# Optimization design of light shelf for visual comfort and energy savings in an office space

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## Kewords

energy savings, light shelf, visual comfort

## Abstract

Visual comfort is important for the building occupants' wellbeing. Visual comfort can be filled with natural lighting (daylighting) and artificial lighting. Efforts to optimize natural lighting can be achieved through façade design, and percentage area of window. However, the problem of the visual comfort is high light intensity and glare at some places. Light shelf is a passive strategy to minimize glare, expanding the area of daylighting and increase the time that meet the visual comfort.

This paper discusses the light shelf design that can fulfill the optimal visual comfort and lighting energy savings for an office space with the case studies Prasetiya Mulya office. The methodology of research used is quantitative research with simulation modeling (DIALUX 4.13, 2016). Through following steps; (1) Making a model of office space based on case studies: Prasetiya Mulya office, Jakarta; (2). Making three models with different light shelf dimension; (3) Simulating and analyzing the light intensity value for each model that meet office visual comfort standard: 350 Lux (Indonesia National Standard, 2010), glare value and optimal energy saving.

The result show that light shelf design can meet optimal visual comfort and save energy for artificial lighting. With right design of light shelves, we can expand daylighting area that meet visual comfort, minimize glare and increasing energy saving in the office.

## Introduction

Visual comfort is an important requirement for office building occupants. Criteria of visual comfort accordance with the type of activity, and visual sensory perception of the environment. The influence factor of visual comfort is light intensity, direction of the light source, the reflection from the surface, surface texture, and activities. For activity in the office, visual comfort must be fulfilled to achieve optimize worker productivity. Usually, the fulfilment of visual comfort with artificial lighting, but must be considered, it affects the artificial lighting energy consumption in the building. It is necessary to design strategies to fulfil visual comfort and energy saving.

Building energy consumption in Indonesia is approximately 55 % of total energy consumption, and for lighting energy consumption is 22 %. (Indonesian National Standard, 2010). Specially for office building energy consumption has IKE (index of energy consumption) value: 220 kWh/m$^2$/year. (Indonesian National Standard, 2000). Then energy lighting consumption for office building approximately 48.4 kWh/m$^2$/year. To reduce the use of energy for lighting, one of strategy is reducing indoor artificial lighting and optimize daylighting. Strategy used to optimize daylighting with use of windows design and light shelves. The use of light shelves will lead to more natural lighting (day lighting) in the building, reducing glare and expanding the area of daylighting that meets occupant's visual comfort.

The aim of this work is to find an optimal width of light shelves for an office while meeting the visual comfort requirements. Another aim is to quantify the reduction of energy consumption.

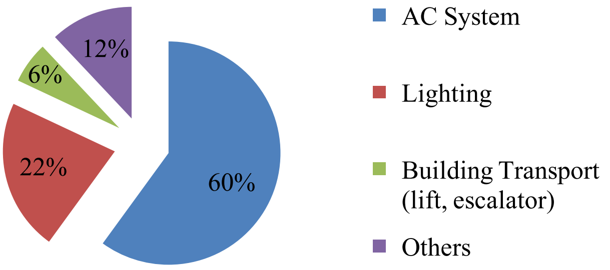


*Figure 1. Percentage of Building energy consumption. Source: Indonesia National Standard, 2010.*

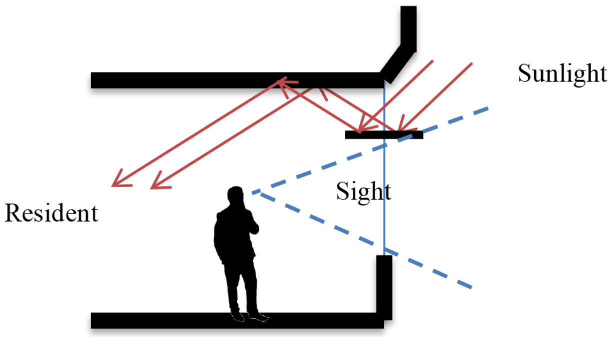


*Figure 2. The principle of the shelf system of light.*

## Research Theory and Methods

### RESEARCH THEORY

#### Daylighting

Daylighting is the sun lighting that supplement or replaces artificial lighting in the building during the day. Daylighting have function as lighting, aesthetics, health and also to save energy in buildings. The architectural designs to optimize daylighting in buildings have several ways:

- Atrium
- Court yard
- Window
- Light shelf

Some building owner do not use atrium and court yard design, because limited land and economically factor more advantageous for the leased space. Then to optimize daylighting prefer to use design using light shelves.

Light Shelf is a horizontal reflective surface that functions extend indirect lighting from the outdoor to indoor. In clear sky conditions range of lighting on the South side could extend the reach to a depth of 7.62 m (www.lrc.rpi.edu).

#### Light Shelf System

Light shelf has a function to protect directly lighting into the room and give the reflection of light deeper into the room. Light shelf also serves to reduce glare due to direct light and minimizing the imbalance of light that disturb visual comfort (eyes full accommodation), due to lack or excess of light intensity standard visual comfort of the building users. Reflection of the light that flowing deeper into the room will expand the area of daylighting that meets the standards of office occupant's visual comfort. The light shelf system can be divide into external type, internal type and mixed type.

### DIALUX SIMULATION METHODS

This research aims to find the optimal width light shelves that meet visual comfort in the room and optimize energy saving. Methodology of research used is quantitative research with simulation modeling (DIALUX, 2016).

- First, making a model of office space based on case studies: Prasetiya Mulya office, Jakarta using climatic conditions and locations in Jakarta.
- Second, making three models with variable of light shelf dimension differences; 0.3 m, 0.6 m, and 0.9 m and using aluminum material with white coating.
- Third, simulating and analyzing the light intensity value every model that meet office visual comfort standard: 350 Lux (Indonesia National Standard, 2010), glare value and energy saving value.
- Fourth, defining conclusion of which light shelves width will best produce a light intensity that meets the office visual comfort and energy saving.

## Results and Discussion

### BUILDING DESCRIPTION

#### Existing building: Prasetiya Mulya Office Space

Prasetya Mulya Office space is an open plan office. Material façade is glass expose, without shade. It is for the aesthetics aspect of the building, and giving modern and futuristic style. The glass material used was grey laminated, 12 mm thickness, while for the color of the walls and ceiling are white. For more detail see building description in the Table 1.

#### Setup of Light Shelf

Light shelf selected in this research is light shelves internal type with continuous design along the window. This type is selected so that the façade of the building has not changed, still expose glass. The Variables are width light shelves: 0.3 m, 0.6 m and 0.9 m. These variables must adjust width of light shelves on the market. Material light shelf is aluminum with white coating. The white color chosen because it can reduce the maximum glare. The variables of light shelf for performance evaluation is shown in Table 2.

The simulation was performed on the location of Jakarta, with -6.22 latitude and longitude 106.8. The selected month is October, time: 12:00–14:00. Choosing October month, because the sky condition in this month is the cloudy sky. Based on Ramli (2000), research shows that although Indonesia is located on the equator, are clear sky conditions: 97 times, intermediate sky: 179 times and overcast sky: 44 times. It shows the sky condition dominant is intermediate sky (cloudy sky).

**Table 1. Prasetiya Mulya Office Space Description.**

| | |
|---|---|
| Area | 770 Sqm |
| Width | 36 m |
| Depth | 22.85 |
| Height | 3.10 m |
| Reflectivity | Ceiling: 74.99 %, Wall: 70 % |
| Glass material | Grey laminated with 12 mm thickness, penetration ratio 75 %, reflection |
| Light Shelf | Without light shelf (0) |

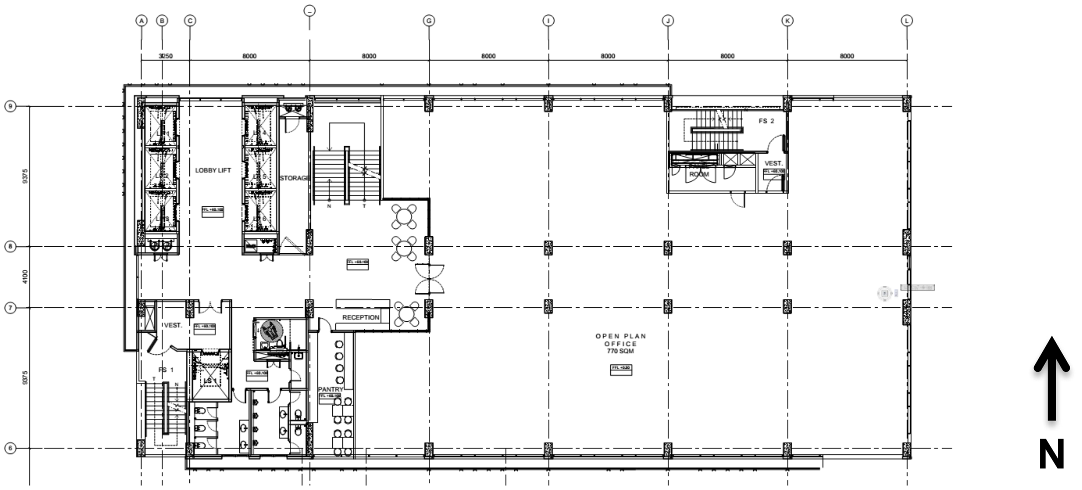


*Figure 3. Open Plan Office.*

**Table 2. Setup of Light Shelf.**

| | | | |
|---|---|---|---|
| Height from floor | 1.9 m | Angle | 0 |
| Width | 0.3 m, 0.6 m, 0.9 m | Reflectivity | 75 |
| Height of light shelf | 0.05 m | Material | Aluminium in white coating |

## DAYLIGHTING ANALYSIS

### Simulation 1: based on case study

Result of simulation showed that the existing condition without light shelves: the percentage of the area above 350 Lux is 42 %. This means that 42 % of area office area do not require artificial lighting. The area of 1–3 meters from the window has a high light intensity value: 1,000–1,500 Lux. This over lighting cause glare on that area. It is mean, this area should be covered with vertical blind and be used artificial lighting. Then all of office area need to use artificial lighting

Light shelves 0.3 m simulation showed that the percentage of the area above 350 Lux increased 10% (42 % to 52 %). And the glare area decreased ranged 1–1.5 meters from the window (15 %). No glare in north side and it use daylighting. In this case 78 % of the office area needs to use artificial lighting. (see Figure 7 and 8). Light shelves 0.6 m simulation showed that

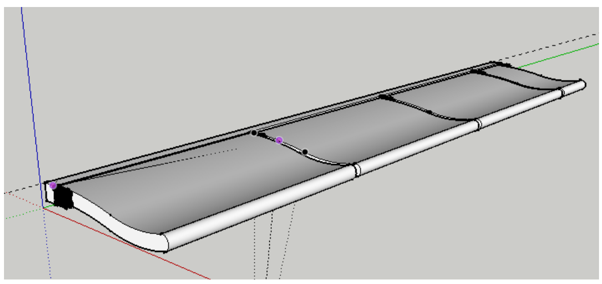

*Figure 4. Detail of light shelf.*

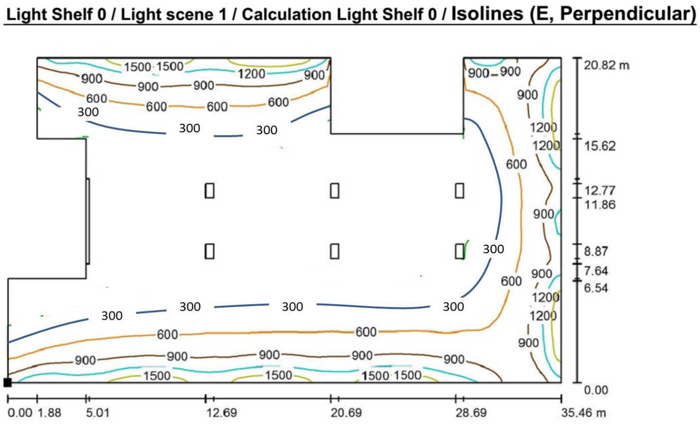


Figure 5. Light Intensity isoline for existing building: Prasetiya Mulya office area. Source: Dialux analyzation result.

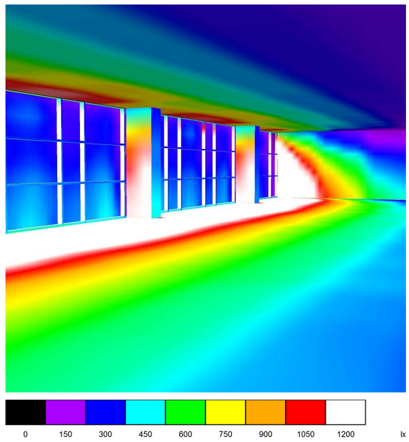


Figure 6. Isometri section light Intensity for existing building: Prasetiya Mulya office area.

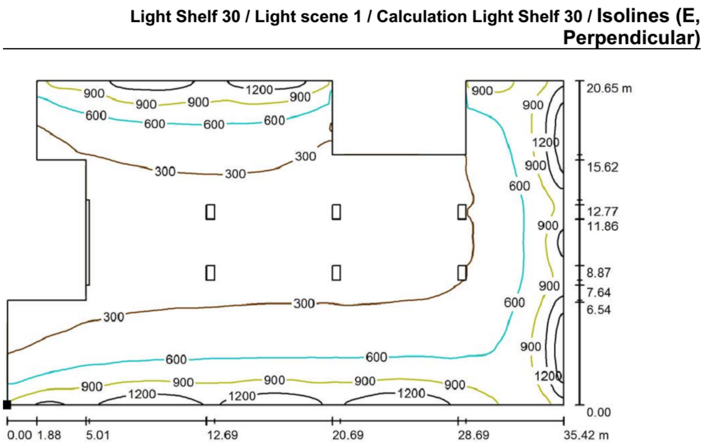


Figure 7. Light Intensity isoline for Light shelf 0.3 m. Source: Dialux analyzation result.

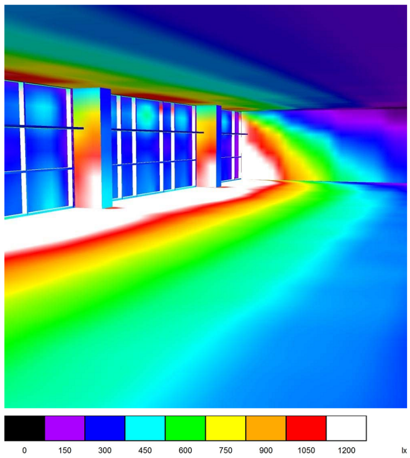


Figure 8. Isometric section light Intensity for Light shelf 0.3 m.

the percentage of the area above 350 Lux are 52 %, which is the same value as with light shelves 0.3 m. For the glare area decreased approximately 10. No glare for North and South side, there daylighting can be used. In this case 55 % of the office space area need to use artificial lighting (see Figure 9 and 10).

Light shelves 0.9 m simulation showed that the percentage of the area above 350 Lux are 52 %, which is the same value as with light shelves 0.3 m. and 0.6 m. There is no glare in the South and North side area and the glare effect in east side areas decreased. In this case 50 % of the office space area need to use artificial lighting (see Figure 11 and 12).

The DIALUX simulation results showed that the addition light shelves could provide expansion area to meets office occupant's visual comfort approximately 10 %. But the addition of light shelves width from 0.3 m to 0.6 m, and up to 0.9 m did not provide the addition of areas that meet visual comfort. While the addition of light shelves and the width difference of light shelves showed decrease of the glare area. It showed the wider light shelves, the more extensive daylighting areas that meet the office's occupant visual comfort (see Table 3).

### ENERGY ANALYSIS

Artificial lighting is used in the office area, during working hours: 08:00–17:00. In existing condition, 42 % of the office space area is fulfilled for daylighting conditions, but it is direct lighting and have high light intensity, causing glare by 20 % in the area close to the window. Therefore, artificial lighting need to be used in the whole area. By using a light shelf, not only the daylighting area that meet visual comfort is expanding, but the light shelf is also reducing glare. Adding light shelves width can reduce the use of artificial lighting and energy lighting consumption. For the details see Table 3.

## Conclusion

This research to establish the basic sources for designing light shelves, which are fulfil office occupant's visual comfort. Conducted performance analyzation of light shelves depending on width the light shelves, area visual comfort and energy saving:

The existing condition that meets the visual comfort area is 42 % of the total office space. But the glare area is large and cov-

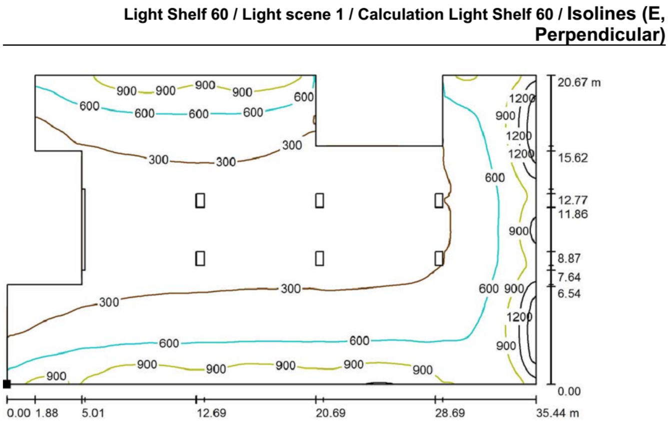


*Figure 9. Light Intensity isoline for Light shelf 0.6 m. Source: Dialux analyzation result.*

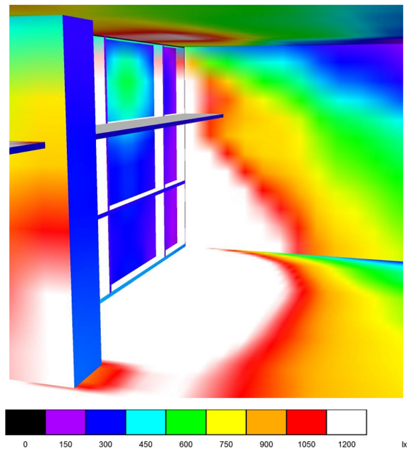

*Figure 10. Isometric section light Intensity for Light shelf 0.6 m.*

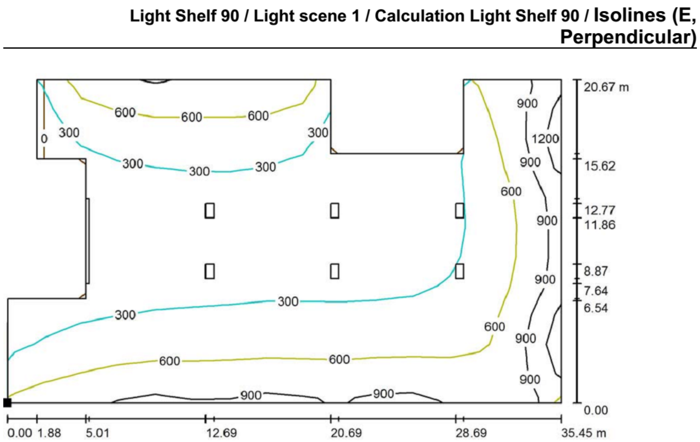


*Figure 11. Light Intensity isoline for Light shelf 0.9 m. Source: Dialux analyzation result.*

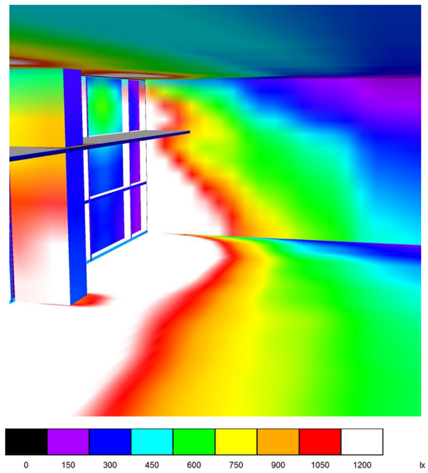

*Figure 12. Isometric section light Intensity for Light shelf 0.6 m.*

**Table 3. Daylighting Light Intensity Result.**

| Light Shelf Width (m) | Office Area (sqm) | >350 lux area (sqm) | Percentage Office Area >350 lux | Glare Area [%] | E Av (lx) | E min [lx] | E max [lx] | E min/ Emax[lx] |
|---|---|---|---|---|---|---|---|---|
| 0 | 770 | 324 | 42 % | 20 % | 544 | 129 | 1,813 | 0.071 |
| 30 | 770 | 401.76 | 52 % | 15 % | 509 | 129 | 1,724 | 0.075 |
| 60 | 770 | 403.38 | 52 % | 10 % | 484 | 126 | 1,732 | 0.073 |
| 90 | 770 | 403.38 | 52 % | 5 % | 447 | 132 | 1,066 | 0.123 |

*Source: Dialux analyzation result.*

**Table 4. Energy Calculation Result.**

| Light Shelf Width (m) | Office Area [Sqm] | >350 lux area [Sqm] | Percentage Artificial Lighting Area [%] | Artificial Lighting Area [Sqm] | Lighting Energy [kWh/m²/Year] | Percentage of Energy Reduction [%] |
|---|---|---|---|---|---|---|
| 0 | 770 | 324 | 100 % | 770 | 48.4 | 0 % |
| 30 | 770 | 401.76 | 78 % | 600.6 | 37.8 | 22 % |
| 60 | 770 | 403.38 | 55 % | 423.5 | 26.6 | 45 % |
| 90 | 770 | 403.38 | 50 % | 385 | 24.2 | 50 % |

ers 1–3 meters from the window. This gives the occupant a tendency to close the windows and use artificial lighting. Depend on energy calculation; the building used 48.4 kWh/m$^2$/Year. To add light shelves width 0.3 m continuous on the window, increasing the office occupant's visual comfort area about 10 % (42 % to 52 %). Thus, glare area decreased significant, and lighting energy consumption decreased to: 37.8 kWh/m$^2$/Year. To add light shelves 0.6 m and 0.9 m continuous on the windows, showing that visual comfort area fixed at 52 %. But there is no glare area on the north and south sides. While the East side decreased glare, and lighting energy consumption decreased approximately to 26.6 kWh/m$^2$/Year and 24.2 kWh/m$^2$/Year.

To add width of light shelf from 0 meter to 0.6 meter, will give a significant increase in energy saving (average 22 %). But to add width of light shelf of 0.9 m, only give 5 % increase energy saving, compared to 0.6 m for optimal light shelves this research recommended is 0.6 m, because this result showed the optimize increased of energy saving, average 22.5 %.

Based on this research, it needs further research with variable light shelves material to reduce glare. In addition variable, we can consider solar sell as material light shelves. Which serves not only reduce glare but also produce renewable energy source.

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