed in the rooms, and they were inspected and measured for comfort levels. The questionnaire included questions about the occupants' perceptions of lighting, air temperature, and humidity in the dormitory building. The subjects of this study were the occupants of the student dormitory building.

The population in this study was all the dormitory residents. The sample size for this study was determined using Slovin's formula, as shown in Equation (1). The notations n, N, and e represent the sample size, the total population, and the margin of error, respectively. As previously mentioned, the population size N was 384 students. Using a margin of error e of 10%, the sample size n was calculated to be 80 respondents. However, during the distribution process, a total of 88 respondents were obtained.

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

2.5 Measurement of Comfort Level

2.5.1 Location and Time of Measurement

The light levels, air temperature, and humidity were measured on each building floor. At least two rooms were observed on each floor, one on the east and one on the west. These two rooms were selected randomly while ensuring representation from both the east and west sides. On the north and south sides of the dormitory building, stairwells represented measurements, which serve as vertical access frequently used by residents from the 1st to the 5th floor. The stairwell in the center of the building was also observed on each floor. The positions of the observed rooms can be seen on the floor plans, along with their functions, as shown in Figure 2 to Figure 7.

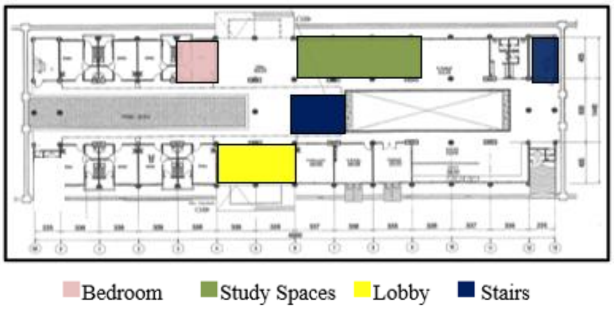


Figure 2. Sampling of spaces on the first floor of building A

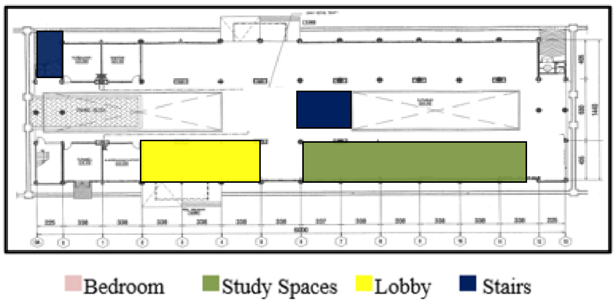


Figure 3. Sampling of spaces on the first floor of building B

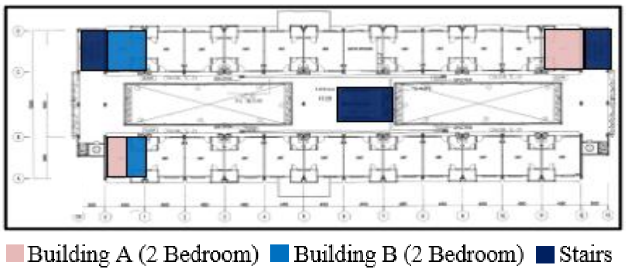


Figure 4. Sampling of spaces on the second floor of building A & B

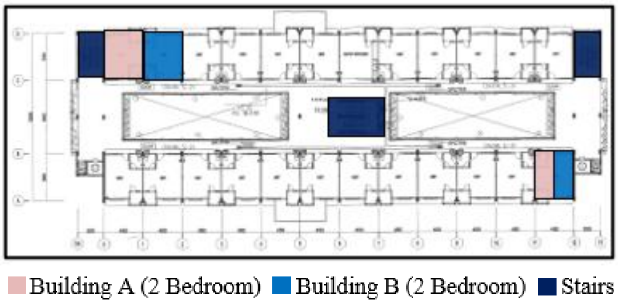


Figure 5. Sampling of spaces on the third floor of building A & B

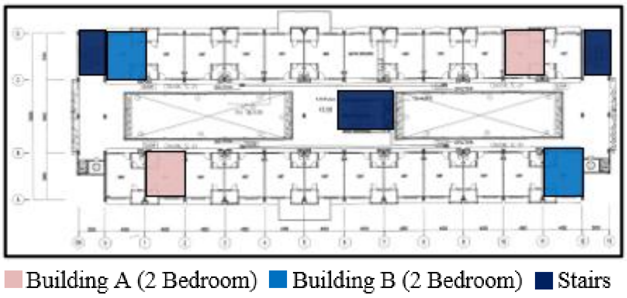


Figure 6. Sampling of spaces on the fourth floor of building A & B

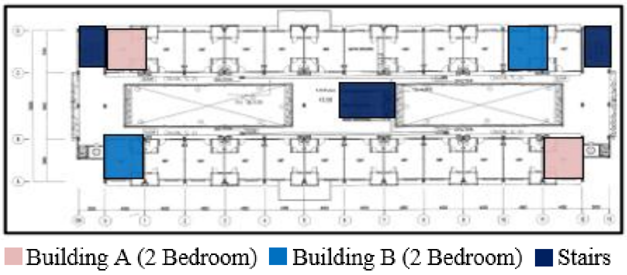


Figure 7. Sampling of spaces on the fifth floor of building A & B

The observed rooms are marked with colors other than white. Field inspections and measurements were carried out in March under clear weather conditions. Natural lighting measurements were taken in the morning (09:00 – 10:30 WIB) and in the afternoon (13:00 – 14:30 WIB), while artificial lighting measurements were conducted in the evening (19:00 – 20:30 WIB). Temperature and humidity measurements were performed three times a day, in the morning, afternoon, and evening, at the same times as the lighting measurements in each predetermined room.

2.5.2 Measuring Instrument

This study used the 4-in-1 Environmental Meter, model Extech 45170 can be seen in Figure 8. This instrument measures lighting levels, temperature, and humidity. Its accuracy for measuring these is ±5% rdg, ±1.2 °C, and ±4% RH (for 10% to 70% RH) or ±4% rdg + 1.2% RH (> 70% RH), respectively.

Figure 8. 4 in 1 Environmental Meter

3. Result

3.1 Lighting Levels

Visual comfort indicators are assessed using natural and artificial lighting levels. The evaluation results based on occupant perception show that the natural lighting levels on the eastern and western sides of the dormitory buildings are 3.41 and 3.54, respectively, while the artificial lighting levels on the eastern and western sides of the buildings are 3.47 and 3.15, respectively. All these values fall into the good category, nearing very good can be seen in Figure 9 and Figure 10.

Based on Figure 11 to Figure 15, the field measurement results for the sub-indicator of natural lighting levels in the morning and afternoon on the eastern and western sides of the dormitory buildings show that the overall lighting meets the standards referenced in SNI 6197:2020. For the sub-indicator of artificial lighting, the field measurement results in Figure 11 to Figure 15 indicate that the artificial lighting levels in the common areas on the eastern and western sides of the dormitory buildings mostly do not meet the standards. The rooms that do not meet the artificial lighting standards include the corridors on both the eastern and western sides.

The occupants' perception of natural lighting comfort aligns with the field measurement results. However, the occupants' perception of artificial lighting comfort differs from the field measurement results. The occupants' perception of artificial lighting in the building is generally in the good category. At the same time, the measurement results indicate that natural and artificial lighting in certain areas of the building (corridors and stairs) does not meet the standards. Field measurements show that the average natural lighting levels in the central stairwell are 48 lux in the morning and 59 lux in the afternoon. The field measurements of artificial lighting levels in the eastern corridor, western corridor, central stairwell, northern stairwell, and southern stairwell are 82, 81, 61, 42, and 53 lux, respectively. The minimum requirement for natural and artificial lighting levels in corridors and stairwells, according to SNI 6197:2020, is 100 lux. The discrepancy between occupant perception and field measurement results may be due to occupants spending more time in the lobby, study rooms, and bedrooms. This leads to a generally good perception rating towards corridors and stairs lighting.

Meeting the natural lighting requirements in a dormitory room enhances the comfort of its occupants during activities [19]. The average natural lighting levels in common rooms on the eastern and western sides of the dormitory building in the morning are 194 lux and 202 lux, respectively. In the afternoon, they are 233 lux and 242 lux, respectively, with a minimum standard of 100 lux. Additionally, the average natural lighting levels in bedrooms on the eastern and western sides in the morning are 134 lux and 150 lux, respectively. In the afternoon, they are 148 lux and 175 lux, respectively, with a minimum standard of 50 lux.

The difference in lux levels between the eastern and western sides is due to the surrounding environment of the dormitory building. Based on field observations, the northern side has low-rise buildings, while the southern side has shops with a maximum height of about 8 meters. On the western side is a soccer field with sparse vegetation of approximately 8 meters in height. On the eastern side is a green open space with trees as tall as the dormitory building. The green open space on the eastern side impacts the natural lighting levels within the dormitory rooms. However, measurements show that the lighting levels in the eastern rooms still meet the established standards.

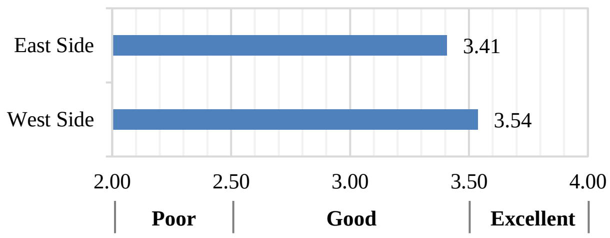


Figure 9. Diagram of residents' perception of natural lighting levels in a building.

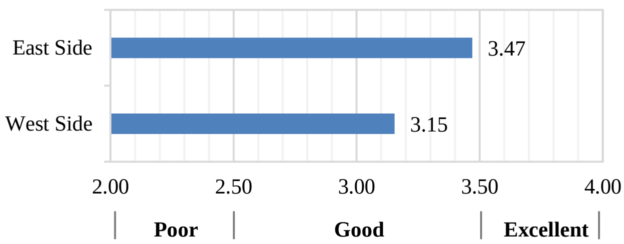


Figure 10. Diagram of residents' perception of artificial lighting levels in a building.

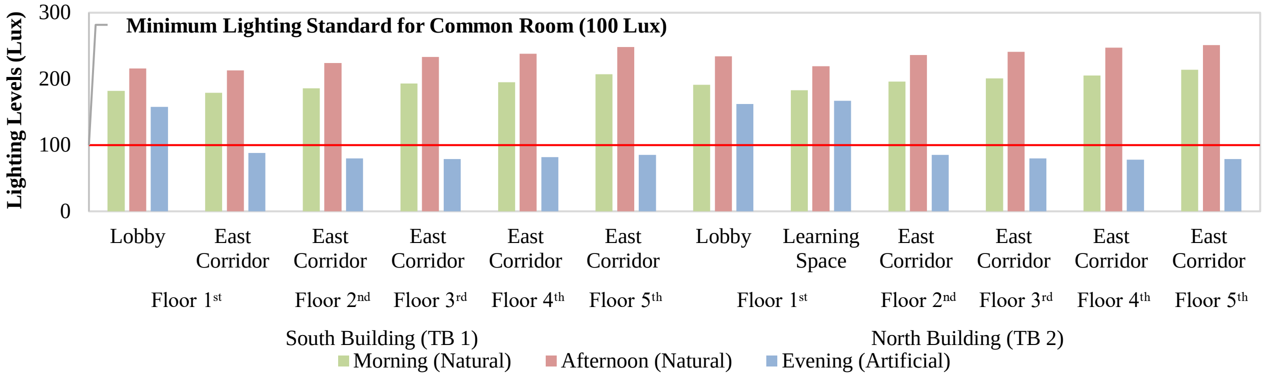


Figure 11. Diagram of lighting levels in the east side common rooms.

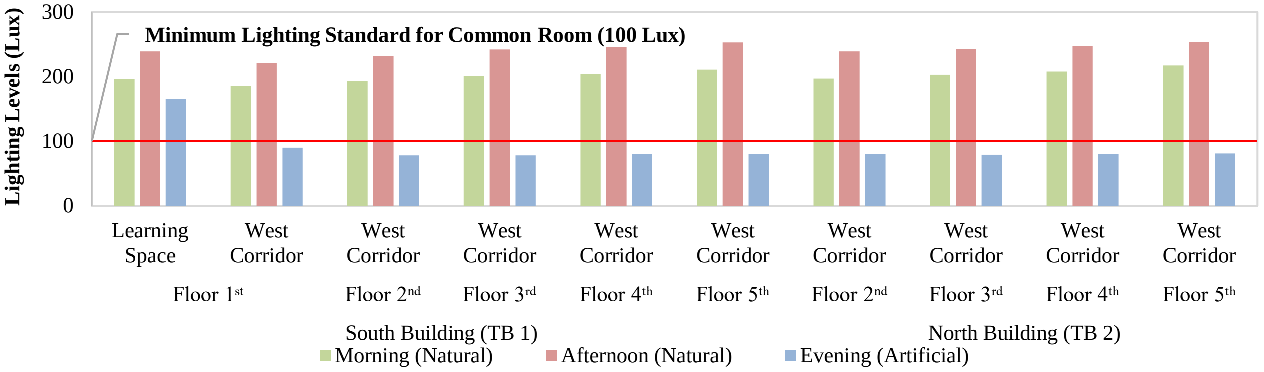


Figure 12. Diagram of lighting levels in the west side common rooms.

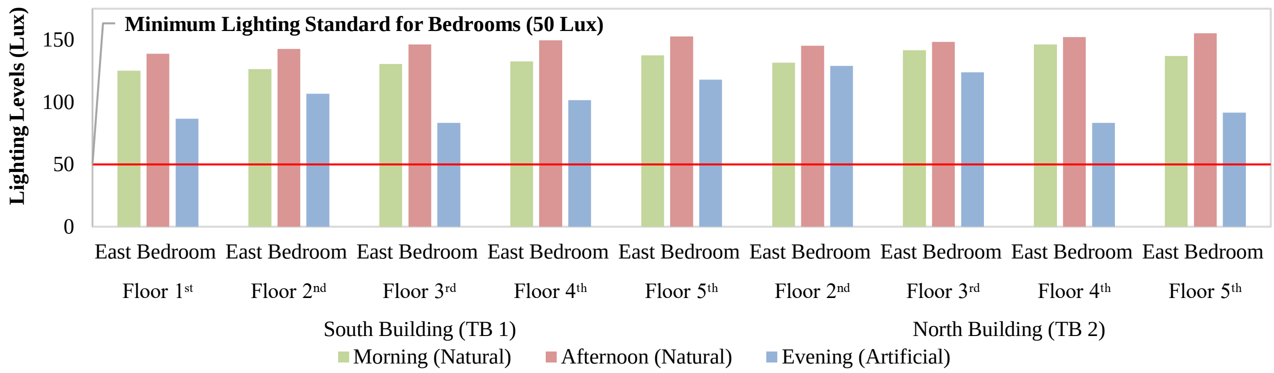


Figure 13. Diagram of lighting levels in the east side bedrooms.

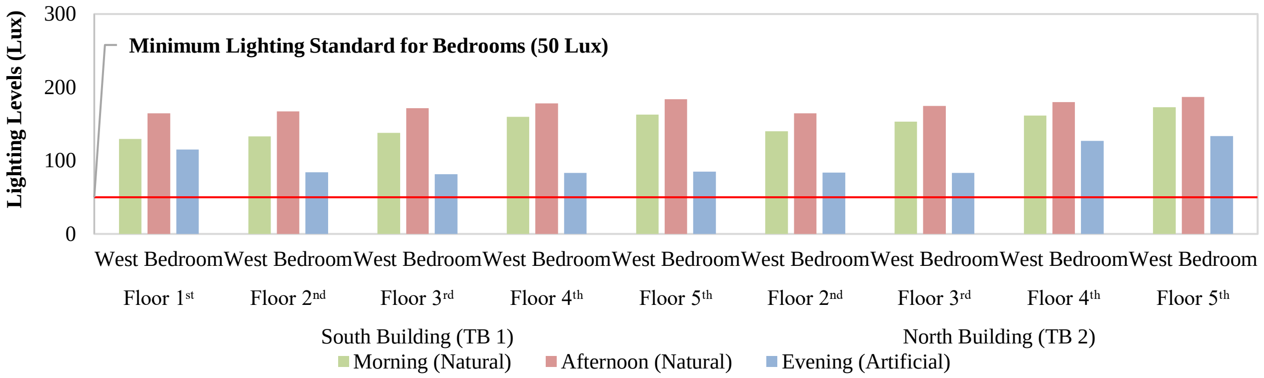


Figure 14. Diagram of lighting levels in the west side bedrooms.

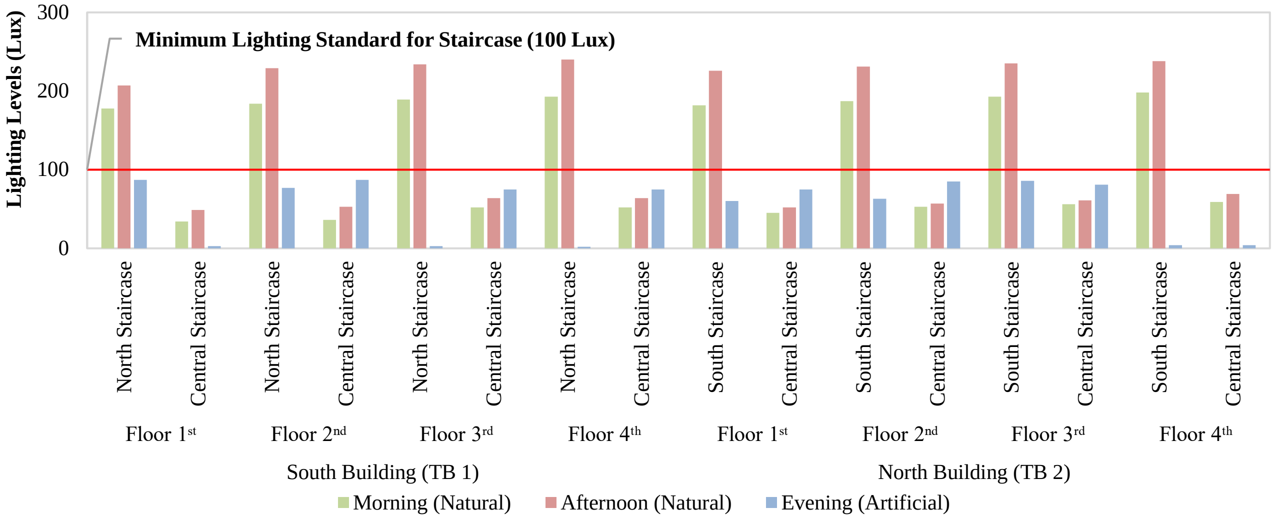


Figure 15. Diagram of lighting levels in the staircases.

Furthermore, the building orientation and openings also affect the natural lighting levels entering the dormitory. The dormitory has an orientation and openings facing east-west, and the building's layout extends from north to south. This orientation and opening direction allow for more intense direct sunlight exposure into the dormitory building, resulting in natural lighting levels exceeding the standards [20]. The higher the building, the greater the natural lighting levels on the upper floors compared to the lower ones [21]. Additionally, achieving adequate natural lighting levels is influenced by the area of ventilation openings in a room, which should be at least one-sixth of the floor area [22]. The area of ventilation openings available in the common room and bedrooms in the dormitory building, based on measurements, have met the requirements, with the percentage of the opening area to the floor area ranging from 40% to 60%. Therefore, achieving good lighting conditions in a building is influenced by several design factors, including the surrounding environment, building orientation, and the availability of openings [23].

The dormitory building's location ensures comfort, especially regarding natural lighting [24]. Additionally, the natural lighting measurements in the dormitory's northern and southern staircases meet the standards can be seen in Figure 14. However, the central staircase does not meet the natural lighting standards due to its position in the middle of the building, which limits optimal sunlight penetration and results in inadequate lighting.

Field measurements of artificial lighting levels in the corridors and stairs show they do not meet the required standards. This issue is mainly due to many non-functional or dead lights. Although some corridor lights are operational, their measured intensity along the corridor is suboptimal, resulting in low intensity or lumen levels. Insufficient or excessive lighting over extended periods can negatively impact health, particularly eye health [25].

The lighting levels in the dormitory building's lobby and study rooms meet the standards. The average artificial lighting levels in the lobby and study rooms are 160 lux and 166 lux, respectively. Additionally, artificial lighting levels in the bedrooms on the eastern and western sides of the building, as shown in Figure 12 and Figure 13, indicate that the bedrooms meet the standards for artificial lighting. Artificial lighting at night can enhance comfort and eye health for residents while engaging in activities [26].

3.2 Air Temperature

The results of dormitory occupants' perceptions of air temperature on the eastern and western sides of the building show average scores of 2.96 and 2.79, respectively. Although these perceptions fall into the good category, they are close to the less-than-good category as shown in Figure 16.

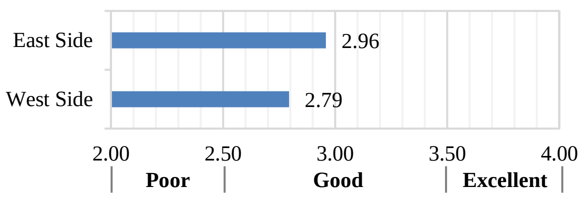


Figure 16. Diagram of residents' perception of Air Temperature in a building.

The occupants' perceptions align with the field inspection and measurement results. Based on Figure 17 to Figure 19, field measurements indicate that the air temperature in the dormitory building's rooms from morning to afternoon is in the comfortably warm category, nearing the uncomfortable threshold, while in the evening, the air temperature is approaching the optimally comfortable range.

Based on Figure 17 through Figure 19, the overall air temperature in each room of the dormitory building is in a comfortably warm range, though approaching the uncomfortable threshold. This is following the SNI 03-6572:2001 standard applicable in Indonesia. In the eastern rooms of the dormitory building, measurements show that air temperatures range from 28.90°C to 29.60°C in the morning, increase to 30.10°C to 30.40°C in the afternoon, and drop to 28.10°C to 28.60°C in the evening. Meanwhile, in the western rooms, morning temperatures range from 28.70°C to 29.50°C, rise to 30.30°C to 30.80°C in the afternoon, and range from 28.30°C to 29.10°C in the evening.

Morning air temperature measurements in the student dormitory building showed that the east side readings were higher than those on the west side. This is because the east side receives sunlight earlier than the west side. Conversely, in the afternoon, the temperature readings on the west side were higher than those on the east side due to the sun moving towards the west, resulting in more sunlight exposure on the west side. The orientation of a building relative to the sun significantly affects the indoor temperature [27]. A dormitory building oriented east-west tends to receive more intense sunlight than other orientations, leading to higher indoor air temperatures [28].

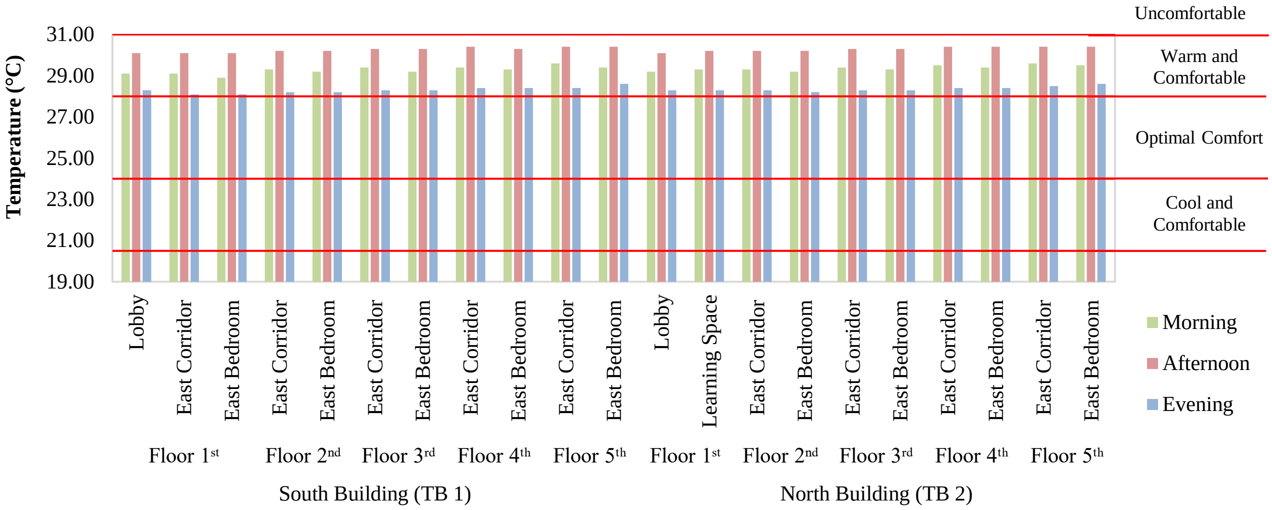


Figure 17. Diagrams of air temperature levels in the east side buildings TB 1 and TB 2.

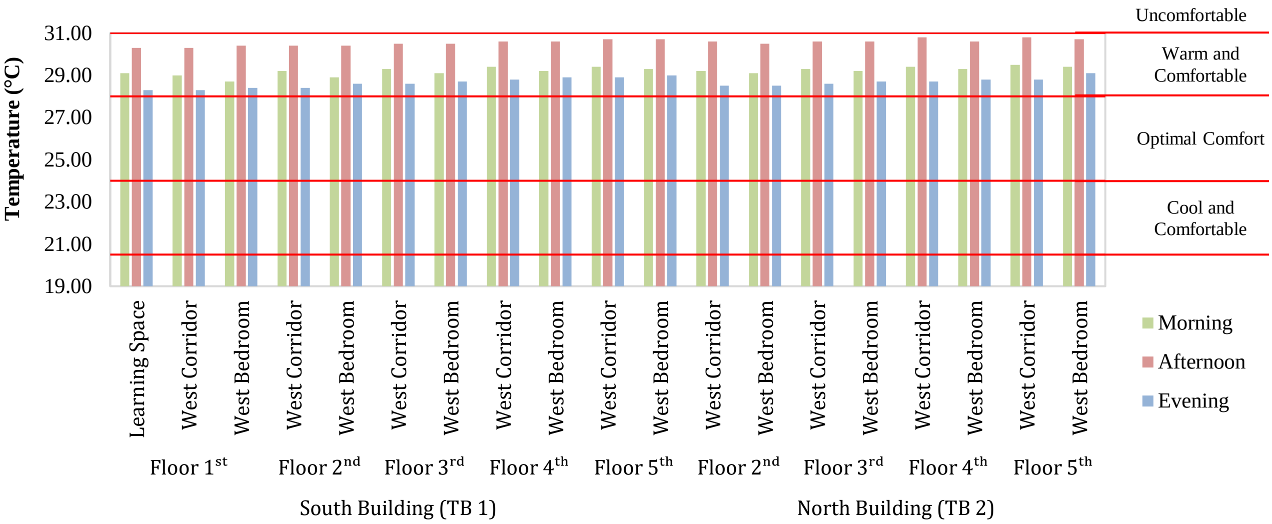


Figure 18. Diagrams of air temperature levels in the west side buildings TB 1 and TB 2.

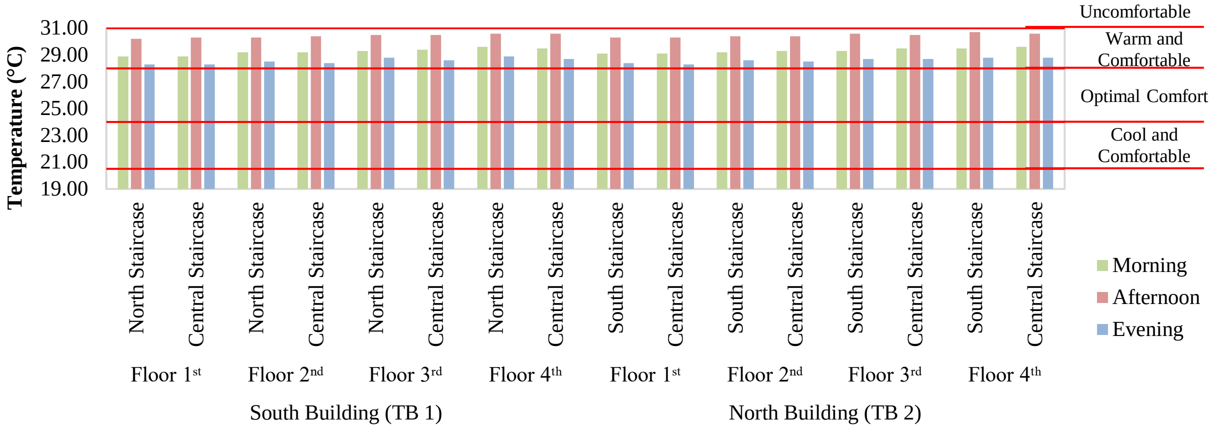


Figure 19. Diagrams of air temperature levels in the staircases buildings TB 1 and TB 2.

On the east side, the dormitory building is shielded by green open space. However, the presence of green open space on the east side has a minimal effect on the indoor air temperature. On the west side, a soccer field with minimal tree vegetation is approximately 8 meters tall along the dormitory and soccer field fence. This direct exposure to intense sunlight causes the indoor air temperature to rise significantly. Essentially, indoor air temperatures in buildings with west-facing openings are higher. High indoor temperatures are closely related to outdoor temperatures [29].

In addition to building orientation and openings, the availability of natural ventilation in the dormitory also influences indoor air temperatures. Field observations revealed that the dormitory uses cross ventilation, which is a factor that aids in the natural exchange of hot air within a room [30]. Moreover, the dormitory employs top-hung casement and horizontal pivoted windows/doors for natural ventilation. These openings facilitate the residents in regulating airflow and natural ventilation within the rooms. The percentage of natural ventilation openings to the floor area in the dormitory ranges from 15% to 20%, meeting the standards set by SNI 6572 of 2001, which require a minimum of 5% to 10% of the floor area. This indicates that the ventilation openings in the dormitory exceed the minimum standard.

However, measurement results suggest that room temperatures in the dormitory are almost close to uncomfortable conditions. This may be due to the average behavior of residents not opening the natural ventilation, thus hindering its function in providing natural air exchange to maintain comfortable indoor temperatures. Additionally, global warming factors also contribute to climate change, increasing average atmospheric temperatures and causing diverse impacts [31].

3.3 Humidity

Based on the perception of dormitory residents, the average humidity scores for rooms on the eastern and western sides of the building are 2.94 and 2.82, respectively. Ideal humidity levels in student living spaces are crucial for health and comfort, making these measurements important. Although both scores are categorized as good, they are close to the borderline of the less favorable category, which could affect resident comfort can be seen in Figure 20. These results are consistent with field inspections and measurements of room humidity in the dormitory building.

Field measurement results, as shown in Figure 21 through Figure 23, indicate that the overall room humidity does not meet the standards set by SNI 03-6572:2001. The SNI standard requires indoor air humidity to range between 40% and 60%. However, measurements on the eastern side show that the average humidity is 76.30% in the morning, 68.8% in the afternoon, and 73.80% in the evening. Meanwhile, field measurements on the western side of the dormitory show average humidity levels of 72.90% in the morning, 69.40% in the afternoon, and 71.70% in the evening. According to data from BMKG (https://www.bmkg.go.id/), the average humidity in Yogyakarta is 79% in the morning, 68% in the afternoon, and 84% in the evening. Given the high ambient humidity, achieving the humidity levels prescribed by SNI 03-6572:2001 necessitates indoor air conditioning.

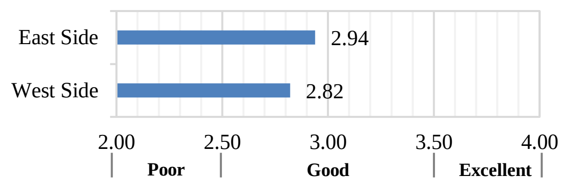


Figure 20. Diagram of residents' perception of humidity in a building.

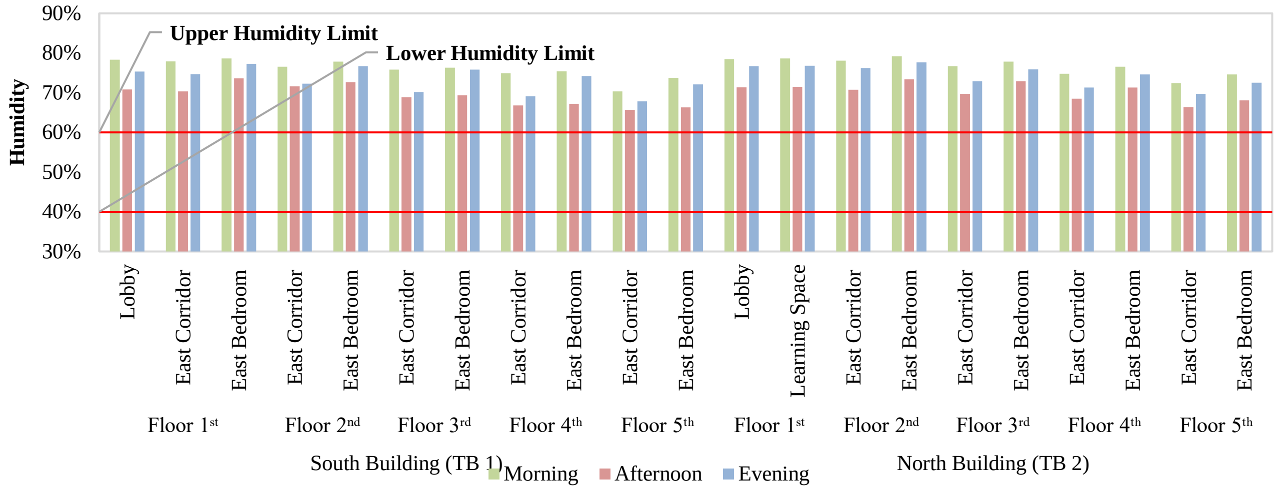


Figure 21. Diagram of humidity levels in the east side buildings TB 1 and TB 2.

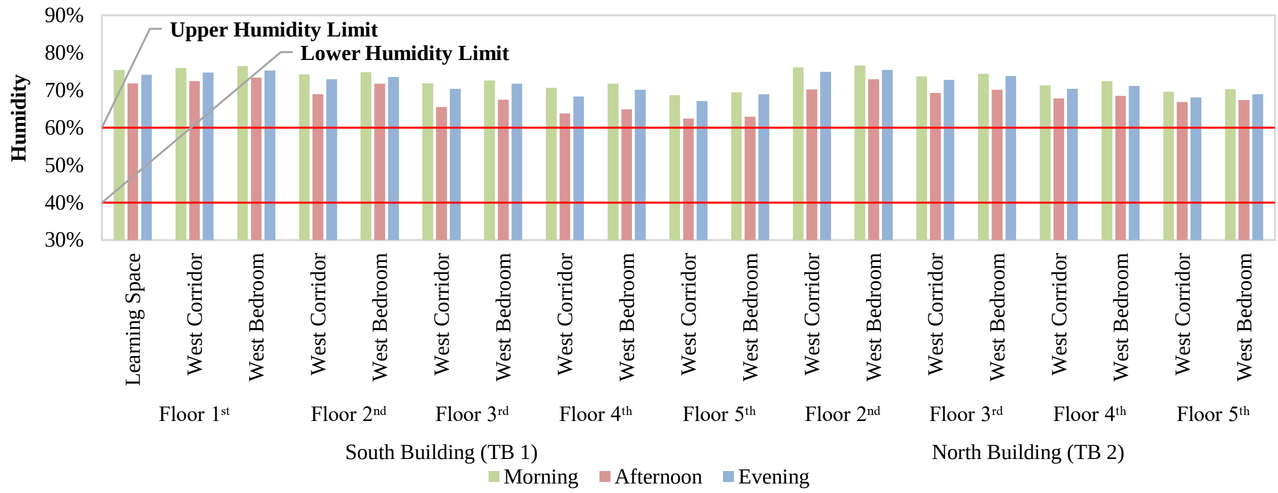


Figure 22. Diagram of humidity levels in the west side buildings TB 1 and TB 2.

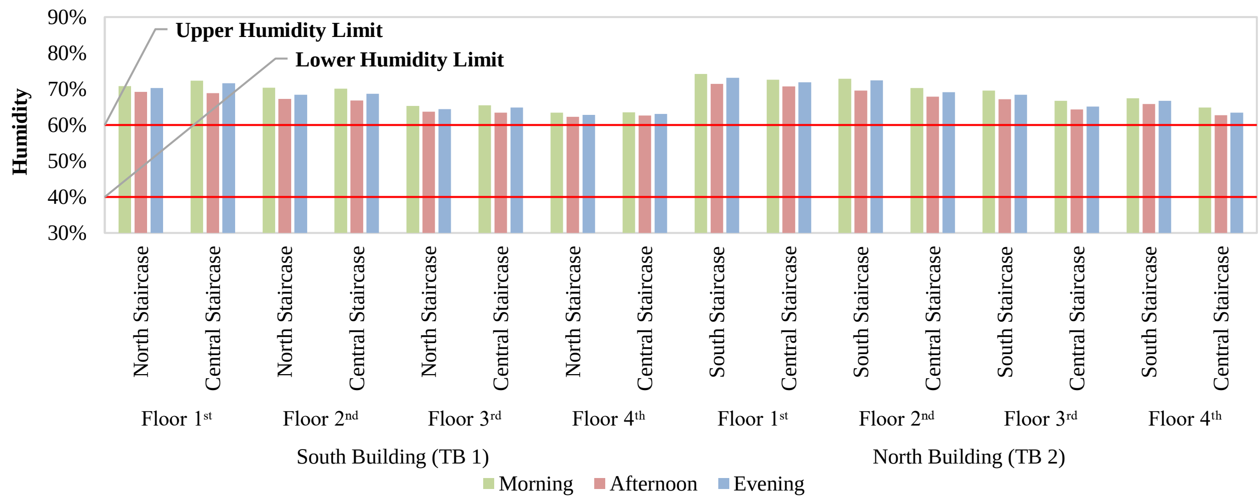


Figure 23. Diagrams of humidity levels in the staircases buildings TB 1 and TB 2.

Measurement results indicate that the eastern side of the dormitory has slightly higher humidity than the western side. Differences in room humidity between the eastern and western sides can be attributed to the surrounding environment. Field observations show that vegetation or green open spaces can cause higher humidity in rooms on the eastern side of the building. High vegetation density in an area tends to increase humidity due to the dense organic material covering the soil surface, which traps moisture—conversely, lower vegetation density results in lower humidity [32].

In addition to vegetation density, natural ventilation in the dormitory rooms can influence indoor humidity. Field observations indicate that dormitory residents typically keep doors and windows closed throughout the day, resulting in poor air circulation [33]. Poor air circulation leads to very high indoor humidity, creating a stuffy, oppressive, and hot environment. If left unaddressed, this can promote mold growth, produce unpleasant odors, and harm resident health. High humidity can also facilitate the growth of Mycobacterium tuberculosis bacteria, increasing the risk of tuberculosis (TB), which primarily affects the lungs [34].

4. Conclusion

In terms of visual comfort indicators in the dormitory building, based on the overall perception of the residents, they are categorized as good, nearly approaching very good. The resident's perception aligns with the results of visual comfort inspections and measurements in the student dormitory building. The levels of both natural and artificial lighting in the dormitory largely meet the standards established by SNI 6197 of 2020. Natural lighting in common areas and bedrooms on the east and west sides of the building meets the minimum standards, with average lighting levels successively exceeding 100 lux and 50 lux. The east-west orientation of the building, along with the presence of green open spaces on the east side and a field on the west side, also influences the level of natural lighting inside the building. Additionally, the levels of artificial lighting in various rooms within the dormitory, such as the lobby, study rooms, and bedrooms, generally meet the standards. However, some areas, including staircases and corridors, must meet artificial lighting standards due to many non-functioning lights and low lumen levels.

Based on the residents' perception of thermal comfort indicators in the dormitory building, they are considered good but nearly approaching poor. The resident's perception is consistent with the results of air temperature and humidity measurement. Room temperatures inside the building tend to be warm and nearly reach uncomfortable conditions, especially during midday when sunlight intensifies. This is attributed to the building's orientation, surrounding environment, and residents' behaviour of frequently closing natural ventilation, leading to suboptimal air circulation and persistently high air temperatures. Moreover, the average indoor humidity in the dormitory shows readings above 60%, exceeding the standards set for thermal comfort. Field measurement results also show that the humidity on the east side is different from the west side. The difference in humidity between the east and west sides is due to the density of vegetation around the building and residents' habits of keeping doors and windows closed throughout the day. Both sub-indicator measurement results in the dormitory align with the residents' perception assessment, which falls into the good and nearly approaching poor categories.

Overall, visual and thermal comfort in dormitory buildings is influenced by several factors, including building design, orientation, the surrounding environment, and residents' behaviour. Moreover, to enhance residents' comfort, improvements in artificial lighting systems, enhancement of natural ventilation, and education about the importance of good air circulation are necessary. With these efforts, a more comfortable environment can be created for all dormitory residents.

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