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Analysis of Daylighting Aspects on Visual Comfort of Building Users: A Case Study of The West Hall of Bandung Institute of Technology

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ABSTRACT

As a multi-purpose building that is often used by academics and students, the west hall of Institut Teknologi Bandung needs to pay attention to space comfort, especially visual comfort from natural lighting when doing indoor activities. Research with the West Hall of Institut Teknologi Bandung as a case study aims to analyze and find out what is good natural lighting for hall buildings and whether the West Hall of Institut Teknologi Bandung meets the standard of light requirements according to its function. The research was conducted by comparing indoor natural lighting data obtained from simulations using DIALux evo software with the indoor lighting requirements set by Standard Nasional Indonesia, as well as comparing them with relevant previous studies. From the measurements taken, it was found that the daylighting in the case study was not good enough. Openings that are covered by a roof cause the effective aperture in the opening to be much smaller than the light opening itself and prevent light from entering the room, requiring artificial lighting to support it. The final results of this research could be used as an evaluation of building performance and recommendations regarding natural lighting both to the agencies concerned and to designers and building designers so that building performance in the future can be more optimal. In addition, this research can also provide information to the public about how natural lighting can affect the comfort, health, and performance of users in a building.

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1. INTRODUCTION

Lighting is one of the important aspects in the design of a building (Soegandhi et al., 2015). Light is used by humans to see, recognize, and learn about their surroundings. Light sources are divided into two categories: natural light sources that come from natural emitters like the sun or stars, and artificial light sources that come from artificial emitters like fire, lamps, and so on. Quoting from the Jakarta Green Building User Guide Vol. 3: Lighting System based on Governor Regulation No. 38/2012, light is a necessity for building users to be able to function properly and achieve visual comfort. In buildings, lighting functions to ensure human safety, facilitate visual appearance, and help creativity in forming a visual environment (Nurhaiza and Lisa, 2019).

Natural lighting is one of the essential factors in the design of architectural works. Paramita (2022) from Mangkuto (2021) state that natural light sources in buildings are divided into two categories: direct sunlight or sunlighting and daylight or daylighting. Unlike sunlighting, which is direct sunlight that causes glare and heat, daylighting is diffused light that has passed through the sky or clouds, does not cause glare, and is often engineered in building design to meet lighting requirements.

According to SNI 03-2396-2001, daylighting in buildings can be considered good if there is enough light entering the room during the day between 08:00 and 16:00 local time and there is a sufficiently even distribution of light in the room or no disturbing contrasts. Some factors of daylighting include the sky factor, which is the direct lighting component from the sky, external reflection factor, which is the lighting component from reflections of objects around the building, and internal reflection factor, which is the lighting component from reflections of surfaces within the room.

Most of the human need for lighting can be fulfilled by natural lighting if the building is optimally designed. The availability of optimal natural lighting can fulfill two basic human needs: the visual need to see, both work areas and rooms, and to experience environmental stimulation from the effects of lighting (Boyce et al., 2003).

In addition to enabling humans to recognize a visual object, natural lighting can also create psychological effects through the formation of an atmosphere or ambiance that supports the function of the space (Pangestu, 2019). As mentioned by Ticleanu (2021), light will affect non-visual effects on human physiology, including biological circadian rhythms. Furthermore, light can also have acute non-visual effects on alertness, attention, and mood, so optimizing human activities in the design space requires attention to lighting. There is a positive relationship between natural lighting and user performance improvement (Heschong, 2002).

Along with the development of human needs for buildings that can accommodate many people, buildings with functions such as auditoriums are specifically designed. An auditorium is a building designed to accommodate a group of people with various activities, so the design of auditorium buildings needs to consider many aspects, one of which is lighting in the space.

A building designed to accommodate a group of people will certainly have a massive or wide-spanning form. In wide-spanning buildings, the central area inside the room tends to not receive natural lighting, so openings in the building need to be designed accordingly. Natural lighting in the room becomes a problem in wide-spanning buildings, this is because of the dimensional depth of the building so that natural light cannot reach the inner room (Vidiyanti and Suherman, 2020).

Optimal room lighting standards differ across countries. The lighting standard or light intensity based on the type of activity in Indonesia has been regulated in SNI 03-6575-2001. The recommended light intensity for a meeting room, lobby, or hall is 100 – 300 lux.

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Meanwhile, the recommended lighting standard in ISO 8995-2002(E) is 500 lux with a glare index of 19 (Salehuddin, Latupeirissa, 2017).

In addition to being influenced by the type and size of openings, lighting quality is also influenced by the building's position relative to its surroundings (Zainurrahman, 2012). Lighting in the room is not only assessed in actual terms but also from environmental lighting that meets visual needs (Vidiyanti and Suherman, 2020).

The West Hall of the Bandung Institute of Technology is a multipurpose building that is often used by academic and student communities as a place for seminars, conferences, meetings, workshops, training, and similar activities. Quoting from the Directorate of Facilities and Infrastructure of Bandung Institute of Technology, this building, which covers an area of 1415 m² and is over a hundred years old, was originally not designed as an auditorium but as a building with many classrooms. The design of the building during different periods and the conversion of its function into an auditorium raises a question about whether the building's performance related to natural daylighting meets the lighting standards regulated by the Indonesian National Standards and can provide visual comfort to users according to its current purpose.

2. THE MATERIALS AND METHOD

The research method used is analytical, with the research variable being the level of natural daylighting. The data collection technique includes documentation, which is used to collect data in the form of drawings of the West Hall of Bandung Institute of Technology. Observation is also employed, involving direct observation of objects related to the discussed issue, namely the level of natural daylighting in the West Hall of Bandung Institute of Technology, with specific measurement techniques used in the main room.

Measurement technique involves using software, DIALux evo, to measure the level of illumination intensity (E) in lux (lx) or lumens/m². Information entered into the DIALux evo software includes a three-dimensional model created using SketchUp Pro 2021 with the help of a tape measure to measure the dimensions of the West Hall of Bandung Institute of Technology and other variables affecting the study, such as opening dimensions, and so on.

Literature review is conducted to deepen understanding of the research and support the research report process, by collecting relevant and credible theories and research references to analyze the data collected in the study. Literature sources used include books, articles, scientific journals, and the internet.

The measurement process is conducted in several stages. First, direct observation of the research object is done by visiting the location of the West Hall of Bandung Institute of Technology to obtain necessary data such as building dimensions, types and dimensions of openings, and opening positions. This step is significant and requires careful attention.

Second, floor plans and three-dimensional models of the research object are created using AutoCAD 2021 and SketchUp Pro 2021 based on field data and official documents such as original drawings of the West Hall of Bandung Institute of Technology obtained through the Internet.

Third, the three-dimensional model of the research object from SketchUp Pro 2021 is inputted into the DIALux evo software, and adjustments are made to ensure that the model can be read by the DIALux evo algorithm in the simulation.

Fourth, simulation is conducted using the DIALux EVO software, and data analysis is performed on the results obtained. The analysis is done by comparing the simulation results with the Indonesian National Standards and relevant previous studies.

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3. RESULT AND DISCUSSION

A. Measurement

The measurement was first conducted on Friday, November 18, 2022, with direct field observation to collect data from the object being studied. From the direct field observation, data was obtained regarding two types of openings in the West Hall of Bandung Institute of Technology, namely openings on all sides of the building with a threshold height of 2 m from the outside and 1.2 m from the inside, with a total window height of 2 m divided into 2 equal parts, and openings in the middle of the room just below the largest roof mass with a threshold height of 6 m from the outside and 5.2 m from the inside, with a total window height of 2 m divided into 3 equal parts. Both types of openings use the same material, which is transparent stained glass.

Figure 1. Opening Detail from Inside the Building

The building dimension data from the field was processed and combined with the building dimension data obtained from the book by Ben F. van Leerdam titled "Henri Maclaine Pont: Architect Tussen Twee Werelden" (1992) regarding the Gebouw voor Wiskunde Mechanica en Technische Tekenen building, now known as the West Hall of Bandung Institute of Technology, to create a building floor plan in the AutoCAD 2021 software.

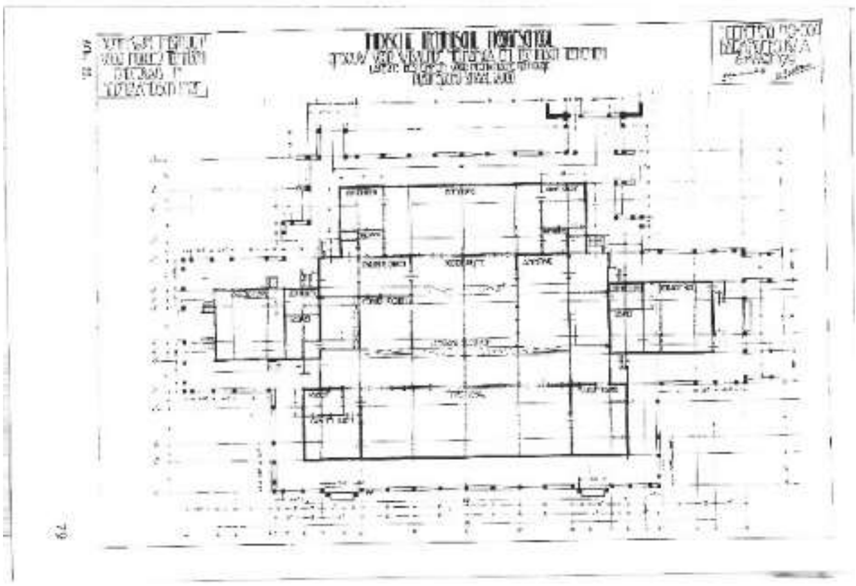

Figure 2. Floor Plan of Gebouw voor Wiskunde Mechanica en Technische Tekenen
(Source: Leerdam, 1992)

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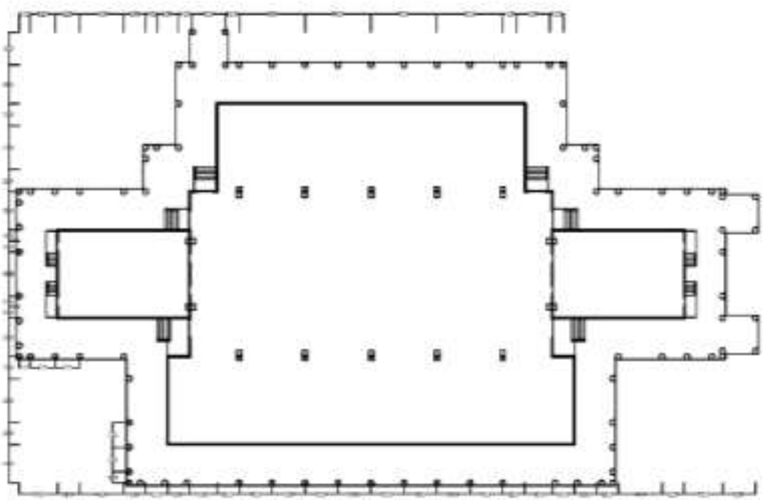

Figure 3. Floor Plan of Aula Barat, Bandung Institute of Technology

The floor plan was then developed into a three-dimensional model using SketchUp 2021 software and inputted into the DIALux Evo software.

Table 1. Table of Building Material Adjustments in DIALux evo

Element Interior	Field Condition	Model Material
Floor	Terrazzo 40x40	Tiles white-42
Wall	White painted brick	9001(cream)
Column	Wood	Palisander
Opening	Glass	Default glass
Ceiling	Gypsum	Ceiling panels
Roof	Sirap	Tiles grey

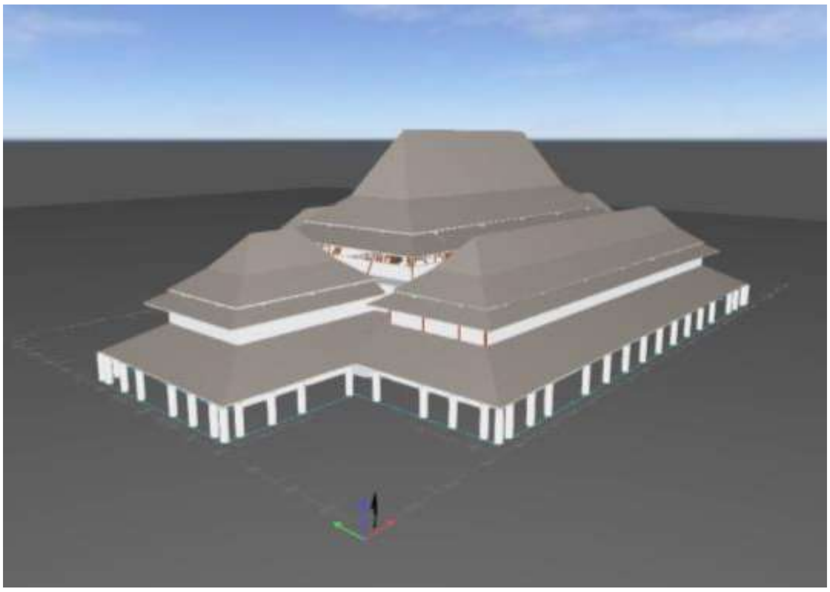

Figure 4. Three-Dimensional Model in DIALux Evo
(Source: author's documentation, 2022)

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Table 2. Table of Building Material Information in DIALux evo

Model Material	Reflection Factor	Reflection Layer	Refractive Index
Tiles white-42	70%	7%	-
9001(cream)	77%	0%	-
Palisander	8%	40%	-
Default glass	10%	-	1.5
Ceiling panels	70%	0%	-
Tiles grey	17%	29%	-

The simulation was conducted with time settings from 07:00 to 17:00 (UTC +07.00) and location settings in Jakarta on December 22, 2022, the longest day in the southern hemisphere, with an overcast or completely cloudy sky type. In the simulation, the working plane was set at a height of 1 meter from the floor of the indoor space or at a height equivalent to the height of a person when sitting in a chair.

The results of the simulation in the main hall of the West Hall of Bandung Institute of Technology conducted using DIALux evo software based on the observation data obtained are as follows:

Table 3. Results of Daylight Simulation in DIALux Evo

Time	E (lux)	E min (lux)	E max (lux)
07:00	10,1	3,58	22,0
08:00	16,2	5,74	35,2
09:00	21,3	7,55	46,3
10:00	25,0	8,89	54,5
11:00	27,2	9,66	59,2
12:00	27,7	9,82	60,2
13:00	26,4	9,36	57,3
14:00	23,4	8,30	50,8
15:00	18,9	6,71	41,1
16:00	13,3	4,72	28,9
17:00	6,88	2,44	15,0

B. Data Processing

From the measurement results with simulation in the DIALux evo software, it was found that natural daylighting in the main room of the West Hall of Bandung Institute of Technology tends to be dim and uneven. Despite the building's symmetrical shape, the distribution of light in the room is higher on the west side. The distribution of light, where the middle part is brighter, is suspected to occur because there are additional openings in the middle of the room, and the corners are darker, suspected to occur because the light source is covered by the terrace roof from two directions. Some anomalies, where the darkest part is between the corners and the middle of the room, are suspected to occur due to the position of the sun at that time.

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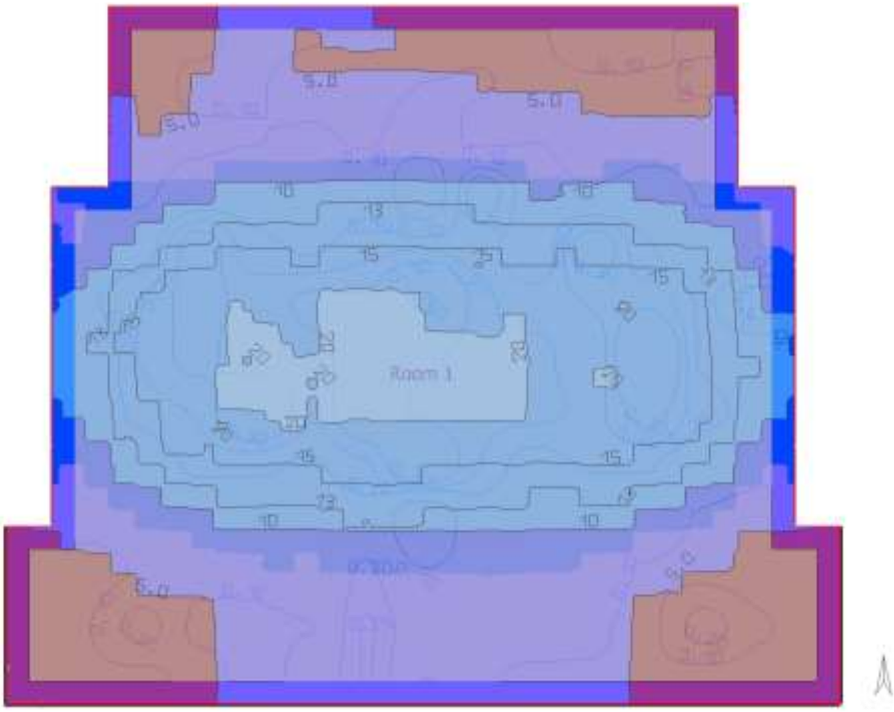

Image 5. Light Distribution in the Main Hall at 07:00
Source: Analysis

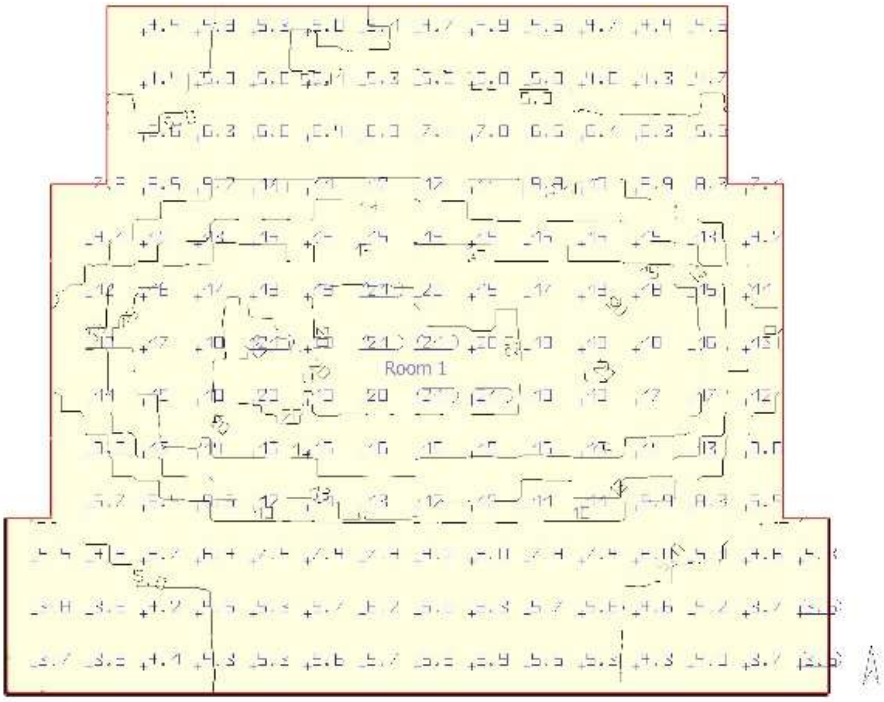

Image 6. Simulation Result at 07:00
Source: Analysis

At 07:00, the main room has a light distribution ranging from 0.50 to 20.0 lux, with 0.50 lux in the corner of the room and 20.0 lux in the middle of the room. The main room of the West Hall of Bandung Institute of Technology is still dark.

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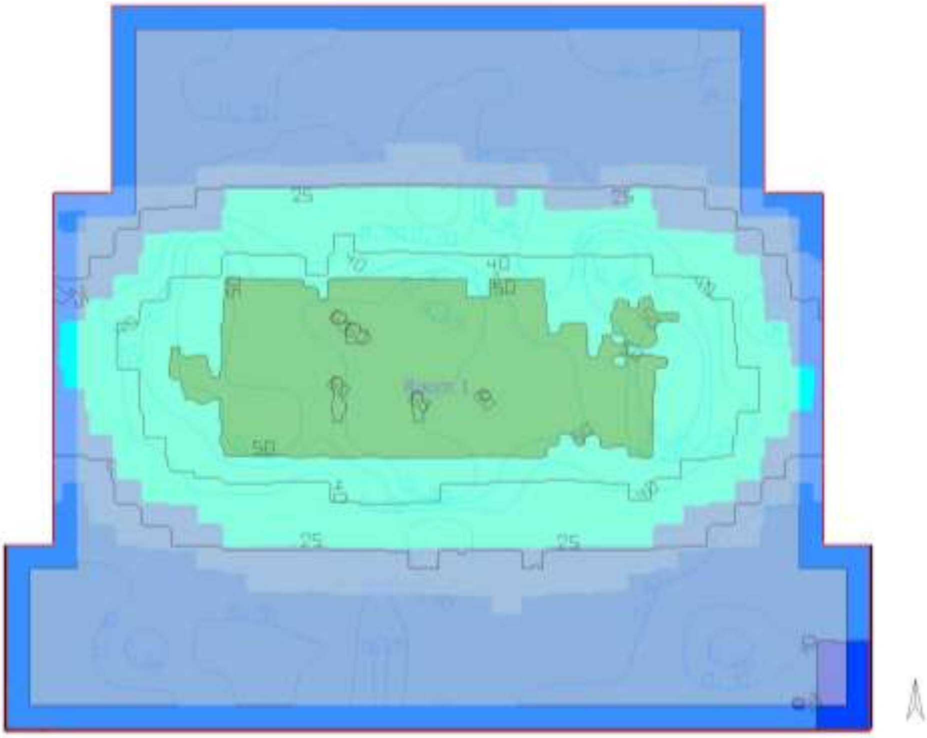

Image 7. Light Distribution in the Main Hall at 12:00
Source: Analysis

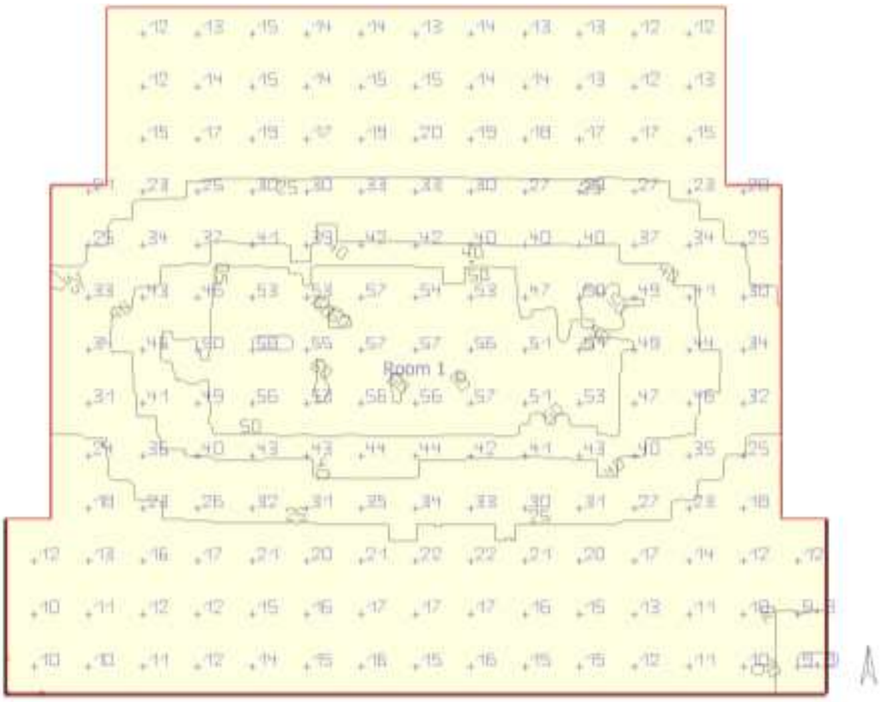

Image 8. Simulation Result at 12:00
Source: Analysis

At noon, the main room has a light distribution ranging from 7.50 to 50.0 lux, with 7.50 lux in the corner of the room and 50.0 lux in the middle of the room. Natural daylighting is at its brightest peak.

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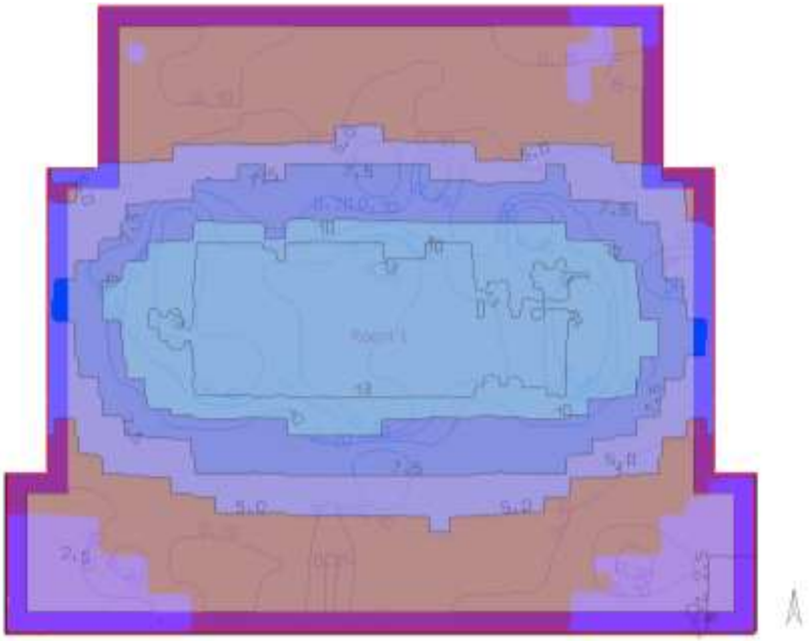

Image 9. Light Distribution in the Main Hall at 17:00
Source: Analysis

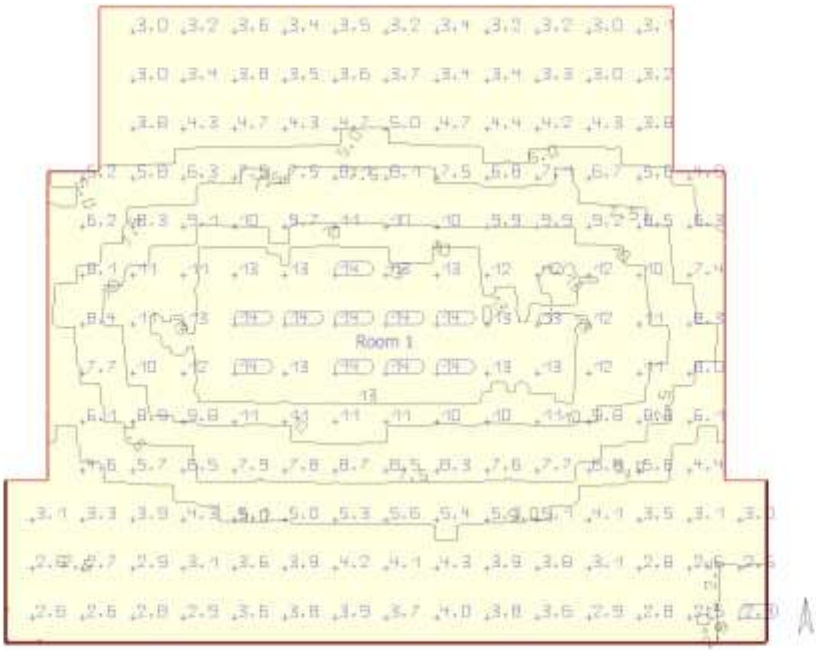

Image 10. Simulation Result at 17:00
Source: Analysis

At 17:00, the main room has a light distribution ranging from 0.50 to 20.0 lux, with 0.50 lux between the corners and the middle of the room and 20.0 lux in the middle of the room. The main room of the West Hall of Bandung Institute of Technology becomes completely dark at 18:00 with 0 lux.

C. Discussion

Referring to SNI 03-6575-2001, the recommended lighting standard for a meeting room, lobby, or hall is 100 - 300 lux. According to SNI 03-2396-2001, daylighting in buildings can be considered good if there is enough light entering the room during the day between 08:00 and 16:00 local time, and there is a sufficiently even distribution of light or no disturbing contrast.

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The results of the simulation of natural daylighting in the main room of the West Hall of Bandung Institute of Technology with the highest lighting level of 60.2 lux and an average lighting level of 21.6 lux do not meet the specified lighting standards. This lighting level does not even meet the recommended lighting standard for classrooms or the building's original function, which is 250 lux.

In general, natural light can be distributed into a room through side lighting, top lighting, or a combination of both. The type of building, height, building ratio, and massing, as well as the presence of other buildings around it, are factors that need to be considered in selecting a lighting strategy (Kroelinger, 2005).

Some aspects of the design decisions of the West Hall of Bandung Institute of Technology may not have maximally considered natural lighting in its design, causing the building to be unsustainable and requiring artificial lighting to meet daylighting needs during the day. However, energy efficiency and visual comfort are key factors in room lighting design (Dora, 2011).

Design decisions such as a 3-meter-wide terrace roof covering the openings on all sides of the building in the West Hall of Bandung Institute of Technology as excessive sun protection (shading) can cause the effective holes in the openings to be much smaller than the light holes themselves, and the openings cannot bring light into the room. These ineffective openings result in insufficient lighting levels in the room.

Humans prefer bright environments with relatively even lighting because light-dark rhythms help control body temperature and hormone secretion into the bloodstream. Good lighting design should not only consider visual appearance but also human biological needs for light (Milaningrum, 2015). Visual comfort can also be achieved depending on the quality of the lighting in the design.

According to William Lam (Sihombing, 2008), human biological needs for light include:

1. The need for spatial orientation, where lighting systems can help indicate place and direction.
2. The need for time orientation, where lighting systems can provide feedback on the passage of time needed by the human body's internal clock.
3. The need to understand the form of structures, which can be disrupted by lighting that contradicts physical reality.
4. The need to focus on activities, where lighting can help shape activity arrangements.
5. The need for personal space, where lighting can define individual personal space.
6. The need for a pleasant space, where a combination of lighting can create an attractive and pleasant design.
7. The need for interesting visual input.
8. The need for arrangement in visual environments.
9. The need for security, where lighting helps the brain receive visual information.

In terms of quality, the West Hall of Bandung Institute of Technology building has met several aspects of human biological needs for light, such as help indicating place, direction, space, time, and activity arrangements. However, even though the level of natural lighting in the room is considered insufficient or below the recommended threshold, users tend to perceive the available natural lighting as sufficient (Konis, 2013). Poor lighting quality can affect the room's atmosphere, create psychological pressure on users, and cause visual disturbances that impact the users' health (Soegandhi, et al., 2015). The insufficient and uneven lighting levels indicate that visual comfort for users has not been achieved and can affect users' health in the long term.

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4. CONCLUSION

From the simulation results, it can be concluded that the natural daylighting in the main room of the West Hall of Bandung Institute of Technology is considered inadequate. Lighting levels in the room that do not meet standards, whether by the Indonesian National Standard (SNI) or the International Organization for Standardization (ISO), can cause visual discomfort for users. Users may perceive the level of natural lighting obtained as sufficient, but they may experience psychological pressure and vision disturbances in the long-term use of the space if the standards for lighting requirements are not met by artificial lighting supplements.

A building design that does not optimize natural lighting and relies on artificial lighting indicates that the building has ineffective energy use performance.

The author's suggestions for improving and optimizing the performance of the West Hall of Bandung Institute of Technology building include modifying the interior by using artificial lighting or lamps during the day to support the lack of light levels in the room when activities are taking place, considering that the West Hall of Bandung Institute of Technology is a cultural heritage site of category A (Bandung City Cultural and Tourism Office, 2022), which does not allow for physical changes such as renovation.

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