Optimization of Thermal Comfort Based on Overhang Length on Widya Puraya Building at Diponegoro University

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Abstract
Buildings in humid tropical climates such as Indonesia frequently encounter thermal comfort issues due to high solar radiation exposure. This study aims to evaluate the effect of overhang length variations on indoor thermal comfort in Widya Puraya Building, Diponegoro University. A quantitative-descriptive and evaluative method was applied using Rhinoceros 3D version 8 integrated with Grasshopper, and Ladybug and Honeybee plug-ins for climate-based thermal simulation. Thermal comfort assessment employed the Predicted Mean Vote (PMV) index. The results indicate that longer overhangs significantly improve indoor thermal comfort and can serve as a reference for adaptive and energy-efficient tropical building design.

Keywords: Thermal Simulation, Tropical Architecture, PMV, Passive Strategy
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INTRODUCTION

Indonesia, as a country with thousands of islands, experiences a hot and humid climate across most of its regions. Throughout the year, the country goes through two seasons: the rainy season and the dry season. In many regions, the rainy season occurs from October to March, slightly reducing outdoor air temperatures, while the dry season happens from April to September (Karyono, 2016). The hot and humid tropical climate is characterized by prolonged warm periods, where outdoor environments often feel more comfortable than indoors, especially without air conditioning. Therefore, climate-responsive architecture is crucial when designing buildings in tropical regions. If overlooked, designers risk creating indoor environments that are overly hot and costly to maintain due to high cooling and artificial lighting demands, especially during the dry season (Nwalusi et al., 2022).

ASHRAE (1989) defines thermal comfort as a concept relating to an individual's level of satisfaction with the surrounding temperature conditions. Thus, comfort is understood empirically through one's physical experience and perception. The term refers to a person’s physiological response—consciously or unconsciously—when in a thermally appropriate condition. Defining a single neutral or ideal temperature for everyone is not accurate, as thermal comfort is subjective and varies by individual (Sitaggang, 2021). According to ISO 7730:2005 and the Predicted Mean Vote (PMV) method, thermal comfort refers to the level of satisfaction a person has with their thermal environment, assessed subjectively. The evaluation involves dry air temperature, clothing insulation (clo), metabolic rate (met), air velocity, humidity, and mean radiant temperature. In bioclimatic design, passive solar systems support heating, cooling, and lighting needs. The PMV index, introduced by Fanger (1982), reflects sensations of cold or heat on a scale from +3 (hot) to -3 (cold), with 0 representing neutrality. The dissatisfaction level can be assessed using PPD (Predicted Percentage of Dissatisfied), where a higher PPD means more occupants are uncomfortable (Susanti & Aulia, 2013).

The PMV-PPD model tends to be more accurate in air-conditioned buildings (AC) compared to those relying on natural ventilation (NV). Similar patterns are observed in mixed-mode buildings (MM) that combine mechanical cooling and natural ventilation. This is attributed to greater thermal control flexibility and occupants’ ability to adapt through clothing and expectations in NV environments. Nonetheless, PMV's accuracy is debated in varying conditions and appears to perform better in AC environments due to more stable thermal conditions (Humphreys & Nicol, 2002).

Manually calculating the PMV value developed by Fanger (1982) is complex. The influencing variables require extensive computation due to non-linear relationships and iterative solutions to nonlinear equations. As a result, the method is impractical for real-time applications. Therefore, computer modeling based on Fanger’s PMV model is needed to evaluate thermal comfort variables (Schaudienst & Vogdt, 2017).

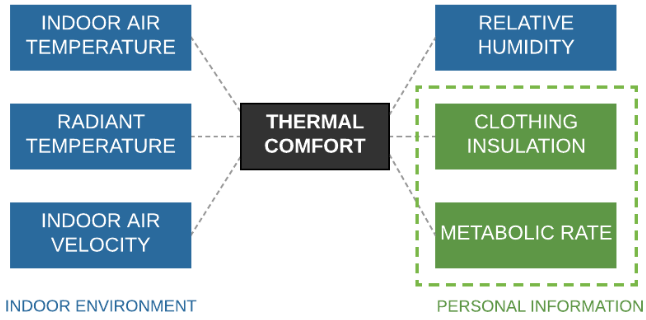

Image 1. 6 Thermal Comfort Factors
Source: (Gao et al., 2021)

A comfortable indoor space design requires consideration of various factors, including microclimate conditions such as humidity, air temperature, and airflow. Moreover, human physiological aspects—like the type of activity performed and the clothing worn indoors—also influence comfort levels (Nasrullah & Hamdy, 2024). In hot and humid climates, although preventing solar radiation is a key concern, one downside of using shading devices is the potential reduction in natural lighting (both direct sunlight and daylight). This can result in increased use of artificial lighting as a consequence (Ossen et al., 2005).

In general, shading strategies can be classified into three categories. First, natural shading, which relies on elements like trees or self-shading effects created by the building's orientation. Second, external shading devices, including horizontal, vertical, and egg-crate (louvered) structures mounted outside the building. Third, internal shading systems such as horizontal blinds (venetian blinds) and roller screens installed indoors (Ossen et al., 2005).

Optimal shading plays an important role in reducing the intensity of sunlight entering the building and supporting effective indoor air circulation. This helps minimize heat gain or loss within the structure. Thermal energy loss is a common issue, especially in buildings lacking efficient design or proper thermal protection elements. Consequently, more energy is needed for heating or cooling systems, ultimately increasing operational costs and greenhouse gas emissions (Idchabani et al., 2017).

Shading systems are designed to control the intensity of solar radiation entering a building—allowing sufficient daylight while preventing overheating. One effective method is the use of overhangs (roof extensions), which cast optimal shadows inside the space. Proper shading design reduces the reliance on artificial lighting and helps maintain a comfortable indoor temperature (Nikolaou et al., 2007). In tropical climates, buildings often adopt wide overhang roofs to respond to environmental conditions. High temperatures, humidity, and intense solar exposure affect indoor thermal comfort (Yoon & Bae, 2020).

Overhangs, also known as eaves or roof extensions, are one of the primary methods for regulating solar intensity entering a building. These are fixed or permanent structural elements that cannot be moved or adjusted. While their fixed nature limits user flexibility, overhangs are still effective in reducing solar radiation exposure and enhancing thermal comfort indoors (Nasution & Rambe, 2023). Overhangs are roof extensions that project beyond the wall line, serving as physical protection against rain and direct sunlight on the building facade—especially on openings like windows. In addition to weather protection, overhangs significantly reduce heat gain, which lowers cooling energy demands and improves overall thermal efficiency. Larger overhang dimensions generally perform better in blocking solar radiation but may reduce natural lighting. As a result, this can increase dependency on artificial lighting during daytime hours, leading to higher electricity consumption (Nikolaou et al., 2007).

In modern building design, geometric modeling plays a crucial role in analyzing energy performance and efficiency through accurate shading simulations (Ascione et al., 2020). A precise geometric model allows architects and engineers to predict how a building interacts with its surroundings, especially in terms of solar exposure and its implications on heating, cooling, and lighting needs (Patiño-Cambeiro et al., 2017). Understanding these interactions enables more effective design strategies to reduce energy consumption and enhance occupants' thermal comfort (Senthilkumar & Taj, 2020).

In Indonesia, research on thermal comfort in tropical buildings has largely emphasized ventilation strategies, building orientation, and the use of general shading devices (Karyono, 2016; Nwalusi et al., 2022). While these studies have enriched the discourse on passive design, empirical investigations that specifically examine overhang length as a determinant of thermal performance remain scarce. Overhangs, although widely applied in tropical architecture, are often regarded primarily as rain-protection elements rather than systematically evaluated components of thermal comfort strategies (Ossen et al., 2005; Nikolaou et al., 2007). This gap in knowledge creates an urgent need to reassess their functional role, particularly in urban contexts where high solar radiation and rising energy consumption for cooling demand more precise passive design interventions. The Widya Puraya Building at Diponegoro University provides a suitable case study, as it operates as a central administrative hub with high occupancy rates during working hours, where thermal comfort directly affects organizational productivity, user well-being, and operational efficiency.

The novelty of this study lies in its quantitative and parametric evaluation of overhang length variations under real building conditions in a humid tropical climate. Employing advanced simulation tools—Rhinoceros 3D integrated with Grasshopper, Ladybug, and Honeybee—this research systematically analyzes the thermal impact of different overhang dimensions across multiple orientations, referencing ISO 7730 and Fanger's PMV model (Fanger, 1982; Humphreys & Nicol, 2002; Gao et al., 2021). Through this approach, the study identifies the minimum effective threshold of overhang design required to maintain acceptable comfort levels without excessive reliance on mechanical cooling. The findings are expected to generate evidence-based guidelines for architects, engineers, and policymakers in developing sustainable, context-sensitive facade strategies. More broadly, the study underscores the importance of simple but effective passive design measures in reducing energy consumption and supporting climate-responsive architecture in Indonesia and other tropical regions (Idchabani et al., 2017; Yoon & Bae, 2020).

RESEARCH METHOD

This study employs a quantitative, descriptive, and evaluative research approach. Quantitative research emphasizes objective measurement of research variables through standardized instruments, enabling statistical processing of data to draw general conclusions applicable to a broader population (Kasiram, 2008). Descriptive methods are used to systematically and accurately describe facts, characteristics, and relationships among phenomena occurring in the present (Sugiyono, 2017). Meanwhile, evaluative research aims to assess the extent to which a program or project achieves its intended outcomes. Evaluation is conducted by collecting and analyzing data objectively to determine whether the program meets its set goals (Yuniarti et al., 2018).

The study utilizes two types of data sources: primary and secondary. Primary data were obtained through direct field measurements of the research object, including spatial dimensions measured with a laser distance meter and measuring tape to determine the length, width, and height of the rooms to be simulated. Additionally, building openings such as windows, doors, and shading devices were measured for their size and placement. Secondary data were obtained from relevant references such as journals, articles, books, and other supporting literature.

The primary data were used as the basis for sample room simulations to assess thermal comfort using the Predicted Mean Vote (PMV) method, conducted in Rhinoceros 3D version 8 software with Grasshopper, Ladybug, and Honeybee plug-ins. The simulation was carried out under two main scenarios: the existing configuration and a variation of overhang lengths. In the existing scenario, each room was simulated using the current overhang dimensions as observed on site. All simulation outcomes were then evaluated by comparing the Thermal Comfort Percentage (TCP) against a comfort threshold, where a TCP of at least 80% is considered indicative of a thermally comfortable space.

Furthermore, PMV and Predicted Percentage of Dissatisfied (PPD) indices were analyzed to determine the sensation of warmth or coolness perceived by occupants, as well as the proportion of thermal dissatisfaction. By employing a Building Performance Simulation (BPS) approach, this study enables a comprehensive and accurate evaluation of the influence of overhang length on indoor thermal comfort under conditions that closely approximate the actual building environment.

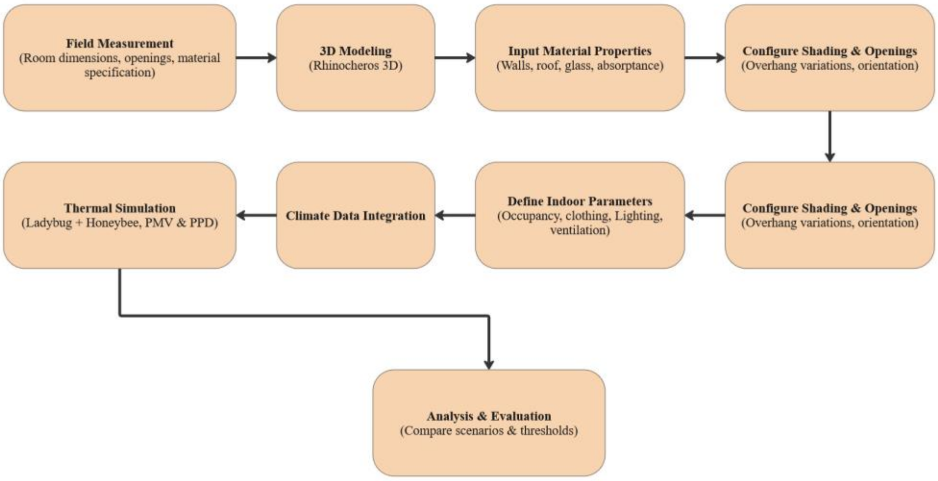

Image 2. Thermal Comfort Simulation Workflow
Source: Authors's Data, 2025

RESULT AND DISCUSSION

This research was conducted in the Widya Puraya Building, Diponegoro University, located in the Tembalang area, Semarang City, Central Java Province. The Widya Puraya Building is one of the main buildings within the Diponegoro University campus, serving a strategic function as the university's administrative center. This building accommodates various administrative and institutional service activities, including offices for university leadership, academic meeting rooms, and key service units such as the Integrated Service Unit (ULT), Legal, Administrative, and Protocol Divisions (HTLP). As the coordination center for both academic and non-academic activities, the Widya Puraya Building experiences high room utilization during working hours, making it a representative object for studying indoor thermal comfort performance in tropical office buildings.

The main material composing the overhangs of this building is concrete, used as a fixed structural element. For research purposes, simulations were conducted on four sample rooms within the building, representing four different cardinal orientations: northwest, southwest, southeast, and northeast. The selection of varied orientations was based on differences in solar radiation exposure throughout the day due to the dynamic position of the sun, which significantly affects the surface heat gain of the building and the indoor thermal conditions. These four sample rooms have different room dimensions, opening proportions, and overhang lengths, enabling comprehensive comparative analysis on the influence of overhang length variation on thermal comfort. The use of varied orientations also provides a more comprehensive picture of the overhangs' performance as a passive design strategy under various solar radiation exposure conditions typical of humid tropical climates.

Image 3. Map of Widya Puraya Building
Source: Google Earth, 2024

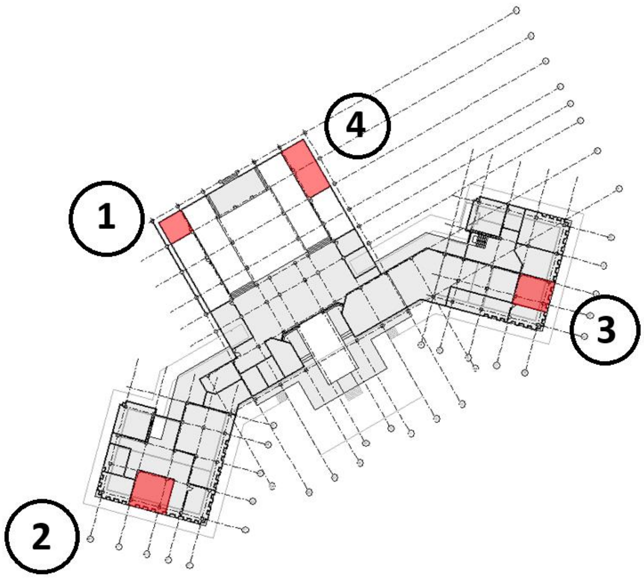

Image 4. Object Models
Source: Authors's Data, 2025

This study was conducted in the Widya Puraya Building, Diponegoro University, Semarang, to evaluate the effect of overhang length on indoor thermal comfort. Thermal simulations were performed using an annual approach with Rhinoceros 3D version 8 software, along with Grasshopper, Ladybug, and Honeybee. The climate data used was based on the EPW file for Semarang, with simulation times set from 08.00 to 16.00, representing active hours of building usage. Four rooms were selected as samples, with varied orientations—northwest, southwest, southeast, and northeast—and overhang lengths ranging from 0 meters, 0.5 meters, to 1.9 meters. In the modeling process, all spatial dimensions, opening areas, wall, roof, and floor materials, as well as glass specifications, were calculated to produce an accurate simulation representation of the building's existing condition. The complete data is shown in the table below:

Table 1. Room's sample programs

No	Name	Area (m2)	Volume (m3)	Opening	Orientation	People/m2	Metabolic Rate	Clothing	Overhang Length
1	Room 1	25	79,9	30,40%	North West	0,079	1,1	*Long-Shirt, Trousers (0,61)*	1,9m
2	Room 2	52	191,78	15,90%	South West	0,079	1,1	*Long-Shirt, Trousers (0,61)*	0,5m
3	Room 3	42	154,47	20,90%	South East	0,079	1,1	*Long-Shirt, Trousers (0,61)*	0,5m
4	Room 4	55	177,25	28,50%	North East	0,079	1,1	*Long-Shirt, Trousers (0,61)*	1,9m

Source: Authors's Data, 2025

Table 2. Material Specification

No	Material	d	K	Density	Specific Heat	Roughness	Thermal Absorption	Solar Absorption	Visible Absoptance
		(m)	(W/m·K)	(kg/m³)	(J/Kg·K)				
1	Concrete Slab	0,12	2,31	2322	832	*Medium Rough*	0,9	0,7	0,7
2	Plaster	0,025	0,533	1837	839,46	*Smooth*	0,9	0,32	0,7
3	Red Brick	0,1	0,9	1920	790	*Medium Rough*	0,9	0,65	0,65
4	Gypsum	0,0127	0,16	800	1090	*Medium Smooth*	0,9	0,5	0,5
5	Ceramic	0,02	1,29	2640	850	*Smooth*	0,9	0,26	0,65

Source: Authors's Data, 2025

Table 3. Window Specification

Window	Asahimas Indoflot
Depth	2mm
U factor	5,9
SHGC	0,8858
Tvis	0,91

Source: Authors's Data, 2025

The software used to estimate the environmental performance of the research object is Rhinoceros 3D version 8.0, integrated with the Grasshopper plug-in, Ladybug (version 1.80), and Honeybee. These tools offer a Python-based visual interface with various components for simulating building energy performance. Their application in Building Performance Optimization (BPO) research has been widely adopted in various countries. BPO is carried out through a multi-parameter approach simultaneously, using simulation and optimization processes to provide a comprehensive and integrated evaluation of building design (Kamel et al., 2024).

The simulation process in this study was conducted through eight systematic stages to ensure accuracy and precision in modeling the thermal performance of the space. The first stage began with the creation of a baseline geometric model based on actual dimension measurements of the research object. Measurements were taken in detail, including the room's length, width, height, and the dimensions of openings (windows and doors), which were then digitally traced into a three-dimensional model using Rhinoceros 3D version 8 software.

The second stage involved determining the building material components by inputting construction type, layer thickness, thermal conductivity, density, specific heat capacity, and absorption and transmissivity coefficients, obtained from field measurements and technical literature references.

In the third stage, modeling of external shading elements was carried out, particularly the addition of roof overhangs as the main shading components, and the window opening configurations were adjusted according to existing conditions. The fourth stage included defining occupancy schedules, lighting loads, natural ventilation, air infiltration, and electrical equipment loads, tailored to the activity patterns of the space during building operating hours.

After all room parameters were input, the fifth stage involved dividing the room into sensor grids with a spacing of 50 cm between measurement points to enhance the accuracy of thermal condition distribution throughout the room.

The sixth stage included inputting the local Semarang climate data into the simulation model using an EPW (EnergyPlus Weather) file, integrated via the Ladybug plug-in. The EPW file contains daily and monthly climatological data such as air temperature, relative humidity, wind speed, and solar radiation intensity over a full year, which forms the basis for simulations based on real environmental conditions.

The seventh stage was the execution of thermal simulations for each spatial configuration and overhang length variation, where all previously input parameters were used to predict indoor thermal comfort conditions. In the eighth stage, the simulation results — including operative temperature, PMV (Predicted Mean Vote) values, and PPD (Predicted Percentage of Dissatisfied) — were processed and evaluated with reference to thermal comfort standards ISO 7730 and the PMV model developed by Fanger (1982). The evaluation was based on a maximum PPD threshold of 10% and a minimum Thermal Comfort Percentage (TCP) of 80% as indicators that the space is thermally comfortable for the majority of occupants.

Through this systematic simulation process, the thermal performance evaluation results for each overhang length variation scenario used in the study were obtained, making it possible to quantitatively and measurably determine the extent to which overhang design contributes to improving thermal comfort in humid tropical buildings. The following are the simulation results:

Simulation Result (Existing)

Table 4. Simulation Result Room 1 (existing overhang 1,9m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	86,0	75,9	90,3	89,5	93,3	91,0	85,0	87,0	89,5	95,2	89,5	93,4	88,8
2	PPD	7,0	7,6	6,7	6,7	6,3	6,5	7,3	7,0	6,8	6,3	6,8	6,4	6,8
3	Condition	-0,21	-0,24	-0,12	-0,01	0,04	0,00	-0,11	-0,11	-0,06	-0,04	-0,09	-0,13	-0,09

Source: Authors's Data, 2025

Table 5. Simulation Result Room 2 (existing overhang 0,5m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	72,6	61,4	79,70	84,7	89,1	86,4	76,5	82,1	87,7	93,6	81,6	84,0	81,6
2	PPD	8,2	9,0	7,7	7,1	6,8	7,1	8,2	7,6	6,9	6,4	7,4	7,2	7,5
3	Condition	-0,27	-0,30	-0,23	-0,18	-0,16	-0,19	-0,27	-0,23	-0,18	-0,15	-0,19	-0,20	-0,21

Source: Authors's Data, 2025

Table 6. Simulation Result Room 3 (existing overhang 0,5m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	77,2	65,1	85,23	87,5	91,7	88,8	8,0	84,8	90,7	96,1	85,4	87,8	79,0
2	PPD	7,8	8,6	7,3	6,8	6,5	6,8	7,8	7,3	6,7	6,2	7,0	6,9	7,1
3	Condition	-0,24	-0,28	-0,20	-0,15	-0,13	-0,17	-0,24	-0,21	-0,15	-0,12	-0,17	-0,17	-0,19

Source: Authors's Data, 2025

Table 7. Simulation Result Room 4 (existing overhang 1,9m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	77,9	65,8	87,25	86,1	90,6	89,0	81,6	83,6	88,3	94,9	83,2	89,5	84,8
2	PPD	7,7	8,4	7,2	6,8	6,5	6,7	7,7	7,2	6,8	6,2	7,1	6,8	7,1
3	Condition	-0,23	-0,27	-0,19	-0,12	-0,11	-0,14	-0,22	-0,19	-0,13	-0,10	-0,16	-0,16	-0,17

Source: Authors's Data, 2025

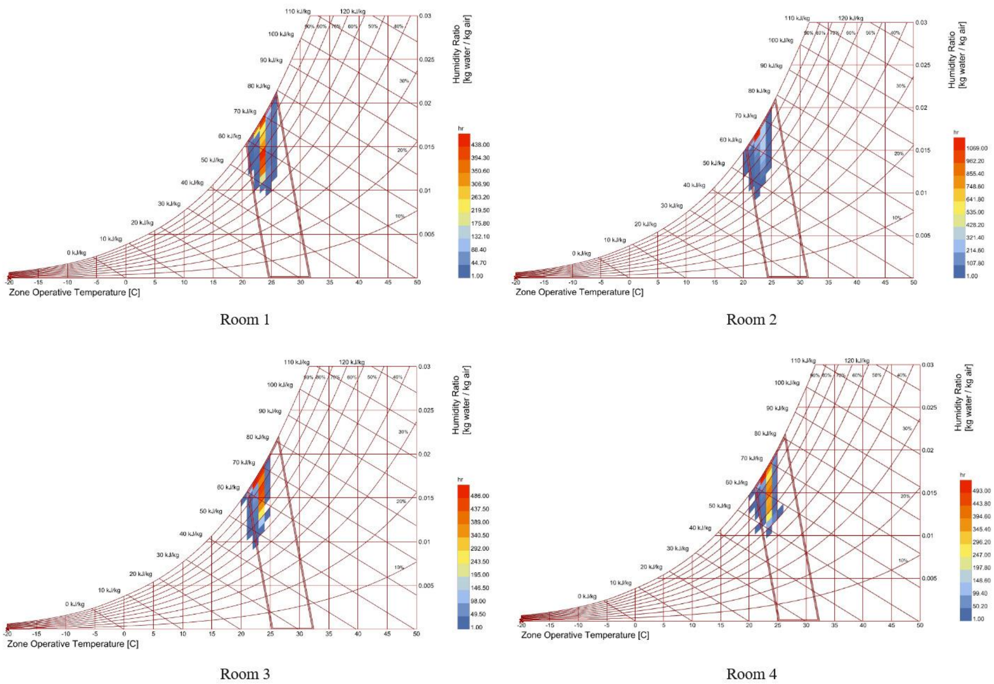

Image 5. Chart PMV (existing)
Source: Authors's Data, 2025

In the initial simulation stage using the existing configuration, the results showed that Room 1, which has an overhang of 1.9 meters, achieved a Thermal Comfort Percentage (TCP) of 88.8%, while Room 4 with a similar overhang recorded a TCP of 84.8%. In contrast, Room 2 and Room 3, which have overhangs of only 0.5 meters, recorded TCP values of 81.6% and 79%, respectively. These values indicate that, in general, all rooms have met the thermal comfort threshold with a TCP value of ≥ 80%, according to ISO 7730 and Fanger (1982), although Room 3 slightly falls below this threshold. It is important to note that the differences in results between rooms are influenced by orientation variations, where northwest and northeast orientations are more exposed to direct solar radiation compared to southeast and southwest orientations, making the role of overhangs more significant in certain orientations.

Simulation Result (Conditioned)

Table 8. Existing result room 1 (existing overhang 0,5m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	84,8	75,3	86,85	82,5	82,8	82,2	76,6	83,0	82,9	88,2	83,1	89,7	83,2
2	PPD	7,4	8,0	7,2	8,4	8,2	8,6	9,1	8,3	8,6	7,8	8,2	7,1	8,1
3	Condition	-0,13	-0,17	-0,09	0,05	0,09	0,07	-0,03	-0,02	0,05	0,07	0,00	-0,03	-0,01

Source: Authors's Data, 2025

Table 9. Existing result room 2 (existing overhang 0m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	75,3	63,0	81,21	84,2	89,5	86,4	76,9	81,6	87,0	92,3	79,6	86,0	81,9
2	PPD	8,0	8,8	7,6	7,1	6,8	7,1	8,3	7,7	7,0	6,5	7,6	7,2	7,5

3	Condition	-0,23	-0,28	-0,22	-0,17	-0,16	-0,19	-0,27	-0,23	-0,17	-0,11	-0,12	-0,14	-0,19

Source: Authors's Data, 2025

Table 10. Existing result room 3 (existing overhang 0m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	78,7	66,0	85,91	85,3	89,1	90,3	81,2	85,4	89,0	93,6	82,9	89,2	84,7
2	PPD	7,6	8,4	7,3	6,9	6,6	6,7	7,7	7,2	6,8	6,3	7,2	6,9	7,1
3	Condition	-0,22	-0,26	-0,18	-0,12	-0,12	-0,16	-0,23	-0,20	-0,13	-0,08	-0,12	-0,14	-0,16

Source: Authors's Data, 2025

Table 11. Existing result room 4 (existing overhang 0,5m)

No	Name	Month												Avg
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	PMV Comfort Percentage	78,4	66,3	85,10	81,6	84,3	82,9	78,0	83,0	85,6	92,5	80,7	87,9	82,2
2	PPD	7,7	8,4	7,5	7,8	7,9	7,8	8,2	7,6	7,4	6,6	7,5	6,9	7,6
3	Condition	-0,21	-0,24	-0,12	-0,01	0,04	0,00	-0,11	-0,11	-0,06	-0,04	-0,09	-0,13	-0,09

Source: Authors's Data, 2025

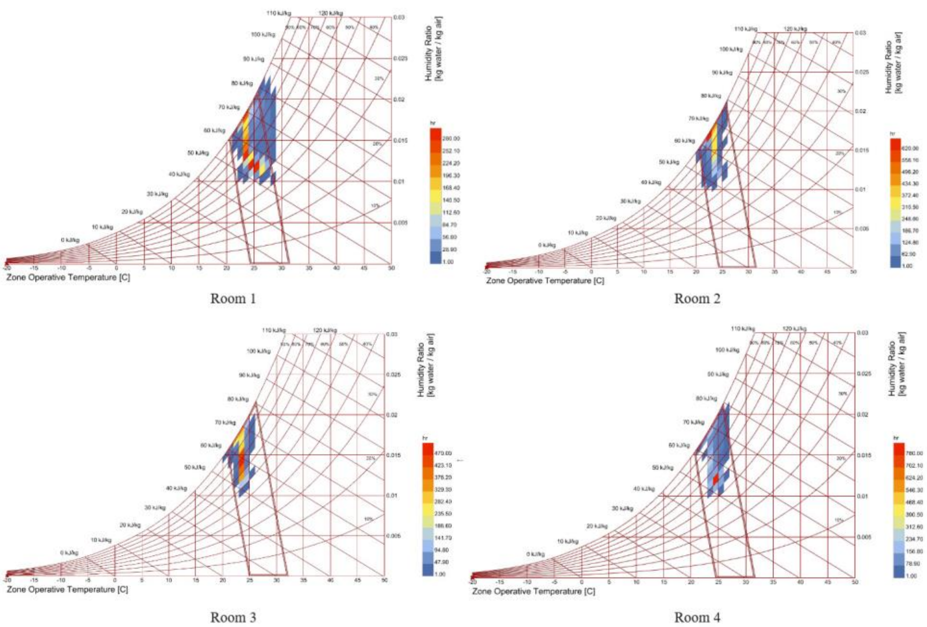

Image 6. Chart PMV (result)
Source: Authors's Data, 2025

Subsequently, an extended simulation was conducted by reducing the overhang length to test the minimum effective limit of overhangs as passive heat control elements. The results showed that in Room 1, reducing the overhang from 1.9 meters to 0.5 meters resulted in a decrease in TCP to 83.2%; however, this value still falls within the comfortable category. Room 2, where the overhang was completely removed, recorded a TCP of 81.9%, while Room 3 without an overhang achieved a TCP of 84.7%. Meanwhile, Room 4, with its overhang reduced to 0.5 meters, produced a TCP of 82.2%. These findings indicate that although the overhang length was reduced, thermal comfort could still be maintained, provided that other building design elements—such as window dimensions, envelope materials, and ventilation—are properly managed. This shows that in some orientations, an overhang length of at least 0.5 meters is sufficient to effectively maintain thermal comfort, while in others, even without overhangs, rooms may still meet comfort standards.

Further evaluation of the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) values showed that all rooms produced PMV values ranging from -0.30 to 0.09, indicating that occupants' thermal sensations remained within the neutral to slightly cool range. Meanwhile, PPD values ranged from 6.3% to 9.1%, suggesting that the level of occupant dissatisfaction with the thermal conditions was relatively low, and the majority of occupants experienced comfort during the simulated time period. The consistency of PMV and PPD results across all rooms reinforces the validity of the findings that reducing overhang length to a minimal threshold still maintains indoor thermal stability.

Furthermore, the analysis of these simulation results shows that indoor thermal comfort performance is not solely influenced by overhang length, but rather is the result of complex interactions among multiple design variables, including window dimensions, thermal properties of building materials, occupant activity levels, and local climatic parameters. In this simulation, a metabolic rate value of 1.1 met (equivalent to light office work activity) and a clothing insulation value of 0.61 clo (long-sleeved shirt and trousers) were used to represent typical office occupants. Additionally, the simulation included an indoor air movement (wind speed) parameter set to a stable condition to ensure consistency in PMV calculation results.

CONCLUSION

The results of this study indicate that a minimum overhang length of 0.5 meters on northwest and northeast orientations, as well as the absence of overhangs on southwest and southeast orientations, is still sufficient to meet thermal comfort standards based on PMV and TCP values. The simulation demonstrated that even when the overhang length was reduced from 1.9 meters to 0.5 meters on the northwest and northeast orientations—or eliminated entirely on the southwest and southeast orientations—the Thermal Comfort Percentage (TCP) of the studied rooms remained above the minimum threshold of 80%, as stipulated in thermal comfort standards (ISO 7730 and Fanger's model). Thus, a 0.5-meter overhang can be considered the minimum effective threshold for maintaining indoor thermal comfort in the Widya Puraya Building, particularly under humid tropical climate conditions such as in Semarang. This dimension can serve as a reference for facade design, ensuring material efficiency without compromising user comfort.

In general, it can be concluded that the use of a minimum 0.5-meter overhang is sufficiently effective in controlling thermal comfort in humid tropical buildings, particularly in Semarang. Longer overhangs still offer additional benefits, especially on orientations more exposed to direct sunlight. Aside from overhang length, a combination of window dimensions, wall material specifications, and ventilation arrangements also contributes significantly to optimizing indoor thermal comfort.

The interplay between wall materials and window size greatly affects thermal comfort. Large openings can maintain comfort if protected by overhangs, while smaller openings help block heat but require compatible materials and effective ventilation. A balanced design incorporating window dimensions, thermal materials, and protective elements such as overhangs is key to creating thermally comfortable and energy-efficient spaces. This study also emphasizes the importance of applying passive design strategies in tropical architecture, which not only enhances occupant comfort but also contributes to energy savings and carbon emission reduction. By optimizing overhang design, buildings can reduce mechanical cooling loads, maintain energy efficiency, and create a healthy and sustainably comfortable indoor environment. The findings of this study are expected to serve as practical guidance for architects designing in tropical climates to determine effective, efficient, and context-sensitive overhang dimensions.

RECOMMENDATION

Based on the results, it is recommended that future studies include more variations of building orientation and room types—such as classrooms or service areas—to understand the performance of overhangs in different functional contexts. In line with this, the use of various overhang materials, such as wood or reflective metals, should also be explored to assess their impact on thermal comfort and the visual integration of the building. The combination of overhang dimensions, material types, and room orientation will provide a more comprehensive understanding for designing effective passive strategies. Additionally, attention should be paid to the relationship between overhangs and natural lighting to ensure that heat control does not compromise visual quality and occupant comfort. Future research should also expand its scope to include various activity zones within buildings to enhance the applicability of the analysis and provide more holistic design guidelines.

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