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Analysis of Natural Daylighting at GPIB Bethel Bandung Using DIALux Evo 10.1 Simulation

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ABSTRACT

Natural daylighting comes from sunlight that is reflected from outside into the building and plays an important role for the building. One of the buildings that must have good natural lighting is the Church. Natural lighting is needed to support religious activities in the Church from a functional and architectural point of view by giving a certain meaning or aesthetic value. Based on the applicable standards, the church as a place of worship has a minimum requirement of 200 lux lighting (SNI) 03-6197-2000. This study aims to determine the suitability level of natural lighting in the church with applicable standards. The method used in this study is a quantitative method with data acquisition through direct observation and simulated using DIALux Evo 10.1 software. Simulation results data in the form of lux calculations and lighting distribution. Based on the simulation results, it was found that natural lighting at GPIB Bethel Bandung did not meet the applicable standards for two effective times. Therefore, a response is needed to overcome this by increasing the number and width of window openings.

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1. INTRODUCTION

Lighting is a process of illumination or the provision of light. Light is the primary instrument in the mechanism of human vision to identify the surrounding environment during activities(Jannah, 2022). Based on its source, lighting is categorized into three types: natural lighting from nature, artificial lighting from lamps or human-made lighting devices, and mixed natural and artificial lighting(Yusvita, 2021). The best lighting is natural sunlight because it has the highest intensity and the most complete color spectrum. In architecture, natural lighting is a crucial factor in designing buildings as it plays a role in presenting spatial forms. Moreover, natural lighting is environmentally friendly and can produce sustainable lighting with low levels of emissions, energy consumption, and maintenance costs(Dianagri, 2021).

One of the buildings that greatly requires the role of natural lighting is a church. A church is a place of worship for Christians that accommodates liturgical activities and other religious activities. To support these activities, natural lighting in the church must accommodate functional needs by providing visual comfort for its users. Visual comfort is achieved by considering the quantity and quality of light, spatial optimization, and contrast(Guerry, Gălătanu, and Zissis, 2019). Besides functional needs, natural lighting in the church must also play an optimal role architecturally and psychologically to create a contemplative and sacred atmosphere during worship(Mandala, 2021).

The lighting standard for churches in Indonesia is regulated and set at 200 lux in the Indonesian National Standard (SNI) 03-6197-2000. The applicable standard serves as a reference to ensure that the lighting in a space is neither too bright nor too dim, thus fulfilling user comfort. Below is a table of the lighting standards for places of worship based on the SNI.

Table 1. Standard of Lighting for Places of Worship

Room Function	Lighting Level (Lux)
Mosque	200
Church	200
Vihara	200

This research aims to determine the level of compliance of natural lighting in churches with applicable ideal standards. The methods used in this research are quantitative methods through direct observation and qualitative methods through interviews and literature study, followed by simulating the obtained data using DIALux Evo 10.1 software.

This research produces several novelties in the field of architecture, namely: 1) proving the compliance of natural lighting in churches with applicable standards along with the influencing factors; 2) appropriate response based on the obtained results to align with the applicable standards. These novelties can serve as guidance for implementing good natural lighting in churches.

2. METHODOLOGY

Observation was conducted at the West Indonesian Protestant Church (GPIB) Bethel Bandung with the church building as the main object. The collected data were simulated using DIALux Evo 10.1 software to obtain analytical data such as illuminance distribution values on the building, which were subsequently adjusted to complete with the applicable lighting standard of 200 lux based on (SNI) 03-6197-2000 to determine the factors influencing the simulation results.

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2.1 Building Specification

Figure 1 shows the location of the research building situated at Jl. Wastukencana No.1, Babakan Ciamis, Kec. Sumur Bandung, Bandung City, West Java with coordinates 6°54'49.0"S, 107°36'31.2"E.

Figure 1: Location of GPIB Bethel Bandung
Source: Google Earth, 2022

The orientation of the building's front façade faces east with the following boundaries:

1. Northern Boundary : SMKN 1 Bandung
2. Southern Boundary : Collector Road – Perintis Kemerdekaan Street
3. Eastern Boundary : Collector Road – Wastukencana Street
4. Western Boundary : Indonesia Menggugat Building

The building has a total area of approximately 450.47 m2 and a circumference of around 97.9 m with the main building's height being approximately 11 m. Figure 2 shows the specifications of the building's dimensions in millimeters (mm), created using Autocad software.

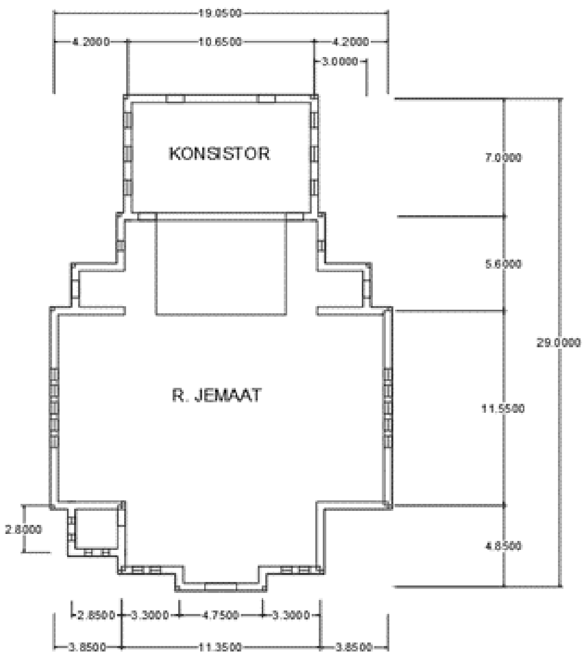

Figure 2: floor plan and dimensions of GPIB Bethel Bandung

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Figure 3: 3D model for the façade of GPIB Bethel Bandung using DIALux Evo 10.1

Figure 3 shows that the openings are focused on the south and north sides, while on the west side, there are only a few openings at the top. The least number of openings is on the east side.

2.2 Room Specification

Broadly Speaking, GPIB Bethel Bandung is divided into two main functional spaces: the consistory room and the congregation room. The consistory room is used for the preparation of pastors and the council before worship activities take place. The congregation room is where the congregation, council, and pastors gather to conduct worship services together. (Napitupulu, 2009)

A. Consistory Room

The consistory room has an area of 66.81 m2, a circumference of 33.5 m, and a building height of 6.5 m. Table 2 shows the material specifications for the consistory room as input for DIALux Evo 10.1

Table 2. Consistory Room Material Specifications

Specification	Material	Reflection Factor	Reflective Coating
Room Enclosure	Concrete walls with thick white paint, 45 cm	84%	0 %
Ceiling	Gypsum	84%	0%
Floor	Concrete Tiles	22%	4%

B. Congregation Room

The congregation room has an area of 325.51 m2, a circumference of 90.57 m, and a building height of 11 m. Table 3 shows the material specifications for the congregation room.

Table 3. Congregation Room Material Specifications

Specification	Material	Reflection Factor	Reflective Coating
Room Enclosure	Concrete walls with thick white paint, 45 cm	84%	0 %
Ceiling	Gypsum	84%	0%
Floor	Concrete Tiles	22%	4%

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2.3 Light Openings Specification in the Room

Orientation, size, and placement of windows are among the factors that influence the depth of light penetration and distribution in buildings. GPIB Bethel Bandung has five types of windows with different sizes and materials tailored for optimizing natural lighting. Table 4 shows the specifications of these windows as input data for the DIALux Evo 10.1

Table 4. Openings with Glass Specifications

Code	Size (m)	Q	Total Area (m2)	Material	Reflection Factor	Transmittance Value	Refractive Index	Lower Threshold (m)
A	2.5 x 0.7	2	3.5	Palisander	8%			2.65
B	2.5 x 0.7	10	17.5	Stained Glass	8%	88%	1500	2.65
C	2.5 x 0.7	1	1.75	Frosted Glass	8%	88%	1500	2.65
D	2.5 x 1	3	7.5	Stained Glass	8%	88%	1500	2.65
E	0.4 x 0.4	2	0.32	Frosted Glass	8%	88%	1500	2.5

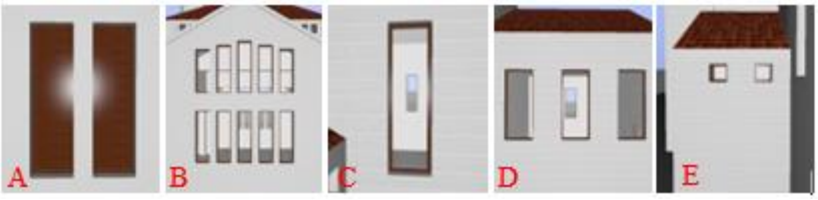

Figure 4: Visualization of Window Glass Types in Table 4

Figure 4 shows that in addition to windows, the building also has air circulation openings without glass, which also serve as entry points for natural sunlight. Table 5 shows the specifications of the openings in the building.

Table 5. Window Glass Specifications

Code	Size (m)	Q	Total Area (m2)	Lower Threshold (m)
F	0.6 x 0.4	3	0.72	10.5
G	0.2 x 0.2	26	1.04	8

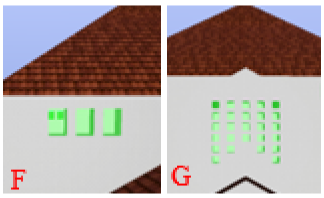

Figure 5: Visualization of Openings without Glass in Table 4

From the top view, the floor plan of GPIB Bethel Bandung has a shape resembling a Portuguese cross with equal-length and symmetrical arms. Consistent with its floor plan, the placement of the openings is symmetrically arranged among each side of the building. Figure 5 shows the locations of glassless openings on the floor plan.

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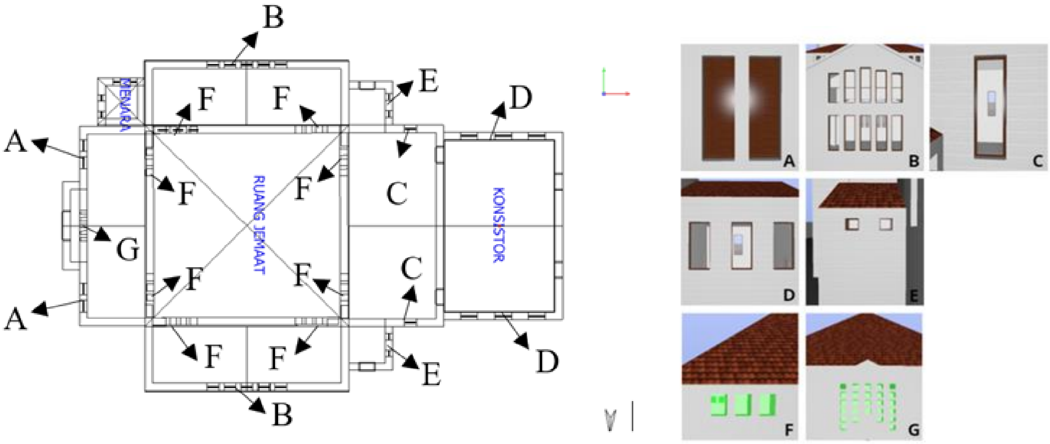


Figure 6: Location Openings from Floor Plan

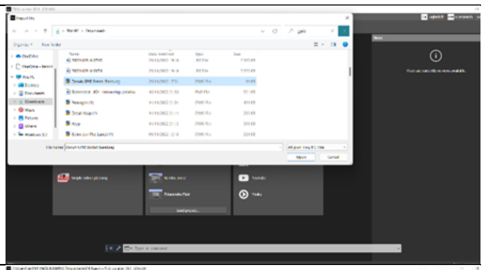
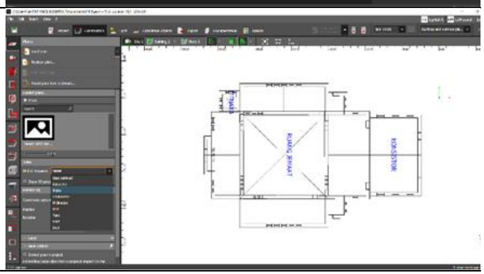
Figure 6 provides information on the location of each type of window with glass and without glass through the floor plan of GPIB Bethel Bandung.

2.4 Simulation using DIALux Evo 10.1

The building specifications, rooms, and openings at GPIB Bethel Bandung are further simulated using the DIALux Evo 10.1 software, conducted at effective sunlight appearance times and effective church activity times at 08.00 WIB, 10.00 WIB, 12.00 WIB, 14.00 WIB, and 16.00 WIB. Sky conditions also affect light distribution. The sky condition used for the simulation is an overcast sky, where this condition can result in deeper illumination penetration into the building. The simulation date is conducted on June 21, 2021, or during the June solstice, when the Northern Hemisphere experiences the beginning of summer and longer daylight hours.

The data generated from the simulation is quantitative data consisting of the range of natural lighting distribution entering and the lux values at specific points above the working plane. Table 6 outlines the steps for simulating natural lighting using DIALux Evo 10.1.

Table 6. Steps for Simulation using DIALux Evo 10.1

Steps for Simulation	Image Information
Open DIALux Evo 10.1 software and start a new project by importing a building floor plan that has been created with AutoCAD for tracing.	
Setting the unit of measurement used to meters.	

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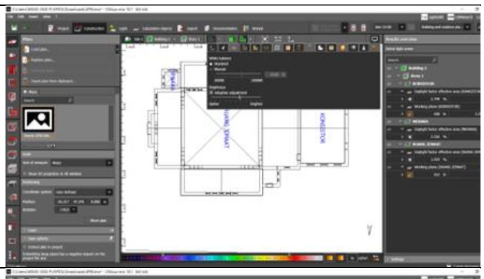
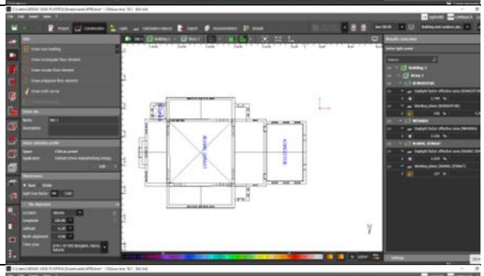
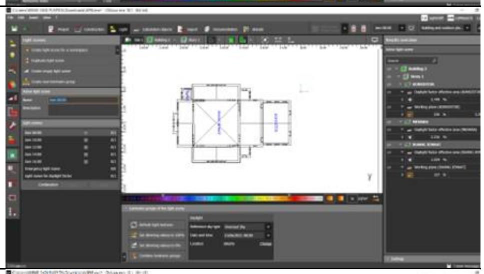
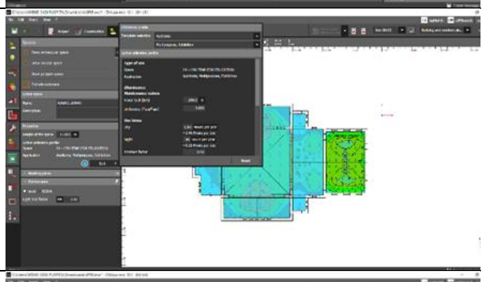
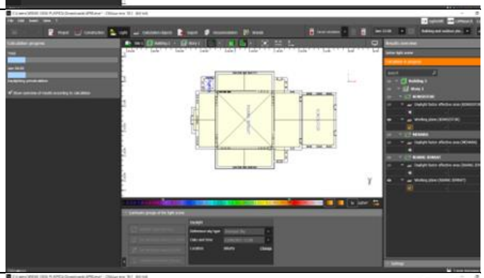
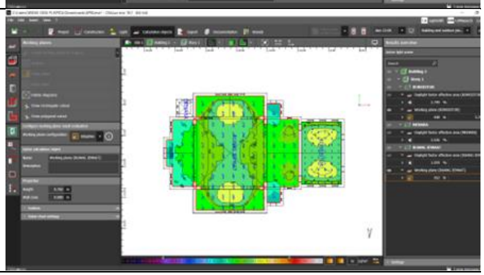
Setting the orientation of the building's front facade towards the East.	
Setting the coordinate point of the building location. Since the location of Bandung is not available, Jakarta's location will be used instead.	
Creating a 3D model of the building with materials, dimensions, and openings adjusted to match the actual data.	
Entering the active lighting simulation time data, which is at 08.00 WIB, 10.00 WIB, 12.00 WIB, 14.00 WIB, and 16.00 WIB, with overcast sky conditions and the date set to June 21, 2021.	
Setting the standard in the church room to 200 lux.	
Starting the simulation as a whole.	
Opening the analysis data of the simulation calculation results for review.	

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3. RESULT AND DISCUSSION

Simulation using DIALux Evo 10.1 software produces data on the distribution and average, highest, and lowest lux values at each testing time. The data is then adjusted to the standard average of 200 lux. In general, the GPIB Bethel Bandung building is divided into two functions, namely the consistory room and the congregation room. Both rooms have different shapes, sizes, and openings, requiring separate assessments.

3.1 Consistor Room

Based on the simulation, the data obtained for the consistory room is presented in Table 7.

Table 7. Simulation Result of Consistor Room

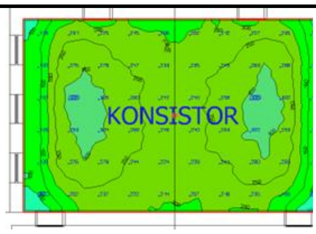
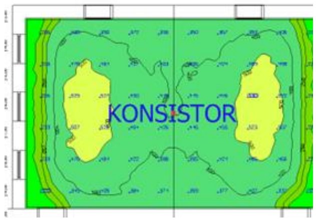
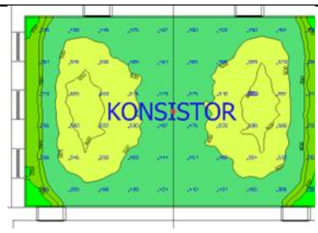
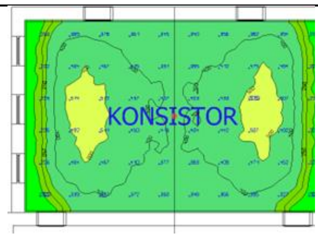
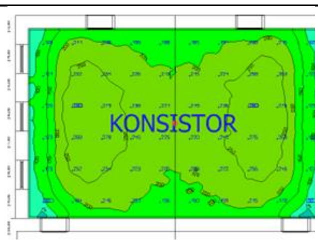
Time	Average Lux	Lighting Distribution	SNI Standard	Note	Conformity
08.00	226 lx		200 lx	Min: 68.8 lx Max: 326 lx	Meet the standards
10.00	392 lx		200 lx	Min: 119 lx Max: 564 lx	Meet the standards
12.00	448 lx		200 lx	Min: 136 lx Max: 646 lx	Exceeds Standards
14.00	380 lx		200 lx	Min: 115 lx Max: 548 lx	Meet the standards
16.00	207 lx		200 lx	Min: 62.8 lx Max: 298 lx	Meet the standards

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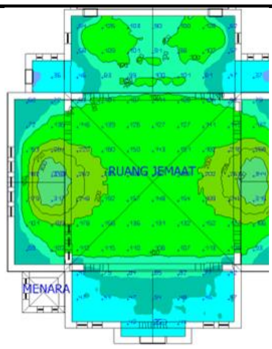
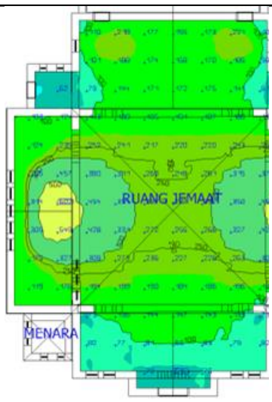
Table 7 provides information that the average lux value in the consistory room has met the SNI standard of 200 lux. The highest average lux value of 448 lux was obtained at 12:00 PM, when the sun was at its highest position. This value significantly exceeds the standard, especially in the area around the windows, which reached a value of 646 lux. The area around the windows receives significant lighting because the glass material used has a high light transmission value. The lowest lux value was obtained at 08:00 AM and 04:00 PM, when the sun begins to rise and set, respectively, resulting in minimal light entering the room.

The light distribution in the consistory room is already quite good, as seen from the value chart points that have values with insignificant gaps. This is influenced by the large size of the openings, with windows placed on two opposite walls, making the light distribution more optimal and minimizing glare. Additionally, the materials used on the walls and ceiling of the room have a high reflection value of 84%, allowing the incoming light to be reflected and spread throughout the room.

3.2 Congregation Room

Based on the simulation, the data obtained for the consistory room is presented in Table 8.

Table 8. Simulation Result of Congregation Room

Time	Average Lux	Lighting Distribution	SNI Standard	Description	Kesesuaian
08.00	127 lx		200 lx	Min: 0 lx Max: 356 lx	Doesn't meet standards
10.00	220 lx		200 lx	Min: 0 lx Max: 616 lx	Meet the standards

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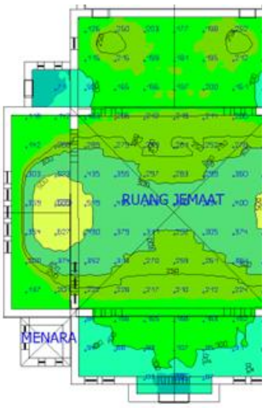
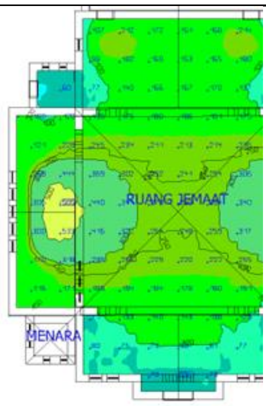
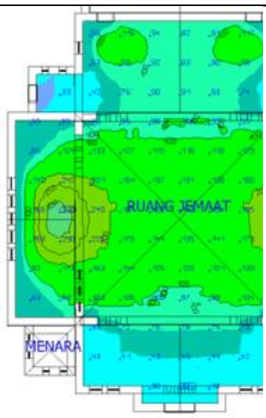
12.00	1 lx	252		lx	200 lx	Min: 0 Max: 705 lx	Meet the standards
14.00	1 lx	214		lx	200 lx	Min: 0 Max: 598 lx	Meet the standards
16.00	1 lx	116		lx	200 lx	Min: 0 Max: 325 lx	Doesn't meet standards

Based on the simulation data in Table 8, the light distribution in the congregation room is still less satisfactory compared to the consistory room, as seen from the significant difference in lux values. The highest average lux value is 252 lux, recorded at 12:00 PM. However, there is a disparity in light distribution during this time, where the highest lux value reaches 705 lux in the area around the large windows, while some areas, such as the front of the main entrance door and the areas around the north and south doors, receive no light at all. This is because the main entrance area's windows, which should be made of glass material, are covered with palisander wood material that does not transmit light, resulting in light penetration only through the openings at the top or when the main entrance door is open. Meanwhile, the small size of the windows in the north and south areas leads to suboptimal light penetration and distribution.

The standard average lux value is not met at 8:00 AM with an average value of 127 lux and at 4:00 PM with an average value of 116 lux. This is because, during these times, the sun is just rising and setting, resulting in suboptimal sunlight. The complex floor plan of the congregation room and its relatively large size also create dark zones. In contrast, the rectangular floor plan of the consistory room with a relatively smaller area ensures even light distribution and avoids dark zones without light.

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4. CONCLUSION

Natural lighting plays a crucial role in supporting religious activities within a church. Natural lighting in a church can be considered good if it meets standards and is evenly distributed throughout the space.

This research indicates that the natural lighting in GPIB Bethel Bandung is generally sufficient as it meets the average lux standards during effective times. The determining factor for this is the placement of window openings. Orienting the windows north and south is a suitable choice as the orientation receives consistent sunlight in tropical climates and avoids the potential for glare and high radiation. (Lechner, 2015) Placing windows on two symmetrical wall planes also helps distribute light evenly into the center of the room. Additionally, the materials used for the windows, such as stained glass and frosted glass, have good light transmission values.

However, there are still areas not reached by light due to the large size of the space and window openings covered by non-transmitting wooden materials, resulting in light being reflected rather than transmitted into the room. This also leads to the failure to achieve the lux standards at 8:00 AM and 4:00 PM. Therefore, it can be concluded that the natural lighting in GPIB Bethel Bandung is sufficient in some areas but not perfect due to the presence of dark zones and the failure to meet lux standards at two effective times.

Recommendations to address these issues include installing glass window openings in the main entrance area and increasing the size of window openings in the north and south door areas. Additionally, the addition of artificial lighting is recommended as it may be difficult for natural lighting alone to achieve optimal light distribution, especially given the complex floor plan and large buildings. (Kartika & Elsiana, 2021)

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