THE INFLUENCE OF WWR AND SHADING DESIGN TO OTTV VALUE IN COWORKING SPACE YOGYAKARTA

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ABSTRACT: *The increasing trend of Work From Cafe (WFC) in urban areas has amplified the demand for comfortable indoor environments in commercial buildings like cafes and coworking spaces. However, many such spaces face overheating issues, compromising user comfort and efficiency. One key factor is the high Overall Thermal Transfer Value (OTTV) caused by large openings on east and west-facing walls without proper shading. This study analyzes the Eplus.Co Coffee & Co-working space in Yogyakarta to assess its OTTV performance. Using ASHRAE 90.1 standards, a maximum Window-to-Wall Ratio (WWR) of 40% was calculated for each side, while the OTTV was measured against the SNI 03-6389-2011 standard, with a maximum allowable value of 35 W/m². The analysis revealed that the building's WWR exceeds 40% on all sides, leading to OTTV values surpassing the standard, especially on the east (56.42 W/m²) and west (51.09 W/m²) walls. To address this, recommendations were made by studying shading designs. Horizontal shading was found to effectively reduce the OTTV, achieving a compliant value of 34.22 W/m². This research highlights the importance of proper shading and envelope design to enhance thermal comfort and energy efficiency in commercial buildings.*

Keywords: *Building Orientation, Co-Working Space, OTTV, Thermal Comfort.*

INTRODUCTION

One of the public spaces that use a lot of air conditioners is a Co-working space and café. It is a place where visitors can do various activities both hanging out with friends and working. The definition of co-working itself based on the UK Dictionary is "The use of an office or other working environment by people who are self-employed or working for different employers, typically so as to share equipment, ideas, and knowledge" (Hermawan, 2022). So in terms of activity, it can be interpreted as a work environment activity where people can work individually or collaborate with other individuals. Therefore, it is not uncommon now to find a co-working space that is integrated with a café, one of the factors is that the café is a public building that can be accessed to work together in a more relaxed atmosphere than an office. This is also supported by "The WFC phenomenon is currently a necessity for urban workers who are looking for a place to work with a new feel to reduce work boredom so that it can reduce the pressure of work targets. This also applies to students who have a lot of tasks, especially to complete their final project" (Septadinusastra, 2022).

The demand of people's need for WFCs is increasing each time, and many cafés have emerged that also provide co-working spaces. “Based on the data of restaurants and cafes in 2016 - 2020, it reached 5,675 throughout Indonesia” (Arisanti Petty, 2021), With an average visit duration of 2-3 hours (Haristianti et al., 2020). The more crowded the co-working space is, the more comfortable users are using the facility. One aspect of comfort working in an indoor area is thermal comfort. The thermal comfort aspect can be measured through room temperature and the least of heat radiation could transfer into the room. According to Idkhan et al., (2018) factors that affect thermal comfort are air temperature, air humidity, radiation on walls and roofs, air movement, lighting levels, and light distribution. The increase in room temperature is also caused by various factors, one of which is the number of openings in the building especially in parts of the building that are directly exposed to solar radiation. Other than the number of openings, according to (Ma et al., 2015) windows affect indoor temperature mainly through window type, gas tightness, and window size.

Picture 1 A building façade of Eplus Co Coffee & Coworking & 3D model
Image Source: https://www.archadipa.id/portfolio/eplus/ & personal documentation 2024

As mentioned in the previous paragraph, thermal comfort is an important aspect for co-working space and café users, where they usually spend a long time doing an activity, especially working. Therefore the use of case studies in this research is needed to measure whether is a café building has optimal building performance and comfortable for users or not. The case study of the selected building is Eplus.Co Coffee & Coworking. This building is located on Jl. Candi Gebang, Sleman Regency, Yogyakarta. This building was chosen because it has a building facade with many windows, moreover, the building facade faces east. As we know, buildings facing west or east are potentially exposed to direct solar radiation. In addition to the case of this building, the facade does not have shading to reduce heat penetration. Some shading devices that mostly found are balconies, louvers, horizontal overhangs, vertical fins, or other devices that incorporate a combination of horizontal and vertical shapes (egg-crate type)(Silalahi et al., 2021).

LITERATURE REVIEW

One of the thermal comfort factors mentioned in the paragraph above is heat transfer, where this aspect can be calculated using OTTV. Overall thermal transfer value (OTTV) measures the average heat gain transmitted into a completely enclosed building through its envelope and is one of the most popular performance-based methods (Chan et al., 2023). Especially in tropical countries that do not have a winter season. Tropical countries that have summer all year round, tend to depend on air conditioners which require a lot of energy. The concept of OTTV includes three basic elements of heat transfer: (1) solar radiation through glass, (2) heat conduction through opaque walls, and (3) heat conduction through glass (Imran, 2019). These three basic elements are the main elements measured in the building case study, where the building facade faces east and has many glass openings. Therefore with this OTTV method, the measurement of the energy saving of a building can be calculated through the amount of heat entering the building through its envelope, one of which is the window. By calculating the amount of heat entering the building, the use of air conditioners in buildings can be balanced to achieve sustainable building architecture.

Window-to-wall ratio (WWR) can be interpreted as a comparison between the total area of windows and the total area of walls in a building. This ratio is used to determine how big the part of the wall consists of windows. As stated supported by Goyal et al., (2022) WWR is the ratio of vertical fenestration area to gross exterior wall area. The use of the right window area or Window-toWall Ratio in the form of an envelope, not only has the potential to regulate the entry of heat into the building but will also control the influx of natural light (Purwoko & Purwanto, 2022). In addition, to achieve energy-efficient building qualification, a series of energy analysis parameters are required to meet the energy conservation criteria of the building envelope, including WWR, type, thickness, and color of external walls, shading devices, glass conductance, roof and wall insulation, roof and wall absorption, facing direction and others (Iqbal, 2015). These criteria mention facing direction, which is relevant to the specific case study of a building facing east with lots of glass openings.

Therefore facing direction is one of the parameters that will be measured in the WWR percentage.

Every building requires a different percentage of WWR due to the need for specific activities in a building. Supported by Troup et al., (2019), WWR in each region has its standard provisions, which are based on standards determined by ASHRAE 90.1 specifies building characteristics to guarantee minimum energy performance across different US climate zones. It sets a maximum WWR of 40% for commercial buildings. Meanwhile, according to PMPUPR NO.21/ 2021, the percentage of WWR is recommended to be less than 30%. Comparing the two standards, the parameters that will be used are from ASHRAE 90.1 since this standard is more specific to the chosen typology which is a commercial building. Knowing the WWR value in the building case study will help calculate the OTTV result. Whether the percentage of WWR on each side of the building meets the standard or exceeds the standard.

The result value of OTTV with the help of WWR calculation shows the performance of the building heat transfer. Therefore the parameters of OTTV result should be determined. The OTTV value required by SNI 03-6389-2011 as a maximum energy-saving effort is 35 W/m2 (Puspanendah et al., 2022). The smaller the OTTV value, the smaller the heat transfer that occurs inside the building (Octarino et al., 2021). By limiting the OTTV to 35 W/m^2, the standard aims to encourage energy efficiency in buildings by reducing the amount of energy needed for cooling. These parameters will determine the OTTV value for each building area. If a specific area's OTTV exceeds the standard, it indicates poor heat transfer performance and requires design recommendations to reduce the OTTV to meet the standard.

An opening is important for commercial buildings, especially café & co-working spaces which require enough natural light to do working activities and liven up the ambiance. But if it is too large it might lead to a problem. Based on the context of the building covered by many large windows without any shading. It is assumed the building will feel hot, especially since the building faces east direction so at 8-9 am the sun's radiation will enter the building directly. The more the size of the window opening, then the Wall to Window Ratio value (WWR) will also increase and result in a value OTTV (Overall Thermal Transfer Value) is also included increase (Wibawa & Hutama, 2019). This statement supports the hypothesis, that the amount of openings in the building facade will affect the amount of heat that will be received by the building, so even the use of air conditioners will feel hot unless the use of air conditioners is very large, but this will affect the sustainability of the building.

This building has an interesting context to analyze because this building appears to have a high OTTV value, especially on the building facade which almost entirely uses glass. So the research question that arises:

1. Does Eplus.Co Coffee & Coworking produce OTTV values above or below the standard in each area of the building? And does the east and west areas have higher OTTV values than other areas?
2. If the OTTV value exceeds the standard, what improvements can be made?

METHODS

Data collection will be done quantitatively. First by measuring the single-story building from the width, length, and height of the building in order to calculate the total wall area of the building. Second by calculating the area that uses the air conditioner which in this building's case, the calculation only will be done in the indoor area. Third, define each type of window opening by (1) its measurement of the width, length, and height of each type of window opening, (2) the total opening area of each type of window, (3) the fenestration type which consists of material, SHGC, U Value, and shading, and (4) the last is the location of each window. Fourth, calculate the percentage of WWR in each area of the building. Last, all of the data collection will be calculated through OTTV spreadsheets where the calculation is simplified based on the OTTV formula SNI 03-6389-2011 in order to calculate the total of building OTTV value in Eplus.Co Coffee & Coworking. The results of the data will be analyzed and calculated whether the OTTV value results in the Eplus.Co Coffee & Coworking building in Yogyakarta is efficient or not. If it's not, there will be a design recommendation to make the building OTTV value efficient.

In order to calculate the percentage of WWR and the OTTV value, there are some formulas that could be applied. According to Khoukhi et al., (2020), to calculate WWR on each building area, it can be calculated using the formula below:

$$\textbf{WWR (\%)} = \frac{\textbf{Window Opening Area (m}^2\textbf{)}}{\textbf{Building Wall Area (m}^2\textbf{)}}$$

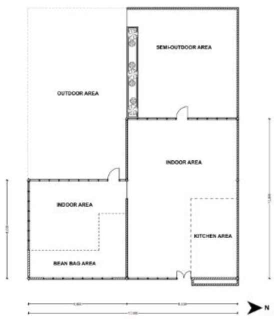
The standard of OTTV that has been determined by SNI 03-6389-2011 can be calculated using the following formula:

$$\textbf{OTTV} = \alpha\ [(UW \times (1- WWR) \times TDEk] + (Uf \times WWR \times \Delta T) + (SC \times WWR \times SF)$$

OTTV= Overall thermal transfer value (Watt/m^2);
α = solar absorptance;
UW = thermal transmittance through wall;
WWR = windows-to-wall ratio;
TDEk = temperature equivalent difference;
Uf = thermal transmittance through fenestration;
ΔT = building temperature difference between the outside and the inside;
SC = shading system coefficient;
SF = solar factor.

RESULT AND DISCUSSION

The research was carried out by taking data in the form of a building plan along with overall building dimensions. The data observed is in the form of floor plan dimensions and building height. From the building plan data obtained, it was identified that the building was divided into three types of space typologies: indoor rooms, semi-outdoor rooms, and outdoor rooms. The primary focus for the OTTV (Overall Thermal Transfer Value) analysis is on the indoor rooms, as these spaces are the most relevant for OTTV assessment. Which fulfills the requirement that the room must use the air conditioner.



Picture 2 A Floor Plan of Eplus Co Coffee & Coworking
Source: Personal Documentation, 2024

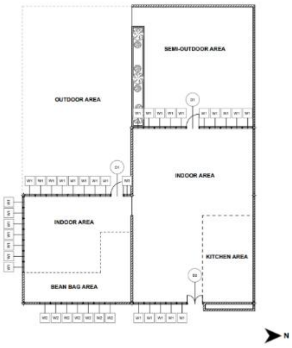
Total wall area data at each building orientation is needed in order to calculate the percentage of WWR. Because this research will only be conducted in the indoor area, the total wall area calculated is only in the indoor area.

Table 1 Total Wall Area of Each Building Orientation

Side Location	Height (m)	Length (m)	Total Wall Area (sqm)
North	3	13	39
South	3	8	24
East	3	17	51
West	3	17	51

Source: Personal Documentation, 2023

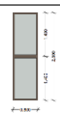
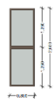
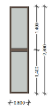
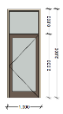
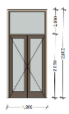
The indoor room context is directly exposed to sunlight, where this room is dominated by windows that face directly to the east side. Therefore the next step is collecting the data consisting of window type, dimension, fenestration, and its location on each side of the building to calculate the WWR (Wall to Window Ratio).



Picture 3 Opening Type Plan of Eplus Co Coffee & Coworking
Source: Personal Documentation, 2023

Based on the types of openings identified in the building plan, there are three different window openings and two different types of door openings. The difference in opening is in the size dimensions. Meanwhile, the fenestration type for all opening types in this building has the same materials and specifications.

Table 2 Detail Types of Opening in Eplus Co Coffee & Coworking

Opening Type	Opening Name	Opening Size (m)	Total Opening Area (sqm)	Fenestration Type	Image	Location
Window	W1	0,8 x 2,8	2,24	F1		South, West, East
	W2	0,8 x 2,5	2	F1		East
	W3	0,6 x 2,8	1,68	F1		West
Door	D1	1 x 2,8	2,8	F1		West
	D2	1,2 x 2,8	3,36	F1		East

Source: Personal Documentation, 2023

Table 3 Fenetration Types

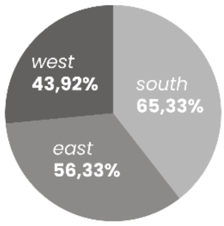
Fenestration Type	Material	SHGC	U Value	Shading
F1	Annealed clear 6 mm	0.32	5	No

Source: Personal Documentation, 2023

Based on all the data above, the results will be calculated to calculate WWR on each side of the building using the formula in the method. By calculating WWR, it can find out the percentage ratio for each side of the building, whether it meets the standard or exceeds the standard of OTTV result. Based on literature references from ASHRAE 90.1, the maximum WWR percentage in commercial buildings is 40%.

Table 4 Wall To Area Ratio Calculation

Side Location	Opening Units	Total Opening Area (sqm)	Total Wall Area (sqm)	WWR (%)
North	-	-	39	-
South	W1 = 7 units	15,68	24	65,33
East	W1 = 5 Units W2 = 7 Units D2 = 1Units	28,56	51	56,33
West	W1=8 units W3 = 1 Units D1 = 1 Units	22,4	51	43.92



Picture 4 WWR pie chart of each building side
Source: Personal Documentation, 2023

However, based on the results of the calculation above, WWR in the south, east, and west areas has a percentage value that exceeds the standard which is more than 40%. A special case is in the west side area, where the total opening area calculated is only half of all openings in the west side area. This is because the opening that leads to the semi-outdoor area has a roof that covers the entire semi-outdoor area, which makes the sun's radiation unable to pass through the opening. Therefore the west side area openings in the semi-outdoor direction are not counted.

After calculating the WWR for each side of the building, the OTTV calculation can be done. Calculation is conducted on each side of the building. Therefore the overall result obtained is that the OTTV value exceeds the specified standard, which is 35 W/m². The north side does not have openings result fulfill the standards, meanwhile the east, west, and south sides have OTTV values that exceed the standards.

Table 5 OTTV Calculation

Side	Conduction Through Wall (Watt)	Conduction Through Opening (Watt)	Radiation Through Opening (Watt)	Total (Watt)	Façade Total Area (m²)	OTTV (Watt/m²)
	A	B	C	D= A+B+C	E	D/E
North	971,01	-	-	971,01	39	24,90
East	558,71	714	1.604,67	2.877,38	51	56,42

South	207,15	392	554,27	1.153,42	24	48,06
West	712,08	560	1.333,58	2.605,66	51	51,09
TOTAL	2.448,94	1.666	3.492,52	7.607,47	165	46,11

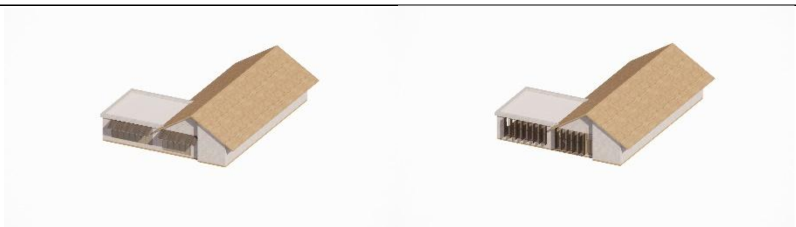
Based on the results of OTTV calculations, it resulting the values exceed the specified standards. The opening areas in the east and west have quite large OTTV values, which are more than 50 watts/m2. These two parts are the areas that are directly exposed to sunlight. Looking at table 5 specifically at the total of all conduction and radiation on each side, it can be seen that the total in the east and west areas has a higher value than the north and south areas. These values prove that the orientation of the building facing east and west has the potential for higher conduction and radiation values.

The results of OTTV calculations that exceed the specified standards, it is necessary to provide design recommendations aimed at optimizing the OTTV value in accordance with the standards. There are several recommendations that could be used, which are changing the window type material, reducing the amount of opening, and making a shading for the opening. The design recommendation that will be used is to make the shading since this solution does not require major renovation which only attaches the type of shading that is suitable to reduce the OTTV value at the higher result. Window shading is also deemed to be the most effective as it can be adjusted to significantly reduce the solar radiation received by the building (Feng et al., 2021, as cited in Abbaas et al., 2023). Therefore the next step is to analyze the type of appropriate shading form to overcome excessive OTTV values on each side of the building. Where in the case of this building, the north area does not have openings and the OTTV value meets the standards, which does not exceed 35 Watt/m2, then the design recommendations will be made in the east, west, and south areas.

Two types of shading will be analyzed to find out which one is the most suitable form to minimize the OTTV. The shading consists of horizontal shading and vertical. The criteria of the recommendation are the type of shading that could minimize the OTTV closest to the standard. In order to calculate the shading performance, therefore the specifications for the new fenestration type must be determined first.

Table 6 Fenetration Types

Fenestration Type	Material	SHGC	U Value	Shading
F2	Annealed clear 6 mm	0.32	5	Horizontal
F3	Annealed clear 6 mm	0.32	5	Vertical



Picture 5 Horizontal shading & Vertical shading design
Source: Personal Documentation, 2023

Table 7 Shading Specification

Shading Type	Width	Height	The Degree of Tilt
Horizontal	3 m	3 m	35°
Vertical	0,8 m	2,8 m	0°

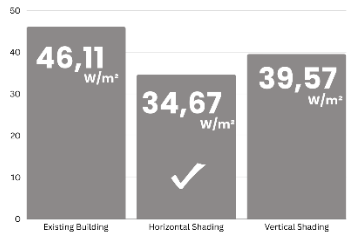
After specifying the shading type and size, these data will be inputted to calculate the OTTV value performance using two shading types, horizontal and vertical. The recommended size is adjusted to the existing window size in the case study building. Horizontal shading will be placed at the top of the window to block direct sunlight from above, while vertical shading will be installed on the sides of the window to reduce sunlight penetration from certain angles.

Table 8 OTTV Calculation With Horizontal Shading Recommendation

Side	Conduction Through Wall (Watt)	Conduction Through Opening (Watt)	Radiation Through Opening (Watt)	Total (Watt)	Façade Total Area (m^2)	OTTV (Watt/m^2)
	A	B	C	D= A+B+C	E	D/E
North	971.01	-	-	971.01	39.00	24.90
East	558.71	714.00	677.49	1,950.20	51.00	38.24
South	207.15	392.00	365.82	964.97	24.00	40.21
West	712.08	560.00	563.04	1,835.11	51.00	35.98
TOTAL	**2,448.94**	**1,666.00**	**1,606.35**	**5,721.29**	**165.00**	**34.67**

Table 9 OTTV Calculation With Vertical Shading Recommendation

Side	Conduction Through Wall (Watt)	Conduction Through Opening (Watt)	Radiation Through Opening (Watt)	Total (Watt)	Façade Total Area (m^2)	OTTV (Watt/m^2)
	A	B	C	D= A+B+C	E	D/E
North	971,01	-	-	971,01	39	24,90
East	558.71	714.00	1,116.37	2,389.08	51.00	46.84
South	207.15	392.00	369.59	968.74	24.00	40.36
West	712.08	560.00	927.77	2,199.85	51.00	43.13
TOTAL	**2,448.94**	**1,666.00**	**2,413.73**	**6,528.67**	**165.00**	**39.57**



Picture 6 OTTV bar chart comparison before and after shading design
Source: Personal Documentation, 2023

Based on the results of OTTV calculations using two types of shading, it can be seen that opening areas that use horizontal shading are more effective in reducing OTTV values. Especially in the east and west areas which previously had the highest OTTV values, but after using horizontal shading the OTTV value results in both areas decreased and approached the specified standard. The overall OTTV results using **horizontal shading** meet the standard, with a total result of 34.22 watts/m2.

CONCLUSION

The OTTV value of the Eplus.Co Co-working & Café building has a value that exceeds the specified standards. Especially in the east and west parts which have the largest OTTV values due to the large number of openings in these areas without any shading. The east and west areas have the largest OTTV values also because these parts are exposed directly to sunlight. This is supported by the comparison between WWR on each side of the building.

The southern area has the largest percentage of WWR among all sides of the building. However, the OTTV value for the southern area is still smaller than the eastern and western areas. Therefore it can be concluded that the direction of building orientation influences the OTTV value. Even though WWR also influences the OTTV value, still the building orientation plays a major influence on the OTTV value.

The OTTV value can also be minimized by shading the building openings, especially in the case of this building, the east and west parts really need shading. So an analysis of the appropriate shading type is carried out to minimize the OTTV value in this building in order to meet the standards that have been determined in the form of a recommended design. The results show that horizontal shading is more effective in minimizing the OTTV value and the results meet the specified standards. Therefore it can be concluded that building orientation influences the OTTV value, especially if the building has many openings, so shading is one of the minor renovation solutions that can be offered.

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