Evaluation of Daylight Performance on the Selected Design Parameters of Light Shelves

Sadaf Noshin, Humaira Kanwal, M.Shahzad Aslam, Uzma Mushtaq

***Abstract*---**Lighting control systems play a pivot role in decreased energy consumption. Increase in environmental concerns enforces the need of lighting control systems without disturbing the future comfort goals. Light shelf is one of the superlative daylighting strategy with brilliant illuminance production and economical possibility by the introduction of natural lights. This study emphases how changes in the light shelf design parameters such as its dimensions, position and height can affect its natural light productivity and visual response. In this research paper, study space of an educational building is selected for the day light simulation on Autodesk Ecotect 2011 on summer solstice and winter solstice days under over cast sky conditions. Analysis is performed on the selected Study space to assess the illumination requirement and simulate the model with designated types of light shelves and the obtained data is exported on Radiance software for detailed daylight analysis. The significance of this study express that the external light shelves at a height of 7' can be observed as the most suitable selection in governing the glaring problems and reducing the brightness nearby the window areas. However, it is very important to pay extra attention to light shelves height and it's position, because it has a better influence on light shelf enactment.

Index Terms: Daylighting, simulation, Light shelf, Overcast sky, Radiance, Ecotect , Illuminance

1 INTRODUCTION

As the global warming is increasing and energy resources are decreasing, it is the need of the time to reduce energy consumption particularly for educational buildings in aspect of their lighting and working area [1]. IEA (International Energy Agency), an international organization that is based in USA for international energy reported that out of total energy consumption of building sector the lighting energy constitutes 18%. This percentage is likely to increase constantly [2]. Energy efficiency refers to the utilization of least energy for lighting and cooling equipment that is used for maintaining comfort inside the building [3].The design for energy efficiency seeks a determined purpose for this, providing the best environmental conditions to attain visual comfort and a good lighting quality, using the least amount of energy possible [4]. Lighting systems have the largest potential of any known appliance to reduce energy use. One third of the electricity used in the commercial buildings is represented by lighting [5], [6].

All the building owners want to cut less the energy consumption by lighting to save their money. Building owners try to utilize efficient schemes for controlling lighting to reduce the energy usage [6], [7].Daylighting is a kind of passive strategy to improve energy performance and users' visual comfort without expensive installation and operational cost.

[1]

However, in some conditions, daylight may cause glaring problems especially in workplaces or any places in the visual environment. Solar shading devices control glaring problems and reduce solar gains, and thus avoid overheating [1].Recently new architectural lighting strategies have been adopted to efficiently reduce the consumption of energy in buildings by introducing different systems in order to optimize the distribution of natural light inside buildings such as light pipes, light shelves and venetian blinds [8]. Controlling daylight decreases the energy consumption of building by 60% and increase the quality of natural light inside the building space. It also has effect on the building thermal characteristics as most of them are operated as shading [9].

2 DAYLIGHTING STRATEGIES

Day lighting technique is an efficient strategy for the maintenance of peaceful and comfortable indoor environment. It also provides a great source of reduction of energy consumption. Day lighting techniques include fiber optic, light tube, holographic solar energy, reflective Louvre, and anidolic day lighting system [10]. More systems like vertical louvers, horizontal louvers, overhangs, and light shelves are developed in recent years [11]. Light shelf is considered one of the most efficient solutions for the light energy issues in buildings [8], [12].

2.1 Light Shelf

The light shelf technique is a method that blocks the flow of light into indoor space and brings the light deep inside the

[1]
Sadaf Noshin, the University of Lahore, Lahore,Pakistan
Sadaf_noshin22@yahoo.com
Humaira Kanwal, the University of Lahore, Lahore, Pakistan
M.Shahzad Aslam, the University of Lahore, Lahore, Pakistan
Uzma Mushtaq, the University of Lahore, Lahore, Pakistan

space. This method helps in prevention of problems like glares and illumination imbalance caused by external direct light [9]. Light shelf can help conserve energy by the reflecting of natural light into the deep inside space of the rooms, as shown in Fig 1. [14]

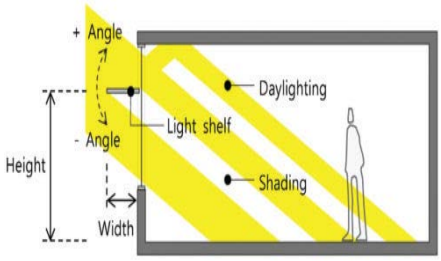


Fig.1: Conception of the light shelf [14]

Light shelf as a passive element of architecture serves two purposes of reflecting light and providing shade [13][15][16]. Horizontal element is the basic component of light shelf that is positioned on the either side of the window façade or it can be present on both sides. The height for the life shelf need to be more than eyelevel dividing the façade of window in two portions: The upper portion that reflects the daylight in the inner areas and the lower portion that allows the direct penetration of daylight [17],[18].

The main objective of this paper is to overcome the glare problems nearby the window areas by introducing the daylight devices such as light shelves.

3 METHODOLOGY

The research method includes various computer software based simulations as shown in fig.2.The method of investigation is performed to check the effects of an individual light shelves (4'-6" x 2') for the selected study space by using Ecotect and Radiance day lighting simulation software's. Daylight simulations is carried out under overcast sky condition on 21st June and 21st December with different simulation parameters position and height by considering six different groups of light shelves including Ext (7') , Int. (7') , Ext. & Int. (7') and Ext (8') , Int (8') , Ext & Int (8') in account to the base case model (No light shelf - No) [18].

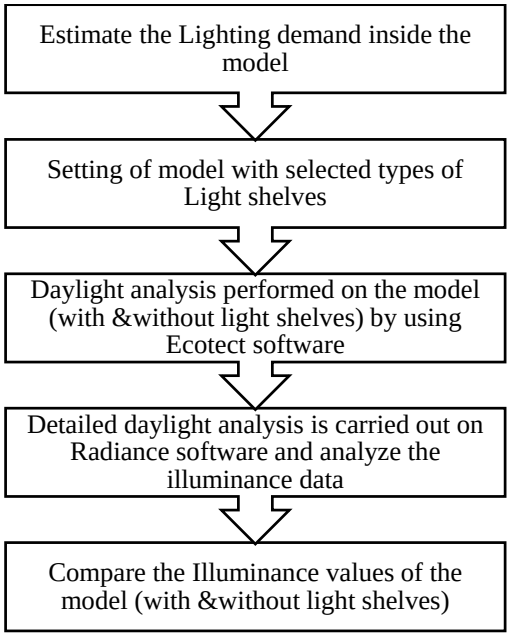


Fig.2 Flow chart of Research Methodology

4 RESULTS AND DISCUSSIONS

4.1 Simulations Process and Daylight Analysis

The simulation process is performed on the selected study space for Ecotect analysis has a dimension of (30'-0" x 50'-0"x 15') which is shown in fig 3 and Individualities are given in table 1.

Fig.3: Architectural Plan of Study Space

Table 1
Individualities of Study Space

Sr.No.	Parameters	Dimensions
1	Floor area	1500 ft²
2	Fenestration Area	31.5 ft²
3	Single light shelf area	9 ft²
4	Window sill height	3 ft.
5	Working plane level	3 ft.
6	Ceiling height	15 ft.

Light shelves are provided on the south facing windows. Two different heights, 7' and 8' for light shelves are selected. Height is measured from the floor level. External, internal or external & internal are three different positions proposed for the simulation process. The specification of Examined light shelves is shown above in Table 2 and Fig 4.

Table 2
Investigated Light Shelves Heights and Positions

Sr.No.	position	Height	Notations
1	No light shelf		No
2	External	**7'**	Ext. (7')
3	Internal	**7'**	Int. (7')
4	External and Internal	**7'**	Ext. & Int. (7')
5	External	8'	Ext. (8')
6	Internal	8'	Int. (8')
7	External and Internal	8'	Ext. & Int. (8')

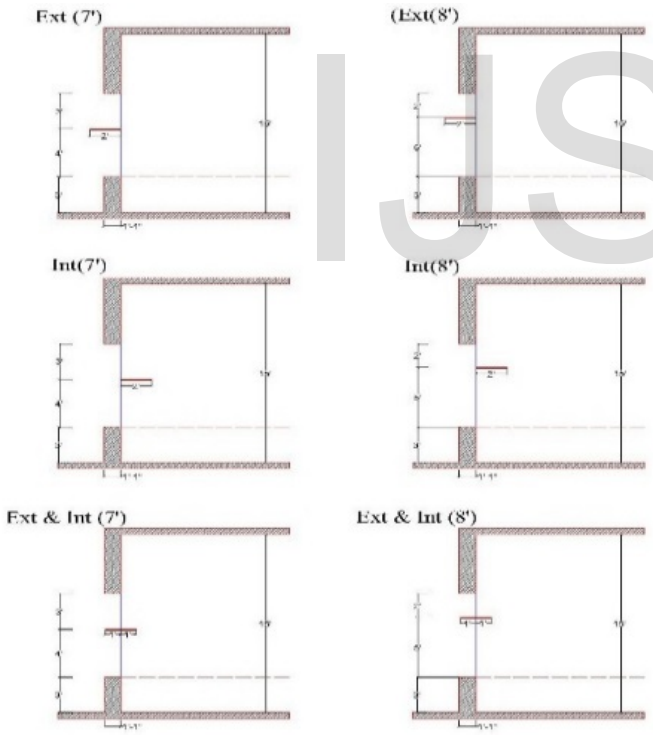


Fig 4: Six Different types of investigated light shelves

Ecotect Analysis includes the setting of analysis grid at 3 feet from the floor level. Floor area (30'-0" x 50'-0") of the study space is covered by the analysis grid. Analysis Parameter settings for imitation are shown in Table 3.

Table 3

Ecotect Analysis Parameters

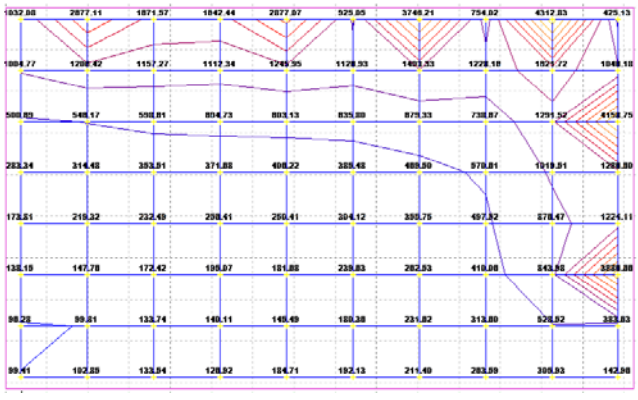
Location	Pakistan, Lahore
Date &Time	21st June and21st December ;12:00 Noon
Sky Illuminance	9000 lux (Derived from model latitude)
Sky Condition	Overcast sky
Accuracy	Medium
Type	Illuminance (lux)

Numerous kinds of materials are assigned to the model of study space for Ecotect analysis. Table 4 shows the list of components, specific materials, and the respected reflectance values that are used in the simulation process. It is very important to note that the highest reflectance factor value is given to the Glass light-shelf

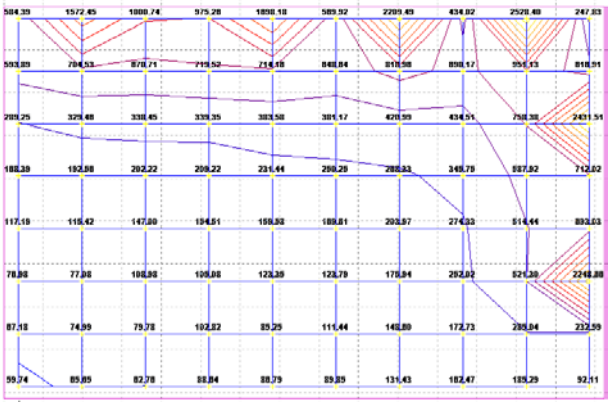
Table 4
Elements, assigned materials, and reflectance values

Sr.No.	Elements	Materials	Reflectance
1	Wall	Plastered bricks	0.70
2	ceiling	White Painted Plaster	0.80
3	Floor	Tiles	0.30
4	Light shelf	Glass Shelf	0.84

The Autodesk Ecotect 2011 is used to perform the day light analysis under the over cast sky condition for the months of June and December at 12 noon. The Radiance software is used for the detailed analysis of day lighting. The results are again exported to Ecotect to display illuminance values on analysis grid as shown in fig 5(a-b).



(a) Illuminance values on the analysis grid in the month of June



(b)Illuminance values on the analysis grid in the month of December

Fig. 5: Illuminance values on the analysis grid (without light shelves)

The similar simulation process is repeated for all examined light shelves. The average illuminance values in 21st June and 21st December for the selected study space is shown in Table 5.

Table 5
Average illuminance values

Sr.No.	Types	Average Illuminance values (Lux)	
		21st June	21st December
1	No	781	462
2	Ext. (7')	677	398
3	Int. (7')	712	417
4	Ext. & Int.(7')	691	404
5	Ext. (8')	680	400
6	Int. (8')	720	420
7	Ext.& Int. (8')	682	406

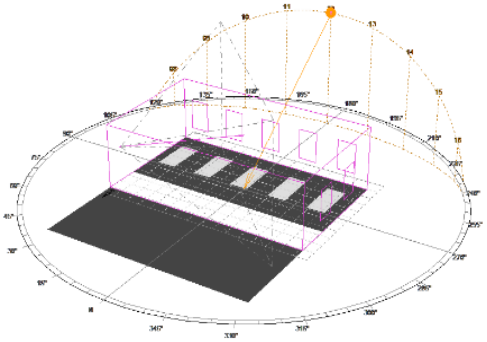
Reviewing the values in Table 4, it is clear that type (without light shelves) has higher Illuminance values 781 Lux and 462 Lux in the months of June and December respectively, as compared to with light shelves types, therefore the level of brightness or discomfort glare are maximum. Light shelves on the south facing façade increases the daylight quality and quantity and also have the ability to overcome glare. In the months of June and December, Light shelf types Ext. (7') give the less average illuminance values 677 Lux and 398 Lux as compared to all types including without light shelves. The Light shelf types Ext. (7') is enhanced the illuminance level approximately 13.31% in the month of June and 13.8% in the month of December as compared to without light shelves. It is also expressed by Sun position and shadow range which is given below in appendix.

It is observed that by using the light shelves on internal side Int. (7') and Int. (8'), the daylight levels are more intense, which may produce glaring difficulties nearby the window areas on the working plane level. Alternatively, light shelves with external part Ext. (7'), Ext. & Int. (7'), Ext. (8') and Ext. & Int. (8') serve as a shading element that is used to prevent the daylight falling directly near the facade or window areas. Drop in Illuminance level is increased with the increase of height which is related to previous research [18].

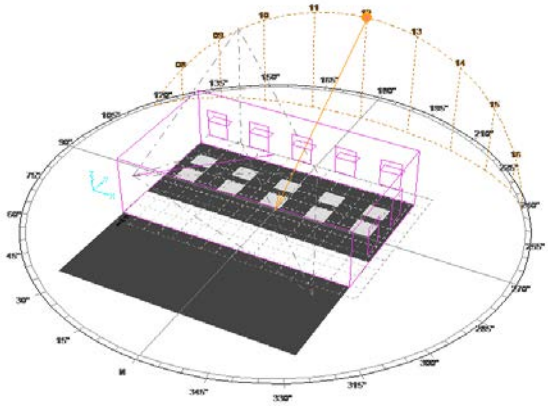
5 CONCLUSIONS

The lighting analysis performed on numerous light shelves under overcast sky conditions, showed a decrease in illuminance levels that resembled with other conclusions from related researches. It is considerably observed that external and external & internal light shelves serve as a shading element that is used to prevent the daylight falling directly near the facade or window areas. So these types of light shelf in the design prove to be more effective in controlling the glaring issues and reducing the brightness nearby the window areas. In general, the consequence of this study showed that, in spite of the fact, that use of light shelves under overcast sky condition has a restricted achievement; the external light shelves at a height of 7' are observed as the most suitable option. The Light shelf types Ext. (7') is enhanced the illuminance level approximately 13.31% in the month of June and 13.8% in the month of December as compared to without light shelves. However, it is very important to pay extra attention to light shelves height and its position, because it has a greater effect on light shelf performance.

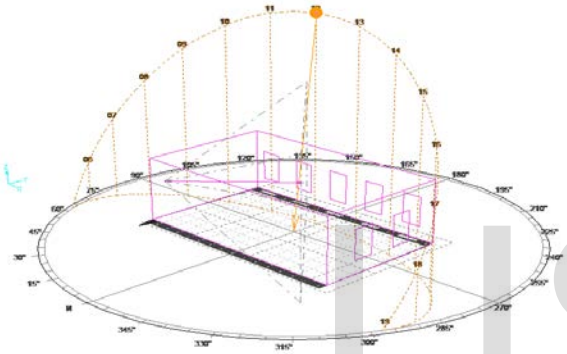
APPENDIX



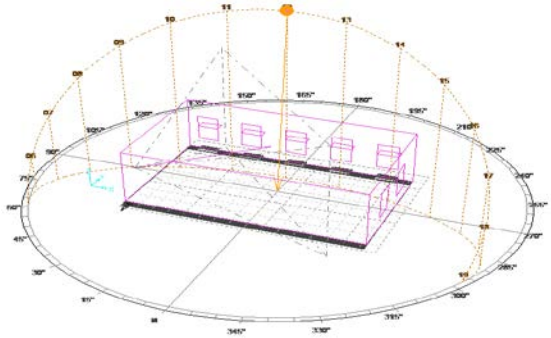
Position of sun and shadow range in the month of December without light shelf



The position of sun and shadow range in the month of December with External light shelf at a height of 7'



Position of sun and shadow range in the month of June without light shelf



Position of sun and shadow range in the month of June with External light shelf at a height of 7'.

ACKNOWLEDGMENT

The Authors wish to thank all the kind people around who helped in them making this research possible. Especially the Authors thanks to Dr. Anis Ahmad, Department of Architecture, Punjab University, who helped us a lot in completing this work. Authors are also thankful to the Department of Architectural Engineering & Design, University of Engineering & Technology, Lahore, Pakistan, for providing information regarding the following research.

REFERENCES

[1] İnan, Tuğba. "An investigation on daylighting performance in educational institutions." *Structural Survey* 31.2 (2013): 121-138.
[2] Lee, Heangwoo, Seonghyun Park, and Janghoo Seo. "Development and Performance Evaluation of Light Shelves Using Width-Adjustable Reflectors." *Advances in Civil Engineering* 2018 (2018).
[3] Ponmalar, V., and B. Ramesh. "Energy efficient building design and estimation of energy savings from daylighting in chennai." *Energy Engineering* 111.4 (2014): 59-80.
[4] Piderit Moreno, María Beatriz, and Constanza Yañez Labarca. "Methodology for assessing daylighting design strategies in classroom with a climate-basedmethod." *Sustainability* 7.1 (2015): 880-897.
[5] Bangali, Jayashri A., and Arvind D. Shaligram. "Simulation and Development of Lighting Control System using daylight for Corridor of a Building." *Simulation* 1.12 (2014).
[6] Soori, Prashant Kumar, and Moheet Vishwas. "Lighting control strategy for energy efficient office lighting system design." *Energy and Buildings* 66 (2013): 329-337.
[7] González, Javier, and Francesco Fiorito. "Daylight design of office buildings: optimisation of external solar shadings by using combined simulation methods." *Buildings* 5.2 (2015): 560-580.
[8] Safa, Daich, Zemmouri Noureddine, and Saadi Mohamed Yacine. "A study of optimization of the light shelf system in hot and arid zones." *Baltimore, USA: American Solar Energy Society* (2013).
[9] Oh, Sangwon, Heangwoo Lee, and Yongseong Kim. "Basic Research on Performance Evaluation of Light Shelf Applying Curvature." *Advanced Science and Technology Letters* 47 (2014): 30-33.

[10] Kurtay, Cüneyt, and Okay Esen. "Efficiency Of Light Shelves According To Latitudes In Office Buildings." *Gazi University Journal of Science* 29.4 (2016): 711-721.

[11] El-Darwish, Ingy I., and Rana A. El-Gendy. "The role of fenestration in promoting daylight performance. The mosques of Alexandria since the 19th century." *Alexandria Engineering Journal* 55.4 (2016): 3185-3193.

[12] Woo, Lee Heang, Seo Jang Hoo, and Kim Yong Seong. "A Preliminary Study on Daylighting Performance Evaluation of Light Shelf based on the Inclined Ceiling during winter solstice." (2014).

[13] Hu, Jianxin, Jiangtao Du, and Wayne Place. "The Assessment of Advanced Daylighting Systems in Multi-Story Office Buildings Using a Dynamic Method." *World Renewable Energy Congress-Sweden; 8-13 May; 2011; Linköping; Sweden*. No. 057. Linköping University Electronic Press, 2011.

[14] Lee, Heangwoo, Suktae Kim, and Janghoo Seo. "Evaluation of a light shelf based on energy consumption for lighting and air conditioning." *Indoor and Built Environment* (2017): 1420326X17719954.

[15] Chien, S. C., and K. J. Tseng. "The Effects of Light Shelf on Climate-based Daylight performance in Tropics-A Case Study." 2014.

[16] Nair, Manju G., K. Ramamurthy, and A. R. Ganesan. "Classification of indoor daylight enhancement systems." *Lighting Research & Technology* 46.3 (2014): 245-267.

[17] Moazzeni, Mohammad Hossein, and Zahra Ghiabaklou. "Investigating the influence of light shelf geometry parameters on daylight performance and visual comfort, a case study of educational space in Tehran, Iran." *Buildings* 6.3 (2016): 26.

[18] Zakhour, Suhail. "The Influence of Selected Design Parameters on the Performance of Light Shelves under Overcast Conditions." *Architecture Research* 5.4 (2015): 113-120.

Sadaf noshin has two and half year experience in teaching in University of Lahore, Pakistan. She has published one research paper in journal. Presently working as a lecturer.

Humeria kanwal has 11 year experience in teaching in University of Lahore and 6 year experience in research. Presently she is working as Assistant professor and pursuing Ph.D. in Architecture. She has published 5 research papers (2 in journal, 3 in conference)

M. Shahzad Aslam, has 5 year experience in teaching in Pakistan. He is pursuing M.S in Geotechnical Engineering from U.E.T Lahore.

Uzma Mushtaq, has two and half year experience in teaching in University of Lahore, Pakistan. She has published two research paper and four are under review. Presently working as Assistant professor.