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Analysis of Glass Facade Walls with OTTV Value Calculation in the Domestic Departure Waiting Area at Yogyakarta International Airport

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Abstract: Global warming, which results in climate dan temperature changes worldwide, causes the load on air conditioning systems in buildings to become heavier. Climate and temperature change lead to higher external heat loads, which are the heat entering the building due to solar radiation, conduction, and infiltration through the building envelope. To reduce these external loads, the SNI 6389-2020 design the criteria specify that the Overall Thermal Transfer Value (OTTV) must be less than or equal 35 Watts/m^2. This Study analyzes the OTTV value on the glass facade of the 33-34 departure waiting area at Yogyakarta International Airport, focusing on the glass facade wall. The method used in this research is quantitative exploratory and aims to determine the factors affecting the OTTV value and ensure whether the value meets the SNI 6389-2020 standard. The study found that the building orientation, material, and surrounding environmental condition affect the OTTV value. An optimal orientation by directing the long side of the building to the north and south can minimize solar radiation exposure. Materials with low U-value can reduce the rate of heat absorption and release, while hot and humid environmental conditions can increase the heat load on a building. The result of this study shows that the OTTV value on the glass facade of the 33-34 departure waiting area Yogyakarta International Airport is 34,43 Watt/m^2, which meets the standard set by SNI 6389-2020.
Keywords: *Global Warming, OTTV, Yogyakarta International Airport*

1. Introduction

the application of green building design or structure, the building facade plays an important role, both in terms of aesthetics and its function in energy conservation. Careful facade design can have a significant impact on building energy efficiency. As the outermost layer of the building, the facade is a crucial element that not only affects the efficient use of energy, but also plays a role in improving thermal comfort inside the building, which in turn can have an impact on the productivity of the occupants (Fahmi & Mutia, 2022). Building designs need to be designed to adapt to local climatic and environmental conditions to maximize the use of natural resources as needed. The application of the passive design concept is one approach to dealing with climate challenges and their impact on the comfort of building occupants in various regions in Indonesia (Santy et al., 2017).

Based on SNI 6389-2020 concerning Energy Conservation of Building Envelopes in Building Buildings, it is explained that the Overall Thermal Transfer Value (OTTV) is a standard value used as a design criterion for walls and glass on the outside of conditioned buildings. The OTTV calculation has a standard, which is that the overall thermal transfer value must not exceed or must be maximally equal to 35 W/m² (Ardyanny & Tee, 2024).

In this study, researchers analyzed the thermal comfort in the domestic departure lounge area of Yogyakarta International Airport. Measurement of thermal comfort is done by OTTV

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calculation method, which is by measuring the heat transfer value obtained from the glass wall in the domestic departure lounge building.

2. Literature review

Based on the Regulation of the Minister of Transportation KM 20 Year 2005 on the Application of Indonesian National Standard (SNI) 03-7046-2004 Regarding Airport Passenger Terminals as Mandatory Standards, a passenger terminal is a building that becomes a link between land and air transportation systems. This terminal accommodates various transition activities, such as access from land to aircraft or vice versa, processing arriving, departing, transit, and transfer passengers, as well as transferring passengers and baggage from and to aircraft. Passenger terminals must be able to accommodate operational, administrative, and commercial activities and meet the security and safety requirements of flight operations, in addition to other building-related requirements (Guan et al., 2024).

The facade is a design element that displays the external appearance of the building and can be the identity or characteristic of the building. Facades highlight certain aesthetic aspects that attract attention and characterize the building. When talking about the “face” of a building, what is meant is the facade, especially the part facing the street (Gehl et al., 2006).

Another aspect that needs to be considered is thermal comfort in building facilities. Thermal comfort can be achieved by reducing heat gain, providing sufficient airflow, removing heat from the building, and preventing direct solar radiation to the building surface. Heat gain in buildings can be reduced by selecting and using materials that have high thermal resistance, so that the flow of heat through the material is inhibited(Sadineni et al., 2011). The selection of light-colored materials is also important because the color can have a large heat absorption rate, which causes the surface temperature to be higher than the outside air temperature. Other climatic factors that affect thermal comfort include air movement, air humidity, and air temperature (Eludoyin et al., 2013).

In the context of passenger services related to thermal comfort, the Regulation of the Minister of Transportation of the Republic of Indonesia PM 41 of 2023 concerning Airport Services at Airports states that room temperature settings must follow predetermined standards ($\leq$ 25 °C) in the check-in area, departure waiting room, and baggage claim area (Pusdatin, 2023). Based on SNI 6389-2020 concerning Energy Conservation of Building Envelopes in Buildings, Overall Thermal Transfer Value (OTTV) is a value used as a design criterion for the outer walls and glass of buildings that have air conditioning systems (Ardyanny & Tee, 2024). The lower the OTTV value of a building, the more effective the building is in maintaining thermal comfort, which means that the use of energy for cooling and heating will be more efficient, so that energy consumption can be reduced (Lam et al., 2005).

Based on SNI-6389-2020 concerning Energy Conservation of Building Envelopes in Buildings, it is explained that the OTTV value for each plane or external wall of a building with a certain orientation or appearance can be calculated through the equation(Ardyanny & Tee, 2024).

$$OTTV = \alpha[(Uw \times (1 - WWR \times Tdek] + (Uf \times WWR \times \Delta T) + (SC \times WWR \times SF)$$

Where:

OTTV : Overall Thermal Transfer Value on the outer wall facing a specific direction (W/m²)
A : Solar radiation absorptance
Uw : Thermal transmittance of the opaque wall (W/m².K)
WWR : Window-to-wall ratio, the ratio of the window area to the total outer wall area in the specified direction

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Tdeq : Equivalent temperature difference (K)
SF : Solar radiation factor (W/m²)
SC : Shading coefficient of the fenestration system
Uf : Thermal transmittance of fenestration (W/m².K)
ΔT : Design temperature difference between the outside and inside (assumed to be 5K)

According to SNI-6389-2020, the value of OTTV should not exceed or be maximally equal to 35 W/m^2. Related to the absorption of solar radiation (α), there are differences in properties or characteristics for each non-transparent wall surface material which results in differences in the value of each α material which can be found in the table below:

Table 1. Solar Radiation Absorption Values for Non-Transparent External Walls And Roofs

Exterior Wall Material	a
Heavy concrete for nuclear buildings	0,91
Red brick	0,89
Bituminous felt	0,88
Slate	0,87
Lightweight concrete	0,05972222
Asphalt pavement	0,82
Smooth wood surface	0,78
Exposed concrete	0,61
White tile	0,58
Light yellow brick	0,56
White roof	0,5
Aluminum paint	0,4
Gravel	0,29
White zinc	0,26
White glazed brick	0,25
Polished aluminum sheet	0,12

Source: (Badan Standarisasi Nasional, 2020)

Based on SNI-6389-2020, if the wall is not transparent and the fenestration consists of various components and types of buildings, the amount of U-value can be calculated with the following equation formula.

$$U = \frac{1}{Rtotal}$$

Where:
Rtotal : Total thermal resistance = Σ Ri
Σ : The sigma symbol, which means addition
Ri **:** Thermal resistance of the i-th component in the system

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The R value refers to thermal resistance or how difficult it is for heat energy through a material or material in this case in relation to the glass wall material to be able to move to the other side of the material. The magnitude of the R value is explained through the following table:

Table 2. Surface Air Layer R-Values for Walls and Roofs

Surface Type		Resistant Thermal R ($m^2.K/W$)
Inner Surface (R_{UP})	High Emissivity	0,12
	Low Emissivity	0,299
Outer Surface (R_{UL})	High Emissivity	0,044

Source: (Badan Standarisasi Nasional, 2020)

Descriptions:

- High emissivity is a smooth surface that is not shiny (non-reflective)
- Low emissivity is a highly reflective inner surface such as aluminum foil.

Furthermore, referring to SNI-6389-2020, the thermal resistance of the material (RK) is determined by the equation formula:

$$R_K = \frac{t}{k}$$

Where:
t = Thickness of material (m)
k = Thermal conductivity value of materials (W/m.K)

As a transparent material, the ability of glass to absorb and control heat is very important. Sunlight radiation entering through glass can increase the indoor temperature, so the selection of glass as a building component must be done carefully. It is important for users to understand the thermal properties of glass when selecting the type of glass or glass component for a building. Improperly selected and positioned glass can show poor performance and can even be damaged when exposed to sudden or gradual changes in temperature (Lestari & Alhamdani, 2014). Factors that affect the results of OTTV calculations include several main factors related to the physical and environmental characteristics of the building (Rizky Atma Satria, 2018).

a. Building Design and Orientation
   The design and orientation of the building, which includes the geometry and massing pattern of the building, can affect the results of the OTTV calculation. Optimal orientation can minimize exposure to direct solar radiation and thus reduce heat loads. For example, a building oriented so that its long sides face north and south can minimize exposure to intense direct sunlight from the east and west. This also helps to reduce heat gain and maintain thermal comfort in the building.
b. Building Material Elements
   Building material elements such as roofs and walls have an important role in determining OTTV values due to the thermal conductivity, thermal resistance, and thermal transmittance (U-value), of these materials. For example, materials with high U-value (metal, red brick, non-laminated glass, etc.) and short time lag on walls and roofs will affect how quickly heat is received and released.
c. External Environmental Conditions of the Building

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External environmental conditions such as air temperature and humidity affect the thermal comfort in the building. So, to also reduce the rate of heat transfer which is one of the key factors in calculating OTTV in humid tropical climates, a building can be designed by applying the principle of maximizing thermal resistance (R) and minimizing the value of thermal conductivity (C) and minimizing the value of heat transmittance (U-value).

3. Research method

This research was conducted at Yogyakarta International Airport, an airport located in Kulon Progo Regency, Temon District, Palihan Village. This airport is operated by PT Angkasa Pura 1, this airport is one of the international airports in Indonesia to support the transportation system in the Yogyakarta Special Region province area. The research method used in this research is exploratory quantitative. Data collection was carried out through literature studies and secondary data collection such as information data on glass wall construction in the domestic departure waiting room of Yogyakarta International Airport.

In this research, the data obtained is processed using several research instruments in the OTTV value calculation stage. In the data analysis process, it will refer to SNI-6389-2020 with the following stages (Zahrah & Octora, 2023):

a. Determine the value of α on the wall according to the guidelines in the table in SNI-6389-2020.
b. To calculate the impermeable wall thermal transmission value (Uw), the second step is to first determine the total thermal resistance value (Rtotal). This includes the material thickness (t) and the thermal conductivity value of the material (k).
c. Next, determine the Window Wall Ratio (WWR) value, which is the ratio between the glass opening area and the wall area on the analyzed side.
d. To determine the equivalent temperature difference (TDEk) value, depending on the material that dominates the wall structure of the analyzed side. This value is then converted according to the TDEk table, based on field observations with the average temperature difference on each side of the building.
e. The value of the shading coefficient of the fenestration system (SC) is influenced by the presence of shading. While the solar radiation factor (SF) is affected by the direction of orientation of the building in accordance with the provisions in SNI-6389-2020.
f. To determine the thermal transmission value of the penetrating system (Uf), the same method is used as in determining Uw, where the Rtotal value of the penetrating system must be known first.
g. After all values are calculated, the OTTV value of the wall against the specified orientation can be known. Furthermore, the calculation of the OTTV value for the entire building envelope can be carried out, provided that the result does not exceed 35 W/m^2.

4. Results and discussion

Yogyakarta International Airport (ICAO: WAHI, IATA: YIA) is an international airport managed by PT Angkasa Pura 1 and located at Jalan Wates KM 42, Kulon Progo, Yogyakarta. This airport has a runway dimension of 3,250 m x 45 m and can accommodate B777 aircraft as critical aircraft that can be served. In addition, Yogyakarta International Airport has a passenger terminal area of 219,000 m2 and is intended to be able to accommodate 20 million passengers per year.

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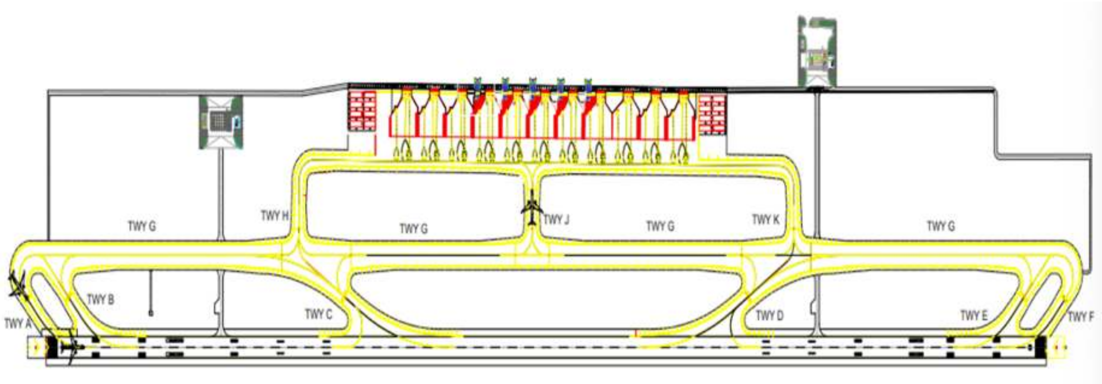
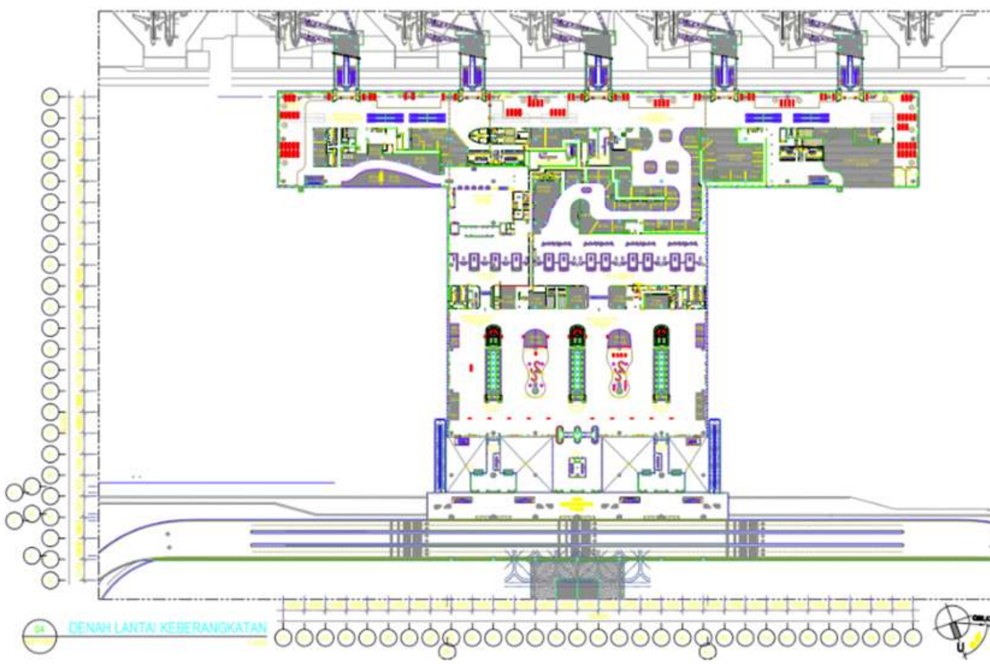


Source: PT Angkasa Pura I

Fig 1. Airside layout of Yogyakarta International Airport



Source: PT Angkasa Pura I

Fig 2. Departure Floor Plan of Yogyakarta International Airport

The analysis was conducted in the domestic departure waiting room area of Yogyakarta International Airport passengers which has an orientation direction to the south. The following is an overview of the floor plan of the domestic departure waiting room. Furthermore, the area to be analyzed is the rear-view glass facade of the YIA Airport terminal building which can be seen in Figure 2 notation of the Yogyakarta International Airport Departure Floor Plan.

Furthermore, the area to be analyzed is the glass module on the rear view of axles 33-34 of the Yogyakarta International Airport terminal building which can be seen in the notation of Figure 3 shown below.

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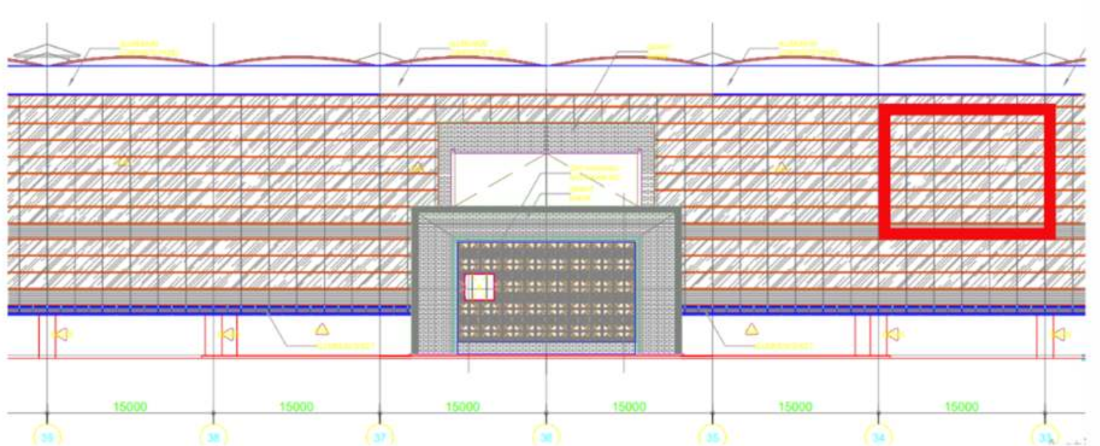
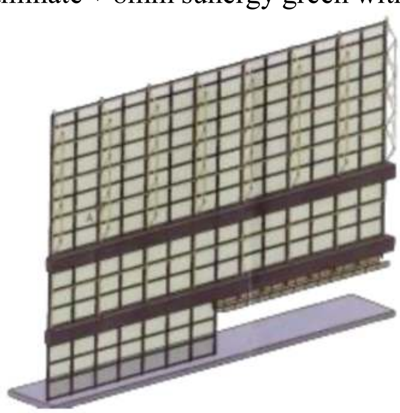


Source: PT Angkasa Pura I

Fig 3. **Rear View of axles 33-34 of Yogyakarta International Airport**

In this study, the analysis will be carried out in the domestic departure waiting room area of Yogyakarta International Airport, especially on the glass facade located at the back of the terminal building and facing directly to the airside area. In analyzing the building for the object of research, researchers used the guidelines of SNI rules and the Regulation of the Ministry of Transportation of the Republic of Indonesia PM 41 of 2023 concerning Airport Services at Airports. SNI rules are used by researchers for building calculations while Permenhub is used by researchers as a standard for service provisions that have been set by the government in this case the Ministry of Transportation of the Republic of Indonesia as a regulatory regulator.

Based on the results of observations carried out by researchers on the existing conditions on the glass facade of the domestic departure waiting room area of Yogyakarta International Airport, it is known that the building material data that researchers will use in calculating the OTTV value. The glass material used at the YIA Airport terminal is 6mm G planibel glass curtain wall + 0.76mm PVB laminate + 8mm sunergy green with aluminum frames and sealent.



Source: Researcher

Fig 4. Glass wall cutout of YIA Departure Level

In this study, the glass facade area to be analyzed for OTTV calculation is located in the area of axles 33-34 which has dimensions of 15 meters x 11.6 meters.

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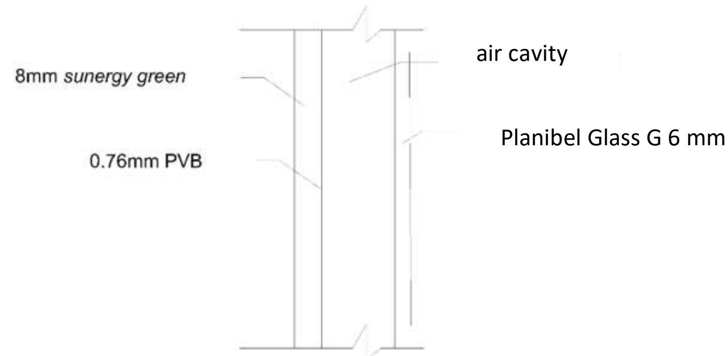

Source: Researcher

Fig 5. Glass Cutout of Analysis Area As 33-34

Based on SNI 6389-2020 concerning Energy Conservation of Building Envelopes in Buildings, it is explained that, before calculating OTTV, there are several variables that must be determined first, such as:

a. Absorbance Value of Solar Radiation
The value for solar radiation absorption in this research object has a material composition consisting of glass walls which are assumed by researchers to have a dark green color. So that based on the standards set in the SNI has a solar radiation absorbance value of 0.88.

Table 3. Solar Radiation Absorption Values for Non-Transparent External Walls And Roofs

Exterior Wall Surface Paint	α
Matte black	0.95
Black varnish	0.92
Dark gray	0.91
Dark blue varnish	0.91
Black oil paint	0.9
Dark brown	0.88
Dark gray/blue	0.88
Dark blue/green	0.88
Medium brown	0.84
Green varnish	0.79
Medium green	0.59
Medium yellow	0.58
Medium green/blue	0.57
Light green	0.47
Semi-gloss white	0.3
Glossy white	0.25
Silver	0.25
White Varnish	0.21

Source: (Badan Standarisasi Nasional, 2020)

b. Impermeable Wall Thermal Transmittance Value (Uw)
The impermeable wall thermal transmittance value (Uw) is calculated against the wall

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material structure analysis area. Where known:
Outside Air : 0,04 m^3K/W
Glass : 0,008m
Aluminum alloy : 0,15m
Inside Air : 0,12 m^3K/W

Table 4. Value Caculation Uw

Component	Thickness (m)	K (W/m.K)	R (m³K/W)
External Air			0,04
Inner Glass	0,006	1,053	0,01
Air Cavity			0,16
Aluminum Alloy	0,150	211	0,00071
Internal Air			0,12
Total			0,326

Source: Researcher

Description:
K : Thermal conductivity value
R : Thermal resistance value

So, the calculation for Uw is found as follows:
Uw = 1/Rtotal
= 1/0,326
= 3,06 W/m2K

c. Equivalent Temperature Difference (TDEk)
The materials found in the research object to be used in the TDEk calculation are glass and aluminum composite panels (ACP). As follows:

Table 5. Calculation of TDek value

Component	Thickness (m)	K (W/m.K)	R (m²K/W)	D (kg/m³)	W (kg/m²)
External Air			0,04		
Inner Glass	0,006	1,053	0,01	2,512	15,072
Air Cavity			0,16		
Aluminium alloy	0,150	211	0,000711	2,672	400,800
Internal Air			0,12		
Total			0,326		415,872

Source: Researcher

Description:
K = Thermal conductivity value
R = Thermal resistance value
D = Building material density value

Based on the results of the TDEk calculation in the table above, the TDEk value of the research object is 415.872 kg/m^2.

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Table 6. Wall Equivalent Temperature Difference Value

Weight/ Unit Area (Kg/m^2)	Tdek
Less than 125	15
125 – 195	12
More than 195	10

Source: (Badan Standarisasi Nasional, 2020)

Based on the SNI table above with the known value of TDEk 415.872 kg/m^2. Then, the TDEk value on the research object is 10.

d. Penetration Thermal Transmittance Value (Uf)
In principle, the calculation of the value (Uf) is calculated using the same formula as finding the value of opaque transmittance (Uw). It is known that the material used in the research object is glass. So, it is found for
Uf calculation as follows:

Table 7. Calculation of Uf Value

Component	Thickness	K	R
	(m)	(W/m.K)	(m^3K/W)
External Air			0,04
Inner Glass	0,006	1,053	0,01
Air Cavity			0,16
Outer Glass	0,008	1,053	0,01
Internal Air			0,12
	Total		0,33

Source: Researcher

Uf = 1/Rtotal
= 1/0,33
= 3 W/m^2K

e. *Wall Window Ratio* (WWR)
In this study, the Wall Window Ratio (WWR) value used is the result of the comparison of the AS 33-34 area with the overall glass area in the AS area.
It is known:
Dimensions per glass module = 2.5m x 1.45m
Glass Area = 174 m^2
Area As 33-34 = 174 m^2
WWR = 174/174
= 1

f. Shading Coefficient of Penetrating System (SC)
In determining the value of the shading coefficient of the fenetration system (SC), it is done by using the calculation formula:

$$SC = SCk \times SCeff$$

In this research object, it is known from the data listed in the Yogyakarta International Airport glass brochure that the SCk value is 0.37. Because, the building of the Yogyakarta International Airport terminal, especially in the domestic departure lounge area, has an

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overstep so that the roof has only partial shading, the value of SCeff is 0.5. Then the calculation of the SC value is as follows:

SC = 0,37 x 0,5
= 0,185

g. Solar Radiation Value (SF)
For the solar radiation factor, you can see the provisions that have been determined in SNI 6389-2020. Because the research object is in the province of Yogyakarta and has an orientation direction facing south, the SF value is 105.

Table 8. City Solar Radiation Factor

Yogyakarta	U	TL	T	TGR	S	BD	B	BL	Roof/Horz
Orientation	152	168	170	130	105	139	178	168	380

Source: (Badan Standarisasi Nasional, 2020)

h. Planning temperature difference between outside and inside (ΔT).
Based on SNI 6389-2020 concerning Energy Conservation of Building Envelopes in Buildings for the value of the planning temperature difference between the outside and the inside (ΔT), a value of 5 is taken.
From the existing data and calculations obtained from each variable, the calculations are as follows:

a. Solar absorbance value (α) 0.88
b. Impermeable thermal transmittance value (Uw) 3.06 W/m^2K
c. Equivalent temperature difference (TDek) 10
d. Penetration thermal transmittance value (Uf) 3 W/m^2K
e. Wall Window Ratio (WWR) 1
f. Phenetrical system shading coefficient (SC) 0.185
g. Solar radiation factor (SF) 105
h. Temperature difference (ΔT) 5

Based on the results of the calculation of the variable values above, it can be calculated in accordance with the OTTV formula found in SNI 6389-2020 as follows:

$$OTTV = \alpha[(Uw \times (1-WWR \times Tdek]+(Uf \times WWR \times \Delta T)+(SC x WWR x SF)$$

Where:
OTTV : overall thermal transfer value on the outer wall that has a certain direction (W/m^2)
α : Absorptance of solar radiation
Uw : Thermal transmittance on impermeable walls ($W/m^2.K$)
WWR : Comparison of the window area with the area of the entire outer wall in a predetermined direction.
Tdek : Equivalent temperature difference (K)
SF : Solar radiation factor (W/m^2)
SC : Shading coefficient of the penetrating system
Uf : Thermal transmittance of the penetration ($W/m^2.K$)
ΔT : Planning temperature difference between outside and inside.

Basically, the OTTV value calculation is divided into three stages, namely:

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a. Wall Conduction
Wall conduction formula is :
Wall Conduction = α[(Uw x (1–WWR x Tdek]
= 0,88[(3,05 x (1-1 x 10)
= 0

Table 9. Calculation of Wall Conduction

(α)	WWR	1-WWR	Uw	TDek	Result
0,88	1	0	3,06	10	0,00

Source: Researcher

Based on the results of the above calculations, the result of wall conduction is 0.

b. Glass Conduction:
Glass conduction formula is:
Glass Conduction = Uf x WWR x ΔT
= 3 x 1 x 5
= 15

Table 10. Calculation of Glass Conduction

Uf	WWR	ΔT	Result
3	1	5	15

Source: Researcher

Based on the results of the above calculations, the results of glass conduction are 15

c. Glass Radiation
The result of the glass radiation calculation is 19.43, with the following calculation:
Glass Radiation = SC x WWR x SF
= 0,185 x 1 x 105
= 19,43

Table 11. Calculation of Glass Radiation

WWR	SF	SCk	SCeff	SC	Result
1	105	0,37	0,50	0,185	19,43

Source: Researcher

So, the result of the calculation of OTTV value in the domestic departure waiting room of Yogyakarta International Airport precisely on glass axles 33-34 is:
OTTV = Wall Conduction + Glass Conduction + Glass Radiation
= 0 + 15 + 19,43
= 34,43 W/m^2

5. Conclusion

From this research, there are three main factors that cause the results of the OTTV calculation value including design and orientation direction of the building, selection of building material elements, and the surrounding environmental conditions of the building. Optimal building orientation design and direction such as directing the long side of the building to the north and south to minimize sun exposure to the building. The selection of building materials is important because materials with low U-value affect how quickly heat can be

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received and released by the building. Environmental conditions around the building such as temperature and humidity, high temperature and humidity cause an increase in heat load on the building and complicate efforts to have thermal comfort.

6. Research Implication

Based on the results of data processing analysis and data calculations in this study, the result of the OTTV value of glass from the domestic departure waiting room of Yogyakarta International Airport precisely in axles 33-34 is 34.43 W/m2. The OTTV value of glass as 33-34 domestic departure waiting room of Yogyakarta International Airport is 34.43 W/m^2 which means that the area has met the OTTV value standard from SNI 6389-2020 which states that the OTTV value should not be greater than or equal to 35 W/m^2.

7. Research limitations

Researchers only use manual calculations contained in SNI 6389-2020. So, it is hoped that in the future for further research it can use software tools to simulate and model building designs against heat such as Integrated Environment Solution-Virtual Environment (IES-VE) and it is hoped that further research can use technological measuring instruments in terms of data collection to be more precise such as solar radiation measuring devices and so on.

For further research, from this research process, researchers hope that a comprehensive calculation of the orientation direction of the Yogyakarta International Airport terminal building can be carried out to prove and as a comparison material that the direction of the building in other orientations is better or worse for the OTTV value. It is hoped that further analysis can also be carried out on the use of variations in building materials to see their effect on the OTTV value.

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