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# Building Lighting Design Considerations

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**Abstract—***Architectural lighting design is a field within architecture and engineering that concerns itself primarily with the illumination of buildings. It uses application of daylighting and artificial light to illuminate human spaces. Lighting design shouldn't be taken for granted, instead it should be designed and planned to provide the best results for the end users. Designing a basic lighting scheme requires the consideration of various factors. The aim shouldn't just be the achievement of a desired lighting level; user needs should be kept in mind. Certain basic questions should be answered, such as 'what sort of tasks will be performed in the area, what 'mood' needs to be created, what type of lighting will create a comfortable environment. Recently the field of lighting has been struggling with two major issues, energy efficiency and lighting quality. Lighting designers are faced with the choice between attractive, well-lighted spaces and spaces that use minimum energy. The aim of this research paper is to understand the building lighting design, how they are implemented, and what design criteria should be taken into consideration while designing a good and efficient lighting system for buildings.*

## 1. INTRODUCTION

Light is an important part of human life. With the discovery of fire in early Stone Age, the only way of using light was in the form of campfire or torches. With humanity taking so many huge leaps in terms of progress and innovation, lighting design has also reached great heights. Architecture is said to be the art and science of designing buildings, and Building lighting design, being an integral part of architecture, can be defined as the art and science of lighting the human environment. Lighting design collaborates the fields which are very distinct from each other to form a harmonious and comfortably built environment for its users. It marries the artistic ability of the architect, with the technical knowledge of electrical and the electronic engineer. It requires the expertise in light in terms of physics, and physiological and psychological aspects to provide visual comfort for humans.

Thus we can say "Like architecture, engineering and other design professions, lighting design relies on a combination of specific scientific principles, established standards and conventions, and a number of aesthetic, cultural and human factors applied in an artful manner"[i].

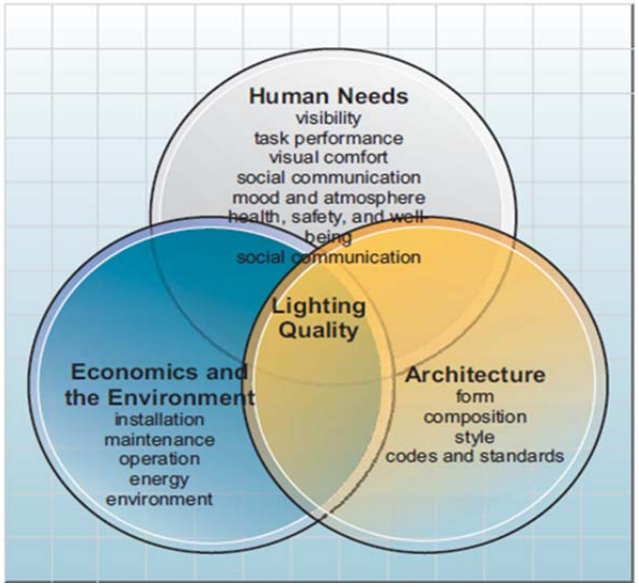


**Fig. 1: Overlapping lighting issues**

## 2. LIGHTING AND HUMAN PERFORMANCE

Lighting is an important element of human life. It provides for our visual needs, and also safety and security. Since it's difficult to accomplish much when we can't see well, it's fairly obvious that lighting is crucial to human performance.

The human eye is a very sensitive and adjustable organ, it is able to compensate and function successfully for a vast range of visual environments. Visual ability and visual comfort varies from person to person. A visual task may not be feasible for an elderly person, but easily achievable by their younger counterparts. The challenge while designing lighting is to understand under what circumstances certain visual conditions might be better than others, and to use that knowledge to design lighting systems that improve overall human performance. It becomes very important for the lighting designers to collaborate the relationship between lighting, productivity, human health, safety and security without compromising the essence of lighting design. The three general areas where light interacts with humans to affect their overall performance are Visibility, Mood and Health.

## 3. LIGHTING QUALITY AND QUANTITY

Lighting quality and quantity is of utmost importance where particular 'task' is to be performed and "appearance and mood" are of prime importance. It depends on various measurable quantities, placed together involving space, finishes and activities. The two major factors by which lighting quality is guided are 'illumination levels' & 'Adaptation levels'. Illumination levels remain constant for particular task, whereas adaptation levels vary from person to person. It depends upon age, physical fitness etc. That means how much amount of light is desired for a particular task and who is performing that particular task. Light intensity which is measured on any plane in a specific location is called illuminance. Illuminance is measured in foot-candles, which is work plane lumens per square foot. Lux is the metric unit for illuminance, measured in lumens per square meter. Lumen is a measure of the total quantity of visible light emitted by a source.

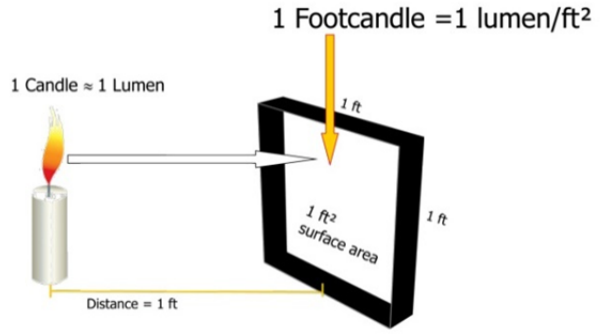


**Fig. 2: One foot-candle of light is the amount of light that a candle generates one foot away.**

Every task to be performed requires a certain illumination level, without which the visual task that is to be performed suffers greatly. The table below gives a brief snapshot of various activities, areas in which they are performed, and illuminance level required to fulfill a particular task comfortably. It must be noted that it is difficult to pinpoint a specific number for the recommended illumination level, because it is contingent to user's physical abilities.

**Table 1: Recommended illumination levels for various tasks**

| Illuminance (Lux) | Activity | Area |
|---|---|---|
| 100 | Casual Seeing | Corridors, changing rooms, stores |
| 200 | Continuously occupied | Foyers. Entrance halls, dining rooms |
| 300 | Visual tasks moderately easy | Libraries, sports halls, lecture theatres |
| 500 | Visual tasks moderately difficult | General offices, kitchens, laboratories, retail shops |
| 1000 | Visual tasks very difficult | General inspection, electronic assembly, paintwork, supermarket |
| 1500 | Visual tasks extremely difficult | Fine work and inspection, precision assembly |
| 2000 | Visual tasks exceptionally difficult | Assembly of minute items, finished fabric inspection |

A simple task of putting a thread in a needle hole can be easily performed by a youngster in an ambient light condition, whereas an elderly person may find the same amount of light insufficient for performing exactly the same task. A series of factors influence the way the viewer perceives light in a given context, which are, the adaptation level of the viewer, viewer's age, and interaction of tasks. Viewer's age influences visibility as the natural aging of the human eyes reduces visual acuity and increases sensitivity to glare. Interaction of the tasks includes the visual size of the task. Many jobs involve adjacent tasks with apparently contradictory specific needs.

Lighting is divided in three quality categories: Bad lighting- where the lighting system suffers from a quality defect. Indifferent lighting- where the lighting system has no quality[ii] defects but doesn't serve any fruitful function. Good lighting- where the lighting system is technically correct and excites the spirit of the viewer.[iii] Another important factor which shouldn't be ignored is contrast. "By its definition, contrast is characterized by the differentiation of one surface or object perceived to another. The greater the contrast in the visual context, the more a surface or object will stand out."[iv] In lighting design contrast can be achieved by creating variations in the levels of illuminations. Contrast is the relationship between the brightness of an object and its background. Contrast = (Luminance object - Luminance background)/Luminance background


**Fig. 3: Contrast**

By introducing variations in the brightness of one area or task with normal field of vision, different characters can be inculcated in that particular area. The nature of task performed decides the desired level of illumination. Once the illumination level range is fixed it becomes very important for the lighting designer to strike a balance between the task and the surrounding areas. Here contrast comes into play. The brightness of other parts of the room should be in harmony such that proper emphasis is given to the visual task along

with visual comfort. As per National Building Code 2005, "*A general guide for brightness relationship with normal field of vision should be as follows*"-

**Table 2: Brightness relationship with normal field of vision**

| |
|---|
| a) For high task brightness (above 100cd/m2) Maximum |
| 1) Between the visual task and the adjacent areas like table tops 3 to 1 |
| 2) Between the visual task and the remote areas of the room 10 to 1 |
| b) For low and medium task brightness (below 100 cd/m2), the task should be brighter than both, the background and the surroundings, the lower the task brightness, the less critical the relationship. |

## 4. LIGHT DISTRIBUTION

A good and efficient lighting system is made up of combination of ambient light, task light, and accent light. A good combination of these lighting schemes improves the visual comfort in the space, reduces the amount of lighting energy used, and helps in performing a task better.

Lighting when done correctly, achieves a balance in the contrast ratio between objects, improves visual appeal, and allows flexibility and control in illumination.

### 4.1 Ambient Lighting

Ambient lighting provides maximum illumination and surface brightness. It is used to provide basic illumination to spaces, and also helps reduce contrast between bright light sources and their surroundings. It is also used to provide basic visibility for utilization of space. Direct or indirect ambient light can be used to illuminate a majority of the space, to achieve about one third of the task illumination level. For example, grid lighting, uplighters, down lighters, covers, fluorescent lighting, coves, etc.

### 4.2 Task or Focal Lighting

Task or focal lighting is used to increase the illuminance of a task at a close range. The lighting level and the type of lighting can differ according to the task. For example, to use a computer, one may need light on an adjacent task, rather than the computer screen itself. Regular reading requires a lower level of light than what is needed for detailed accounting tasks. Focal lighting can be adjusted as per the need of users.

### 4.3 Accent or feature lighting-

Accent lighting highlights particular architectural features or artwork. If the ambient light level is too high, no amount of accent lighting will increase the brightness of a feature enough to make the contrast apparent. Selective use of accent lighting increases its effect. Too much accent lighting will wash out the impact of any single feature. Accent lighting can be used for statues, paintings, moldings, graphics etc. E.g.: low voltage spot lights, track lights, mini spots, picture lights, uplighters etc.

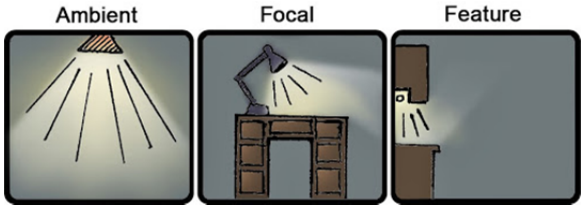


**Fig. 4: Types of light distribution system**

## 5. DAYLIGHTING

Daylight strategy is basically borrowing light into the inside of any enclosed space. It is the capturing of light falling on the exterior of the building and transporting it into the interior spaces where it is needed. Daylighting is the passive strategy; it not only cuts the lighting loads but also affects the physiological and psychological well-being of the users. It uplifts the mood and increases productivity. Daylight is not only the source of free illumination of a space but it also aids in invigorating the mood of the users accessing the space. The sun transmits huge amount of energy on the earth's surface. *The efficacy of daylight is defined as the ratio of visible radiation to the total amount of the spectrum present. It can be expressed in lumen per watts. This efficacy is highly variable as a function of solar position, atmospheric conditions, and cloud cover. Sunlight has much more heat content per lumen than daylight.* [v] But sun is not stationary. It has various positions throughout the day and throughout the year. So, in an enclosure it can be sometimes too bright or other times not bright enough. If the footprint of the building is deep, then strategies have to be drawn out so that the daylight penetrates the building. It is important that the daylight is well distributed throughout the building. Difference in the intensity of light, i.e. too bright in one area and too dark in another within the same room leads to an uncomfortable situation called glare. It can cause difficulty and discomfort in seeing, or may even lead to disability in performing certain visual tasks.

Daylighting is a design process in which both the aspects – functional and aesthetics are achieved successfully with apt consideration of the factors such as - Building Orientation, Sky conditions, Cross-section of the fenestrations, Other devices, building footprint, Room dimensions and Visual task. Daylighting does not only involve just adding windows or skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability. A successful design depends upon the use of shading devices to reduce glare and excess contrast in the workspace. Window size and spacing, glass selection, the reflectance of interior finishes and the location of any interior partitions must also be considered.

### 5.1 Building Orientation

Correct orientation and alignment of the structure proves to be advantageous in terms of harnessing daylight for the structure throughout its lifetime. Daylight affects the amount of solar gain, and penetration of natural light affects the illumination level of the space. Obstructions and hindrance should be avoided while illuminating the space through natural light. Buildings must not be constructed near too large obstructions, and enable the designers to achieve the desirable illumination of spaces.

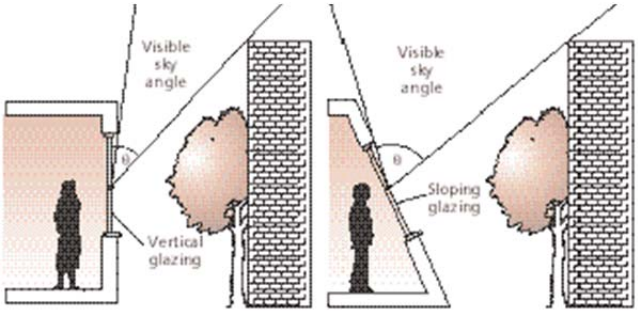


**Fig. 5: The visible sky angle is measured from the centre of the window, in the vertical plane perpendicular to it**

### 5.2 Building footprint

In order to allow more penetration of daylight into the building and to Increase Perimeter Daylight Zones, the perimeter footprint can be extended to maximize the usable daylighting area.

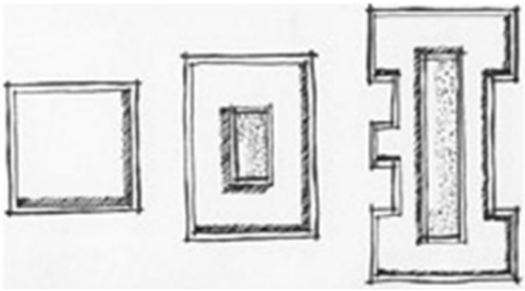

**Fig. 6: Increased footprint enhances daylight penetration in the buildings**

### 5.3 Daylight Devices

The design of a room is greatly affected by the function and integration of daylight devices into the building. In a daylighting scheme, the building itself serves the function of a luminaire. The windows and skylights deliver daylight to the interior spaces and the building surfaces act as shading devices and reflectors to shape the resulting distribution of daylight.[vi].Various daylighting devices are discussed in the following sections.

#### 5.3.1 Light Shelves

Light shelves are architectural elements that allow daylight to penetrate deep into the building. They have the capacity to increase the room brightness and decrease the window brightness. They are interior horizontal reflective surfaces or extended projections which allow the natural light inside, and provide a glare free space. The shelves are always placed higher than the eye-level.

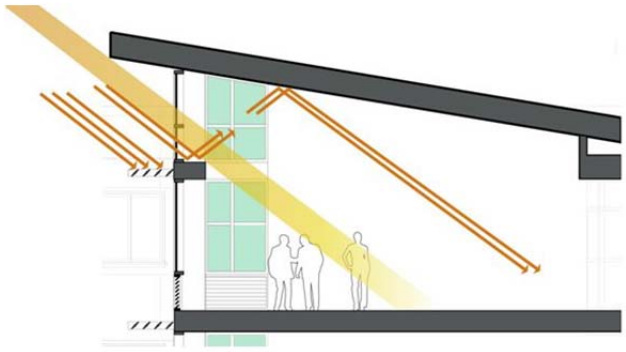

**Fig. 7: Light shelf**

#### 5.3.2 Sky Lights

Sky lights are used to provide direct light where a bright environment is required and diffused light where ambient lighting with minimal lighting is needed. Sky lights are installed in the roof of the building and thus eliminate the need for side windows for lighting. They are also used in achieving non-glare spaces.

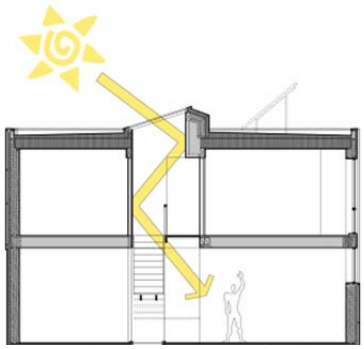

**Fig. 8: Sky light**

#### 5.3.4 Light Pipes

Light pipes system consist of cylindrical tubes, and have a domical roof as their prime source inlet. The inlet is lined with highly reflective material which is designed to transmit light to the lower level of buildings by directing natural light. They are extremely useful in buildings that do not have exterior walls.

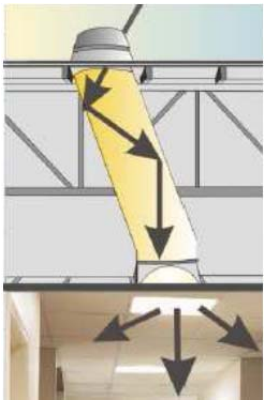

**Fig. 9: A light pipe consist of light- collection, transmitting and emitting device**

### 5.3.5 Clerestory

The Clerestory windows are installed at a comparatively higher level than the lintel level, which ensures a deeper penetration and distribution of natural light in the space.

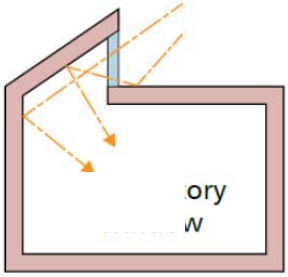

**Fig. 10: Clerestory window**

### 5.3.6 Atrium and Courtyard

Atriums and Courtyard are other natural lighting mediums that allow penetration of light. Atriums give the impression of spaciousness. Courtyards are open wells that allow light transmission to the surrounding areas.

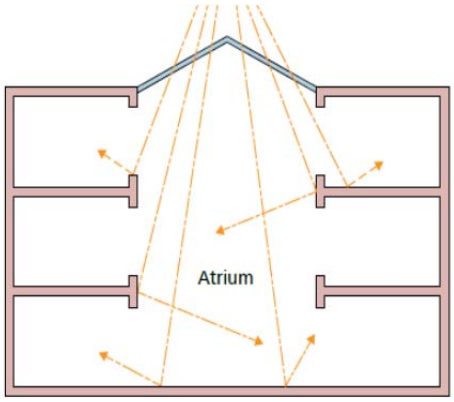


**Fig. 11: A skylight in the atrium allows daylight penetration in the core of the building**

## 6. ARTIFICIAL LIGHTING

When adequate lighting is not achieved by daylighting, it can be compensated by energy efficient artificial lighting. The requirement of light in any enclosure depends upon how much lumen is required to perform a certain visual task. Depending upon the functionality of the workspace and user requirement, a particular type of light is chosen. Various types of lighting have been already discussed in section 4. The user and the task requirement decide how the lighting strategies can be implemented. Artificial light is obtained mostly from electric lamps and luminaires, fitted in various positions to perform their functions. A luminaire is a complete lighting unit, comprising of a light source, together with the parts that distribute the light, position and protect the lamps, and connect the lamps to the power supply. The luminaire's function is to direct light to appropriate locations, without causing glare or discomfort.Types of luminaires are generally categorized by their light distribution as shown in Fig. 12. Measurement of lighting efficacy implies how many lumens of light a luminaire delivers per watt of electricity. The field of artificial lighting has seen much advancement lately, and has enabled lighting designers to create iconic architectural marvels with sustainability in lighting design.

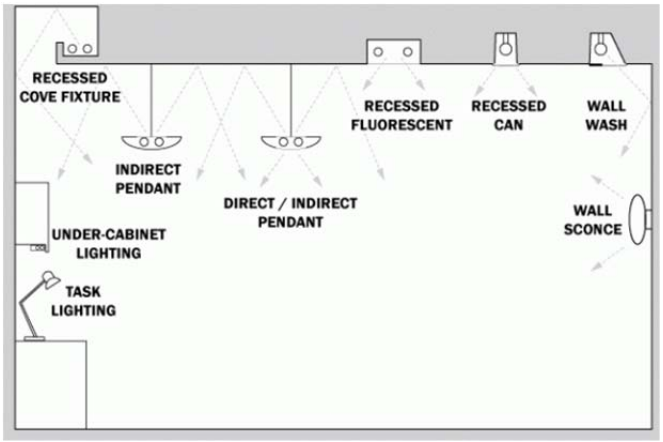


**Fig. 12: Some common distributions: direct, semi-direct, and direct-indirect.**

## 7. SMART LIGHTING

Getting smart about lighting has become very important in recent times. With energy resources depleting all over the world the time has come to manage and keep our resources safe. Smarter lighting system brings down energy demand of building manifolds. A good lighting design means using the abundantly available daylighting, efficient artificial lights and a good control system of the installed lighting system.

In commercial buildings, electric lighting accounts to about 30-50% of the total energy consumption. More efficient lighting systems can be achieved by having smart combinations of Strategic Daylighting, artificial lighting

controls, and user controls. Better lighting design not only saves electricity but it also lowers the HVAC cooling loads and brings down the overall operating cost of the building. We should aim at having just enough light when needed.

## 8. ACKNOWLEDGEMENT

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