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# The Efficiency of Light Shelves According to Latitudes in Office Buildings

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**ABSTRACT**

Light shelf is one of the improved daylight systems, helping to contribute to energy saving by using daylight effectively. Many regional studies have been conducted on light shelf efficiency especially in recent years. This original paper investigates the effect of different latitudes (0°, 15°, 30°, 45°, 60°, 75°) on the light shelf efficiency on a sample unit for 3 different (3m, 3,9m, 4,8m) office heights. First, the most suitable light shelf conditions are determined for each condition by using Ecotect & Radiance softwares in CIE* Standard Overcast Sky and then the desired daylight intervals for offices are compared without and with light shelf. Consequently, it is determined that the light shelf increases the desired daylight levels in all latitudes for 3 different office heights and light shelf efficiency generally diminishes with the increase in office heights between 0°-15° latitudes and increases with the increase in office heights between 30°-75° latitudes. In addition to that, the distribution of daylight levels are analysed in plans and the results are presented to designers interested in daylight efficient design.

**Keywords:** *Daylight simulation, light shelf efficiency according to latitudes/office height, daylight in office buildings, design sky illuminance, natural lighting.*

## 1. INTRODUCTION

Day lighting is an effective strategy to maintain a comfortable indoor environment and provides great opportunities for energy savings in buildings [1]. Many daylight systems like anidolic daylight system [2], reflective Louvre [3], holographic solar energy [4], light tube, fibre-optic [5] etc. have been developed in recent years. Light shelf is one of the improved daylight guiding system help to increase the illuminance quantity within desired levels [6] and contribute energy saving by using daylight effective [7]. In addition to that, light shelf helps to diminish environmental pollution caused by the fossil sourced energy usage and minimize psychological, physiological, visual discomforts caused by artificial lighting [8]. In offices, it is important to take advantage of the natural light through a daylight responsive architecture [9]. Latitude, environment of building, interior &exterior obstacles, shape-colour of room, window-wall ratio on facade, level of floor, light reflectance of materials, furniture placement & colour, glazing type, geometry of ceiling, light shelf size/position etc. are both effect the daylight illuminance levels of interiors & suitable light shelf size-position. It is understood that latitude is naturally one of the main determinative of the suitable light shelf size-position connected with Design Sky Illuminance value.

The aim of this original manuscript is to identify the effect of latitude to the light shelf efficiency for different office heights. For this purpose, a typical office unit (8mx14m) is modelled with Ecotect software [10] and variations size/position of light shelves are tested to

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determine the most suitable light shelf size/position on 6 latitudes (0°,15°,30°,45°,60°,75°) for 3 different office heights (3m,3,9m,4,8m) in CIE Standard Overcast sky condition with Radiance software [11]. Consequently, it is determined that light shelf increases the desired daylight levels in all latitudes, for 3 different office heights and light shelf efficiency generally; diminishes with increasing of office heights between 0°-15° latitudes and increases with increasing of office heights between 30°-75° latitudes. In addition to that the distribution of daylight levels are analysed on sample office plan.

Findings are significant for designers to comment how effective the application of light shelf according to latitudes for different office heights. In addition, the depth of the office unit could be determined related with distribution of daylight levels to interiors in connection with analyses performed in this study.

Some researches about light shelf daylight system are as follows. Meresi [12], studied on which daylight can be efficiently used in a typical classroom in Athens-Greece. The system that is chosen for study consists of a light shelf and semi-transparent movable external blinds, which are mounted on the glazing of a south-facing classroom. The experimental study consists of six stages, all performed in Radiance software. The individual results and conclusions lead to the definition of the optimum characteristics of the system, including the light shelf's width, mounting height, inclination and reflection index, which upgrade the daylight performance in the space under study. Soler & Oteiza [13] investigate the light shelf performance in Madrid, Spain. The performance of a light shelf with a reflectance of about 91% after excluding the specular component, providing for solar protection during the long, hot, dry summer season, is studied in Madrid using two scale models with rectangular openings facing south, one taken as a reference and the other equipped with the light shelf. Joarder et al [14] aims to determine the most suitable height of fixed sized light shelf in Dhaka, Bangladesh. The objective of the study is to highlight the effectiveness of light shelves in tropical office buildings to enhance interior day lighting quality. Daylight simulation was performed for custom light shelves for a typical office floor of Dhaka City in Bangladesh, to determine the best possible location under overcast sky condition. Six alternative models of a 3m high study space were created with varying heights of light shelves. The results showed that for achieving light levels closest to specified standards, light shelves at a height of 2m above floor level perform better among the seven alternatives studied including the alternative where no light shelves are present.

It is seen that studies are generally based on local effects of light shelf in the literature and there is no research available about the correlation between light shelf efficiency and latitudes for different Office heights.

## 2. METHOD

The efficiency of light shelf is calculated on 6 main latitudes (0°,15°,30°,45°,60°,75°) for each 3 different office heights (3m,3,9m,4,8m) and results are evaluated in this part.

First, a typical office unit with 8m wide and 14m length is modelled with Ecotect software. High length/width ratio dimensioned plan is determined to observe the effect of light shelf to the backside of the office unit. Sensors with 50 cm distance between each other are placed 75 cm up from the floor (task area) to evaluate the illuminance values connected with light shelf efficiency. 300Lx-500Lx illuminance interval is determined as the desired daylight levels in offices and the difference between the percentage ratio of sensor numbers between 300Lx-500Lx to total 432 sensors without and with light shelf represents the light shelf efficiency. *E.g.* The sensor numbers between 300Lx-500Lx is 81, ratio of sensor numbers to total is %18,75 (81/432*100) without light shelf & the sensor numbers between 300Lx-500Lx is 136, ratio of sensor numbers to total is %31,48 with suitable light shelf obtained from variety of light shelf size/position calculations on 0 latitude for 3m office height. The difference of the ratio of sensor numbers to total without and with light shelf %12,73 is determined as the light shelf efficiency.

The process of the study is as follows;

1. Calculation of daylight levels between 300lx-500lx obtained from the most suitable light shelf determined from variety of light shelf placement and size for each condition.
2. Calculation of daylight levels between 300lx-500lx without light shelf for 3 different Office heights (3m,3,9m,4,8m) on 6 main latitudes (0°,15°,30°,45°,60°,75°).
3. Comparison of daylight levels between 300lx-500lx with and without light shelf to determine the light shelf efficiency.

Calculations are done in CIE Standard Overcast sky type related on Daylight Factor (DF) and Design Sky Illuminance values are used for exterior daylight illuminance values according to latitudes.

Definitions of acceptances and determinations of virtual environment to detect the most suitable light shelf size/position according to latitudes for three different office heights are as follows:

### 2.1. Determination of design sky illuminance and desired illuminance levels for offices

Design Sky Illuminance (DSI) value is used as the exterior illuminance level in calculations according to latitudes used in this study.

DSI is the sky luminance level that is exceeded 85 percent of the time between the hours of 9 a.m. and 5 p.m. throughout the working year. This is a conservative design value for day lighting analysis. Once the DSI has been determined for a particular site, the product of the daylight factor and the DSI approximates the illuminance that should be exceeded 85% of the working hours [15]. *E.g.* The design sky illuminance for London is 5000 Lx and in a specific point of a sample room with %6 daylight factor (DF) is above 300 Lx (5000Lx x %6 = 300Lx) for 85% of working hours between 9 a.m. and 5 p.m. in London.

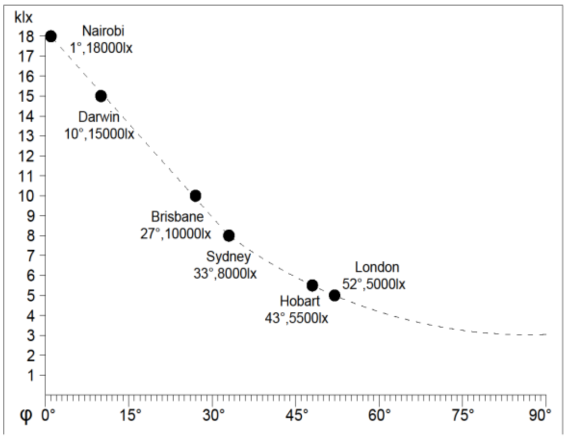



Figure 1.a. DSI values as a graphic.

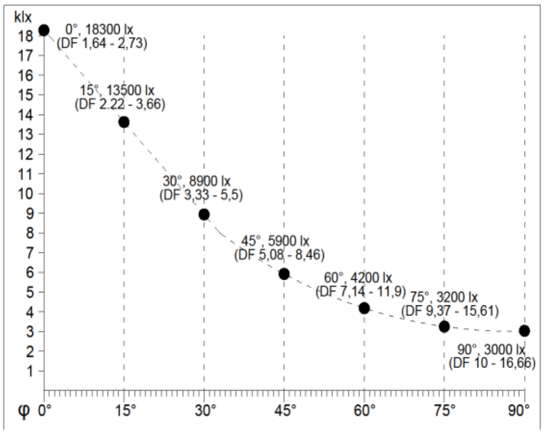



Figure 1.b. DSI values according to latitudes used in this study.

Figure 1. DSI values according to latitudes

Latitude is the main determinative of daylight illuminance. Some of the DSI values according to latitudes are as follows: London (52°)-5000 Lx, Hobart (43°) -5500 Lx, Sydney (33°)-8000 Lx, Brisbane (27°)-10000 Lx, Darwin (12°)-15000 Lx, Nairobi (1°)-18000 Lx [16]. The curve shown in Figure 1.a is obtained from the DSI values according to latitudes mentioned above. DSI values according to latitudes (0,15,30,45,60,75) used in this study are getting from this curve as shown in Figure 1.b. *E.g.* The DSI value for 30 latitude is found by drawing a vertical line from 30 latitude to curve. The 8,9 Klux (8900 Lx) value which is obtained from the intersection point with the line and the curve represents the DSI value on 30 latitude used in calculations as the exterior luminance level for 30° latitude(Figure 1.b)

It is obtained from the European Standard EN 12464-1 that 300Lx-500 Lx illuminance level interval is essential for writing, reading, data processing activities in offices [17]. Daylight Factor (DF) values equal to 300Lx-500Lx illuminance interval is used in day light calculations with Radiance software. DF values for 300Lx-500Lx have been obtained from DSI values according to latitudes used in this study. *E.g.,* 18300 Lx is the DSI value for 0° latitude (Figure 1.b) and 300Lx/18300Lx*100=1,64 is obtained as the DF value equal to 300 Lx on 0° latitude.

Determined DF intervals equal to 300Lx-500Lx according to latitudes used in this study are shown in Figure 1.b.

### 2.2. Determination of sample office unit dimensions

A square shaped, 12th floor office building is modelled with Ecotect software and a typical office unit with 8m wide and 14m length is chosen from the 6$^{th}$ floor of the office building as seen in Figure 2.a. It is planned that there is no exterior obstacles such as buildings, trees, hills etc. around the office building. High length/width ratio dimensioned office unit plan is determined to observe the effect of light shelf to the backside of the office room.

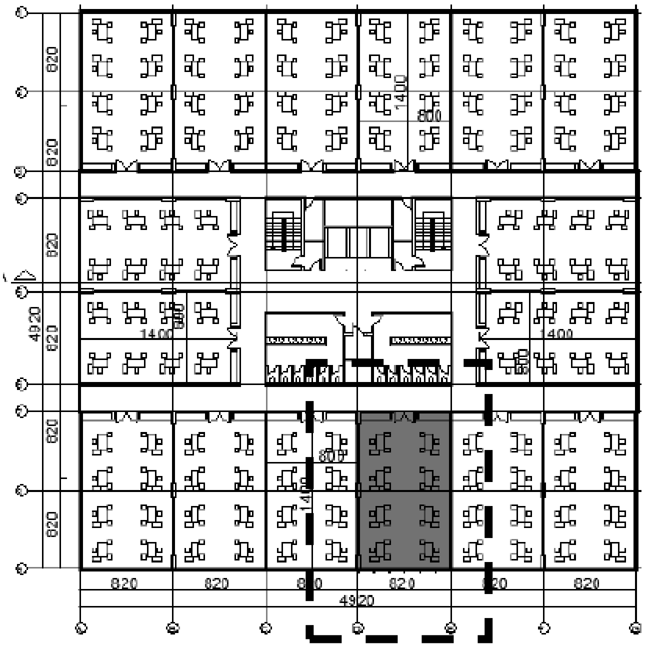



Figure 2.a. Typical floor plan of the office building.

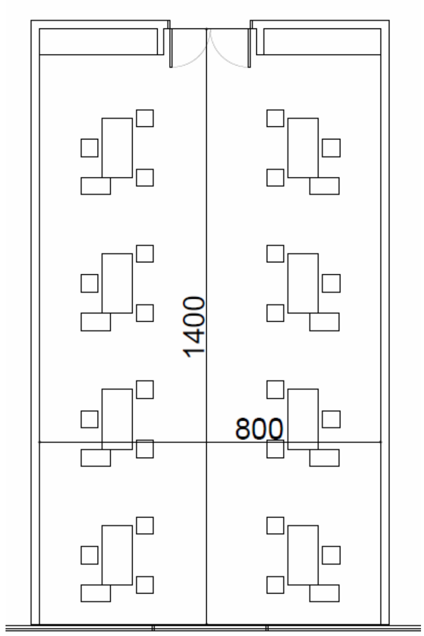



Figure 2.b. Typical office unit.

Figure 2. Typical floor plan (a) and 8m x 14m typical office unit (b).

The furniture is placed in plan view as seen in Figure 2.b. Plan dimensions of the office unit and all materials belonging to the area are used constantly in calculations. Only latitude is taken as a variable parameter to identify the effect of location on earth to the light shelf size/position for three different office heights. In other words, calculations to determine the most suitable light shelf size/position are done on 6 different latitudes (0°,15°,30°,45°,60°,75°) for 3 different office heights separately.

### 2.3. Determination of materials and light reflection values in the office unit

Light reflectance value (LRV) is a measure of visible and usable light that is reflected from a surface when illuminated by a light source.

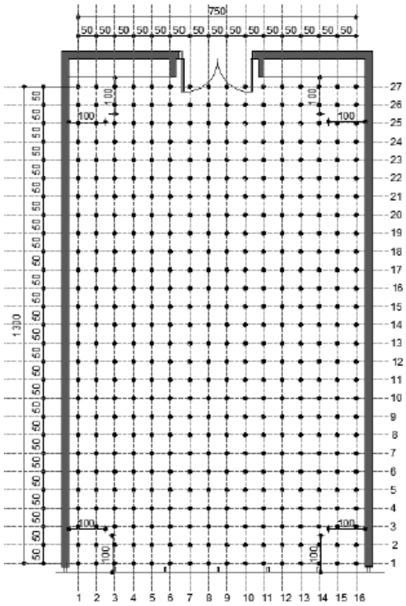
LRV of materials is essential parameters to realize the calculations. These numeric values are used as constant for all varieties of calculations to determine the suitable light shelf size/position on 6 main latitudes for 3 different office heights.

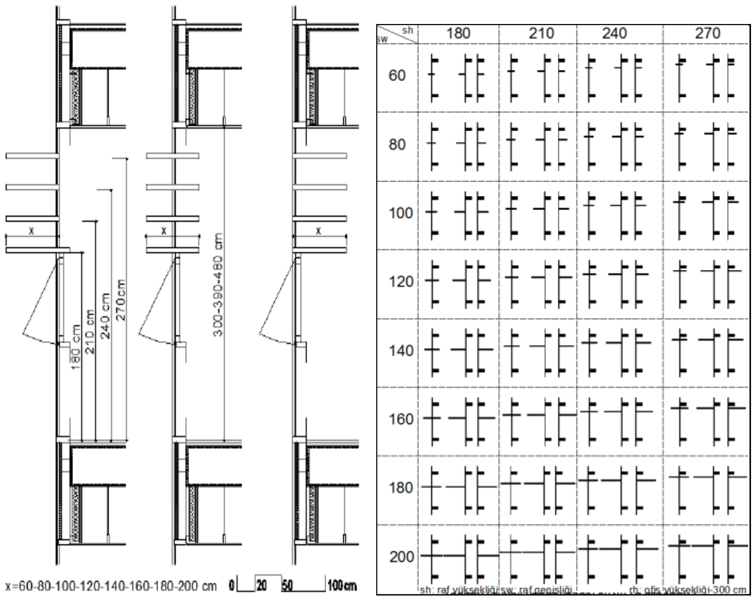
Light reflectance of materials (ρ) and transmittance of glazing surface used in sample office unit is as follows: MDF covered desk and board (ρ: 0,7), laminated door (ρ: 0,7), aluminium seat construction (ρ: 0,75), fabric part of the seats (ρ: 0,4), carpet covered floor (ρ: 0,4), wall (ρ: 0,7), gypsum board ceiling (ρ: 0,8), composite light shelf (ρ: 0,8), aluminium window profile (ρ: 0,75), double glazing transmittance: 0,643. Materials used in exterior are; sidewalk (ρ: 0,75), greenery (ρ: 0,4) [18].

### 2.4. Determination of Sensor Placement

The calculations are based on the difference between the desired illuminance levels without and with suitable light shelf. Sensors are indispensable to measure the daylight illuminance levels.

The distance between sensors is important both for continuity of daylight distribution and precision of the calculation. The minimum distance between sensors have to be under 60 cm according to Leedv4.0 [20]. Hence, sensors with 50 cm distance between each other are placed 75 cm up from the floor (task area) as seen in Figure 3.




(a) (b)

Figure 3. Sensor placement on plan view

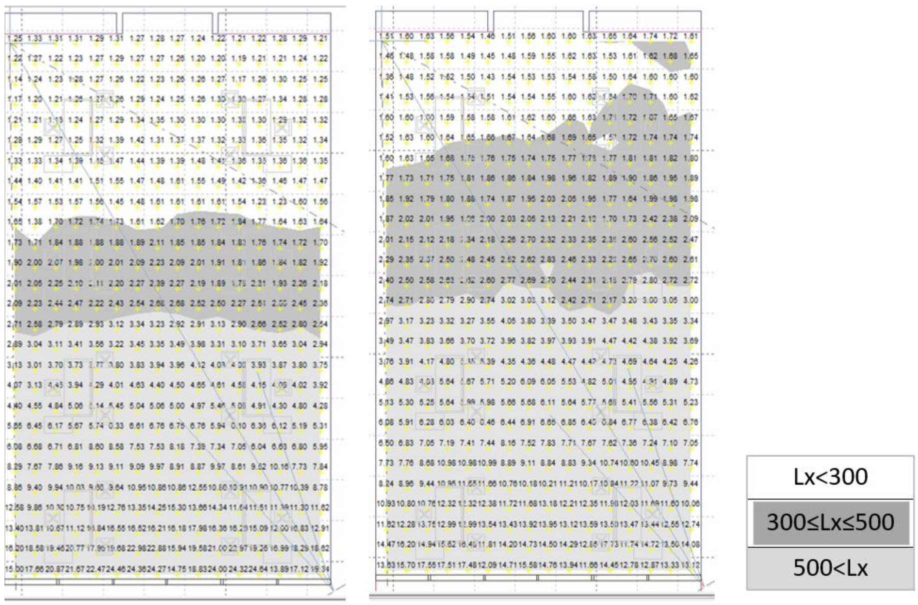
Figure 4. Placement variations for 60 cm width light shelf (a), light shelf placement variation table for 3m office height (b)

**2.5. Determination of suitable light shelf size/position on 6 main latitudes for 3 different office heights**

Variety of light shelf size/position is tested to obtain the most suitable condition of light shelf on 6 main latitudes for 3 different office heights used in this study. Light shelf placement table is prepared for this purpose and calculations are performed based on comparing DF values equal to desired daylight illuminance value interval (300Lx-500Lx) without and with light shelf. Different positions (interior, mid, exterior), size and height of light shelves are tested connected with light shelf placement table. The light shelf width is chosen from 60 cm to 200 cm by increasing 20 cm and the height of light shelf is started from 180 cm above eye level to 270 cm for 3m office height by increasing 30 cm. The top level of the light shelf is 360 cm for 3,9m office height and 450 cm for 4,8m office height.

The variety position (exterior, mid, interior) and height of light shelf with 60 cm width for 3m office height are tested separately to determine the suitable light shelf as seen in Figure 4.a. All light shelf placement variations with width from 60 cm to 200 cm are as seen in Figure 4.b.

*E.g.,* the suitable light shelf on 0° latitude for 3m height office unit is determined by comparing 1.64-2.73 DF interval equals to desired 300Lx-500Lx daylight levels without and with light shelf in CIE Standard Overcast Sky condition. All varieties of light shelves in light shelf placement table are tested for this purpose. Exterior light shelf with 160 cm width and 240 cm height from the floor gives the best results for the desired daylight illuminance interval. The difference of daylight illuminance distribution levels between without light shelf (Figure 5.a) and with light shelf (Figure 5.b) are as seen in Figure 5.




(a) (b)

a) Daylight distribution without light shelf    b) Daylight distribution with suitable light shelf

Figure 5. Daylight illuminance distribution on 0° latitude for 3m height office unit.

Total 96 variation of light shelf size/placement is calculated on 0° latitude for 3m office height. The number of variations is 168 for 3,9m office height and 240 for 4,8m office height on each latitude.

## 3. RESULTS AND DISCUSSION

The suitable light shelf placement according to latitudes for 3 different office heights is determined and the comparison of light shelf efficiency is done in this part of the study. The determination of suitable light shelf is performed as described in methodology section. The efficiency of light shelf is obtained by comparing the difference between desired daylight levels (300lx-500lx) in the sample office unit without light shelf and with suitable light shelf for all conditions. In addition, the effect of light shelf to the distribution of interiors' is described as a result.

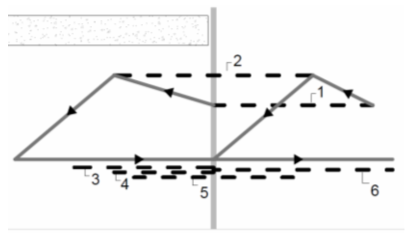
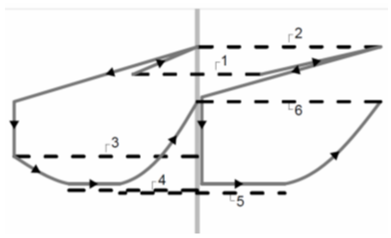
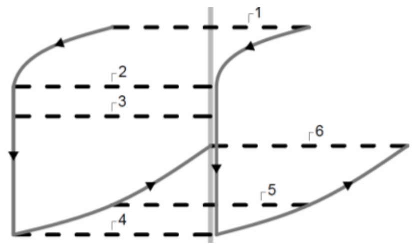
### 3.1. Suitable Light Shelf Placements According to Latitudes for 3 Different Office Heights

Suitable light shelves (dashed horizontal lines) according to 6 main latitudes for 3 different office heights and CUN-OKAY light shelf curves [21] obtained from arrangement of light shelves are as shown in Table 1.

CUN-OKAY light shelf curve pairs are obtained from the joining of interior and exterior end points of light shelves separately as shown in Table 1.

E.g. For 4,8m office height, light shelf numbered 1 expresses the suitable size/position of light shelf for 0° latitude. The CUN-OKAY light shelf curve pair for 4,8m office height is created by joining the end points of suitable light shelves with splines according to latitudes separately.

Table 1. Suitable light shelf sizes and positions according to latitudes for 3 different office heights (Ho).

| Ho | No | Latitude | Position | Width (cm) | Height(cm) | Shelf arrangements according to latitudes |
|---|---|---|---|---|---|---|
| 3m | 1 | 0° | exterior | 160 | 240 |  |
| | 2 | 15° | middle | 200 | 270 | |
| | 3 | 30° | interior | 100 | 180 | |
| | 4 | 45° | interior | 100 | 180 | |
| | 5 | 60° | middle | 160 | 180 | |
| | 6 | 75° | exterior | 180 | 180 | |
| 3,9m | 1 | 0° | middle | 140 | 300 |  |
| | 2 | 15° | exterior | 200 | 330 | |
| | 3 | 30° | interior | 200 | 210 | |
| | 4 | 45° | interior | 140 | 180 | |
| | 5 | 60° | middle | 180 | 180 | |
| | 6 | 75° | exterior | 200 | 270 | |
| 4,8m | 1 | 0° | middle | 200 | 390 |  |
| | 2 | 15° | interior | 200 | 330 | |
| | 3 | 30° | interior | 200 | 300 | |
| | 4 | 45° | interior | 200 | 180 | |
| | 5 | 60° | middle | 200 | 210 | |
| | 6 | 75° | exterior | 200 | 270 | |

CUN-OKAY curves

Suitable light shelf

### 3.2. Light Shelf Efficiency According to Latitudes for 3 Different Office Heights

The comparison of number and percentage of sensors within desired daylight interval (300lx-500lx) between conditions with suitable light shelf obtained from Table 1 and without light shelf for 3 different office heights on 6 main latitudes is listed in Table 2. Percentage of sensors are calculated by dividing sensor numbers to total 432 sensors.

*E.g.* For 3,9m office height on 45° latitude the percentage of sensor numbers within 300lx-500lx is calculated by 58/432 (x100)= 13,43 without light shelf condition.

Table 2. Number and percentage (%) of sensors between 300lx-500lx with and without light shelf.

| Ho | No | Latitude | Without lightshelf | | With lightshelf | | % difference |
|---|---|---|---|---|---|---|---|
| | | | # sensors | % | # sensors | % | |
| 3m | 1 | 0° | 81 | 18,75 | 136 | 31,48 | 12,73 |
| | 2 | 15° | 55 | 12,73 | 85 | 19,68 | 6,94 |
| | 3 | 30° | 55 | 12,73 | 81 | 18,75 | 6,02 |
| | 4 | 45° | 39 | 9,03 | 72 | 16,67 | 7,64 |

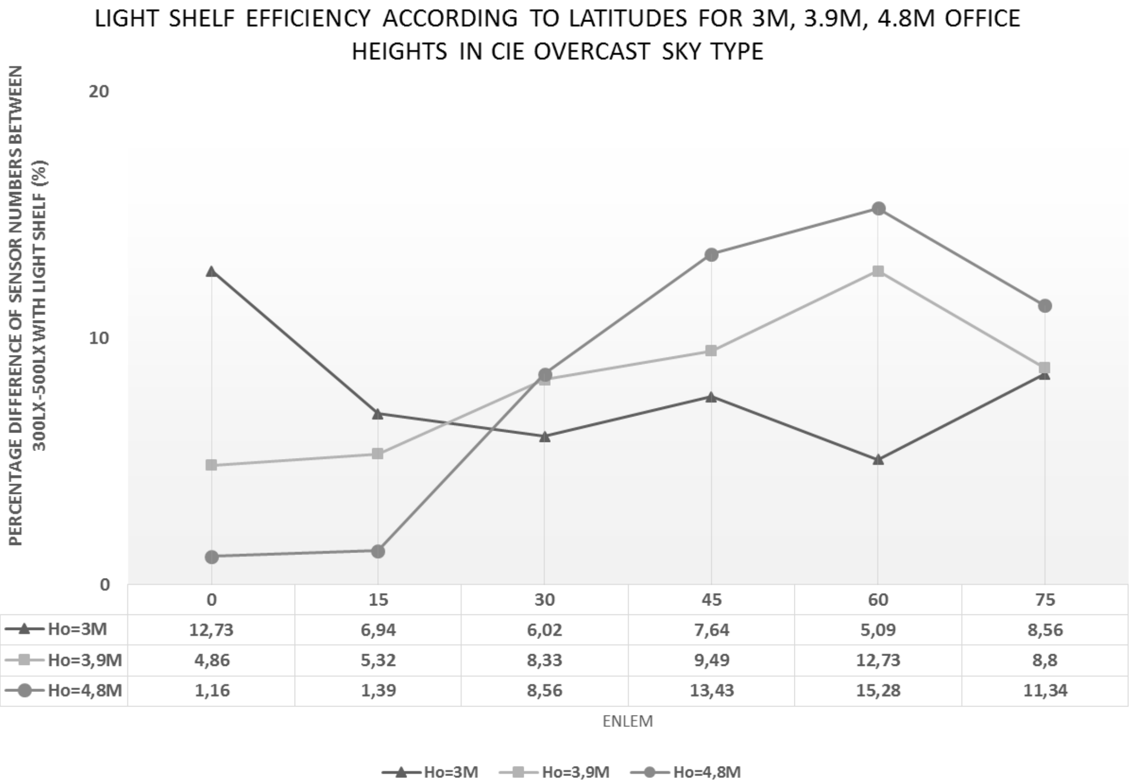
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 60° | 49 | 11,34 | 71 | 16,44 | 5,09 |
| | 6 | 75° | 44 | 10,19 | 81 | 18,75 | 8,56 |
| 3,9m | 1 | 0° | 163 | 37,73 | 184 | 42,59 | 4,86 |
| | 2 | 15° | 87 | 20,14 | 110 | 25,46 | 5,32 |
| | 3 | 30° | 63 | 14,58 | 99 | 22,92 | 8,33 |
| | 4 | 45° | 58 | 13,43 | 99 | 22,92 | 9,49 |
| | 5 | 60° | 55 | 12,73 | 110 | 25,46 | 12,73 |
| | 6 | 75° | 57 | 13,19 | 95 | 21,99 | 8,80 |
| 4,8m | 1 | 0° | 97 | 22,45 | 102 | 23,61 | 1,16 |
| | 2 | 15° | 179 | 41,44 | 185 | 42,82 | 1,39 |
| | 3 | 30° | 84 | 19,44 | 121 | 28,01 | 8,56 |
| | 4 | 45° | 66 | 15,28 | 124 | 28,70 | 13,43 |
| | 5 | 60° | 60 | 13,89 | 126 | 29,17 | 15,28 |
| | 6 | 75° | 66 | 15,28 | 115 | 26,62 | 11,34 |

The efficiency of light shelves according to latitudes for 3 office heights are represented by "% difference" of sensor numbers between 300lx-500lx without and with suitable light shelf

The light shelf increases desired daylight levels in all conditions as seen in Table 2. The light shelf efficiency for 3 different office heights on 6 main latitudes respectively is as shown below.

- Percentage of light shelf efficiency for 3m office height according to main latitudes from 0° to 75° respectively is %12,73, %6,94, %6,02, %7,64, %5,09 and %8,56.
- Percentage of light shelf efficiency for 3,9m office height according to main latitudes from 0° to 75° respectively is %4,86, %5,32, %8,33, %9,49, %12,73 and %8,80,
- Percentage of light shelf efficiency for 4,8m office height according to main latitudes from 0° to 75° respectively is %1,16, %1,39, %8,56, %13,43, %15,28 and 11,34.

The light shelf efficiency graphic is obtained from the results (% difference) in Table 2 for 3 different office heights on 6 main latitudes (Figure 5).




| | 0 | 15 | 30 | 45 | 60 | 75 |
|---|---|---|---|---|---|---|
| Ho=3M | 12,73 | 6,94 | 6,02 | 7,64 | 5,09 | 8,56 |
| Ho=3,9M | 4,86 | 5,32 | 8,33 | 9,49 | 12,73 | 8,8 |
| Ho=4,8M | 1,16 | 1,39 | 8,56 | 13,43 | 15,28 | 11,34 |

Figure 5. Light shelf efficiency according to latitudes (0°, 15°, 30°, 45°, 60°, 75°) for 3 different office heights (3m, 3,9m, 4,8m).

When the light shelf efficiency graphic is examined generally, it is seen that the light shelf efficiency is decreased with increasing of office height between 0° & 15° latitudes and increased with increasing of office height on 30°, 45°, 60° and 75° latitudes. The light shelf efficiency values are clearer on high latitudes (Figure 5).

The use of light shelf is accepted suitable if only the efficiency of light shelf is above %5 in this study. The efficiency of light shelf for 3 different Office heights on 6 main latitudes is described briefly below according to Figure 5.

- The efficiency of light shelf is %12,73 on 0° latitude, %6,94 on 15 latitude, %6,02 on 30° latitude, %7,64 on 45° latitude, %5,09 on 60° latitude and %8,56 on 75° latitude for 3m office height. It is recommended the use of light shelf on every latitude for 3m office height due to all light shelf efficiency values above %5.
- The efficiency of light shelf is %4,86 on 0° latitude, %5,32 on 15 latitude, %8,33 on 30° latitude, %9,49 on 45° latitude, %12,73 on 60° latitude and %8,80 on 75° latitude for 3,9m office height. It is recommended the use of light shelf on 15°, 30°, 45°, 60°, 75° latitudes for 3,9m office height due to light shelf efficiency values above %5 on these latitudes.
- The efficiency of light shelf is %1,16 on 0° latitude, %1,39 on 15 latitude, %8,56 on 30° latitude, %13,43 on 45° latitude, %15,28 on 60° latitude and %11,34 on 75° latitude for 4,8m office height. It is recommended the use of light shelf on 30°, 45°, 60°, 75° latitudes for 4,8m office height due to light shelf efficiency values above %5 on these latitudes.

### 3.3. Investigation of Light Shelf Effect to the Distribution of Daylight Illuminance to Interiors and Design Advices

Table 3. Distribution of daylight levels between 300lx-500lx according to latitudes for 3 office heights with and without light shelf

| Distribution of Daylight Levels Within 300Lx-500Lx According To Latitudes For 3 Office(8mx14m) Heights With and Without Light Shelf | | | | | | |
|---|---|---|---|---|---|---|
| Latitude(°) | 3M | | 3,9M | | 4,8M | |
| | Without light shelf(m) | With light shelf(m) | Without light shelf(m) | With light shelf(m) | Without light shelf(m) | With light shelf(m) |
| 0° | 6,5-9 | 6,5-13,5 | 8,5-13,5 | 7,5-13,5 | 9,5-13,5 | 9-13,5 |
| 15° | 5-7,5 | 5,5-8,5 | 7-10 | 6-11 | 7-13,5 | 6,5-13,5 |
| 30° | 3,5-6 | 2,5-5,5 | 5-7,5 | 3-7 | 5,5-9 | 4-8,5 |
| 45° | 2,5-4,5 | 1,5-4,5 | 3,5-6,5 | 1,5-5,5 | 4-7 | 2,5-7 |
| 60° | 1,5-3,5 | 0,5-4,5 | 2,5-4,5 | 0,5-4,5 | 3-5 | 0,5-5 |
| 75° | 1-2,5 | 0,5-2,5 | 1,5-3,5 | 0-3,5 | 2,5-4 | 0-4 |

Distribution of daylight levels between 300lx-500lx from window to interiors according to latitudes for 3 office heights with and without light shelf is shown in Table 3.

*E.g.* Desired daylight interval (300lx-500lx) for office is between 6,5m-9m distance without light shelf and 6,5m -13,5m with suitable light shelf from window on 0° for 3m office height. Thus both desired daylight level and the distribution of daylight to interiors is increased.

Effect of light shelf to distribution of daylight could be considered for office design. *E.g.* Despite daylight reaches to 9m from window without light shelf; it reaches up to 13,5m with suitable light shelf. In other words, the office length could be planned 13,5m with suitable light shelf contrary to 9m without light shelf on on 0° for 3m office height. 1m-2m circulation areas (cabinet etc.) could be added to this value (13,5m).

## 4. CONCLUSIONS

Light shelf help to increase the illuminance quantity within desired levels and contribute energy saving by using daylight effective. In addition to that, light shelves help to diminish environmental pollution caused by the fossil sourced energy usage and minimize psychological, physiological, visual discomforts caused by artificial lighting.

Many regional studies have been performed about light shelf efficiency especially in recent years. This original paper investigates the effect of different latitudes (0°, 15°, 30°, 45°, 60°, 75°) to the light shelf efficiency on a sample unit for 3 different (3m, 3,9m, 4,8m) office heights. The results about this study are summarized below.

When the light shelf efficiency according to latitudes for 3 different office heights is examined generally, it is seen that the light shelf efficiency is decreased with increasing of office height between 0° & 15° latitudes and increased with increasing of office height on 30°, 45°, 60° and 75° latitudes. The light shelf efficiency values are clearer on high latitudes

It is recommended the use of light shelf on every latitude for 3m office height due to all light shelf efficiency values above %5.

It is recommended the use of light shelf on 15°, 30°, 45°, 60°, 75° latitudes for 3,9m office height due to light shelf efficiency values above %5 on these latitudes.

It is recommended the use of light shelf on 30°, 45°, 60°, 75° latitudes for 4,8m office height due to light shelf efficiency values above %5 on these latitudes.

Effect of light shelf to the distribution of daylight could be considered on different latitudes for office unit design. Typical plans could not be suitable on every latitude because of difference of daylight distribution related with suitable light shelf placement. Length of office unit could be changed from latitude to latitude with the same office width in daylight efficient design.

The methodology to determine the light shelf placement and efficiency on a sample office unit in this study could be used for any type of building on a random latitude.

## CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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