Optimization of lighting design in classroom for visual comfort
(Case Study : Universitas Tridinanti Palembang Tower)

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Abstract. Currently, the learning process in the classroom uses an LCD projector to display material on the white board. This LCD projector produces its own light, so the light source in the room will be added (beside daylight and artificial light). This condition makes a visual discomfort and not efficient energy uses. Based on previous study, the classroom users in UTP tower got visual comfort when the lamps were on 100% if projector used. But, in other condition when the projector is off, users will comfort if daylight and electric lighting combined. Based on these problems, this study is aimed to test the effective combination of daylight and artificial lighting so that the iso-contour of illumination spread evenly and visual comfort achieved. The method of experiment is used to find out the effect of various placements of artificial light that are on to the iso-contour of illumination. The experiments conducted with the help of simulation to experiment with design parameter is the placements of artificial light that turn on. The evaluation of visual comfort is based on the iso-contour of illumination and reflectance value on the indoor surface. The result of this research will show that the placements of light on will affect the illumination contour.

Keywords: classroom, visual, comfort, lighting, design.

1. Introduction
Lighting in classrooms is a major problem in educational buildings. Classroom has varying lighting needs because of the adding use of electronic equipment [3]. Currently, there is a shift in the teaching and learning process that teacher uses the projectors when delivering material. The projector uses turns out to provide different effects, such as visual comfort and the effectiveness of using artificial lighting. In some cases, such as the results of previous research at the Tridinanti University Tower in Palembang, students as a users feel more comfortable when using artificial lighting (lamps) when the projector turn on. The opposite is the case, if daylighting used when the projector turn on, students experience glare when looking at the whiteboard [11].

Today, the challenge in lighting design is to provide high quality lighting, visual comfort and save energy on a fixed budget. This is a challenge for architects and researchers. On the other hand, daylight is still important, previous studies have shown that the use of natural light in classrooms can support the teaching and learning process [3] Daylight is an effective and sustainable development strategy to increase visual comfort. Window openings provide a dual function, not only receiving light for a pleasant indoor environment but also for increasing work productivity [5] and perfect color spectrum [2] In energy conscious lighting design, daylight is treated as one of the energy saving options [6]. On the other
hand, daylight systems has a weakness compared to artificial lighting, which is uncontrollable [10] and sometime daylight makes the glare effect if incorrect design. Artificial lighting systems play an important role in the energy consumption of a room. Incorrect placement of lamp points and parallel lighting zoning will result in excessive use of artificial lighting. Appropriate lighting controls can improve visual performance, occupant satisfaction and energy-efficiency [6]. The result is the amount of energy used in the building. Based on these problems, this study aims to evaluate the daylight and artificial lighting conditions in a classroom with a capacity of 20 people in the tower of Universitas Tridinanti Palembang. Evaluation is carried out to see the lighting performance in the room and then optimization is carried out by testing different configuration of lamp zone. Thus we can get the ideal conditions for visual comfort and effective energy uses.

2. Methods
This research is an experimental research with the aid of computer simulations. The research stages began with direct measurement of light intensity in the room as a verification process for the Simulation program. Researchers have previously used Dialux Evo to predict various aspects of daylight illuminance value, including the illuminance distribution based on information about the incoming light, and the lamp illuminance. The basic steps of the research process are shown in Fig. 1.

![Figure 1. Basic step of research](image)

2.1. Models
The room model will be carried out on a class model with a size of 6.00 x 3.75 m, the windows orientation leads to the Northwest, the WWR is 10% (Fig.2). The choice of this room was motivated by the survey results, that users in this room tend to use lamps lights as light sources and when using daylight they feel uncomfortable.

The model made in the simulation process is arranged similar to the real conditions with material details (see Table 1). The room model on simulation shown on Fig.3 Simulations conducted on lecture schedules at 08:00 am, 10:00 am, and 04:00 pm. The schedule of simulation based on the schedule of lecture activities. The simulation is carried out in 3 schemes, namely: (1) Daylight scheme at 08:00am, 10:00am, and 04:00pm; (2) Daylight and artificial scheme with existing condition at 08:00am; (3) daylight and artificial scheme on optimization design 08:00am.
First scheme, the aim is to find out the overlit and underlit area. From the result, we will know the best lamps position and configuration. Second scheme aims to determine the illuminance that occur using daylight and lamps in existing condition. Third scheme is re-design of configuration lamps zone.

![Room Model Existing](image)

**Figure 2.** Room Model Existing

| Name of Construction | Material Properties                      |
|----------------------|------------------------------------------|
| Window               | Sill height : 0,7 m                      |
|                      | Height : 1,65 m                          |
|                      | Width : 1,245 m                          |
| Glass                | Reflection Factor : 10%                  |
|                      | Degree of Transmittance : 90%           |
|                      | Reflective Index: 1.500                 |
| Wall                 | Colour : Light Ivory                     |
|                      | Reflection Factor : 82%                 |
| Floor                | Tile : White                             |
|                      | Dimensions : 0,6 x 0,6 m                 |
|                      | Reflection Factor : 76%                 |
|                      | Reflective Coating : 11%                |
| Ceiling              | Colour : White                           |
|                      | Reflection Factor : 70%                 |
| Lamp                 | Philips BN132C PSU L1200 1 xLED12S/830  |
|                      | Luminaire Luminous Flux : 1250 Lm       |
|                      | Connected Load : 16 W                   |
2.2. Direct Measurement

Direct measurement was conducted on September 23, at 08.00 am. Direct measurement used two Luxmeters. Measurement was taken at the work plane level is 0.8 m from the floor. The results obtained from the measurement process can be seen in Figure 4.

2.3. Calculation of relative error

In the process of correction between measurement and simulation results, the researcher uses the Relative error (RE) formula with the following formula [4]:

\[
RE = \frac{(ME - SE)}{ME} \times 100\%
\]

RE = Relative Error  
ME = Measurements Illuminance  
SE = Simulation Illuminance

The result of correction between measurement and simulation can be seen in Table 2.

| September 23 | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 |
|--------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| Measurement  | 1550| 1210| 246| 144| 407| 369| 316| 220| 223| 220 | 215 | 198 |
| at 08:00 am  |    |    |    |    |    |    |    |    |    |     |     |     |
| Simulation   | 1405| 1183| 179| 85 | 426| 326| 204| 195| 259| 229 | 197 | 169 |
| At 08:00 am  |    |    |    |    |    |    |    |    |    |     |     |     |
| Relative     | 0.1 | 0.02| 0.3 | 0.4 | 0.05| 0.1 | 0.4 | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 |
| Error        |    |    |    |    |    |    |    |    |    |     |     |     |

Table 2. Correction between Measurement and Simulation Result.
3. **Result and Discussion**

3.1. **Daylight Simulation**

The result of daylight simulation is shown in Figure 5. The average illuminance that occurs is 222 Lux at 08:00 am, 369 Lux at 10:00 am, and 202 Lux at 04:00 pm. When evaluated with the standard of intensity of illumination requirements for Classroom, the standard intensity of illumination is 300 Lux (Indonesian National Standard) [6]. So, the classroom’s intensity of illumination is not in accordance with standards at certain times.

At 08:00 and 16:00 the angle of incidence of sunlight is almost the same, it shows 10% of the study room area with an illumination value of 300 Lux, 5% area with an Illumination value > 300 - 2000 Lux (overlit), 65% area with an illumination value of 100 - 220% and 20% of area with illumination value <100 Lux (underlit). The underlit area is around the whiteboard and the lecturer table, while the study area (student seats) is dominated by Illumination values ranging from 100 - 300 Lux. Then the overlit area is near the window. At 10:00 am, shows 5% area near the overlay window with illumination value > 300%, 10% area with illumination value of 300 Lux, 35% area with illumination value ranging from 200-285 Lux and 50% area with illumination value ranging from 155 -200 Lux.

| Time   | Max. E | Min E | Average E |
|--------|--------|-------|-----------|
| 08:00 am | 1405 Lux | 90 Lux | 222 Lux   |
| 10:00 am | 3429 Lux | 155 Lux | 369 Lux   |
| 04:00 pm | 1679 Lux | 85 Lux | 202 Lux   |

Comparison between these condition shows that at 10:00 am the iso-contour of the illumination value in the classroom looks better and higher than at 08:00 am and 04:00 pm. This condition shows that sometimes the room can still take advantage of daylight rather than artificial light, so that the energy uses for artificial light can be minimized. However, for certain hours too, artificial lighting can be adjusted according to the use of illumination iso-contour. So the lights that are activated are adjusted to the underlit area.
3.2. Artificial Lighting Simulation

Artificial lighting simulations are carried out in two schemes, namely scheme 1 existing conditions and scheme 2 alternatives. The existing conditions are based on the zoning of parallel lamps consisting of two zones (Fig. 2). For Scheme 2, the light zone is changed by adjusting the overlit and underlit areas of the simulated natural lighting.

| Scheme 1.a: Daylight and 50% Artificial Light | Scheme 1.b: Daylight and 100% Artificial Light | Scheme 1.c: Daylight and 50% Artificial Light (with different lamp is on) |
|------------------------------------------------|------------------------------------------------|---------------------------------------------------------------------|

The results of simulation were carried out at 08:00 with the trial of scheme 1, show that:

Figure 6 (a) shows that when the lamp is turned on 50% according to the zoning of the lamp in the existing condition, the illuminance that occurs is about 191-873 Lux in the student sitting area. Based on the illumination contour, it can be seen that there are areas with too high (250-800 Lux) and low (191-250 Lux) illumination values. This will result in quite a significant difference between the two areas. Based on previous research, 65% of room users stated that they were uncomfortable and experienced glare [11].

Figure 6 (b) shows that when all of the lamps turned on, the illuminance is between 326 - 1001 Lux. This condition indicates that the room has an illuminance in accordance with the standard needs of the classroom. However, there is a possibility that users will feel eyestrain due to the average illumination value above 300 Lux. In addition, area near the whiteboard has a high illumination value. This condition has a high risk of occurring in high light reflections on the whiteboard so that the user will experience glare.

Figure 6 (c) shows that when the lamp turned on 50% with different zoning under condition 5 (a) will create a different illumination contour. Based on the result of illumination contours, it divided into two areas with different illuminance. The area near the window to the centre has an illumination value above
300 Lux, while the area from the middle to near the whiteboard has an illumination value ranging from 140-200 Lux. The illuminance is below standard, but this condition indicates that allowing the additional light produced by the projector. This condition will minimize the risk of reflected light on the white board.

| Scheme 2.a: Daylight and 50% Artificial Light | Scheme 2.b: Daylight and 100% Artificial Light | Scheme 2.c: Daylight and 50% Artificial Light (with different lamp is on) |
|-----------------------------------------------|-----------------------------------------------|---------------------------------------------------------------------|

**Figure 7.** Daylight and artificial light simulation at 08:00 am
(a) Scheme 2.a; (b) All lamps turn on; (c) Scheme 2.c

The results of simulation was carried out at 08:00 with the trial of scheme 2, show that:

Figure 7 (a) shows that when the lamp is turned on 50% according to the zoning of the lamp in the existing condition, the illuminance that occurs is about 180-873 Lux in the student sitting area. Different with the scheme 1, in this condition (scheme 2) the illumination contour shows that the illuminance is similar in all area of classroom. In scheme 2, no overlit area and only 10% of classroom area is underlit. Actually, it is the best condition if we compare with Scheme 1.a, because the contour of illumination is more equal.

Figure 7 (b) same with Scheme on Figure 5(b)

Figure 7 (c) shows 50% lamps is turnd on, opposite with the scheme 1. The result is the illumination value is more equal. The illumination value is about 238 – 612 (near the window) Lux. If the lecturer does not use the projector, this condition is advantageous compare scheme 1 (c) and 2 (a). This light condition gives more visual comfort, because the overlit area is not too much, and the underlit area is small.
4. Conclusion
This paper presents the simulation result of daylight and artificial lighting in a classroom. The aim of daylight simulation is to know the daylight performance and the illumination distribution in the room. The lighting standard directed from the Indonesian National Standard becomes the main reference for the evaluation stage. Evaluation of visual comfort proves that classrooms facing Northwest with WWR 10% still need artificial lighting to reach the standard illuminance (300 Lux in the work plane). The illumination contours resulting from the simulation are very helpful for seeing which areas are overlit and underlit. By proving the overlit and underlit areas, this will provide benefits for determine the lamps point and zoning of parallel lamps. Based on the simulation results, it is known that scheme 2 (a) and scheme 2 (c) can be used as a recommendation for setting an artificial lighting model to minimize the energy uses. Because, turning off the electric lamp during available daylight will save electricity [8]. However, especially for the conditions when the projector is used, scheme 1 (c) provides an opportunity for higher light reflection is not occur in the whiteboard area. The simulation results are expected to be a reference for determining parallel lamps points and zoning.

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