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A Review of Daylighting Design and Implementation in Institutional Buildings

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Abstract: ***It is well known fact that lighting plays a very important role in the performance of any task in a space. Source of light can either be artificial or the sun. Institutional buildings are type of construction in which the occupant uses it the most at the times when natural light is available in plenty. In a learning environment, the lighting plays a very important role. The aim of this research is to study about the lighting requirements of any institutional building by performing a comparative analysis of institutional building. For the purpose of this research, the space that was limited to laboratories and classrooms alone. Building codes specify the average illumination levels required in a space according to the type of function that particular space will host. But case studies reveal that although average illumination levels may be within the recommended range, the actual level of illumination at individual position in the observed space may be too high or too low in the same space, i.e. there is large variation in the distribution of lighting in the space. This distribution of light is affected by several architectural parameters that can be controlled by the architect through the affected design process. The final output of the dissertation consists of design guidelines for the spaces observed, based on the analysis of finding form the live case study and the literature review. The design guidelines deal with the mail architectural parameters that have a direct impact on the indoor light quality.***

1. INTRODUCTION

The sun is the biggest source of light and energy on earth and the light we receive today comes from the sun in two ways: either directly as sunlight, or modified and redistributed by the atmosphere as diffused skylight. The light from the sun not only enables us to see, but provides energy and power to the whole ecosystem on earth. The combination of the direct sunlight and the diffused skylight can be defined as daylight (2002). The quality and intensity of light vary according to geographical latitute, season in a year, time of day, local weather, sky conditions and building geometry. Despite artificial lighting has long being used to supplement lighting in the interiors of building, reports suggest negative effect of artifical lighting on health. The advantages of daylighting design and applications in the built environment have been largely documented. Despite various methods used to measure and predict daylighting performance have been reported in the past, most daylighting technologies and methods used are tailor made or designed for specific case only. Such information would be useful for engineers, researchers and designers to asses the suitability of applying these system and technologies in different types and examine the potential of enerygy and cost savings.

1.1 Need to study lighting

In today's scenario energy crisis are in demands, than the use of natural agencies of lighting, of building. Although the expenditure on artificial lighting of building are reducing energy budget due to advancement in the field of light source and low cost electrical energy at present, yet daylighting will continue to be an important functional aspect of building design. Research has proven that when case study was conducted in Institutional buildings to measure the amount of illumination on the surfaces, it was seen that majority of the examples had insufficient light even by prescribed standards((Cook, 1990). However there is no evidence of any such study being conducted in the Indian context.

1.2 Aim

To perform comparative analysis of different institutions on the basis of daylighting and derive guidelines for the same.

1.3 Objective

1) To study lighting design requirements for any institutions.
2) To study and analyze natural lighting importance.
3) To derive the key elements for provision of light.
4) To develop design guide lines for light efficiency.

1.4 Scope and limitations

Institutional buildings are one of those building types in which lighting design plays an important role due to the nature of activities that occur inside them. People require continue light, which can be achieved by lighting design. Lighting efficiency is major confirm. Most institutions are owned by private organizations and hence energy consumption also matters to them. A balance has to be achieved in the lighting design process so that operational cost is low. The integrated scheme can be mix of daylighting and artificial lighting.

There are different components of an institutional building all of which have different requirements where lighting is concerned. There are classrooms, conferences rooms, Auditoriums, OAT's libraries, toilets. All these have different lighting requirements that must be considered by the designer in the initial planning stage itself. The extent of study is limited to study institutional building and its key elements. Colleges are selected on the basis of certain architectural features that have an effect on the light quality.

1.5 Methodology

The problem identifies was the lack of implementation of lighting specific design strategies in institutional building. These buildings usually do not consider natural lighting as important factor that should influence design. Rather most intuitions. Just take some basic rules regarding façade and fenestrations so that lighting levels meet the recommended level specified in the building codes.

- Literature study on basis theories of lighting and lighting design to understand the various parameters that affect quality of light inside any space and design.
- Literature study analysis helped to derive the architectural parameters that affect lighting of a space.
- All institutions selected are designed by well-known architects.
- Case study will help to understand how architectural parameters affect the quality of light inside the space.
- The observations will be compiled and analysed.
- Design guidelines for the various architectural parameters will be derived on the basis of analysis of the observations from literature review.

2. Daylighting as an Alternative to Artificial Lighting

Artificial lighting contributes to significant carbon emission and as a result, leads to global warming. Literature revealed that electric lighting consumes up to 40% of the annual energy consumption(Krarti M, 2005), 20 to 30% of the total energy use in commercial buildings, one third of the electricity bill or 35% of the total electric load in conventional building. In build environment, we benefit from solar energy in various ways, such as heating and lighting. Passive solar energy design in buildings, which uses building elements fro collecting, storing and distributing solar energy, is important. Spaces heating and daylight are the most direct and efficient way to passive solar energy design approach. Daylighting which is an important strategy in modern architecture by which natural can be brought into a room via buildin opening to replace or supplement artificial lighting, can contribute to the reduction of building energy consumption enhance visual comfort. The exploitation of daylight has been recognised as a valuable means of achieving energy efficiency in building and improving visual quality of interior building spaces. Previous studies indicated that, by employing daylighting, reduction of 223 milion tonnes of CO_2emisions or 24000MW of energy demand could be achieved(McHugh J, 2004).

However excessive daylight exposure could cause glare. Overheating problems and thermal discomfort to building occupant. Surveys show that the lumious comfort of building occupants is affected by the quality of daylighting. The benefits of daylighting can be only be realised if visual needs and comfort criteria are carefully considered in building design. Daylight in a building does not by itself lead to energy saving. Daylighting can only contribute to cost and energy savings if lighting control strategies or photo sensors can be integrated to dim or switch off artificial lighting when sufficient daylight is available.

3. Design of Luminous Environment

Conventional design processes are fragmented and compartmentalized. Usually decisions are made one at a time, usually in this sequence- planning- structure- mechanical system- lighting- dealing- finishing.

Irreversible decision made at the onset option available to the design team. The end result is a luminous environment that shows nearly no variation through a project.

The typical method to do lighting design for a space-

- Determining the required average level of illumination from the given lighting standards(may be single level for a type of building)
- Calculating the number of fixture necessary to get the require levels of illumination.
- Finding an appropriate layout for the required number of fixture that will distribute light uniformly over the work plane.

Visual comfort probability index rates the various arrangement of fixtures according to the proportion of viewers who find the arrangement tolerate from the point of view of glare. If VCP objective is 70%, it means that 70% of total occupant of that space should find glare condition of that space acceptable(Choi, 2013). VCP rates only glare, it doesn't deal with the fact that HOW people are going to perceive that space (comfort or pleasant or otherwise).

3.1 Principle of measurement

- The efficiency of a light source is indicated by luminous efficacy, Im/Watt. Manufacturers usually give this value after testing the lamps at laboratories. It is difficult to establish the luminous efficacy value of lamps at site conditions.
- All the light emitted by the lamp does not reach the work area. Some light is absorbed by the luminaire, walls, floors and roof etc. the illuminance measured in lumens/m^2 i.e. lux, indicates how much light i.e. lumens is available per sq. meter of the measurement plane.
- However , over a period of time the light output from the lamp gets reduced, room surfaces become dull, luminaire becomes dirty and hence the light available on the work plane deviates from the target value.
- A second aspect of efficiency of utilization is to take into account, the light available at task and non-task areas. Usually for commercial area, the recommended illuminance at the non-task is at least one-third of the average task illuminance, while keeping a minimum illuminance required at the horizontal plane to be 20 lux.(gupta, 2015)

3.2 Method of measurements

The following parameters were measured.

- Illuminance levels
- Length and width of room
- Daylight factor

The accuracy of 5% and suitable range up to 10000 lux should be used as per the BEE second draft code of lighting (2004).

3.2.1 Determination of illuminance measured points

Based on the room index, the minimum number of illuminance measurement points is decided.
Room index, RI= LxW/ H_m x (L+W)

Where L= Length
W= Width
H_m= Height of the luminaires above the plane measurement(Efficiency, 2006)

Table 2.1: Number of points measured illuminance

Room index	Minimum number of measurement points	
	For+5% accuracy	For + 10% accuracy
RI<1	8	4
1<RI<2	18	9
2<RI<3	32	16
RI>3	50	25

For a space having length L=5m, Width W=5m and lamp mounting height of 2.6m, RI= 0.96 i.e. there must be at least 8 measurements points for 5% accuracy and at least 4 for 10% accuracy. The measurement grid should be positioned to cover a representative area of the work plane.

3.2.2 Measurement of illuminance

- Defining the workspace where evaluation is to be done, in this case science classrooms.
- Measuring the room length 'L' width 'W' and mounting height 'Hm'
- Calculation of room index, RI= LxW/ H_m x (L+W)
- Based on room index, determining the minimum number of illuminance measured points required and distributing these points evenly in the room.
- Calculating the average value of measured illuminance at all points. If E1, E2,…..En are illuminance measured at points 1,2,…..,n.

Average illuminance,

$$E_{av} = \frac{(E1+E2+E3+\ldots+En)}{N} \text{ X correction factor}$$

The correction Factor is given in the table for different types of lamps.

- Multiplying average illuminance with the area to get total luminous flux(lumens) incident on the measurement plane. Total available lumens on the measurement plane= average illuminance X(LXW) i.e.φm=E_{av}X LXW

Table 2.2: Correction factor for lux meter

Light source	Correction factor
Mercury lamp	X 1.05
Fluorescent lamp	X 0.99
Sodium Lamp	X 1.11
Daylight	X 0.95

4. Measurements, Estimation and Predictions of Daylight Performance

It is difficult to characterise indoor daylighting because of the numerous design parameters that have to be considered, such as, view factor, aperture size and room depth. Nevertheless, experiments, numerical studies and simplified procedures are common methods used to determine interior illuminance. In early 1980s, BRE had developed simplified procedures to characterise lighting performance in the interiors of day lit buildings. The amount of daylight inside a room can be measured by comparing it with the total daylight available outside the room. This ratio is called daylight factor (DF), which can be measured in percentage (%). Two types of DF can be calculated: DF at a given position (Point DF) and DF over a given floor area (Average DF, DF_{ave}). DF can be accurately determined by Eq (1), which is expressed as the ratio of indoor daylight illuminance to outdoor daylight illuminance under the standard overcast sky.

$$DF = \frac{\text{Indoor illuminance from daylight}}{\text{Horizontal unobstructed outdoor illuminance}} \times 100\% \quad (1)$$

The value of DF depends on building types, window sizes, frames and position, types of glazing, transmission characteristics of glazing, cleanliness of glazing, and interior room surface reflectance. DF can be measured using scale model with artificial skyor field measurement in a real building. It can also be predicted using computer simulation programs or calculated using simple manual procedures. DF is made up of three principal components: sky component, internally reflected component and externally reflected component, which can be calculated separately and added together. These components can be calculated using Building Research Station (BRS) daylight table, Waldram Diagram, BRS Daylight Factor Protractors, pepper pot diagram or numerical formulas. The resulting DF need to be corrected to allow for deterioration of room reflectance, types of glazing, dirt on glass and the window frame. The calculated DF excludes the effects of building orientation or direct sunlight from both indoor and outdoor illuminance, whilst the overcast sky on which it is based is very much a worst-case condition.

Point DF can only be used once the window size, shape and position have been decided, which may be too late to alter glazing areas at this stage. It is higher near the openings, but decreases significantly further away from the openings. Compared with Point DF, DF_{ave} is easier to calculate and considerably less dependent on window shape and position, as it can be simply related to glazing area. Derived from Eq (1), DF_{ave} is the ratio of average interior illuminance to external global horizontal illuminance under standard overcast sky conditions and can be used to represent the arithmetic mean of DF obtained throughout the room. To date, DF is still the most frequently used parameter to characterise the daylight situation in a building. Almost all national standards and international directives recommend DF as criteria for sufficient daylight quantity assessments. Minimum values of DF_{ave} are normally recommended for different building interior spaces, ranging from less than 2%

(artificial lighting dominates daytime appearance) to more than 5% (fully day lit where daytime artificial lighting rarely needed). Such recommendations have been widely discussed in a number of publication, such as, DETR Good Practice Guide 245, The Code of Practice on daylight (BS 8206 Part 2), CIBSE Window Design Manual and BREEAM. DF_{ave} can be calculated based on the theory of the split-flux principle that divides the flux entering the interior through window over its lower parts of the room surface areas and total internal surface areas, which can be determined by Eqs 2 to 5.

$$DF_{ave} = \frac{A_g \theta T}{A(1-R^2)} \quad (2)$$

$$DF_{ave} = \frac{TMA_g \theta}{A(1-R^2)} \quad (3)$$

$$DF = DF_{winave} + DF_{sklave} \quad (4)$$

$$DF = (SC + ERC + IRC + FC) \times MF \times FR \times GL \times MG \quad (5)$$

A variety of aids and methods used for calculating the availability of daylight and the effect of sun shading is shown in Table below. These mainly refer to indicators developed to quantify the amount of skylight or sunlight reach a window. Majority of these indicators are less suitable and rarely used nowadays since they still involve plotting obstruction from reference points using transparent direction finder and building layout plans with different scales. Such aids and methods have actually posed a difficulty for architects, where Poole(D., 1993)has called for the need to standardise calculation method for providing consistent and practical guidance for designers and engineers.

Performance indices other than DF used to assess the daylight performance and availability inside buildings have been discussed, compared and critically analyzed. It was concluded that, DF is the most frequently used indices and widely accepted by international standards, despite improvement has been done by developing other indices. However, one significant weakness of DF is that it is not suitable for direct sunlight calculation and the calculation was highly influenced by building properties (J, 2012). To overcome the limitations of DF for direct sunlight calculation, Vertical to Horizontal illuminance (VH Ratio) has been used as a function of the light decrease on a vertical plane(Love JA, 1994); while Daylight Autonomy (DA) has been used to measure how a certain illuminance level can be maintained by the use of daylight alone and can be expressed as a percentage of occupied time, either annually or on a month-by-month basis.

Table 1: A summary of different methods used to determine the availability of daylight in buildings

Daylight prediction indicators	*Assessments*
Waldram diagram	Vertical sky component
BRS daylight factor protractors	Sky component
BRS daylight table	Sky component
Sun-on-ground indicators	Availability of sunlight on the ground at the equinox
Sunlight availability indicators	Probable sunlight hours
Skylight indicator	Vertical sky component
The no-sky line rule of thumb	Availability of direct light from the sky
Sun path indicators	Availability of sunlight at particular times of day and year
Pepperpot diagram	Percentage of total skylight

5. Analysis

5.1 Orientation

- Classes' orientations are perfectly aligned to the cardinal direction. Though that wasn't enough in many cases, because glare was coming from windows. No curtains were provided.
- Ideally fenestration should face northern direction when possible. This will reduce heat load and light coming in will be diffused, compared to the south light. North facing classrooms should have room orientation from west to east to have light coming in from the left.
- South facing classes should have room orientation from east to west to have light come in from the left.
- Window façade should preferably not face or west due to high heat loads.
- In all the classes spread of light is highly varied with the points in proximity to the window having very illumination and far corners having very les

5.2 Plan and plan form

- Rectangular or square plans in which length> width are preferred as reflections on the blackboard or white board can be distracting for students sitting on outer seats. For classes having fenestration only on one side, width of room should not exceed 6mts.
- Different plans shapes can cause distraction because angles at which the walls are placed can cause some walls to appear brighter than the rest.

5.3 Glazing

- Walls should have light colours so that they make the room appear larger.
- Glossy finish should be avoided, as they create distraction.
- Double glazing windows should be there to avoid the glare, if the orientation is in such direction.
- If using single glazing windows, curtains must be provided.

5.4 Fenestration

- Sill height of windows should be 90cms, which was found in 4 classes out of 6. It should be above the table top height. Very large windows will create distraction for the users siting at the window side.
- Proper fenestration wasn't found in any of the classes. Ideally there should be fenestration on 2 walls is that distribution of light. Ventilators on the far side wall can bring in light form the corridor side. But these are more effective when the corridor is well lit artificially or naturally.

- Ventilators should be the larger enough to allow light in come in properly. They can act as diffused light source if provided with frosted glazing.
- Lintel height for windows should not be less than 60cms from the celling as it creates a sense of distortion of space, by creating the illusion that room is taller than it is. The sense of proportion of the room should not be lost.
- Light shelves can be provided for rooms in which corners are not getting sufficient.

6. Conclusions / Recommendations

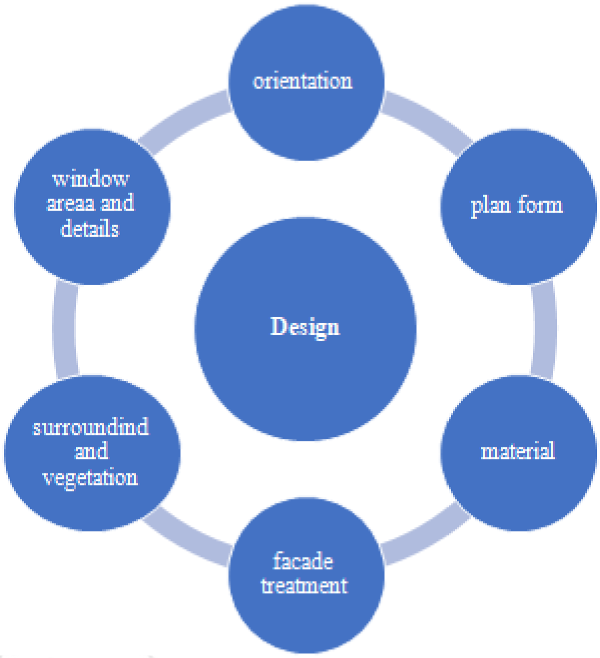
Institutional designing falls in the category of spaces in which the quality of light and quantity of light entering the rooms has a direct impact on the performance of users. Too much light can have negative impact on performance. Just the same as lack of lighting would have. There are several architectural parameters that affect the quality of lighting inside a space. The parameters range from plan form and interior surface treatment to building orientation. These parameters can be controlled by an architect by the design process.

Natural light is a component of environment. It can add vibrancy and colour to an dull space. Artificial light is a static component that can be directly controlled. However it doesn't have the same effect that a dynamic light source will have upon a space. Most of the new light technology aim to have efficiency by integrating natural light along with artificial light.

Parameters that affect natural light inside a space are: Building orientation, plan form, dimension of space, surface treatment, window areas and details, position of surrounding buildings and vegetation.

All these factors can be controlled by architect through the design itself. When designing institutional building, the orientation of the building has to be decided with respect to site. Usually buildings have typical floor plans and classroom plans. This type of designing should not be preferred, rather plan in grid form.

Windows position size play and important role. It allows flow of light into the building and also affects the distribution pattern of light in the space. Fenestrations are the main areas that can be modified for light.



Unless the function of the room is incompatible with daylighting, or it is used only for short periods, every workplace and every habitable room in a dwelling should have a view through a window to the outside. If a workplace must necessarily be a windowless room, workers should have free access to a nearby space with a good exterior view. A view into another internal space is less liked than an external view; and, if there can be only an internal view, this should be into a large day lit space, such as an atrium. The variation of daylight on the walls and ceiling of a room should not be masked by electric lighting.

Architectural design is the creation of place. So, therefore, is the choosing of brightness and colour, because these are elements of architecture. The lighting and materials of a room, the distribution of light and dark, of Chroma and texture, not only determine the physical visibility of things, but they establish the nature of the place, its character, its meaning. Whether or not the designer intends it, the room that is created will be associated in the mind of every user with places that he or she has experienced.

Designing With Natural Light

1) Determine Availability of Natural Light.
2) Identify Program Needs.
3) Identify Daylighting Design Strategies.
4) Integrate Daylighting Strategy w/ Whole Building Concept.
5) Integrate with Electrical Lighting.
6) Effectively Optimize Design Strategy.
7) Check and Test Design

References

[1] Baker, N. and Steemers, K. (2002).Daylighting Design of Buildings, James & James SLtd, London.
[2] Brownlee, D. B., and Long, D. G. (1991). Louis I. Kahn : In the Realm of Architecture, Rizzoli International Publications, Inc., New York.

[3] Plummer, H. (2003).Masters of Light, Architecture and Urbanism, Tokyo.
[4] Plummer, H. (1987).Poetics of Light, Architecture and Urbanism, Tokyo.
[5] Plummer, H. (1995).Light in Japanese Architecture, Architecture and Urbanism, Tokyo.
[6] Evans, B. (1997). Daylighting Design. In: Watson, D. Crosbie, M. Callender, John.
[7] DeBartolo, J. (1992). The Perception of Illumination. B. Arch. Massachusetts Institute of Technology. Dept. of Architecture.
[8] Baker, N. Steemers, K. (2002).Daylight Design of Buildings. Hong Kong: H & Y Printing Ltd.
[9] DUXBURY, Liane (2013). Daylight and Modeling Case Studies (2013).
[10] GUZOWSKI, Mary. (2000). Daylighting for sustainable design.New York, McGraw-Hill.HOURANI, May, and HAMMAD, Rizeq (2012). Impact of daylight quality on architectural space dynamics: Case study: City Mall--Amman, Jordan. Renewable and Sustainable Energy Reviews.
[11] LECHNE, Norbert. (2009). Heating, cooling, lighting: sustainable design methods for architects. 3rd ed., Canada, John Wiley, Hoboken and NJ.
[12] PHILLIPS, Derek. (2004). Daylighting: natural light in architecture. Oxford, Architectural Press.
[13] SMITH, Peter F. (2005). Architecture in a climate of change: A guide to sustainable design. 2nd ed., Oxford, Architectural Press.
[14] Berman, T. (2003). Purchasing and selecting school lighting. School Planning &Management.
[15] Jaen, M., &Kirschbaum, C. F. (2001). Flicker and visual performance: a psychologicalexperiment with fluorescent lamps. Perception.
[16] DfEE. (1999). Lighting design for schools, Vol. 90. London: The Stationery Office
[17] Hathaway, W. E. (1983). Lights, windows, colour: elements of the school environ-ment. In 59th Annual meeting of the Council of Educational Facility Planners.
[18] later, A. I., Perry, M. J., & Carter, D. J. (1993). Illuminance differences between desks:limits of acceptability. Lighting Research and Technology
[19] Blehm, C., Vishnu, S., Khattak, A., Mitra, S., & Yee, R. W. (2005). Computer visionsyndrome: a review.
[20] CIBSE.Clanton, N. (1999).Lighting the school of the future. School Planning and Manage-ment.
[21] Alberta, Canada.Hathaway, W. E. (1994). Non-visual effects of classroom lighting on children.Educational Facility Planner.
[22] Heschong, L., & Knecht, C. (2002). Daylighting makes a difference. EducationalFacility Planner.
[23] Day Star Sunlighting Systems.(1998). Benefits of Natural Daylighting.
[24] Heerwagen, J.H. (1986). The Role of Nature in the View from the Window.
[25] Ander, G., (2003). Daylighting Performance and Design,Hoboken, NJ: Wiley
[26] Baker N, S. K. (2002). [1]. *daylight design of buildings*.
[27] Choi, R. G.-S. (2013). A comparison of the visual comfort probability and unified glare rating system. 1.
[28] Cook, G. (1990). *Artificial Lighting in classroom results of a lighting survey*.
[29] D., P. (1993). how to let in the light. *architects journal 27th january*, 49-50.
[30] Efficiency, B. o. (2006). *Bee code*. new delhi: Devki Energy Consultancy Pvt. Ltd.
[31] Gupta, P. (2015). Earth and architecture. *the sustainable in architecture*.
[32] J, M. (2012). Daylight indoor illimination and human behaviour. 69-111.
[33] Krarti M, E. P. (2005). A simplified method to estimate energy savings of artificial lighting usefrom daylighting. *building and environment*, 747-754.
[34] Love JA, N. M. (1994). vertical to horizontal illuminance ratio. *illumination engineering society*, 50-61.
[35] McHugh J, P. A. (2004). Effectiveness of photocontrols with skylighting. . 1-18. steamers, b. a. (n.d.). daylight .