Analysis of Lighting Performance in the Hall of the Faculty of Engineering, State University of Gorontalo by using the DIALux Evo 9.0 Simulation

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Abstract. The need for light in the room is something that cannot be negotiated. Meeting these needs can be obtained through natural lighting and artificial lighting or a combination of both. The purpose of this study is to analyze the performance of natural lighting, especially the daylight factor in the Hall of the Faculty of Engineering, State University of Gorontalo, and provide solutions to improve lighting performance in the room. The research method was carried out through a computer simulation (computer simulation) with DIALux Evo 9.0 software by comparing the existing model and the engineering design model. The latter was carried out by changing the handrail material into transparent material such as glass, adding windows on both sides, and adding light shelves outside and inside the building. The FT Hall room simulation was conducted on September 21 with clear sky conditions within the significant lecture period from 07.00 to 17.00. The simulation results show that the engineering design can increase natural light intensity on the left and right edges compared to the existing conditions, with an average increase of 18%. However, this engineering has not reached the middle of the stands, so that additional engineering is needed to optimize natural lighting. Interestingly, this engineering design reduced excessive light intensity at points A1 and A3 with an average of 847 lux at the existing A1 point, down to 709 lux in the engineering design. Meanwhile, A3, with an average of 653 lux for the existing one, drops to 569 lux in the engineering design. The result shows that the engineering design can optimize the direction of light according to the target point and reduce glare, although additional engineering is still needed.

Keywords: lighting design, natural lighting, DIALux software.

1. Introduction

Most power system planners are interested in the savings of electrical power consumption. Various references demonstrate that the highest consumed power is by the lighting systems standing around 19% of worldwide energy consumption [1]. Light is an essential part of human life, especially recognizing the environment and carrying out its activities. Without the light of the dark, scary world, nothing to recognize, no visual beauty. With light, humans can move comfortably and enjoy the arts, natural and artificial environments [2]. The need for light in the room is something that cannot be negotiated. Meeting these needs can be obtained through natural lighting and artificial lighting or a combination of both.

According to Gligor (2004), lighting ought to be planned to supply individuals with the correct visual conditions to perform visual errand productively, securely, and comfortably. The glowing environment acts through a chain of instruments on human physiological and mental components, which advanced
impact human execution and efficiency [3]. According to IESNA (2000), to obtain a good lighting system; theoretically, five criteria must be met. Namely, the quantity or amount of light on a specific surface or the level of light intensity; light density distribution; restrictions so that the light does not dazzle the eye; lighting direction and shadow formation; as well as light color and color reflection [4].

To achieve the visual comfort of a space, it is necessary to know the level of illuminance recommended in the prevailing literacy standards. For information, referring to SNI 03-6575-2001, it is stated that for the ballroom/hall category, the recommended minimum illuminance is 200 lux [5]. Whereas in the ISO 8995: 2002 (E) standard, the recommended illumination is 500 lux with a glare index of 19 [6]. According to SNI 03-2396-2001, the level of natural lighting in the room is determined by the level of sky lighting on a flat plane in an open field at the same time. The ratio of natural light levels in the room and natural lighting on a flat plane in an open field is determined by (a) The geometric relationship between the measuring point and the light hole; (b) The size and position of the light holes; (c) Distribution of skylight; (d) The part of the sky that can be seen from the measuring point [7].

The only and the source of daylight is the Sun. The relative contributions of direct daylight and diffuse daylight in interior lighting depend on the latitude and longitude of the place and the local climate regarding the distributed sky [8]. The variation of sky components varies depending on the cloudy sky (overcast), clear sky, or cloudy (intermediate / mixed-sky). Natural light in a bright sunny sky consists of two components, namely skylight and direct sunlight [9]. According to Satwiko (2009), skylight is the celestial sphere's light. This light is used for natural lighting in the room, not direct sunlight. Direct sunlight will be very dazzling and bring heat, so it cannot illuminate the room [10]. Bringing natural light to buildings is, therefore, one of the most critical aspects of design. Designing for the optimal level of natural light that gets inside a building is complicated by many factors that may affect the distribution of light. The building's typology and its possible impact on optimum daylight rates in its internal areas are one of these criteria [11].

This study examines the Hall of the Faculty of Engineering, Gorontalo State University (UNG). This hall is often used for activities such as guest lectures, seminars, and other student activities. Seeing how important this hall is, so comfort is a factor that needs attention. However, unfortunately in the field, this hall feels dark, especially in the rear seats. This makes the hall necessary to re-analyze its lighting performance. One of the methods is using the Dialux Evo 9.0 simulation. The purpose of this study is to analyze the performance of lighting, especially the natural lighting factor (daylight factor) in the Hall of the Faculty of Engineering, State University of Gorontalo (UNG).

2. Method

This research activity took place in the campus environment of Gorontalo State University 4 in Bone Bolango district, Gorontalo province. The location of the room observed was the Engineering Faculty Hall, Building C5. This research is a quantitative study using a simulation method. Analyzed by descriptive statistical analysis, namely statistics used to analyze data by describing or describing the data that has been collected as it is without intending to make general conclusions or generalizations [12]. The simulation results are made in the form of tables and graphs, which are then described.

Lighting performance analysis was performed using the Dialux Evo 9.0 program to simulate. DIALux is a fast-growing natural and artificial lighting program that meets the information needs of the latest lighting technology and can generate automatic technical reports and have improved visual rendering capabilities.

Several studies using DIALux simulation include research with the title Lighting Quality Analysis Using Numerical Modeling according to SNI Lighting, Direct Measurement Data (On-Site) and Simulation. This study uses three methods, namely numerical calculations based on the reference of the Indonesian National Standard (SNI) study on lighting, direct measurement methods, and computer simulation using DIALux [13]. Another study entitled Evaluation of Interior Lighting Design in Public Meeting Rooms Based on the Value of Lighting Intensity. This study uses measurement and simulation methods using DIALux Evo [4].
The DIALux Evo 9.0 simulation was carried out in the climatic conditions of Gorontalo on September 21, 2019. This date was chosen because the sun's position is in the middle of the equator. Meanwhile, the simulation is carried out in a sufficient lecture period, starting at 07.00 to 17.00 with clear sky conditions and latitude 0° 33' longitude 123° 8' (+8.0 DPL).

![Image of the Hall of Engineering Faculty, Gorontalo State University](image1)

**Figure 1.** Condition of the Hall of Engineering Faculty, Gorontalo State University

Based on observations in the field, the lighting of the audience seat area in the form of a tribune is considered insufficient or tends to be dark. This study simulates both existing data according to field conditions and engineering design. The current handrail area in opaque material (plastered brick) is considered to block the spread of light from the window opening towards the stands. As a result, the light intensity from the handrail position towards the center of the stands continued to decrease. The engineering design carried out is to change the handrail material into a transparent material such as glass, the addition of windows on both sides, and light shelves on the outside and inside of the building to introduce more light into the stands.

Light shelves have been discussed in numerous studies as suitable solutions for controlling daylight in side-lit spaces. It is a system that can be easily modified, offering a range of design solutions. It can be easily mounted on the exterior and/or the interior of a vertical opening, it can come in various shapes from static platforms to curved reflective surfaces, or it can even be actively controlled. A light shelf can offer shading and at the same time can redirect a significant part of the incoming light flux towards the ceiling, improving daylight uniformity [14].

![Image of Light Shelves Position](image2)

**Figure 2.** Light Shelves Position
The level of lighting in a room is generally defined as the average lighting level in the workplane. What is meant by the work area is an imaginary horizontal plane located 0.75 meters above the floor in the entire room. Each level is given a workplane, including a spectator seat in a stand as high as 0.75 meters above the floor.

Figure 3. Addition of Light Shelves and Windows

The placement of the measuring point is divided into several segments, namely A1 in the northeast corridor, A2 in the middle of the stage, A3 in the southwest corridor, B1-I1 in the northeast seats, B2-I2 in the middle of the audience seat, and B3-H3 are in the southwest spectator seats.

Figure 4. Workplane of the Hall of Engineering Faculty, using DIALux Evo 9.0
3. Findings And Discussion
3.1. Simulation result on the existing Hall of Engineering Faculty, using DIALux Evo 9.0

Figure 5. Measuring Points

Figure 6. Simulation Results on Existing Condition using DIALux Evo 9.0 from 07.00 to 09.00
Figure 7. Simulation Results on Existing Condition using DIALux Evo 9.0 from 10.00 to 17.00
Table 1. Existing Condition Simulation Results

| Measuring points | Maximum Light intensity (lux) | Measured time | Minimum Light intensity (lux) | Measured time | Average intensity (07.00-17.00) |
|------------------|-------------------------------|---------------|-------------------------------|---------------|-------------------------------|
| A1               | 1674                          | 08.00         | 284                           | 17.00         | 847                           |
| A2               | 113                           | 16.00         | 69                            | 17.00         | 88                            |
| A3               | 962                           | 16.00         | 366                           | 07.00         | 653                           |
| B1               | 401                           | 08.00         | 70                            | 17.00         | 190                           |
| B2               | 94                            | 08.00         | 49                            | 17.00         | 70                            |
| B3               | 269                           | 16.00         | 82                            | 07.00         | 140                           |
| C1               | 349                           | 08.00         | 58                            | 17.00         | 158                           |
| C2               | 84                            | 08.00         | 40                            | 17.00         | 60                            |
| C3               | 242                           | 16.00         | 82                            | 07.00         | 133                           |
| D1               | 322                           | 08.00         | 52                            | 17.00         | 141                           |
| D2               | 69                            | 08.00         | 35                            | 17.00         | 50                            |
| D3               | 203                           | 16.00         | 68                            | 07.00         | 108                           |
| E1               | 270                           | 08.00         | 46                            | 17.00         | 121                           |
| E2               | 58                            | 08.00         | 27                            | 17.00         | 41                            |
| E3               | 179                           | 16.00         | 63                            | 07.00         | 98                            |
| F1               | 220                           | 08.00         | 37                            | 17.00         | 96                            |
| F2               | 45                            | 08.00         | 23                            | 17.00         | 32                            |
| F3               | 131                           | 16.00         | 46                            | 07.00         | 68                            |
| G1               | 135                           | 08.00         | 26                            | 17.00         | 61                            |
| G2               | 35                            | 08.00         | 19                            | 13.00         | 24                            |
| G3               | 100                           | 16.00         | 31                            | 07.00         | 49                            |
| H1               | 71                            | 08.00         | 15                            | 17.00         | 33                            |
| H2               | 26                            | 16.00         | 14                            | 12.00-13.00   | 18                            |
| H3               | 84                            | 16.00         | 28                            | 12.00         | 39                            |
| I1               | 33                            | 08.00         | 10                            | 17.00         | 17                            |
| I2               | 22                            | 08.00         | 10                            | 12.00-13.00   | 14                            |

Reference: author’s own work

The simulation results show that the farther back towards point I, the lower the light intensity. This is because the stands’ height, which rises higher than the height of the opening and the handrail is opaque and blocks the light from reaching the stands.
3.2. Simulation result on the Engineering design of Hall of Engineering Faculty using DIALux Evo 9.0

Figure 8. Simulation result on the Engineering design of Hall of Engineering Faculty using DIALux Evo 9.0 from 07.00 to 09.00
Figure 9. Simulation result on the engineering design of Hall of Engineering Faculty using DIALux Evo 9.0 from 10.00 to 17.00
### Table 2. Simulation Results on the Engineering design

| Measuring points | Maximum | Minimum | Average intensity (07.00-17.00) |
|------------------|---------|---------|------------------------------|
|                  | Light intensity (lux) | Measured time | Light intensity (lux) | Measured time |
| A1               | 1306    | 08.00   | 254  | 17.00     | 709 |
| A2               | 111     | 08.00   | 69   | 17.00     | 87  |
| A3               | 969     | 16.00   | 325  | 07.00     | 569 |
| B1               | 362     | 08.00   | 66   | 17.00     | 172 |
| B2               | 93      | 08.00   | 58   | 12.00     | 72  |
| B3               | 253     | 16.00   | 89   | 07.00     | 151 |
| C1               | 328     | 08.00   | 99   | 16.00     | 162 |
| C2               | 88      | 08.00   | 53   | 17.00     | 64  |
| C3               | 263     | 16.00   | 79   | 07.00     | 149 |
| D1               | 305     | 08.00   | 89   | 16.00     | 148 |
| D2               | 73      | 08.00   | 41   | 12.00     | 55  |
| D3               | 217     | 16.00   | 74   | 07.00     | 129 |
| E1               | 280     | 08.00   | 81   | 16.00     | 135 |
| E2               | 61      | 08.00   | 35   | 12.00     | 46  |
| E3               | 234     | 16.00   | 71   | 07.00     | 130 |
| F1               | 256     | 08.00   | 71   | 16.00     | 119 |
| F2               | 49      | 08.00   | 27   | 13.00     | 37  |
| F3               | 185     | 16.00   | 56   | 07.00     | 95  |
| G1               | 208     | 08.00   | 60   | 16.00     | 99  |
| G2               | 38      | 16.00   | 21   | 12.00-13.00 | 29 |
| G3               | 156     | 16.00   | 44   | 07.00     | 76  |
| H1               | 167     | 08.00   | 30   | 17.00     | 74  |
| H2               | 31      | 08.00   | 15   | 11.00     | 21  |
| H3               | 125     | 16.00   | 38   | 07.00     | 59  |
| I1               | 102     | 08.00   | 21   | 17.00     | 48  |
| I2               | 24      | 08.00   | 12   | 12.00-13.00 | 16 |

Reference: author’s own work
3.3. *Comparison of simulation result between the existing and the Engineering design of Engineering Faculty Hall using DIALux Evo 9.0*

Analysis of the auditorium space’s lighting performance is carried out by dividing the space into the edge area (A1-A3) and the grandstand area (B1 to I2). The division is done to separate the room's assessment that serves as the circulation room and the sitting room.

The comparison to the edge areas of A1 and A3 shows that the light intensity in the existing conditions is much higher than in rooms that have used glass handrails. This is due to the existing stands in opaque material that reflects light coming from outside the building to the measurement plane (see figure 6). Whereas at point A2, the light intensity in the stands with glass handrail is higher. The light that has reached the stands can be reflected in all directions up to point A2. In the existing condition, the amount of light reaching the stands is inadequate so that only a few traces could be reflected in all directions. As a result, the room is darker.

Table 3. Comparison between the existing stands and the modified handrail stands

| Time   | A1 Existing Engineering Design | A2 Existing Engineering Design | A3 Existing Engineering Design |
|--------|--------------------------------|--------------------------------|--------------------------------|
| Pkl 07.00 | 1154                          | 938                           | 77                             | 78                             | 366                          | 325                          |
| Pkl 08.00 | 1674                          | 1306                          | 113                            | 111                            | 528                          | 437                          |
| Pkl 09.00 | 1387                          | 1157                          | 103                            | 103                            | 588                          | 471                          |
| Pkl 10.00 | 978                           | 792                           | 83                             | 82                             | 587                          | 484                          |
| Pkl 11.00 | 832                           | 686                           | 79                             | 76                             | 623                          | 497                          |
| Pkl 12.00 | 714                           | 608                           | 74                             | 74                             | 648                          | 506                          |
| Pkl 13.00 | 623                           | 564                           | 81                             | 80                             | 691                          | 577                          |
In the stands, the comparison is again divided into two parts, namely the edges and the middle. The edge of the stands is the part closest to the auditorium window opening, so it is assumed that it will receive the highest light intensity compared to the middle. Comparisons were taken at 07.00, which is at an hour when the sun's rays are at a low altitude angle so that the penetration of sunlight into the room can be more significant and at 12.00 when the sun is at head height and less penetrates inward.

The comparison of light intensity between each level (B-I) in the stands is shown in the following graph:

**Figure 10.** The reflection of the opaque plane increases the light intensity at the edges of the room

**Graphic 3.** The difference of light intensity between the edge and the middle of the stand on 07.00
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Graphic 4. The difference of light intensity between the edge and the middle of the stand on 12.00

The low light intensity in the rear stands is influenced by the height of the stands and the window openings' height, which do not differ much from the workplane height or the height of the light measuring point. The higher the opening area, the farther the light penetrates the room [15].

Figure 11. Hall’s section, showing the level of stand and the height of window

From the comparison, it can be seen that the engineering design can increase the light intensity at the edge of the stands, from the lowest level (B) to the highest level (I). With an average increase of 18%. However, in the middle of the stands there was no significant increase. So that it takes more effort to improve the performance of natural lighting in the auditorium space. Data from the comparison between existing conditions and engineering design can be seen in the following charts:
Graphic 5. Comparison of simulation result between the existing and the engineering design from 07.00 to 10.00
Graphic 6. Comparison of simulation result between the existing and the engineering design from 11.00 to 13.00
Graphic 7. Comparison of simulation result between the existing and the engineering design from 14.00 to 17.00
Based on the simulation results that have been described. The lighting performance, especially the natural lighting factor (daylight factor) in the Hall from 07.00 to 12.00 o’clock, has the highest light intensity at the A1 measuring point with 1674 lux for existing and 1306 lux for engineering design. The average light intensity of the existing A1 is 847 lux and 709 lux for engineering design. Meanwhile, from 1:00 p.m. to 5:00 p.m., the highest light intensity level is at the A3 measuring point with the highest light intensity of 962 lux for existing and 969 lux for engineering design, and the average light intensity of existing A3 is 653 lux and 569 lux for engineering design.

Meanwhile, for the spectator seats, namely those at measuring point B1 to measuring point I2 from 07.00 to 17.00, the highest light intensity level is 401 lux for existing and 362 lux for engineering design, and the lowest light intensity is 10 lux for existing and 12. lux for engineering design. Meanwhile, the average light intensity is 77 lux for existing and 91 lux for engineering design.

4. Conclusion
The simulation results show that the engineering design can increase the level of natural light intensity on the left and right edges compared to the existing conditions, with an average increase of 18%. However, this engineering has not reached the middle of the stands, so that additional engineering is needed to optimize natural lighting. Interestingly, this engineering design reduced excessive light intensity at points A1 and A3 with an average of 847 lux at the existing A1 point, down to 709 lux in the engineering design. Meanwhile, A3, with an average of 653 lux for the existing one, drops to 569 lux in the engineering design.

The engineering design can optimize the direction of light according to the target point and reduce glare, although additional engineering is still needed. Another method for maximizing natural lighting can be using Daylighting systems range from simple static (louvers, light-shelves, fixed overhangs, laser-cut panels, prismatic elements, anidolic systems, etc.) to adaptable dynamic elements (blinds, movable lamellae, advanced glazing), holographic optical elements, etc.), and / or combinations of these (IEA Task 21, 2000) [15].

This result is consistent with the research conducted by Nazanin et al. (2020) that the position and dimensions of the windows, space proportions, vertical and horizontal placement of the surfaces (the type of furniture layout) in space, and reflectivity of the inner surface materials had the most significant impact on the lighting distribution in space, respectively [16].

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