OTTV ANALYSIS AND POSSIBLE DESIGN IMPROVEMENTS ON ASRI MEDICAL CENTER YOGYAKARTA TO REDUCE ENERGY USE

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ABSTRACT: *As a public building that runs continuously, hospitals need a lot of energy. In addition, the building industry in Indonesia has previously been blamed for 50% of the sector's entire energy use, which amounts to almost 70% of all power usage. In order to regulate and minimize energy usage, an examination of OTTV (Overall Thermal Transfer Value) is required. Asri Medical Center in Yogyakarta will be used as the study's subject since it mostly uses glass for its exterior and is oriented east and west, which is thought to have a higher heat transmission. Due to this, the OTTV will be carried out to guarantee that the building's current score does not exceed 35 W/m2 (SNI, 2011). In order to reduce the score, a quantitative method will be used by doing modifications on the WWR, U value, as well as a shading device. These modifications have resulted in some improvements whereas the WWR modification can reduce the OTTV scores by 41%, and glass material changes by 43,4%. However, there is no significant change in the shading device modification since it only improves by 16,4% and not meeting the standard yet.*

Keywords: *Energy Use, Hospital, OTTV Calculation*

INTRODUCTION

Background

As a public facility that operates nonstop, hospitals consume large amounts of energy such as electricity which plays a crucial role in powering up the cooling system inside. In addition, the building sector in Indonesia has already been held accountable for 50% of energy consumption from the whole sector and reaching over 70% of the overall electricity consumption (Sandi & Ismail, 2019). The report follows it in 2019 where 4.4% of the world's carbon footprint was produced by healthcare facilities (Marshal et al., 2021). This number represents the high electricity consumption of most hospitals in Indonesia that reach 225 kWh/m which scored higher than Japan, 175 kWh/m.

The growing need for space cooling not only puts a heavy burden on the power system but also increases the emission of greenhouse (IEA, 2018). The use of space cooling has attributed to the global greenhouse emission for 4% (Sorongan, 2022). In 2016, space cooling systems contributed to approximately 14% of peak electricity demand worldwide. However, the high costs associated with maintaining and operating electricity capacity to meet this demand stem from its limited usage during specific periods, ultimately leading to an increase in overall expenses. Therefore, an attempt to control and reduce energy consumption is needed by utilizing OTTV (Overall Thermal Transfer Value) analysis. It measures the heat transfer through a building's envelope and acts as an indicator to compare the building's thermal performance (Vijayalaxmi, 2010). This analysis considers the use of shading devices, building materials, opening types, and others that affect the increasing heat inside the building so that later on, the value could be reduced.

With that being said, a study on OTTV analysis to reduce the energy consumption of a hospital is needed. Asri Medical Center Yogyakarta will be taken as the object of this study since the building is mostly using glass as its envelope but it is oriented east and west which could be assumed to have a higher heat transfer. For that reason, the OTTV will be done to ensure the building's existing score by not exceed 35 W/m^2 (SNI, 2011). As a response, the main design factor will be redefined to produce possible design improvements to lower the score and save up more energy in the future.

The novelty of this study is formed by the other related studies which have been conducted prior to this one. The first existing study is written by Vijalaxmi in 2010 about the fundamental concept of OTTV which is also being shown through a case study in India. Following this theory, other studies have been conducted for instance an analysis of the hospital's OTTV by Arifin et al. which includes the number and type of air conditioners used in the building as well as the OTTV evaluation on Meuraxa Hospital in Banda Aceh written by Wahyudi et al. that takes double glazing into account.

However, the study of OTTV value of hospitals in Yogyakarta is still lacking, especially the one that is almost entirely wrapped in glass or transparent material for instance, Asri Medical Center. Therefore, the research questions that can be generated are:
1. What is the OTTV score for Asri Medical Center?
2. What is the design factor that could improve the OTTV score?

Research Objective
This study aims to analyze the existing building's OTTV score and generate possible design improvements in an effort to have more efficient energy use for the building in the future.
Scope
1. The research is only focusing on the OTTV value of Asri Medical Center
2. The variables are related to architecture (e.g. number of openings, type of shading, wall material, etc.)
3. The design will only be used as a tool to prove the correlation between the main design factor and the final OTTV value

LITERATURE REVIEW
OTTV (Overall thermal transfer value) is energy conservation in buildings that regulates the heat transfer value on the building wall facade. In this case, the value should not exceed 35 watts/m^2 (SNI, 2011). The higher the OTTV value, the more watts per square meter of energy a building will receive. The opening area affects the OTTV value of a building. The larger the translucent wall opening, the greater the energy load produced by a building.

The concept of OTTV encompasses three fundamental components related to heat transfer through a building's exterior: the conduction of heat through solid walls, the penetration of solar radiation through glass, and the conduction of heat through the glass surfaces. The overall thermal transfer (OTTV) value for each area of the outer wall of a building with a certain orientation can be calculated through the equation:

$$OTTVi = 15\alpha\ [1 - WWR)\ Uw + 5(WWR)\ Uf$$
$$+ (194 \times CF \times WWR \times SC\ (1)$$

WWR : Window-to-Wall Ratio
Uw : The wall's U value
Uf : The glass' U value
SC : Shading Coefficient

Several parameters in the OTTV equation can be altered to lower the OTTV value, including the solar absorptance (Î±), thermal transmittance (U), WWR, equivalent temperature difference (TDEQ), and the shading coefficient (SC). According to the parametric study, adjustments in the WWR parameter had the most significant influence on OTTV value change (Haidar, 2016).

1. WWR
Window-to-Wall Ratio (WWR) is the fraction of the upscale wall area covered by the fenestrations, calculated as the ratio of the wall fenestration area to the gross area of the upscale wall. Indeed, WWR has a major influence on the change of OTTV. However, if the WWR continues to be reduced, it will actually make the room in the building dark and will

increase energy consumption due to the increased lighting load in the building (Purwoko & Purwanto, 2022). WWR could be calculated with a formula below,

$$\text{WWR}\ (\%) = \frac{\sum \text{Glazing area}\ (\text{m}^2)}{\sum \text{Gross exterior wall area}\ (\text{m}^2)}$$

Any space with glass on it, including the frames and mullions holding it together, is referred to as a glazing area. Meanwhile, exterior wall area refers to the total area of the walls dividing the building's interior and outside. Typically, WWR can be considered effective if it results in between 50%-60% (Sari et al., 2017).

2. Uw and Uf

A building component's U-value, such as a wall, roof, or window, quantifies the amount of energy (heat) lost through a square meter (m2) of that material for every degree (K) change in temperature between the interior and outside. In this case, the U value of the wall and the glass are different because of their transparency. Hospitals commonly use glass facades to maximize the lighting that could penetrate the building. The ability to display a beautiful aesthetic supported by properties that have heat resistance, high radiation levels, and acoustic capabilities is considered an advantage of glass materials. On a side note, we also must be aware of its ability to absorb heat. That is why most buildings with glass facades use another layer/glazing on top of it either to reflect or muffle the heat. The opaque wall's U-value ranges from 1.0 to 4.0 W m-2K. Lowering the U-value of the wall can help to limit heat conduction through the wall.

3. SC

The shading coefficient is a numerical value that represents the ability of a glazing system (such as windows or glass) to block solar heat gain. It indicates how much solar heat is transmitted through the glazing material compared to standard clear glass. On the other hand, a shading device refers to any element or system installed on the exterior or interior of a building to control the amount of sunlight and solar heat entering the building such as overhangs, awnings, louvers, blinds, and shades. By strategically using shading devices, the solar heat gain through windows or glazed surfaces can be reduced, affecting the shading coefficient.

METHOD

The method that will be quantitively used in this study is OTTV calculation which will be done in four stages. The first one is to calculate the existing condition, which is the current building of Asri Medical Center. After getting the result, possible designs and other modifications can be generated. These modifications consist of WWR, shading devices, and U Value or type of glass material. After obtaining three results from three modifications in total, the best result can be chosen to be developed into a comprehensive design strategy that can be implemented for the hospital in the future time. All of the calculations will be done by utilizing the OTTV Calculator spreadsheet by the Ministry of Public Works and Public Housing of the Republic of Indonesia.

Existing Data

Asri Medical Center or AMC is a prominent healthcare facility located in Yogyakarta, Indonesia. It is known for its advanced medical services, state-of-the-art facilities, and a comprehensive range of medical specialties and provides both outpatient and inpatient care. To be exact, it is located at Jl. HOS Cokroaminoto No.17B, Pakuncen, Wirobrajan, Kota Yogyakarta.

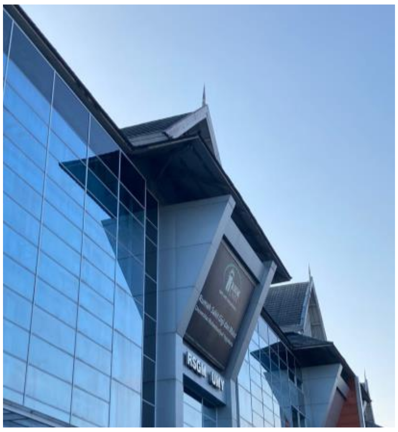

Figure 1 The front view of AMC
Source: Author, 2023

The research process is started with the simplest one, building size and area. Without these dimensions, the WWR and OTTV values can't be calculated. This data was officially retrieved from the building's technical drawing, which can't be included in the paper due to privacy matters.

Table 1 Building Dimensions

Elevation	Length (m)	Height (m)	Total Area (sqm)
West	90	19	1710
East	90	16	1440
North	41,7	19	792,3
South	33,7	19	640,3

Source: Author, 2023

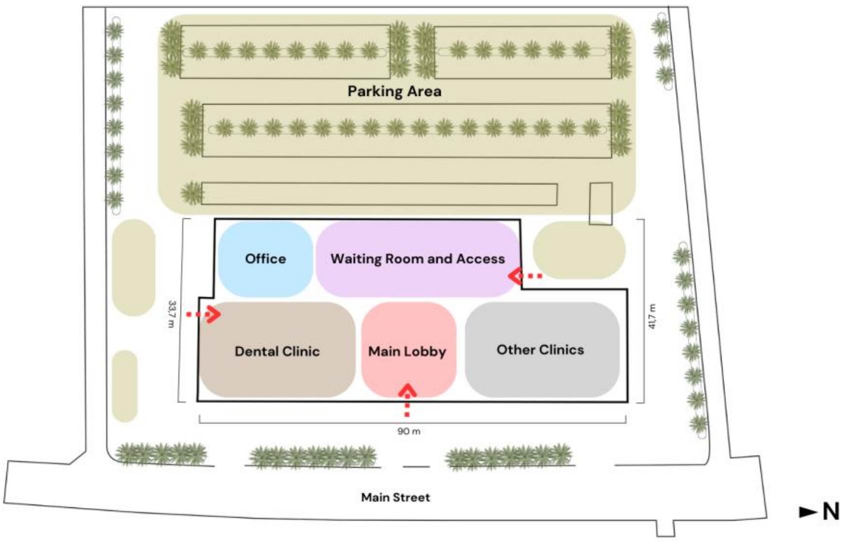

Figure 2 Schematic Site Plan of AMC
Source: Author, 2023

The second step that needs to be done is defining the existing condition of the building such as the dimension, area, as well as the amount and type of opening. Based on the building's technical drawings combined with a direct survey, there are 28 types of openings which are listed in the following table.

Table 2 Opening Types

Opening Type	Opening Name	Opening Size (m)	Total Opening Area (sqm)	Fenestration Type	Location(s)
Curtain Wall	CW1	5,5 x 3,5	19,25	F2	West
	CW2	12 x 12	144	F4	East
Window	W1	3,1 x 3	9,3	F3	East
	W2	2,5 x 3	7,5	F3	East
	W3	2,05 x 3	6,15	F3	East
	W4	5,6 x 1,2	6,72	F2	West
	W5	7,4 x 1,2	8,88	F2	North, South
	W6	2,6 x 1,2	3,12	F2	West
	W7	6,6 x 1,2	7,92	F2	South
	W8	2,5 x 1,2	3	F2	West
	W9	3,4 x 1,2	4,08	F2	West
	W10	1,9 x 1,2	2,28	F2	West, South
	W11	1,525 x 1,2	1,83	F2	West
	W12	0,575 x 1,2	0,69	F2	West
	W13	3,57 x 1,2	4,28	F4	East
	W14	6,8 x 1,2	8,16	F2	North
	W15	6,8 x 1,2	8,16	F4	East
	W16	3,8 x 1,2	4,56	F4	East
	W17	5,075 x 1,2	6,09	F2, F4	West, East
	W18	1,025 x 1,2	1,23	F2	West
	W19	3,85 x 3	11,55	F2	South
	W20	2,62 x 1,2	3,14	F4	East
	W21	1,815 x 3	5,5	F2	North
	W22	0,8 x 1,2	0,96	F4	East

Opening Type	Opening Name	Opening Size (m)	Total Opening Area (sqm)	Fenestration Type	Location(s)
	W23	1,445 x 1,2	1,73	F1	West
	W24	1,445 x 1,2	1,73	F2, F3	East
	W25	2,85 x 1,2	3,42	F2	West
	W26	0,9 x 1,2	1,08	F2	West

Source: Author, 2023

From both sources, technical drawings and direct survey, it can be defined that the glass material or type of fenestration of every opening may be different from each other. Hereby the 4 types of fenestrations that can be found, along with the SHGC, U Value, and the existence of the shading device.

Table 3 Fenestration Types

Fenestration Type	Name	SHGC	U Value	Shading
F1	Panasap Dark Blue 6 mm	0.67	5.7	No
F2	Indoflor Clear 8 mm	0.93	5.7	No
F3	Indoflot Clear 8 mm	0.93	5.7	Yes
F4	Glass (Indoflot Clear 8 mm) + Secondary (Panasap Dark Blue 6 mm)	0.62	5.7	No

Source: Author, 2023

Figure 3 Example of the fenestration types in the building (From left to right, F1, F2, F3, and F4)
Source: Author, 2023

RESULT

1. WWR Result

The Window-to-Wall Ratio (WWR) of the building was calculated by dividing the total facade area by the total opening area. The percentage in the following table shows how much space the opening took place. WWR has a strong correlation with OTTV. Thus, to define whether the WWR result is already considered as good enough or not, OTTV needs to be calculated.

Table 4 Existing Window-to-Wall Ratio

Side	Total Opening Area (sqm)	Total Facade Area (sqm)	WWR (%)
North	112.02	792.3	14.14
East	436.9	1440	30.34
South	65.28	640.3	10.20
West	504.91	1710	29.53

Source: Author, 2023

2. OTTV Result

The result shows the current OTTV of AMC is 59,32 W/m2, which exceeds the standard of OTTV (35 W/m2). In the following table, it could be seen that most of the sides are exceeding the OTTV standard, except the south side which has 33.67 for its OTTV result.

Table 5 Existing OTTV

Side	North	East	South	West
Wall Conduction	16,937.44	24,974.93	14,316.70	30,004.03
Opening Conduction	3,192.57	12,451.65	1,860.48	14,337.78
Opening Heat Gain	16,353.62	47,673.40	5,379.47	84,366.66
Total	36,483.63	85,099.98	21,556.66	128,708.47
Facade Area	792.30	1,440.00	640.30	1,710.00
OTTV	46.05	59.10	33.67	75.27
Total OTTV	**59.32**			

Source: Author, 2023

DISCUSSION

Based on the result, it can be determined that the possible design factors to improve the OTTV result are:

1. WWR

The WWR can be lowered by reducing the number of windows or openings. In this case, the opening that doesn't positively affect the user's needs to be removed. For instance, on the west side, the curtain wall that is arranged along the rampway can be replaced with a normal window since it gives too much exposure to the space or simply reduce the number of openings. Moreover, it is the west side–where it tends to get the maximum amount of heat afternoon.

Table 6 WWR Modification

Side	**West**	**West**	**East**	**North**	**West**	**East**	**East**	**North**
Modification	Type of Opening	Number of Opening (W23)	Type of Opening	Type of Opening	Type of Opening	Type of Opening	Number of Opening (W2)	Type of Opening
Before	CW1	32	CW2	W5	W4	W16	4	W14
After	W10	16	W16	W10	W10	W11	0	W10
Previous Opening Area (sqm)	346.5	55.36	288	71.04	47.04	27.36	30	24.48
Modified Opening Area (sqm)	27.36	27.68	54.72	18.24	6.84	10.98	0	4.56
Previous WWR	29.53	10.86	30.34	14.14	9.25	14.14	13	7.47
Modified WWR	10.86	9.25	14.14	7.47	6.89	13	9.51	4.96
Previous OTTV	75.27	42.3	59.10	46.05	40.23	40.79	39.5	36.08
Modified OTTV	42.3	40.23	40.79	36.08	36.08	39.5	35.6	32.32
Total OTTV	47.02	46.25	40.49	38.77	37.57	36.82	35.59	**34.94**

Source: Author, 2023

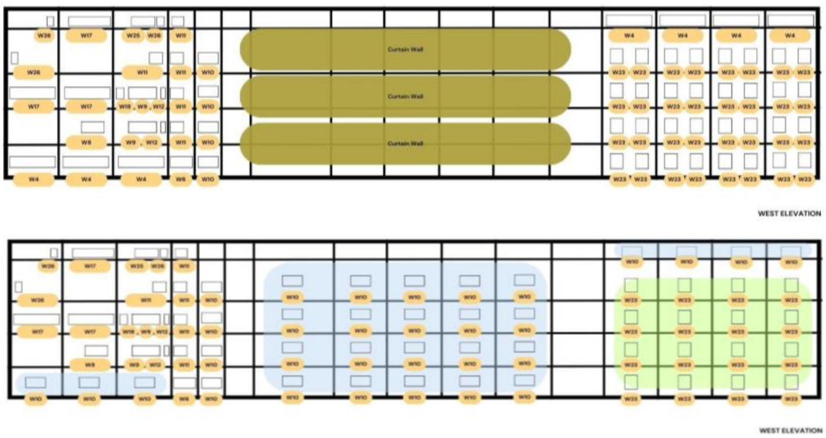

Figure 4 Changes of opening type (blue highlight) and number of openings (green highlight) on the west side, before and after (upper, lower)
Source: Author, 2023

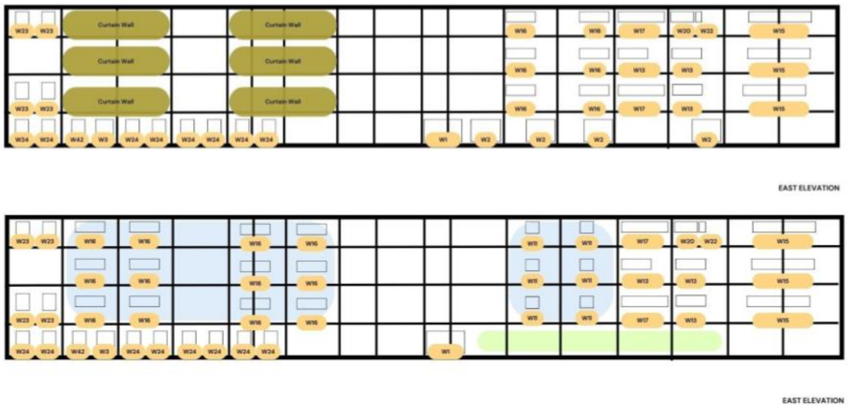

Figure 5 Changes of opening type (blue highlight) and number of openings (green highlight) on the east side, before and after (upper, lower)
Source: Author, 2023

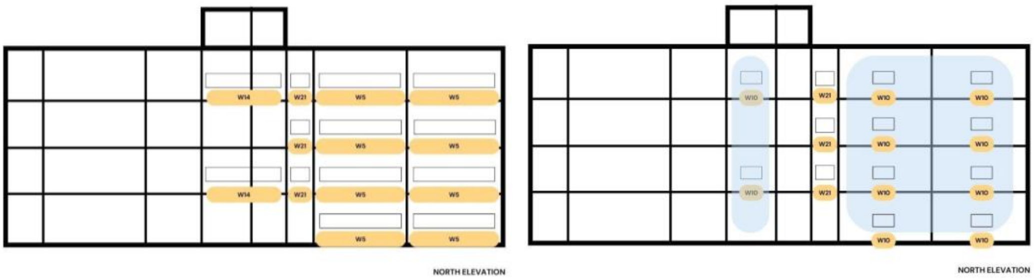

Figure 6 Changes of opening type (blue highlight) on the north side, before and after (upper, lower)
Source: Author, 2023

2. Glass Material

The second alternative that can improve the OTTV is to change the transparent material, glass. AMC uses many usual clear glasses instead of glazed glass material that has the ability to handle the heat, whether to absorb or to reflect. In this case, every opening that is using Indoflot Clear 8 mm will be replaced with other clear glass materials that have lower SHGC or U Value. This strategic switch aims to optimize the building's thermal performance and, consequently, its overall energy efficiency. By selecting glass materials with improved thermal properties, AMC can reduce its cooling load and contribute to a more sustainable and energy-efficient operation.

Table 7 Glass Material Modification

Glass Material	SHGC	U-Value	OTTV	Improvement
Indoflot Clear 8 mm (Existing)	0.93	5.7	59.32	-
Sunergy Clear 8 mm	0.68	4.1	49.79	16%
T-Sunlux On Clear 8 mm	0.22	4.3	34.45	41.9%
Stopray Clear 8mm Vision 40T	0.25	1.6	**33.57**	**43.4%**

Source: Author, 2023

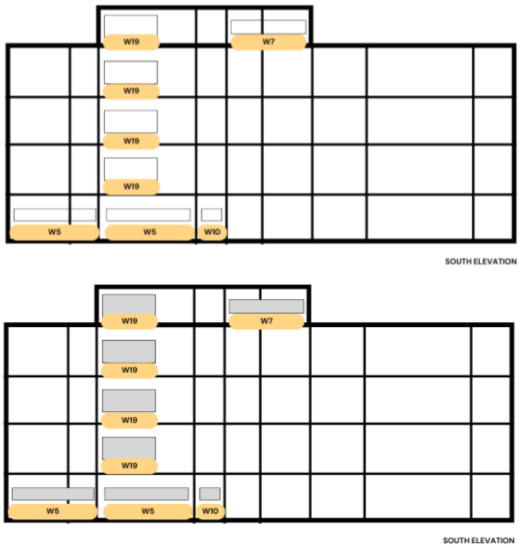

Figure 7 Changes of glass material on the south side, before and after (upper, lower)
Source: Author, 2023

3. Shading Device

The other way is to maintain the current WWR but add shadings. The building has a lot of unshaded openings with clear glass, especially those sides that are directly exposed to the sunlight (east and west). Therefore, a shading device might be an effective option since it doesn't need to demolish the openings beforehand. In addition to that, since the east side already has shading on its first floor and the rest are covered with secondary skin, shading device modification can be tested on the west side.

Table 8 Shading Device Modification

Shading	Dimension		OTTV	Improvement
Horizontal 1	Length	1 m	56.44	4,8%
	Height	4 m		
Horizontal 2	Length	2 m	52.93	10,7%
	Height	4 m		
Vertical 1	Length	1 m	54.63	7,9%
	Width	1 m		
Vertical 2	Length	2 m	52.53	11,4%
	Width	1 m		
Eggcrate 1	Length 1	2	51.52	13,1%
	Height	3		
	Length 2	2		
	Width	6		

Shading	Dimension		OTTV	Improvement
Eggcrate 2	Length 1	3	49.56	16,4%
	Height	3		
	Length 2	3		
	Width	6		

Source: Author, 2023

CONCLUSION

Hospitals consume large amounts of energy such as electricity which plays a crucial role in powering up the cooling system inside. Therefore, an attempt to control and reduce energy consumption is needed by utilizing OTTV (Overall Thermal Transfer Value) analysis. At Asri Medical Center, the number of OTTV scores is considered as high (59,32 W/m2), since it exceeds the standard of OTTV (35 W/m2) by 40,9%. With the OTTV spreadsheet template, several modifications can be done to lower the OTTV score. By reducing the WWR, the OTTV score can be improved by 41%. Other than that, changing the glass material to Stopray Clear 8 mm can also improve the OTTV score by 43,4%, which is possible to be taken into consideration since it shows a better improvement than the WWR reduction or modifying the shading device, which only can improve by 16,4% and not meeting the standard yet.

Nonetheless, this study still lacking in many aspects including the limited access to sharing the official technical drawings within this paper due to privacy matters. Another obstacle was also in terms of the mismatch between the current building condition with the one that is shown on the technical drawing since by the time this study was conducted, the building hasn't been fully constructed as it is in the technical drawings because the construction process is divided into several phases and currently the hospital has not reached the final phase of construction yet.

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