LIGHTING

Luke Osburn
Researcher
CSIR

INTRODUCTION

Lighting consumes about 30% of the energy used within commercial office space and about 10% of the energy used in a residential environment. Through conscientious design of the lighting systems, the lighting load can be significantly reduced within both environments. These estimates can vary significantly because buildings vary significantly in shape and size as well as function. Also, the behaviour of the building occupants and the nature in which the building is operated can significantly affect the lighting load. Additionally, the more inefficient a building is, the greater the potential to accrue savings.

Office environments operate very differently to residential environments. Consequently, the same technological interventions will have different results depending in which environment it operates.

LIGHTING QUALITY

The perception of lighting quality is a qualitative concept and could be described as either being comfortable or uncomfortable. There are many quantitative properties of lighting that directly influence its lighting quality and recommended values for these properties do exist and can be relied upon to provide a comfortable lighting solution within the context of the considered space. This section will discuss those quantitative properties that are important when providing a comfortable lighting solution.

Colour Rendering Index (CRI)

The colour rendering index is a relative indication of how well colours can be distinguished under the light produced by a lamp. A high colour rendering index indicates that the lamp can accurately reproduce the colours as produced by a natural light source, with the sun having a colour rendering index of 100.

Most objects are not a single colour, but their appearance is a combination of many different colours. Light sources that are deficient in certain colours will not be able to accurately reproduce what the object looks like when lit by natural light. In these circumstances the light source can significantly effect how an object appears.

Energy Star recommends a colour rendering index of 80 for office environments and this is easily achieved through the application of fluorescent lighting. A higher colour rendering index is often used in retail for the sale of goods.

Low pressure sodium lamps, while being highly energy efficient generate virtually monochromatic light, with a CRI of less than five. As a consequence these lamps are limited in their application to situations that do not require colour rendering, such as highways and security lighting.

Light source	CRI range
Incandescent	100
Ceramic metal halide	85 to 94
T5 fluorescent	80s
T8 fluorescent	75 to 98
Quartz metal halide	65 to 70
T12 fluorescents	58 to 62
High-pressure sodium	22

Table 19.1: Colour rendering index ranges (Energy Star Lighting Guide, 2006).

Colour Temperature

Colour temperature refers to the temperature of an ideal black body radiator at which the colour of the light source and the black body are identical. Some lamps with different colour temperatures are shown below: the yellowish lights correspond roughly to a colour temperature of about 2700K while the white light would correspond to a colour temperature of about 4000K.

Fig 19.1: Lamps with different colour temperatures

Colour temperature is often described using qualitative terms such as warm or cool, with warm describing light sources that are yellowish in nature and a low colour temperature. Cool lamps have a higher colour temperature than warm lamps and appear brighter.

The colour space is shown in figure 19.2, including the Black Body Radiator Curve, which describes the colours that a black body emits depending on its temperature.

A comfortable lighting solution depends largely on context and personal preferences and the colour temperature certainly has a large effect on perceived comfort. Warm lights are generally favoured for residential and romantic settings and cool white lights are generally preferred in office and work-related environments and especially in environments where the perception of cleanliness is important.

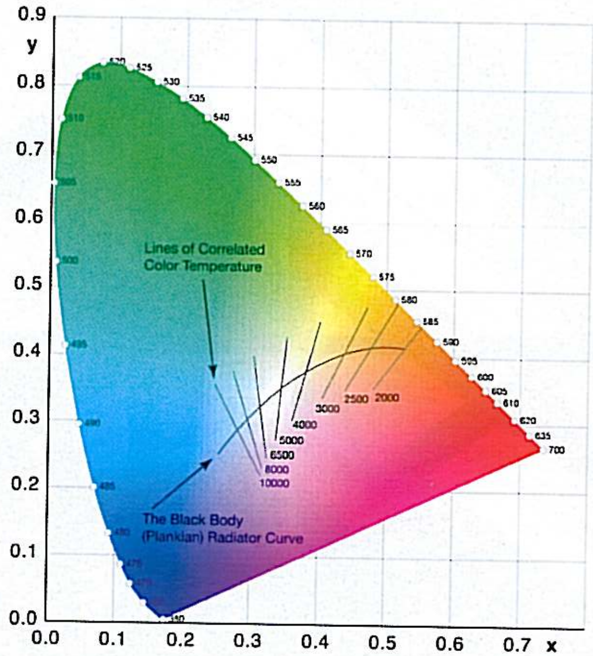

Fig 19.2: CIE chromaticity diagram including the Planckian Locus of the black body colour as well as lines of correlated colour temperature

Uniformity

The uniformity of illuminance describes how evenly light spreads over an area. Creating uniform illumination requires proper fixture spacing. Uniformity ratio can either mean the ratio of average illuminance to minimum illuminance or from maximum illuminance to minimum illuminance over an area. It is important to understand which definition is being used as they can have very different values.

Low uniformity ratios of illuminance create bright and dark spots, which can cause discomfort for some occupants. A high uniformity ratio can cause a space to appear brighter than it really is, producing a greater level of lighting quality without expending any additional energy.

Very low uniformity ratios are commonly experienced when exiting an underground or multi-storey parking lot, where the quantity of light produced by the artificial lighting systems is very low compared to that which is experienced outside. Such scenarios can cause discomfort for drivers and usually the lighting level at the exits is increased in order to improve the uniformity ratio.

LIGHTING LEVEL

The amount of light available in a particular environment should be appropriate for the tasks or activities being performed therein. Appropriate lighting levels can vary significantly depending on how the space is being used. Lighting levels that are either too high or too low can cause discomfort.

GLARE

Glare is a sensation caused by relatively bright objects in an occupant's field of view. Glare is produced by relative brightness, for example, the bright lights from an oncoming car can cause significant discomfort at night, however, those same lights, producing the same amount of light cause no discomfort during the day.

Glare should be avoided within work spaces and particular attention should be given to address glare that can be caused by both direct and indirect sunlight.

LIGHTING COMFORT

The perceived comfort from lighting solutions is a consequence of all the features previously mentioned. They should all be addressed as appropriate for the space in which the lighting system is to be installed. Neglecting just one characteristic could cause significant discomfort.

Ultimately it is the users within the space who determine the quality of the lighting solution using qualitative descriptions. Quantitative measures of lighting solutions are a tool that should be used in order to provide a comfortable lighting solution for the users.

LIGHTING CONTROL STRATEGIES

Often spaces are lit when they do not need to be and constitute a waste of energy. Lit, unoccupied spaces can either be caused through the negligent behaviour of users of the space or as a consequence of inappropriate lighting controls that make it difficult or impossible to turn the lights of without impacting occupied spaces.

The appropriate specification of lighting controls can be used to address either of these issues. The cost of implementing such controls should also be weighed against the potential gains, as each building is operated differently with different occupants. The same interventions will not have the same effect in all circumstances. Thus, it is important to understand who the occupants are and how they are likely to behave and then to implement controls that are appropriate to their behaviour.

MANUAL CONTROLS

The correct implementation of manual controls will allow the building to be operated efficiently; however, whether it is in fact run efficiently is dependant on the building occupants. Manual controls are cheaper than automatic ones and would be preferable when the building occupants can be relied upon to operate the building efficiently.

Bi-Switching

More than one luminaire is often installed within individually occupied spaces and one switch is installed to operate them. However, the user in the space may find that s/he often doesn't need all the luminaries on and by providing additional switching the user can turn on only those luminaries that s/he deems necessary. Such a strategy also provides greater control to the user on the environment in which s/he operates; such control is generally appreciated by building users.

Alternatively, the switching can be used to select the number of operational lamps within the luminaries. Therefore, for a fixture of two luminaries with three lamps each, three switches can be provided, each switch controlling one lamp in each luminaire. This provides the user with the ability to reduce the amount of light generated by a third or two thirds.

Zone-Switching

In large open-plan offices, large areas are often controlled by a small number of switches or even by a single switch. Consequently, even during low occupancy levels within the space, the entire area is lighted to full capacity and thus wasting energy.

Zone-switching divides large open areas into zones that are individually switched, allowing sections of the open space to be lit while not lighting the others. Green Star South Africa Office Rating Tool recommends that all areas larger than 100m^2 should be individually controlled.

Zone switching can also be applied to large corridors and should indeed be applied to any large area.

Manual Dimming

With the appropriate lamps and ballasts installed, manual and automatic dimming of the luminaries can be used as a strategy to reduce energy loads as well as providing a high degree of control over the interior environment.

The amount of available daylight varies throughout the day and consequently the amount of light produced by the lamps will need near constant adjustment in order to provide a consistent lighting level. Particular attention needs to be taken during partly cloudy days.

This strategy generally has poor user acceptance due to the need for constant adjustment. However, if it is to be installed, the adjustment controls should be installed near the work station so that the user can adjust the controls without leaving his work station. Alternatively the system could be controlled by means of a remote.

AUTOMATIC CONTROLS

Occupancy Sensors

Occupancy sensors can be installed to control the lights within given spaces and when they do not detect motion for a set period of time the lights are turned off. The delay for turning the lights off is typically set at between 5 and 15 minutes, depending on the space and user preferences. It is important that the users within the space are not inconvenienced by a delay time that is too brief.

The benefit to be accrued can be very difficult to calculate, depending largely on occupant behaviour and assumptions that are made regarding the operation of the lights outside office hours. Motion-detection switching is best used within spaces that are haphazardly used and with a high level of installed lighting. Areas that should be considered for occupancy sensors are:

- Basement parking
- Individual offices
- Board rooms and meeting rooms
- Restrooms

The benefits to be accrued from occupancy sensors are highly variable, even within the same building, as the results from a study show below.

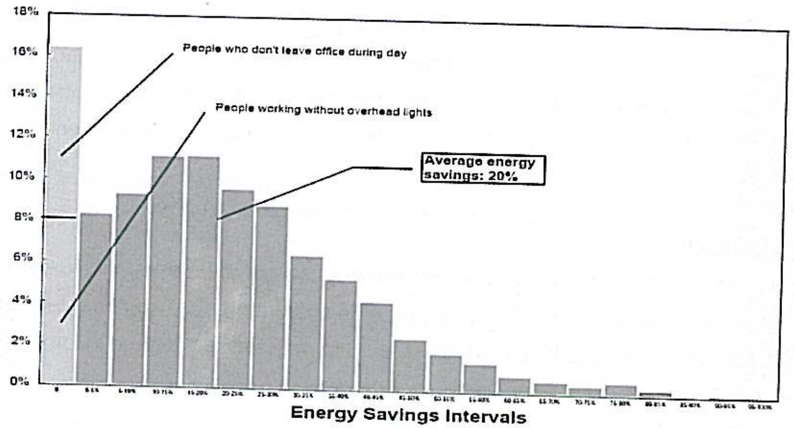

Fig 19.3: Energy savings from occupant sensors in 21 offices, (Jennings et al., 2000).

The large variations occur as a result of some occupants not using their lights, some occupants not leaving their offices during the work day and variability in the occupancy of the other offices. Additionally in work environments where building occupants diligently switch the lights off as they leave their office, the installation of motion detection switching will accrue no savings.

Daylight Dimming

In areas that receive large amounts of daylight, the installation of light sensors that can automatically control the light output of the luminaries should be considered. Daylight sensing and occupancy sensors can be incorporated within the same sensing unit.

Daylight sensors are expensive, but the cost savings that can be accrued can be enhanced by the application of passive techniques that increase the amount of daylight available within the space. The installation of light shelves, light tubes and reflective interior surfaces, including ceilings, will all increase the amount of daylight available within the space.

BASEMENT PARKING

In multi-storey office blocks with multiple-storey basement parking, the energy required to light the basement parking can indeed be a significant fraction of the total energy use of the building. Frequently basement parking lots have higher lighting levels than is necessary. When such a building is being retrofitted or is being considered for a retrofit then the possibility of delamping the basement should be investigated.

Delamping is the practice of removing a lamp from a luminaire when it is established that fewer lamps can indeed provide the appropriate lighting levels. The minimum maintained illuminance required for indoor parking lots is only 75 lux as required by SANS 10114-1:2005, Edition 3.

IMPORTANT ENERGY PROPERTIES OF A LIGHTING SYSTEM

With a large variety of different lighting technologies, manufacturers and products available, significant effort needs to be expended in order to identify the most appropriate lighting solution for any given circumstance. The following characteristics should always be considered when an energy-efficient lighting system is called for:

Luminous Efficacy

A lumen is a measurement of the quantity of light whereas lux level is the amount of lumens within a particular area. One lumen per m^2 produces one lux, so in order to produce a lighting level of 400 lux over an area, 400 lumens need to be provided per m^2. Luminous efficacy is given in lumens per watt and is essentially a measure of the energy efficiency of a lamp.

Light Output Ratio

A complete lighting solution consists of lamps, luminaries and ballasts, each of which affect how much energy is consumed and how much light enters the space. Depending on the luminaire and the maintenance thereof, a significant amount of light that is generated will be trapped within the luminaire and not enter the space and can thus not be used. There is little value to be gained from putting a lamp with a high luminous efficacy into a luminaire that blocks most of the light produced.

The light output ratio of a luminaire is the ratio of the amount of light leaving the luminaire and entering the space compared to the sum of the light produced by the lamps within the luminaire.

GLOSSARY

Ballast: A device connected between the supply and one or more discharge lamps that serves mainly to limit the current of the lamp(s) to the required value.

Blackbody Radiator: An ideal object that absorbs perfectly radiation of all wavelengths incident on it. It also emits perfectly at all wavelengths.

Lamp: A source made in order to produce visible light.

Luminaire: An apparatus that distributes, filters or transforms the light transmitted from one or more lamps and that includes, except the lamps themselves, all parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting the lamps to the electric supply.

REFERENCES

Energy Management Handbook, Turner.W and Wayne S., 2006.
Jennings et al., 2000. Comparison of Control Options in Private Offices in an Advanced Lighting Controls Test bed, Journal of the Illuminating Engineering Society.
Final Report, Lot 8: Office lighting Study for the European Commission DGTREN unit D3.
Energy Star Lighting Guide, 2006.
Bhusal, P., 2009. Energy-Efficient Electric Lighting For Buildings in Developed and Developing Countries, Helsinki University of Technology.
Kats, G., 2003. The Costs and Financial Benefits of Green Buildings. A Report to California's Sustainable Building Task Force.
SANS 10114-1:2005, Edition 3
Technical Manual Green Star SA – Office v1