Evaluation of Facade Design for Thermal Comfort inBuilding Case Study: Digital Library Cube Room (5th floor) Universitas Negeri Medan

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Abstract. Humans need certain room conditions that are considered comfortable to be able to work properly and productively. Comfortable room conditions include thermal comfort, visual comfort and audio comfort. This study discusses the condition of thermal comfort and its relationship with the building facade, in a case study of the 5th floor cubical room of the Universitas Negeri Medan digital library building. Data retrieval was carried out using quantitative methods, namely measuring temperature, air flow and humidity at 3 different times (morning, afternoon, and evening) in the cubical room on the 5th floor of the Universitas Negeri Medan digital library building. Then the field data was analyzed using Autodesk Vasari software to compare the measurement results with thermal comfort standards. The final output of the research is a facade design recommendation on the 5th floor cubical room of the UniversitasNegeri Medan digital library which is expected to increase thermal comfort in the building.

Keywords: thermal comfort, cubical room, facade

1. Introduction

Universitas Negeri Medan has a vision to become a university that excels in the fields of education, industrial engineering and culture, to realize that Universitas Negeri Medan seeks to maximize existing facilities to support the achievement of this vision. One of them is the librabry digital facility which is the pride of Universitas Negeri Medan . The Unimed Digital Library building was inaugurated in 2013 with a building area of 13,585 m2 consisting of 5 floors.

On the 5th floor of the Unimed Digital Library Building, there is a cubicus room, which is a special study room measuring 3.7m x 3.6m which is a closed room equipped with tables and bookshelves where users can be more comfortable studying or reading.

Based on the results of surveys and interviews conducted as part of a preliminary study it was found that Most of these rooms are not in use or are in an empty condition. One of the reasons why users do not want to use the room is because of the hot condition of the room. A comfortable environment around during the learning and educational process is an important factor that can

ICIESC 2022, October 11, Medan, Indonesia

DOI 10.4108/eai.11-10-2022.2325474

influence the academic performance performed by the individual.

Comfort Heat is the feeling by which a person is comfortable with his situationroom temperature which in the context of feelings is described as a state in which a person doesnot feel hot or cold in a particular environment [1]

2. Literature Review

To organize their activities in the space to be carried out properly, humans need certain physical conditions around them that are considered comfortable. One of the requirements of a comfortable physical condition is a comfortable temperature, that is, a complete thermal condition of the air in the chamber that does not interfere with its body. Room temperature that is too low will cause cold or chills, so that the ability to move decreases. Meanwhile, high room temperature will result in overheating and sweating of the body, thus interfering with activities as well. It can be said that the working conditions will decrease or not be maximum in uncomfortable air conditions. According to Olgyay [10], the level of productivity and human health is greatly influenced by local climatic conditions. If the climatic conditions (related to air temperature, humidity, solar radiation, wind, rain, and so on) correspond to human physical needs, then the level of productivity can reach its maximum point. Similarly, the level of health will reach optimal if climatic conditions also support this achievement. The peak of human productivity and health is achieved in different climates from one place to another in this world. In the polar regions man reaches the maximum level of productivity in the summer (July – September), while in the subtropical regions optimal conditions are achieved in winter. Meanwhile, in the tropics with the scorching heat of the sun, humans are easily tired in the summer, so productivity is low. Air temperature is the factor that most affects the comfortable (thermal) conditions of humans.[2]

A further rise in room temperature does not cause the skin temperature to rise, but causes the skin to sweat. At a room temperature of about 20ºC a comfortable temperature for the skin is achieved. In addition to air temperature, the temperature of solar radiation from around the surface (ceilings, walls, doors, windows and floors) also affects the comfort of the space [3]. Meanwhile, the influence of air humidity on the comfort of the room is not as great as the influence of air temperature. The airspeed factor also affects thermal comfort, where the greater the air speed will affect the lower the temperature of human skin. According to Lippsmeir [7] the limits of comfort for equatorial conditions are in the air temperature range of 22.5ºC - 29ºC with air humidity of 20 – 50%. It is further explained that such comfort values should be considered with the possibility of a combination of heat radiation, air temperature, air humidity and airspeed. The completion achieved results in an effective temperature (TE). This effective temperature is obtained by trial experiments that include air temperature, air humidity and airspeed. According to the investigation, the limits of comfort for equatorial conditions are 19ºTE (lower limit) - 26ºTE (upper limit). At a temperature of 26ºTE, many humans begin to sweat. Meanwhile, human workability begins to decrease at a temperature of 26.5ºTE - 30ºTE. Environmental conditions began to be difficult for humans at a temperature of 33.5ºTE – 35.5ºTE and no longer allowed at a temperature of 35ºTE – 36ºTE.

Comfort consists of auditory comfort (acoustic), visual comfort (visual) and thermal comfort [6] Thermal comfort can be defined as a state of mind that expresses satisfactionwith the thermal environment [9]

Thermal comfort can also be defined as a condition where the body temperature is stable at a comfortable limit which means that the body does not feel disturbances caused by thermal factors that are possible by the balance of body temperature and the environment and climatic factors that are in the comfort zone [4].

3. Research Methods

3.1 Research Methods

The research site is in the Unimed Digital Library Building, with the object of research being the Cubical Space of the Unimed Digital Library. The position of the Cubicus Room that is the object of study is on the Southwest side of the Building on the V floor, with Space Code 177.5.34.

The activity begins by observing existing conditions through measurements of room temperature, wind, room humidity, room size, and materials used as consideration in determining the design criteria to be produced.

3.2 Research Materials and Tools

The materials needed are: existing images of cubical space, standard technical specifications for room comfort, and research objects obtained from direct observations and speakers. The tools used in this study are: laser / digital meter, digital thermal sensor camera, digital thermometer and hygrometer, and digital anemometer. For more details can be seen in table 1. below.

Table 1. Research Materials and Tools.

No	Tool Name & Specifications	Function
1	Digital Meter (Leica Disto D1)	This tool serves to measure the dimensions of the room in the form of length, width and height of the space andopenings
2	Thermal Sensor CameraDigital (Flir CX-3)	This tool serves to provide thermalimaging of an object and room. In addition, it can also serve as a tool for documenting objects and rooms
3	Thermometer dan Hygrometer Digital(ThermoPro)	This tool serves to measure the temperature and humidity of the room in the building
4	Anemoneter Digital(Hold Peak)	This tool serves to measure the speed of wind entering the building space

3.3 Research Design

- Research Approach

The method in the research uses a qualitative method approach with an Experimental Research approach.

- Data collection techniques

This study used primary and secondary data collection methods. Primary data is data that comes from the original or first source. Secondary data is data that refers to information collected from existing sources. Primary data collection uses the field survey method in the form of taking data on room area, opening area, room temperature data, wind and humidity. Secondary data obtained from a literature review of technical and non-technical requirements related to the thermal comfort of the building and questionnaires to room users

- Object of Research

The object of the study is the cubic room on the V floor of the Unimed Digital Library building with Room Code 177.5.34.

- Data analysis

This study uses the Experimental Research method, with the focus of the study aimed at determining the condition of the scale of the level of thermal comfort of the space in the cubicus room on the V floor of the Unimed Digital Library building. The influence of the design of the openings and the orientation of the building on the solar trajectory is evidenced by observation and data collection of room temperature, wind and humidity data. After that this data is compared with the Thermal comfort standard (19-26°TE).

After the thermal condition of the room is known, a simulation model is made including the details of the opening, the type of material and the design of the new opening. The next step is the implementation of testing with the help of the Autodesk Vasari program instrument. The results of the analysis of this program are in the form of air temperature, average solar radiation and air movement into the building space, then used as inputs to obtain a scale of the thermal comfort level of the cubicus room.

The first step, determines to redraw the AIGS building. The second step is to create a more detailed simulation model including the type of material, color and density of the material used. Finally, the third step of the test implementation with the help of the Autodesk Vasari software program instrument

4. Results and Discussion

4.1 Room Temperature

Variable Temperature is an important factor in the thermal comfort of a room. The tools used in this study to retrieve temperature data are Thermometer and Digital Hygrometer with the trademark ThermoPro. The placement of this research tool is placed in the position of the user's chair (in the middle of the room) as an illustration of the actual position of the space user using it daily. While the smartphone is placed in a room with a live position during the data retrieval process (1 week), so that the data obtained is not interrupted, as shown in Figure 1.

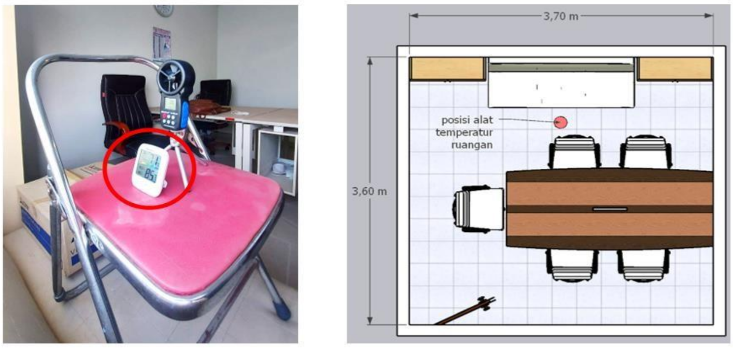

Fig. 1. Documentation of Room Temperature Data Collection (b) Position of Room Temperature Measuring Device in Cubic room

Data checking is carried out once every 3 days to ensure that the process of inputting temperature data is no problem. After 1 week, room temperature data can already be obtained and directly depicted through a temperature graph, as shown in Fig. 2.

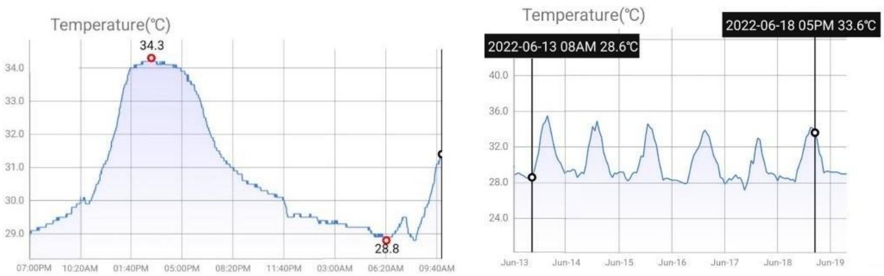

Fig. 2. (a) Daily Temperature (b) Weekly Temperature of Cubicus Inner Room 177.5.34 at the Digital Library Building, Universitas Negeri Medan

From the results of this 1-week room temperature measurement, information can be obtained that:

- The highest Daily Temperature indicated by the ThermoPro device is 34.3 °C between 01.40 WIB – 05.00 WB

The Curve Chart from Monday (June 13, 2022) to Saturday (June 18, 2022) shows almost the same shape, it can be concluded that the temperature conditions of this room in the morning (08.00 WIB) the average room temperature is estimated at 28-29 °C and in the day(at 12.00 WIB) the average temperature is estimated at 33-34 °C and in the afternoon (at 17.00 WIB) the average temperature is estimated at 31-32 ° C

4.2 Room Humidity

Relative humidity is the ratio between the actual amount of moisture in the air and the maximum amount of moisture that the air can hold at that air temperature. The relative humidity between 40% and 70% does not have a major impact on thermal comfort. An environment with high humidity has a lot of steam in the air, which prevents the evaporation of sweat from the skin. In a hot environment, humidity is important because less sweat evaporates when humidity is high (80%+). The room humidity variable is obtained along with the room temperature data, using the same tool, namely ThermoPro, for more details can be seen in Figure 3.

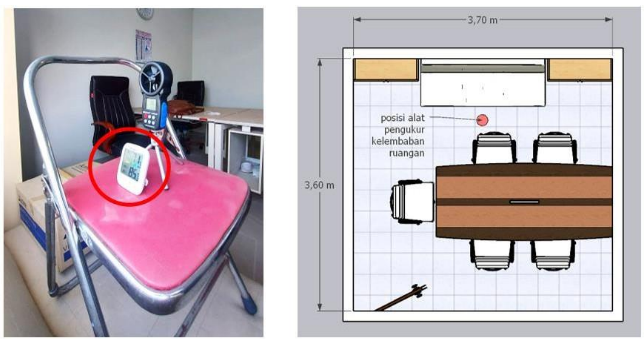

Fig. 3. (a) Documentation of Room Humidity Data Collection (b) Position of Room Humidity Measuring Device in Cubicus Room

From 1 week of data collection (June 13 – June 18, 2022) a graph of cubicroom humidity was obtained as shown in Figure 4

Fig.4. (a) Daily Humidity (b) Weekly Humidity of The Room In Cubicus 177.5.34 in the DigitalLibrary Building of Universitas Negeri Medan

4.3 Wind Speed

The influence of wind speed on thermal comfort is different if we compare it with other climatic factors that have been described above. The greater the value of wind speed (air) will affect the lower the average skin temperature (Tsk). When the airspeed increases from 0.00 m/s to 0.002

m/s, the Tsk value will drop by about 2°C. However, this only applies to environments where the air temperature is below the skin temperature. If the air temperature is higher than the skin temperature, the effect of airflow will be the same as other climatic factors, where an increase in wind speed will raise the skin temperature.

The tool used to retrieve wind speed data in this study is Anemoneter Digital with the trademark Hold Peak. Place this research tool placed in a position in front of the opening (window), where the window is at the maximum open condition as shown in Figure 5.

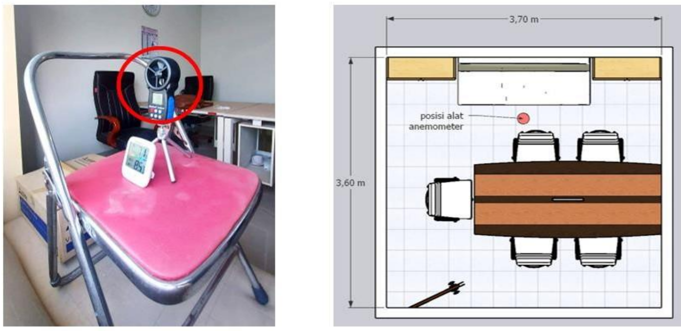

Fig. 5. (a) of Room Wind Speed Data Collection (b) Position of Room Humidity Measuring Device in Cubicus Room

After 1 week then the wind speed data can already be obtained and depicted through the wind speed as shown in the following Figure 6.

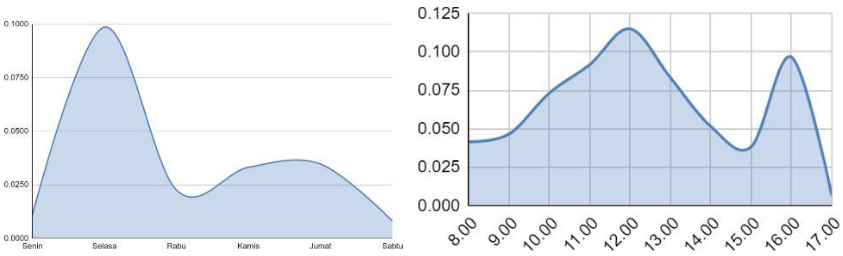

Fig. 6. (a) Daily Wind Speed (b) Weekly Wind Speed of Cubicus Inner Room 177.5.34 at the Digital Library Building of Universitas Negeri Medan

4.4 Solar Radiation

The orientation of the building to the sun will determine the amount of solar radiation that the building receives. The wider the field that receives solar radiation directly, the greater the heat that the building receives

The solar radiation received by the building will provide the effect of lighting (natural lighting) and heat that is passed on to the building. Measurement of solar radiation variables in this study using the Digital Thermal Sensor Camera tool with the Flir CX-3 trademark. This tool serves to provide an overview / imaging of the thermal condition of the space in the effect of solar radiation received by the building.

The use of this tool is carried out at 13.00 WIB where the room temperature is at the peak temperature. From the imaging of this tool, it can be known the areas that are the greatest exposure to heat to the room and the areas that are not exposed to solar heat radiation. For more details can be seen in Figure 7.

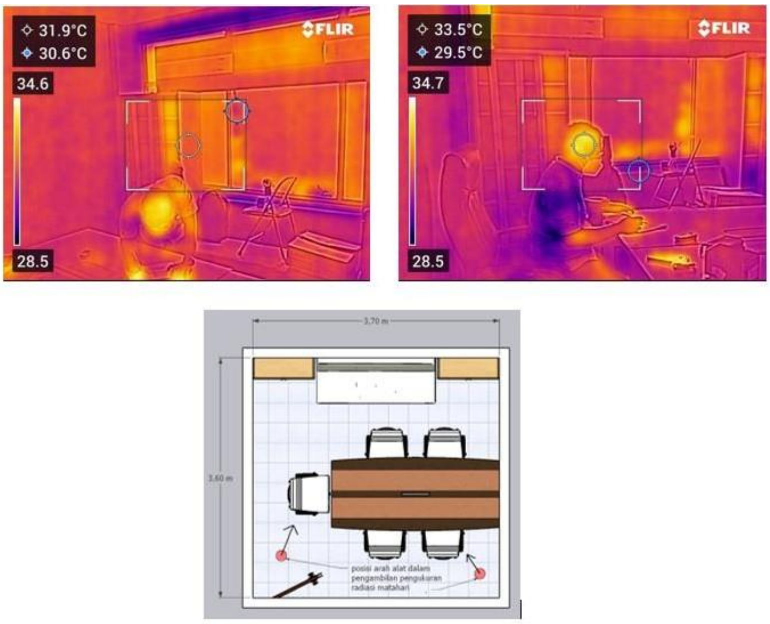

Figure 7. Documentation of Solar Radiation Data Collection Results (b) Tool Retrieval Positionin Cubicus Room

4.5 Data Analysis Results

On the Standardization of thermal comfort in Indonesia issued by SNI with the number 03-6572-2001 and linking Lippsmeier's research [7] (stating that at 26 ° C TE temperatures generally humans have begun to sweat and human endurance and workability begin to decrease) with the division of comfortable temperatures of Indonesians according to the LPMB PU Foundation, the temperature we need to be able to carry out properly is the optimal comfortable temperature(22.8 ° C - 25.8 ° C with a humidity of 70%). This figure is below the condition of air temperature in Indonesia which can reach 35 °C with a humidity of 80%. The Standard Procedure for Technical Planning for Energy Conservation in Building Buildings published by the LPMB-PU Foundation divides comfortable temperatures for Indonesians into three parts as follows, as shown in Table 2.

Table 2. Comfortable Temperature according to Standard Planning Procedurestechnical Energy Conservation in Buildings

No	Effective Temperature(ET)	Moisture (RH)
Comfortable CoolUpper Threshold	20,5°C - 22,8°C 24°C	50% 80%
Optimal ComfortUpper Threshold	22,8°C - 25,8°C 28°C	70%
Warm Cozy Upper Threshold	25,8C – 27,1°C 31°C	60%

From the analysis of the four variables above we can get the average value, like in table 3 show.

Tabel 3. Results of Variable Analysis of Thermal Comfort Cubicus Room of Digital Library Building

able ThermalComfort	Morning	Noon	Afternoon
Average Temperature	29 °C -31°C	31-34°C	32-34°C
Average humidity	65-70 %	70-80%	65-70 %
Average Wind Speed	0.025-0.085 m/s	0.085-0.01 m/s	0.025-0.085 m/s
Solar Radiation	Partial Heat	All-Round Heat	All-Round Heat

4.6 Facade Design Recommendations

From the analysis that has been carried out, the main cause of the thermal discomfort of the cubic room of the Digital Library Building is the factor of solar radiation that is passed to a large enough room and the air flow (wind speed) that cannot be maximized due to the wrong opening design. For this reason, it is necessary to make façade design recommendations based on the analysis of existing problems :

- It is necessary to make shadding (Shadowing) of buildings in the form of overhangs, in accordance with recommendations in other studies where overhang type shadding is very effective for buildings that have a North-South building orientation. The function of this shadding (Shadower) is to reduce exposure to solar radiation entering through windows / openings [8]
- window glass material is replaced using glass with an anti-UV (Ultra Violet) type that can retain heat from the outside
- The window opening model is designed to be the Casement Side Hung model, where with this opening model, the circumcision of air flow from the outside can enter the maximum into the building and cross ventilation will be created.

4.7 Thermal Comfort Related Computer Simulation After Façade Design Improvements

From the results of the recommendations that have been determined, design testing is carried out using Autodesk Vasari software. Autodesk Vasari itself is a software produced by Autodesk which is a combination of several modeling software, such as Autodesk revit (building modeling), Autodesk Ecotect (radiation modeling, temperature) and Autodesk CFC (air flow modeling). As a first step, after the indoor room is surveyed for its existing, the modeling is made both the length, width, and height of the cubicle room of the Unimed Digital Library Building, for this modeling can be helped by using Sketchup Software. Not forgetting that we must describe the openings of the building that correspond to the criteria of the previous design recommendations. For more details can be seen from figure 8

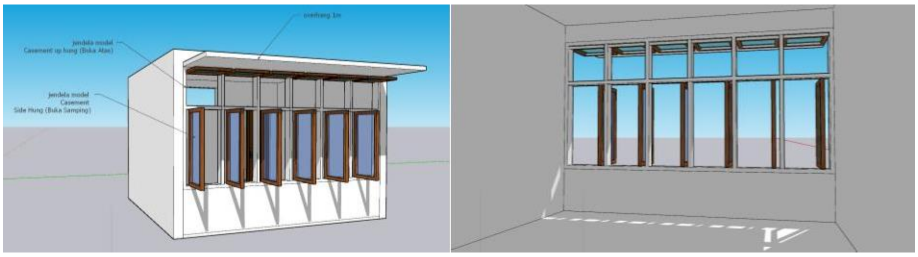

Figure 8. Modeling with Sketchup Software (a) Outdoor Space (b) Inner Space

After modeling the façade design, where what is focused is the design of the openings (windows) which initially consisted of 2 dead glass, and 1 live glass. However, this live glass opening can only open 10% of the opening, this is one of the causes of air flow not being able to enter optimally into the cubicus room.

The new façade design will provide better airflow, so that angina tau air from outside can enter the space optimally, and will eventually create conditions for cross-ventization in cubic rooms. With the creation of cross ventilation, the room temperature can be significantly lowered. For solar radiation problems, the façade concept is made by adding an overhang to the outside of the room, precisely above the window bouven. With this overhang / shadding, it is hoped that sunlight can be reduced to entering the room.

After the modeling sketchup, it was continued by importing this model into Autodesk Vasari to see the results of the simulation of solar radiation and air flow designs. For more details can be seen in Figure 9.

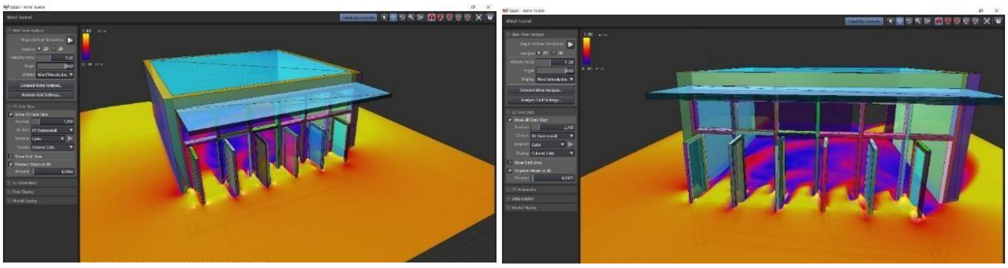

Figure 9. Simulation of Air Circulation Program Autodesk VASARI

Base on the results of simulations that have been carried out in the Autodesk VASARI program, it can be concluded that there is a better process of air flow from outside the room entering the cubicus room, this proves that the new façade design is effective in lowering the room temperature through better openings

5. Conclusions and Suggestions

5.1 Conclusions

The results of field data processing of the cubicus room of the Unimed digital library building show that the cubicus room conditions are not thermally comfortable to be a study room. The cubicus room should be a comfortable space both visually, thermally and noise, because it is used by lecturers in compiling their S3 disetation. From the results of the analysis, the causes of thermal discomfort were high room temperature and poor natural air circulation due to the wrong design of the openings (windows). Plus the factor of the absence of shadding elements in each opening / window, this will certainly make solar radiation directly enter the cubicus room without any obstruction.

To solve this problem, it is necessary to redesign the openings and façade elements that are in this cubicle room area. One of them is by changing the concept of openings to the Casement Side Hung system, with this system air circulation becomes more optimal. In addition, a 1-meter-long overhang element was added to reduce solar radiation into the Unimed digital library cubicle room building. To convince the design concept, a simulation of air flow and incoming solar radiation was carried out using the Autodesk VASARI application, from the results of the simulation, it can be concluded that the new opening design and the addition of overhangs are effective in making air circulation optimal and making the room thermally comfortable.

5.2 Suggestions

Some of the things suggested for related parties include:

1) Policy Determinants at Unimed Campus: it is advisable to consider this new façade design plan so that cubical space becomes more thermally comfortable

2) Cubicus space user ; With the presence of thermal comfort in cubicle space, space users will feel more at home lingering and focusing on completing their studies, as well as reducing the use of portable fans or air conditioners which are the choice of users today.

3) Students (who take Building Physics courses); by doing research and producing outputs in the form of teaching materials containing knowledge of technical and non-technical knowledge of the design of openings and facade elements, students are able to understand the concept of thermal comfort of a building.

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