

Estimation of Energy Saving in Educational Building from Daylighting to Improve the Visual Comfort

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ABSTRACT

Daylight is the occupied-range of light that is appropriate to the human visual response. Thus, it can contribute to human health, performance and productivity. Energy consumption can be reduced by improving in energy efficiency. The study emphasizes on the design of lighting system that will be energy efficient. The basic purpose of this paper describes how to reduce the mounted lighting load and improve the illumination level as per international standards. A good lighting scheme should be based on more energy efficient & longer life and maintenance free equipment. In this research paper, a hypothetical study space is selected for the daylight analysis on the Ecotect and the Radiance software on summer solstice and winter solstice days under over cast sky condition. Ecotect software is used to determine lighting demand inside the selected study space and the obtained data is exported on Radiance for detailed and more accurate daylight analysis. It is pragmatic that illuminance level is varied with respect to date and time that are clearly expressed by the daily sun path and shadow range. It is also perceived that the installed artificial luminaries does not provide the required illuminance on the working plane and consume more energy. The major aim of this research is to reduce the lighting load by introducing energy efficient artificial luminaries into the room that provide the required illuminance level on the working plane. Lumen method is used to explain the energy saving which is carried out according to existing energy consumption compared with the proposed one. At the end cost comparison of energy consumption and payback period is also calculated. This study shows that overall cost saving in energy consumption is approximately 34.37% and the calculated payback period for the newly installed lights is comprising of approximately 11 months.

Key Words: Daylighting, Lighting Load, Illuminance, Artificial Luminaries, Energy Efficient, Lumen Method, Energy Consumption.

1. INTRODUCTION

Spending more time indoor may cause many psychological and physiological problems that may cause sickness due to inadequate light. The purpose of the study is optimizing the glare free natural light inside the building as to create the place with great

visual quality [1]. Humans are not only concerned about the visual performance of the lighting supply but also it is optimized use in the building industry [2]. Electrical energy constitutes almost 40% of the total energy consumed in commercial buildings.

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Cooling load can be decreased significantly by the use of effective daylighting scheme. Resident's health and the students' performance is greatly affected by daylight quality [3].

The formulation of building's fenestration, configuration and site affects the crucial decisions in capturing of daylight for the interior of the building [4]. The architectural layouts should be well integrated with the sun path charts and the orientations of windows [5]. In huge urban surroundings, sky obstruction that is caused by the huge buildings causes the minimum daylight to reach the lower floors and interior spaces located deeply. Indoor lighting can be enhanced by using the available sunlight with the help of innovative day lighting schemes [6]. To get the perfect results simulation tools need a huge amount of iterations and time [7]. Expanding population and scarcity of natural resources demands the development and implementation of energy saving methods to meet the human needs without having an impact on future sustainability [8]. LEED (Leadership in Energy and Environmental Design) certification is a step to enhance the choice and use of efficient products [8-9].

Increased energy consumption due to improving living standards, migration, urbanization and all time increase in population is a serious threat on consumption of traditional energy sources and we are facing the gigantic energy crises. WAPDA (Water and Power Development Authority) states that, it is worse in Islamic Republic of Pakistan since last ten years, as there is a huge gap in supply and demand. Pakistan requires 20,000MW/day, and only 13,500MW is produced thus creating a shortfall of approximately 6500MW. Under this scenario, energy must to be conserved [10]. The diminishing of energy uses in buildings and progression of consumer physical comfort by means of practical day lighting strategies take on more and more meaning and relevance. In this circumstances, we have to optimize natural light uses in functional spaces to reduce using of artificial light power. The awareness of effective daylight in an architectural space is both an art

and a science. The main challenge facing the architect is to confess only as much light as necessary and allocate it consistently throughout the space without introducing glare or heat [11-12]. New emerging technologies have great potential in daylight saving. Energy efficiency and high quality in lighting is achievable by the suitable retrofits [11]. Reflective glasses or internal gaps are not efficient enough to remove glare or overheating, in turn they increase energy consumption by reducing the amount of light entering the room [13]. The artificial light and daylight systems are integrated to save energy by 65% and green light source gives the good aesthetic look as given by the LED light. Moreover, it is "secondary energy saving" that again saves the energy and gives a lot of pattern options to the people [14].

2. DAYLIGHTING

Energy consumption cost is reduced up to numerous range by the entrance of the natural light in buildings. It has been investigated by Capeluto that in a well-deliberate building, daylighting lessens energy consumption costs, increases visual excellence [15], awareness, health and emotions of well-being [16-17] and delivers inner relaxation that are very hard and luxurious to produce with artificial lights [15]. It is necessary and useful methodology for achieving friendly growth of building, energy efficiency and visual comfort [16]. Day lighting or artificial lighting can enhance the visual comfort [18]. Daylight provides sense of brightness and cheeriness that plays a vital role in peoples' life. Using natural lighting proves to be an important element of modern architecture and improves the environment and makes it pleasant. Day lighting can be used as an alternative for artificial lighting as it matches very closely to the visual response of humans. It provides attractive, pleasant and cheerful indoor environment as people wish to have a nice daylight in their working and living environment. It is proved that efficient daylight has a positive impact on the performance of the workers and has healthy impact on the working space [16].

3. OBJECTIVES

The main objective of this paper is to reduce the installed lighting load and provide required illumination level on the working plane by adding energy efficient artificial luminaries. Energy consumption cost of existing and proposed artificial luminaries in study space is also evaluated.

4. METHODOLOGY

A hypothetical modeling approach is utilized to investigate potential energy savings due to daylight and artificial lighting integration in educational buildings under the specified climatic conditions [11]. The research methodology is based on using different computer software simulations which is shown in Fig. 1. Autodesk Ecotect 2011 software is used for the daylight analysis under overcast sky condition on 21st June and 21st

December at 12.00 pm for the selected theoretical case study having a dimensions of (50'-0" x 30'-0" x 15'). The long façade of the study space is south facing consisting of five large windows having dimensions of (4'-6" x 7') and the sill height is (3') [19].

Further, evaluate the energy consumption cost of existing and proposed artificial luminaries by using lumen method and compare cost of energy saving of existing and proposed electrical plan. At the end payback period is calculated according to proposed artificial luminaries cost and their energy consumptions on the yearly bases.

5. RESULTS AND DISCUSSION

All the illuminance values and energy saving estimation is obtained through daylight analysis and Lumen method.

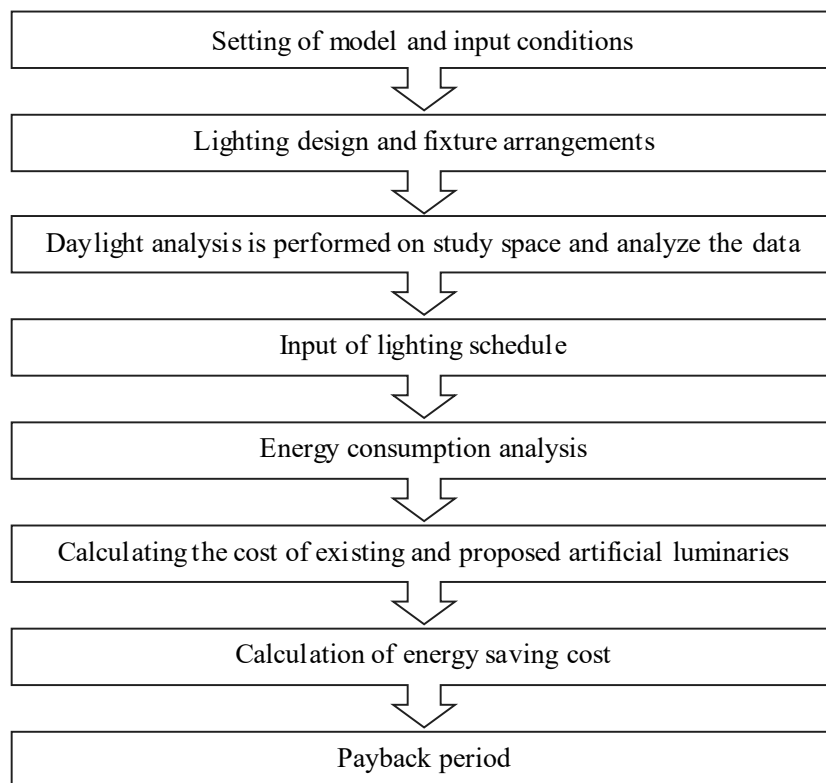


FIG. 1. FLOW CHART OF RESEARCH METHODOLOGY

5.1 Daylight Analysis

The study space has a dimension of (50'-0" x 30'-0" x 15') and its Architectural plan and another dimensions of the selected study space is shown in Fig. 2 and in Table 1.

An analysis grid is set that is located at a height of 3' above the floor level for the daylight analysis on Ecotect software. Ecotect Analysis parameters for simulation process are set towards precise values as shown in Table 2.

After setting all the simulation parameters and dimensions of the study space the daily sun path and shadow range in the month of June and December is shown in Figs. 3-4.

The existing electrical plan of Study space is shown in Fig. 5.

Existing design energy load calculation is shown in Table 3.

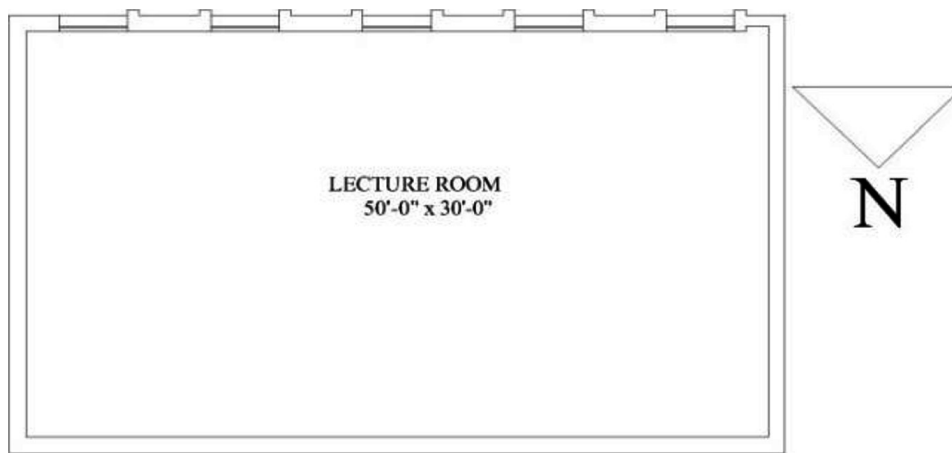


FIG. 2. ARCHITECTURAL PLAN OF STUDY SPACE

TABLE 1. CHARACTERISTICS OF STUDY SPACE

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

TABLE 2. ECOTECT ANALYSIS PARAMETERS

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

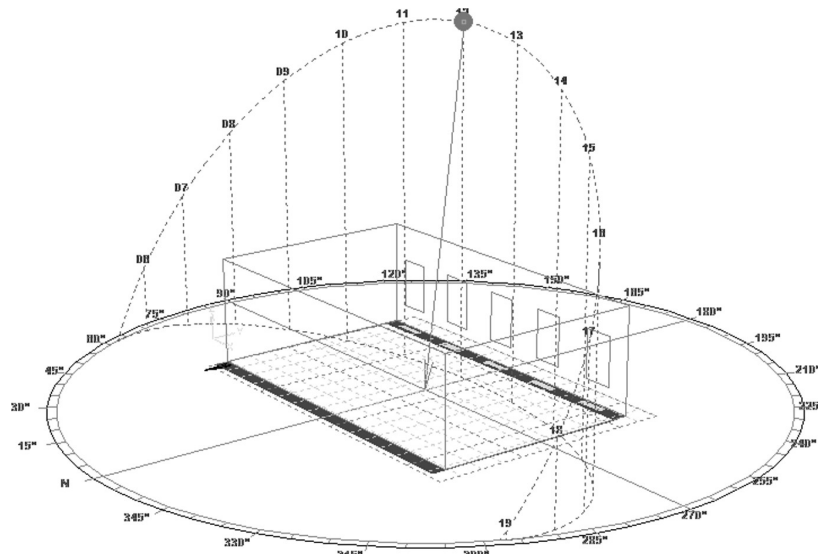


FIG. 3. THE POSITION OF SUN AND SHADOW RANGE IN THE MONTH OF JUNE

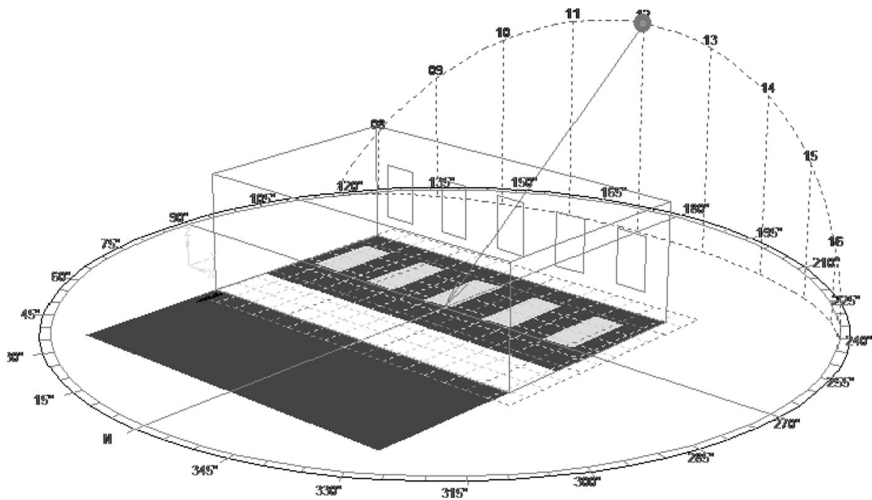


FIG. 4. THE POSITION OF SUN AND SHADOW RANGE IN THE MONTH OF DECEMBER

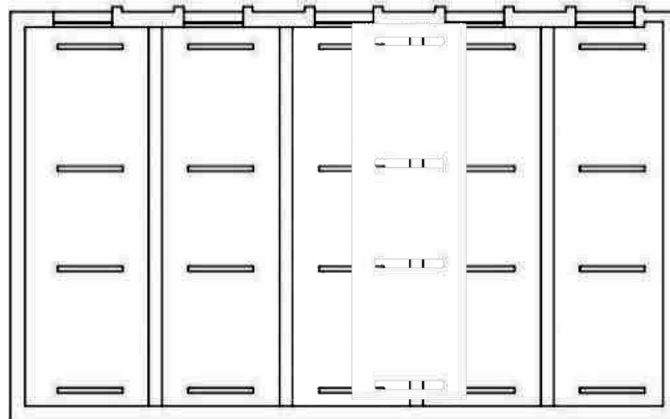


FIG. 5. EXISTING ELECTRICAL PLAN

Daylight Analysis on Ecotect software is carried out under over cast sky condition in the months of June and December and the results are exported to Radiance for detailed daylight analysis. Then the obtained data from

radiance are imported to Ecotect Analysis so that the simulation values (Illuminance values) are clearly expressed on analysis grid which is shown in Fig. 6(a-b).

TABLE 3. EXISTING DESIGN ENERGY LOAD

Appliances	Quantity (Nos.)	Wattage per Appliance (Watts)	Time (Hours)	Energy Consumed (Quantity x Wattage xHours÷1000) Kilowatt-Hour
Tube Lights	20	40	8	6.4

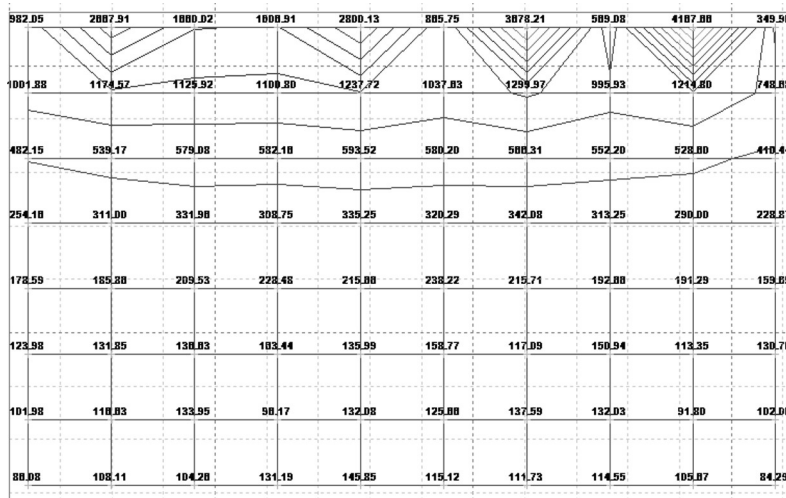


FIG. 6(a). ILLUMINANCE VALUES ON THE ANALYSIS GRID IN THE MONTH OF JUNE

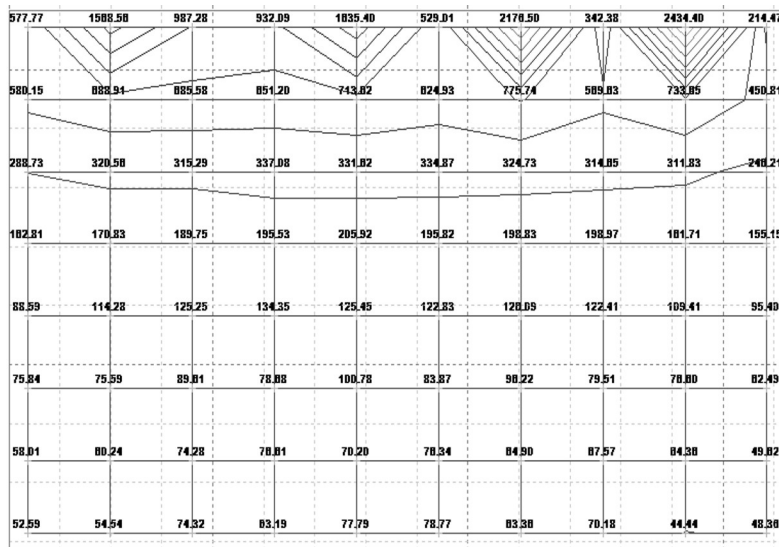


FIG. 6(b). ILLUMINANCE VALUES ON THE ANALYSIS GRID IN THE MONTH OF DECEMBER

FIG. 6. ILLUMINANCE VALUES ON THE ANALYSIS GRID

Average Illuminance values that are obtained from the Radiance and Average values of daylighting and electric light level are estimated which is given in **Table 4**.

When the daylight analysis is completed, Lumen method is used to explain existing and proposed energy consumption results which are shown in Table 5. Authors recommend 35-Watt T5 5 ft. Soft White (3000K) Linear Fluorescent Light Bulb having Average life of this light is 25000 hours and output of tube light is 3650 lumens.

The Proposed electrical plan of selected study space is shown in Fig. 7.

Estimation of energy saving is carried out according to existing energy consumption compared with the proposed one as per international standards. It is our major aim to reduce the lighting load by adding the daylighting into the room. Proposed design energy load calculation is shown in Table 4.

TABLE 4. AVERAGE ILLUMINANCE AND VALUES OF DAYLIGHTING AND ELECTRIC LIGHT LEVEL OF THE SELECTED STUDY SPACE

No.	Date and Month	Artificial Light Level (Lux)	Daylight Level (Lux)	Overall Daylight Level (Lux)	RADIlluminance alues
1.	21 st June	140	400	540	555
2.	21 st December	140	350	490	326
Recommended Lux Level = 300-400 Lux (As per standards)					

TABLE 5. PROPOSED LIGHTS IN STUDY SPACE

Area of Survey Lab (m2)	Total Required Lumens(lm) (Area x Required Illuminance)	Output of Proposed Tube Light (lm)	Number of Proposed Tube Lights (Total Required Lumens/Output of Light)
139.35	400x139.35=55740	3650	55740/3650=15.2

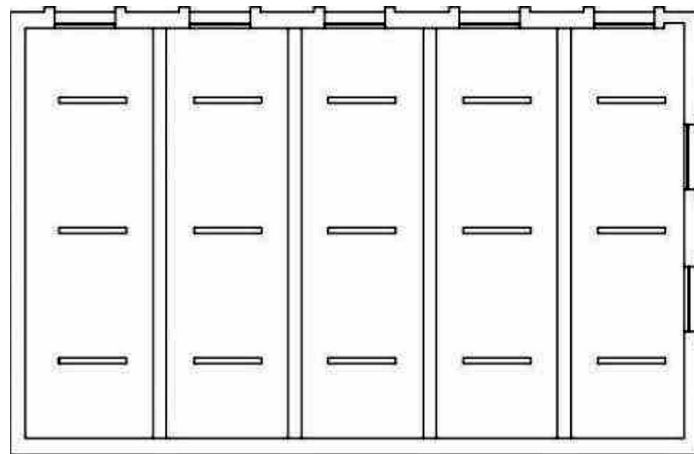


FIG. 7. PROPOSED ELECTRICAL PLAN

TABLE 6. PROPOSED DESIGN ENERGY LOAD

Appliances	Quantity (Nos)	Wattage per appliance (Watts)	Time (Hours)	Energy Consumed (Quantity x Wattage xHours÷1000) Kilowatt-Hour
Tube Light	15	35	8	4.2
Saving in Energy = 6.4 -4.2 = 2.2 Kilowatt-Hour				

Cost analysis is performed on the existing and proposed energy consumption and saving in energy is considerably observed. For this purpose, assuming 8 working hours for 22 days a month. The average rate for 1-Unit (1 kWh) would be Rs.15/-.

Running Electrical Energy Consumption of Existing Design

Existing design Consumption of Electricity in 24 hours = 6.4 Kilowatt-Hour

Existing Design Consumption of Electricity in 1-Month = 6.4x22=140.8 Kilowatt-Hour

Running Electrical Energy Consumption Cost of Existing Design

Energy consumption Cost for One-Month = 140.8 x15.00 = Rs. 2112

Running Electrical Energy Consumption of Proposed Design

Proposed Design Consumption of electricity in 24 hours = 4.2 Kilowatt-Hour

Proposed design Consumption of electricity in 1-Month= 4.2x22 =92.4 Kilowatt-Hour

Running Electrical Energy Consumption Cost of Proposed Design

Energy consumption Cost for One-Month = 92.4x 15= Rs. 1386/-

Saving in Energy Consumption Cost = EC-PC = 2112-1386 = Rs. 726/-

It is estimated that total cost saving is approximately 34.37% in the selected case study.

Total cost of newly mounted Tube lights = 500x15= Rs. 7500/-

5.2 Payback Period

It is very important to determine the payback period of a retrofitting design projects. It describes how much time is required t

o recover the cost of initial investment. It is a term which is defined as the extent of period required to recover the cost of initial installation cost. Payback period is equal to the initial cost divided by the estimated annual savings.

Simply,

Payback Period= 7500/726x12 = 11 months approximately.

The amount invested in installing lights in selected study space can be retrieved in 11 months by reducing the energy consumption which can be obtained by minimizing the electricity usage cost [20].

TABLE 7 RATE SCHEDULE OF LESCO

No.	Tariff Category/Particulars	Fixed Charges (RS/KWH/M)	Variable Charges (RS/KWH)	
			Peak	Off-Peak
1.	For Sanctioned Load less than 5 kW		16.00	
2.	For Sanctioned load 5 kW and above	400.00	12.00	
3.	101-300 Units		Peak	Off-Peak
	Time of Use	400.00	15.00	9.50
The average rate for 1-Unit (1 kWh) would be Rs.15/-				

6. CONCLUSIONS

This paper is focused on reducing the installed lighting load as well as the glare and brightness issues associated with it. A good lighting scheme is based on energy efficiency and longer life maintenance free equipment and intensity of light covering the whole area for which it is designed.

It is investigated after the detailed daylight analysis on the Ecotect and Radiance that average Illuminance values in the month of June exceed the standard values and in December it is within the standard range. But the artificial luminaries that are already used within the study space are consuming more wattage (energy) so it effects the monthly electrical cost. We proposed energy efficient artificial luminaries that provides the required Illuminance level on the working plane.

Estimation of energy saving is carried out according to existing energy consumption compared with the proposed one as per international standards. It is estimated that total cost saving is approximately 34.37% of the selected case study. The estimated payback period is 11 months which can be obtained by minimizing the electricity usage cost.

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REFERENCES

- [1] De Carli, M., and Valeria De, G., "Optimization of Daylight in Buildings to Save Energy and to Improve Visual Comfort: Analysis in Different Latitudes", Proceedings of 11th Conference on International Building Performance Simulation Association, Glasgow, 2009.
- [2] Wang, X., "Assessment of Daylighting and Electric Lighting Performance in a Retrofitting Project: A Case Study in Sweden", Master Thesis, Faculty of Engineering, Lund University, Sweden, 2017.
- [3] Moazzeni, M.H., and Zahra, G., "Investigating the Influence of Light Shelf Geometry Parameters on Daylight Performance and Visual Comfort, A Case Study of Educational Space in Tehran, Iran", Buildings, Volume 6, No. 3, pp. 26, 2016.
- [4] Leslie, R.P., Radetsky, L.C., and Smith, A.M., "Conceptual Design Metrics for Daylighting", Lighting Research & Technology, Volume 44, No. 3, pp. 277-290, 2017.
- [5] Khan, M.A., Arif, S., and Alamgir, K., "Comparison of Buildings Thermal Loads against Building Orientations for Sustainable Housing in Pakistan", Mehran University Research Journal of Engineering & Technology, Volume 31, No. 3, pp. 431-436, Jamshoro, Pakistan, July, 2012.
- [6] Nair, M.G., Ramamurthy, K., and Ganesan, A.R., "Classification of Indoor Daylight Enhancement Systems", Lighting Research & Technology, Volume 46, No. 3, pp. 245-267, 2014.
- [7] González, J., and Francesco, F., "Daylight Design of Office Buildings: Optimization of External Solar Shadings by Using Combined Simulation Methods", Buildings, Volume 5, No. 2, pp. 560-580, 2015.
- [8] Sharp, F., Lindsey, D., Dols, J., and Coker, J., "The Use and Environmental Impact of Daylighting", Journal of Cleaner Production, Volume 85, pp. 462-471, 2014.
- [9] Giarma, C., Katerina, T., and Dimitris, A., "Daylighting and Visual Comfort in Buildings' Environmental Performance Assessment Tools: A Critical Review", Procedia Environmental Sciences, Volume 38, pp. 522-529, 2017.

- [10] Siddique, S., Arif, S., and Khan, M.A., "Optimum Insulation Thickness for Walls and Roofs for Reducing Peak Cooling Loads in Residential Buildings in Lahore", *Mehran University Research Journal of Engineering & Technology*, Volume 35, No. 4, Jamshoro, Pakistan, October, 2016.
- [11] Asaad, A., and Almusaed, A., "Efficient Daylighting Approach by Means of Light-Shelve Device Adequate for Habitat Program in Aarhus City", *International Journal of Smart Grid and Clean Energy*, Volume 3, No. 4, pp. 441-453, 2014.
- [12] Al-Ashwal, N.T., and Ismail, M.B., "Energy Savings Due to Daylight and Artificial Lighting Integration in Office Buildings in Hot Climate", *International Journal of Energy and Environment*, Volume 2, No. 6, pp. 999-1012, 2016.
- [13] Secchi, S., Scurpi, F., Pierangioli, L., and Randazzo, M., "Retrofit Strategies for the Improvement of Visual Comfort and Energy Performance of Classrooms with Large Windows Exposed to East", *Energy Procedia*, Volume 78, 3144-3149, 2015.
- [14] Bangali, J.A., and Arvind, D.S., "Simulation and Development of Lighting Control System Using Daylight for Corridor of a Building", *Simulation*, Volume 1, No. 12, 2014.
- [15] Yousuf, S., Alamgir, A., Afzal, M., Maqsood, S., and Arif, M.S., "Evaluation of Daylight Intensity for Sustainability in Residential Buildings in Cantonment Cottages Multan", *Mehran University Research Journal of Engineering and Technology*, Volume 36, No. 3, pp. 597-608, Jamshoro, Pakistan, July, 2017.
- [16] Alrubaih, M.S., Zain, M.F.M., Alghoul, M.A., Ibrahim, N.L.N., Shameri, M.A., and Omkalthum, E., "Research and Development on Aspects of Daylighting Fundamentals", *Renewable and Sustainable Energy Reviews*, Volume 21, pp. 494-505, 2013.
- [17] Jakubiec, J.A., and Christoph, F.R., "The 'Adaptive Zone'—A Concept for Assessing Discomfort Glare Throughout Daylit Spaces", *Lighting Research & Technology*, Volume 44, No. 2, pp. 149-170, 2012.
- [18] Al-Khatatbeh, B.J., and Ma'bdeh, S.N., "Improving Visual Comfort and Energy Efficiency in Existing Classrooms Using Passive Daylighting Techniques", *Energy Procedia*, Volume 136, pp. 102-108, 2017.
- [19] Zakhour, S. "The Influence of Selected Design Parameters on the Performance of Light Shelves under Overcast Conditions" *Architecture Research* 2015.
- [20] Ponmalar, V., and Ramesh, B., "Energy Efficient Building Design and Estimation of Energy Savings from Daylighting in Chennai", *Energy Engineering*, Volume 111, No. 4, pp. 59-80, 2014.