# Task and Building Lighting: The Link Between Lighting Quality and Energy Efficiency

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**ABSTRACT**

Quality in lighting is a much debated subject and yet it receives little explicit attention by most designers. Recent investigations suggest that a lighting installation that meets not only the task requirements but the quality, or appearance aspects as well, would be more energy efficient than a traditional installation that provides an appropriate task illuminance, with a high level of illuminance uniformity. The author believes that by using a holistic approach to lighting design, an approach which considers both the occupants tasks and the appearance of the building, could lead to improved energy efficiency with the benefit of substantial saving in energy consumption and running costs.

**AN HOLISTIC APPROACH TO LIGHTING DESIGN**

To produce a successful electric lighting installation the designer needs to consider a number of important but inter-related elements which need to be combined to form an holistic approach to lighting design. For example the occupants need to be able to carry out their particular tasks comfortably and efficiently. The tasks could range from the simple to the complex and could be either two dimensional or three dimensional. Also the tasks may vary with time. For example in a typical office they may include reading and writing, using a visual display screen and face to face communication – so in the task aspect alone there is lot to consider.

But the lighting of a space has the power to create particular impressions and this applies to both daylighting and electric lighting. Stage lighting designers understand this very well when they create a lit effect to compliment the action of a play, but the same effect can apply to more normal working environments. For instance it is possible to make a space appear 'light and airy' or 'confined and cave like' just by the way it is lit. This second aspect of lighting could be described as appearance lighting or lighting to create a visual amenity, but the lighting also needs to be considered as an element of the architecture.

In a simplistic sense there is no architecture without light, but the lighting needs to be more than just illumination. It needs to complement the building and be a natural extension of it. This applies to the appearance and installation of the lighting equipment (lamps, luminaires and lighting controls), it also applies to the light pattern it produces. The light pattern needs to reinforce the architectural theme, to respond to the shape and form of the interior and to the hierarchy of adjoining spaces. It also needs to respond to the finish and reflectance of the room surfaces. Overall good lighting should not be noticed in its own right but provide a natural extension of the architecture. It is only when lighting is used to draw attention to something, as in a display situation, or as a decorative element, that it should form a prominent part of the scene.

It is considered by many that the appearance aspect of lighting will have benefits for the occupants of a building in terms of performance, if not directly, then indirectly through an improved sense of well-being which in turn could benefit performance.

So far there is little research evidence to prove this but the indications are there.

Although most lighting designers would agree that lighting can provide an added benefit to the appearance of an environment, it is an aspect that is often ignored. The reasons for this include the lack of experience of the

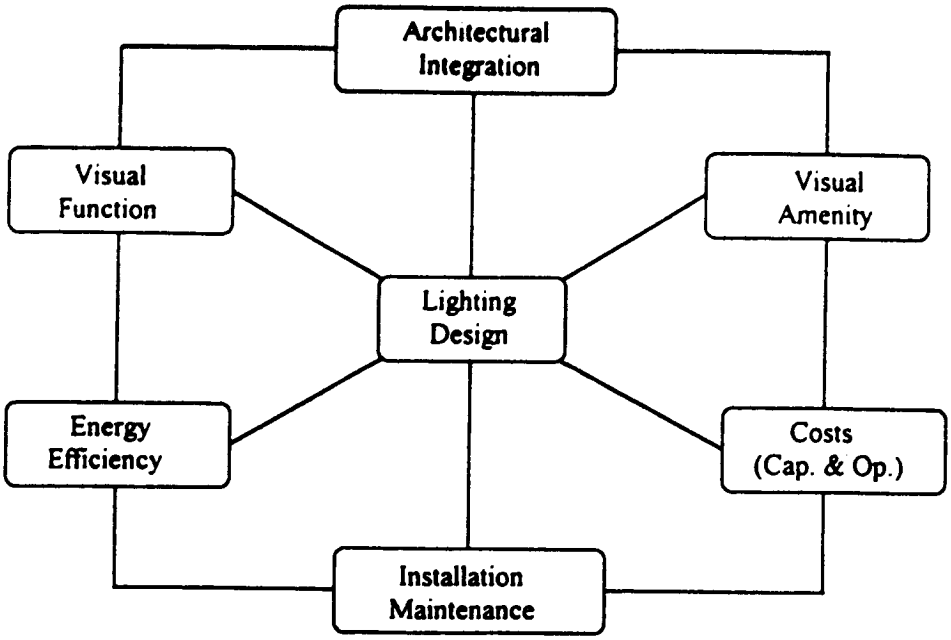


**Figure 1. Lighting design framework.**

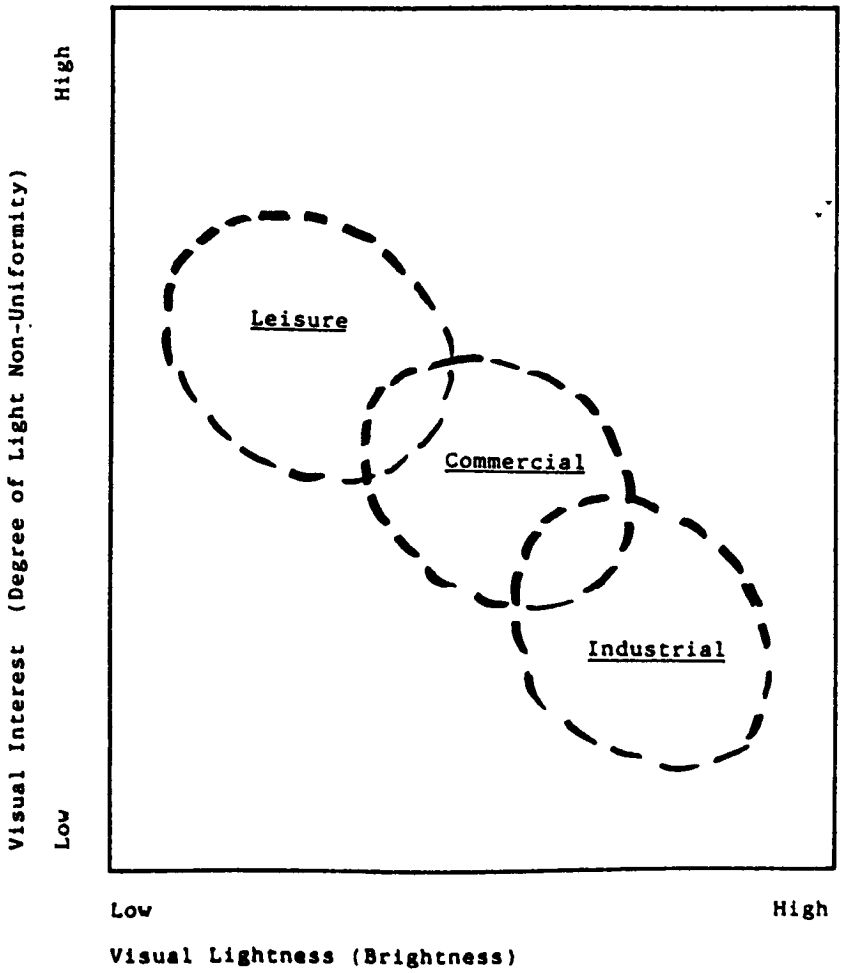


**Figure 2. Map showing the possible location of three application areas (leisure, commercial and industrial) on a schematic diagram linking subjective impressions of visual interest and visual lightness (brightness).**

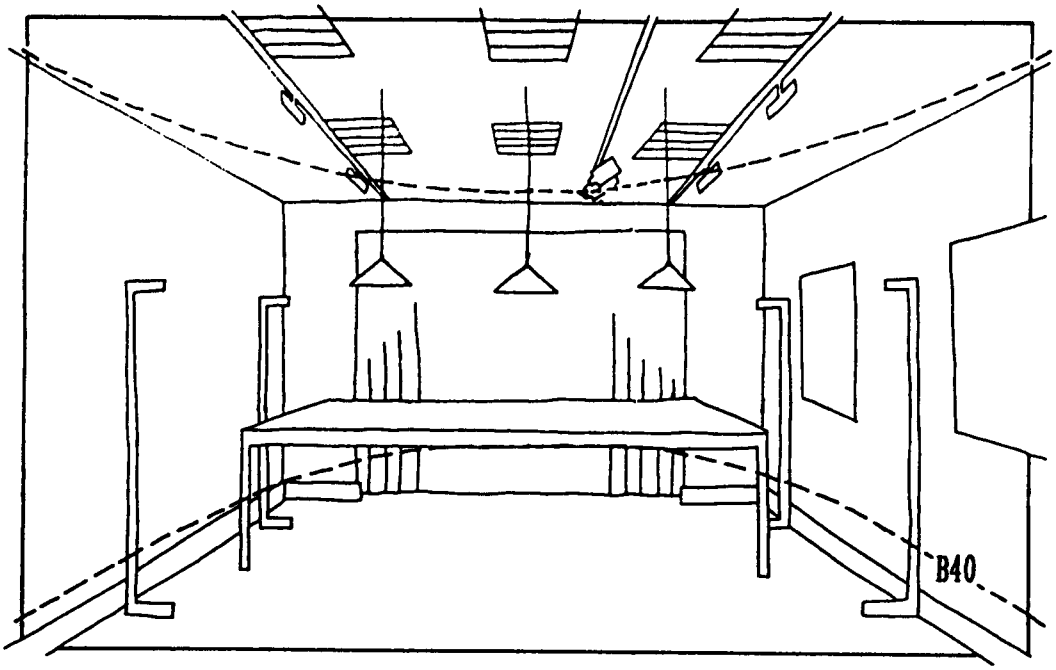


**Figure 3. Diagram showing a conference room indicating the 40° horizontal field of view (B40).**

designers in this aspect of lighting design, but also because the client does not appreciate its value.

In addition to the lighting effect the designer will also need to consider the energy efficiency, the installation maintenance and the installation costs, considering both capital and operation. Figure 1 illustrates a design framework that could help to achieve an holistic approach to lighting design. By combining the basic elements into a design framework it can act as an aide memoire to remind the designer to consider all elements. Although each of the elements need to be considered and balanced one against another, they may not carry equal weight; this will depend on the particular application, or building type.

## LIGHTING QUALITY

Much has been said of the need for lighting quality but what does it mean? In the most fundamental sense it could be described as the degree of 'goodness' of all elements of the design framework. However it is the author's view that it is a term that is used to describe the *appearance* aspects of lighting – lighting that goes beyond lighting for the tasks. To aid the consideration of this aspect of lighting it may be useful to describe it in the following way:

**Lighting Quality: Lighting which is not directly concerned with tasks, but aims to provide a visual amenity as an integral part of the architecture – Lighting Appearance.**

There have been a number of studies to explore lighting quality in recent years. These include work by Waldram(1), Flynn(2), van Ooyen et al.(3), Shepherd et al.(4), Carter et al.(5), Tiller and Veitch(6), as well as recent work carried out by the IESNA Quality of the Visual Environment Committee and the IALD Metric of Quality Committee (7). The author has also researched the subject (8-10). Many of the studies have indicated the importance of the distribution of luminance within a space and in particular the luminances of vertical surfaces: the walls are especially significant but the ceiling may also need to be included depending on the size and height of the room.

The general message that emerged from these studies was that people prefer an interior to have a measure of 'visual lightness' combined with a degree of 'visual interest'. The 'visual lightness' referred to the brightness of the major surfaces within the main fields of view, particularly the vertical surfaces, whilst 'visual interest' applied to the non-uniformity of the light pattern. For example people preferred an interior that had elements of light and shade rather than the even light pattern provided by a regular array of ceiling mounted luminaires. One of the studies(9) showed, where a commercial type interior was investigated, that a horizontal band about 40° wide, centred at normal eye height was an important part of the visual field and that for the room to be assessed as 'bright', the average luminance of this area needed to be at least 30cd/m$^2$. It also showed that for the room to be 'visually interesting', the ratio of maximum/minimum luminance, again within the horizontal 40° band, needed to be at least 13:1. Perhaps it is not surprising that this area is important since it is region that forms the normal area of view as people look horizontally. Figure 2 shows the extent of the 40° band in a mock-up conference room. It can be seen that in a relatively small room the zone mainly covers the wall area, however in a large room it would also include part of the ceiling.

The weakness of these numerical values is that they suggest a simple approach to lighting quality which is almost certainly not the case. What the experimental work shows is the importance of particular features of lighting. Another

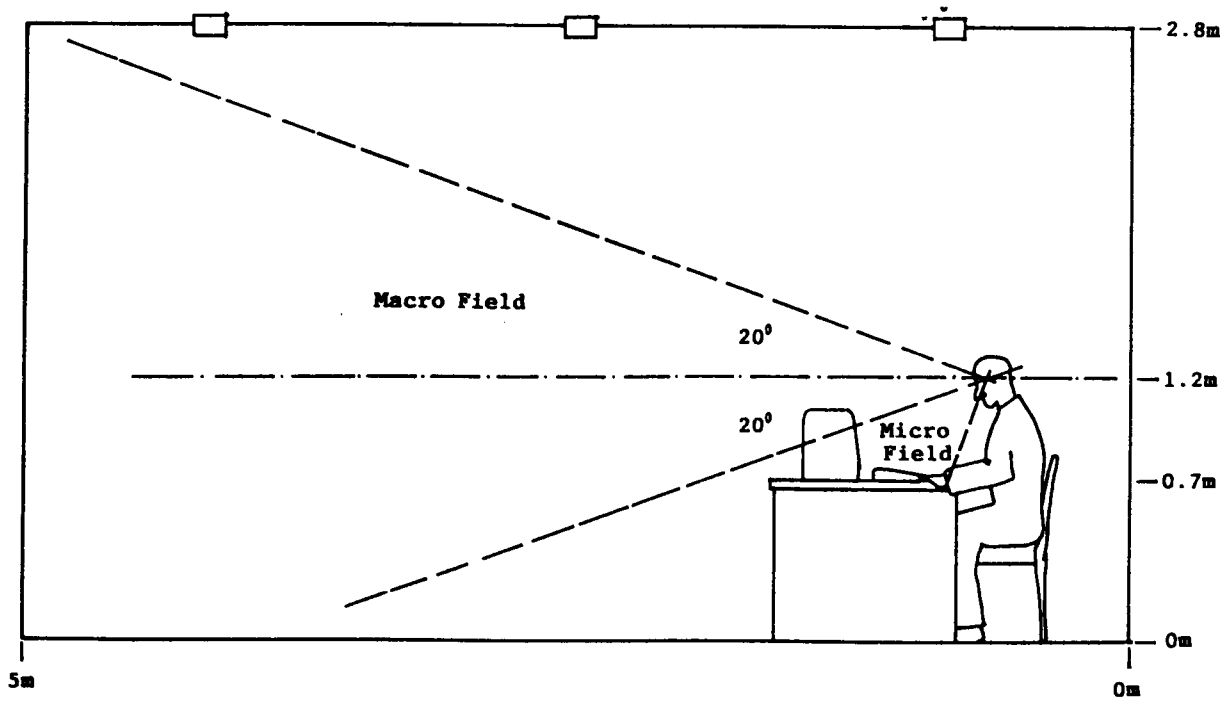


**Figure 4. Section through a typical office situation showing the Macro and Micro fields of view.**

weakness of specifying lighting appearance by luminance is that because the luminance of a matt surface is the product of the incident illuminance and its reflectance, a luminance pattern could be achieved either with a uniform illumination and variations of surface reflectance or a uniform reflectance and variations in illumination. These would almost certainly not produce the same effect unless information on brightness constancy was obliterated.

The experimental work has shown, that for commercial type interiors, there is a preference for a pattern of light that appears 'light' and 'interesting'. It is possible that these same criteria would apply to other types of interior but that the combination of 'lightness' and 'interest' might be different. Figure 3 suggests how the relationship might occur, although it must be stressed this has not been tested experimentally. However it can be reasonably assumed that people would prefer a restaurant, part of the leisure group, to have a higher level of 'interest' and therefore light non-uniformity, together with a lower level of 'lightness' than say a computer assembly plant.

Much work still needs to be done to extend our knowledge of lighting quality and its benefits, but it is important that it forms an element of lighting design now.

#### ENERGY EFFICIENCY IN LIGHTING

Today energy efficiency is a vital aspect of lighting design; this is to minimise the rate by which primary energy resources are consumed and to minimise emissions which contribute to the greenhouse effect. Saving energy will also reduce running costs and limit the need for increased generation capacity. In recent times the lighting industry has made considerable advances in producing products that improve energy efficiency. These include lamps with improved efficacy (many with increased life, improved lumen maintenance and good colour rendering), luminaires with high light output through improved optics and efficient high frequency control gear, and through the use of lighting controls which ensure that the electric light is only used when required e.g. when there is insufficient daylight and the space is occupied.

It is unlikely that there will be further dramatic improvements in lighting efficiency through improved equipment in the near future. However, further savings could be made by designing lighting which does not light the whole interior uniformly with the same task illuminance i.e. lighting which responds to the user preference for a degree of light non-uniformity.

Currently most electric lighting installations aim to provide a uniform horizontal plane task illuminance, usually over the whole room and with a high illuminance uniformity; not less than 0.8 minimum/average illuminance over the task area is typical, which often means most of the room. This is obviously wasteful in energy terms but, as was shown earlier, it also provides lighting that is not preferred. This is particularly the case when low-brightness louvre type luminaires are used which project very little light onto the vertical surfaces and are likely to produce a gloomy interior.

It can be seen therefore that if electric lighting is designed to respond to the requirements for visual quality, particularly visual amenity, then not only is there likely to be improved performance through a greater sense of well-being but there could be improved energy efficiency as well.

## TASK AND BUILDING LIGHTING

Task performance and therefore task illumination is an important aspect of lighting design and is an obvious element of the design framework (Figure 1). The principles for this are generally well understood but the problem for the designer is to balance these requirements with those for lighting quality. To do this it is useful to divide the field of view into two main parts: the micro field, or main task area, and the macro field which contains the remainder of a normal field of view. The two fields are shown in Figure 4 for an office situation, but the main room surfaces could be replaced by the perimeter of a work station or other elements depending on the interior design. It is vital that the lighting of both parts are compatible with each other since the occupant's gaze will alternate between the two and hence need to be appropriate for one condition of visual adaptation.

For the micro field, or task area, the task illuminance, the task illuminance distribution, as well as the avoidance of glare, will need to be considered for the particular application. Although task illuminance is important it has been shown that visual performance can be enhanced by highlighting the task area with an illuminance ratio of 3:1 between the immediate task area and the surround area. This is a criterion that is often discussed but was demonstrated in a study into the lighting of paintings in a gallery situation(11). The study showed that people felt that their visibility was improved if the paintings were lit preferentially with a painting illuminance approximately three times the background lighting. This also reflects user's desire to have task lights.

Users often appreciate the opportunity to be able to adjust their level of task lighting to allow for different tasks. There would also be an advantage if the task lighting could incorporate an occupancy sensor to switch lights off when the area is unoccupied. This means that the task lighting, if possible, needs to relate specifically to a particular task area and perhaps be physically linked to the work station. This would also allow for a flexible use of space, since if the workstation were moved the lighting could move with it.

For the macro field the quality issues described earlier need to be considered i.e. visual lightness and visual interest. However these will need to be considered in terms of the building design, including its form and its surface treatments (colour, reflectance and texture). It is difficult to determine the exact limits of the macro field but the earlier description referring to the 40° band provides a useful indicator.

To develop a design, a good starting point would be to assess the objects and surfaces that are visible from the work station, then to make a similar assessment as for a person moving around the space. With this information it will be possible to identify areas to be illuminated to create the required level of 'lightness' with a composition of light and shade and that is meaningful to the design of the building as a whole. This part of the lighting installation, which can be described as 'building lighting', needs to integrate with the daylighting and to work for all the occupants at all times. This can then be complemented by the task lighting which relates to the individual when required. It is possible that the lighting would be a free-standing unit which incorporates both task and building lighting.Early indications suggest that this form of lighting could reduce energy consumption by as much as 40% compared to an installation which provides a uniform task illuminance over the whole area.

## CONCLUSION

Using the 'Task and Building' approach to lighting design, which considers the whole visual field, should provide lighting which is effective in terms of user performance and preference, is energy efficient and forms an integral part of the architectural design. Although the basic cost of the installation is likely to be higher (a factor between 1.5-1.75 times a conventional installation has been suggested) the benefits are felt to be considerable. It is expected that with improved performance and energy efficiency the additional capital costs could soon be recovered. ●

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