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CPD Article

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Is Street Lighting Damaging our Health?

Introduction

LEDs are efficient at lighting our roads yet people complain of discomfort. As LED technology improves, can we keep all the benefits that come from using LEDs and increase visual comfort?

This article supports the need for a new glare model for assessing discomfort glare caused by LED luminaires and to improve the understanding, calculation, and criteria for the evaluation of discomfort glare.

A shift can be accelerated if we review and update the calculations that are used to determine street lighting standards, such as the volume of acceptable glare. Originally developed back in the 1970s, before LEDs were commonplace, the current calculations do not justify the specification of the best quality lighting option - and we'd argue, they do not ensure the safest or healthiest option either.

We are calling for a change to the method of calculation to consider the opportunities of using the very latest LED and optical technology. This will ensure more human and nature-centric street lighting is specified across the world.

Key Learning outcomes

- A short history of LED and street lighting standards
- The issue with glare: Discomfort
- The issue with glare: Pixelation
- It's a physical (and neural) reaction
- The issue with street lighting metrics and the urgent need to reassess street lighting standards

A short history of LED and street lighting standards

Before 2006, LED lights were considered under the same legislation as lasers because historically, LEDs were used as marker lights rather than for illuminating wide areas. As LEDs were considered not suitable for general lighting, there were no product or street lighting standards compatible with LED products.

As the push for energy savings increased, so did the call for a more widespread use of energy efficient LEDs.

In 2008, the IEC General Lighting Standards were updated to include LED lighting. Great for energy savings and a low lux level, however, the previous calculation methods were simply transferred over to the new standards.

After ongoing complaints from the public and concerns from experts and environmental groups, the lighting standards were revised in 2013. Unfortunately, the research used
to update the legislation did not consider the luminance differences introduced by using LED technology.

For the past years, the specification of street lighting has been based on the 2013 standards.

A type of solid-state lighting, LEDs use a semiconductor to convert electricity into light and emit it in a specific direction, reducing the need for reflectors and diffusers that can trap light.

- A research of Global LED & Smart Street Lighting Market (2016-2026) states that "There are 315mln streetlights in the world, growing to 359mln by 2026." Furthermore, "LED streetlights are projected to reach 89% of the total streetlight market by 2026.1"
- Studies estimate that around 70% of UK streetlights have undergone or are contracted for LED adoption2.

The difficulty with using LEDs is there are often unintended, undesirable side effects: harshness, glare, uneven illumination, and sharp shadows. These are not trivial concerns. Many campaigners have cited how these side effects influence mood, productivity, alertness, safety, comfort, spatial awareness, and perception of depth. Whilst others go further and suggest that on a deeper level, our circadian rhythm and sense of well-being is negatively impacted.

Is there a reason for these unintended consequences?
Simply, we retained the metrics to determine comfortable lighting levels for drivers and comfortable brightness, or luminance, for pedestrians as we moved away from luminaires providing a large, single source of uniform luminance. This is despite the fact that today's luminaires contain multiple small, high intensity light sources.

1 https://www.prnewswire.com/news-releases/global-led-and-smart-street-lighting-market-forecast-2016-2026-street-lights-numbers-to-increasefrom-315-million-in-2016-to-359-million-by-2026---research-and-markets-300392637.html

LEDs are efficient at lighting our roads yet people complain of discomfort. As LED technology improves, can we keep the benefits that come from using LEDs and increase visual comfort?

The issue with glare: Discomfort

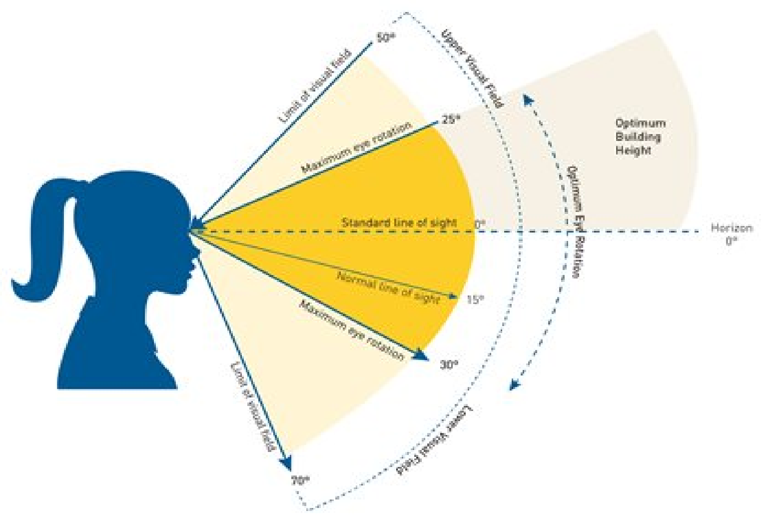
Glare is a very complex phenomenon caused by the contrast between bright and dark areas in the field of view. It causes a physical and neural response from the human eye which ranges from discomfort to disability, and it is exacerbated when the eye can see the source of the light, for example, the bulb within a luminaire.

Glare occurs because some intense light in the peripheral scatters when it enters the eye, which, in turn, reduces the sharpness of vision and raises the differential light threshold of the object you are trying to view. When glare interferes with or blocks vision, it is known as disability or veiling glare.

Disability glare tends to become more problematic as we age, as the transparency of
the crystalline lens decreases. Whilst the issue of a driver being temporarily blinded by glare is obvious, less understood is the uncomfortable psychological response that they or others experience, for example, passengers in the car or pedestrians. Having excessively bright elements within their view may cause discomfort rather than an inability to see, and over time may cause eyestrain and fatigue, often revealed as headaches or migraines or in the longer term, stress.

Discomfort glare is defined as ‘‘glare that causes discomfort without necessarily impairing the vision of objects’’ by the Commission Internationale de l’Eclairage (CIE). In general, the brighter or larger the glare source or the darker the background - compare the amount of light in a city compared to in a forest - the more discomfort glare observers will report, while the darker the background or the smaller the angle of the glare source from the line of sight, the greater the discomfort glare will be.

The eye responds to discomfort glare by constricting the pupil and it is natural for the affected individual to squint and shield the eyes. Interestingly, there is no widely accepted theory about why humans experience discomfort nor is there a fully satisfactory index for quantifying it.
As it does not directly impact safety, discomfort causing glare is often labeled ‘subjective’.



Eyes and brain are working continuously to decode light and dark

The issue with glare: Pixelation

Pixelation is a negative phenomenon for the human eye and one of the physical causes of discomfort. To resolve the issue, there is a clear need to accurately quantify what the eye experiences in a real-world scenario.

Firstly, the effects of the discrete LED sources on the lighting of the scene. We are aware of pixelation on computer screens, when images break down into their individual colour pixels, and it's the same phenomenon in streetlighting. It occurs because of the ratio of contrast between the high intensity emitting source, and the surrounding area, which tends to be at a lower intensity.

Secondly, the inadequacy of the photometric measurements that assumes the source is a single point. Instead, it is an array of closely spaced sources: very small high luminance zones separated by low luminance zones.
The current photometrics for glare assumes a single source of luminance and so requires only a snippet of information - a measurement taken from one spot facing this single point source. Of course, a LED luminaire contains multiple light sources within that single luminaire, so it's obvious that new metrics are needed to take account of this. As our technology advances and new tools are available, such as high-resolution digital cameras, we can utilise radiant imaging to measure every single point on the screen and quantify what people experience.

We can take this further when we compare the eye to a camera sensor. In raw terms, the human brain uses the eye to take many HDR-style images in very quick succession, stitching them together into a constantly updated image. This is better than existing cameras.

A photometric measure uses a light sensor to collect the light from multiple LED sources as if the light has been emitted from a point source of light where distance is irrelevant. In other words, the photometry cuts down the luminaire's details to one pixel of information. In glare calculations then we are comparing a very small number of pixels (one per luminaire) to the background (this gives us contrast) and relating that to user experience.

Users on the other hand experience glare and see every single nuance of intensity change within the luminaire optic against a super detailed intensity map of the background. This is why the photometry used for light calculation causes problems for real human beings and why research into more relevant measures is needed.

Led lighting Pixelation

It’s a physical (and neural) reaction

Glare is the loss of visual performance or discomfort produced by an intensity of light in the visual field greater than the intensity of light to which the eyes are adapted. Simply put, glare occurs when too much light enters your eye and interferes with your brain’s ability to manage it. This means that the glare source - in this case, the LED streetlight – appears excessively bright when compared with its surroundings, leading to visual impairment and/or visual discomfort.

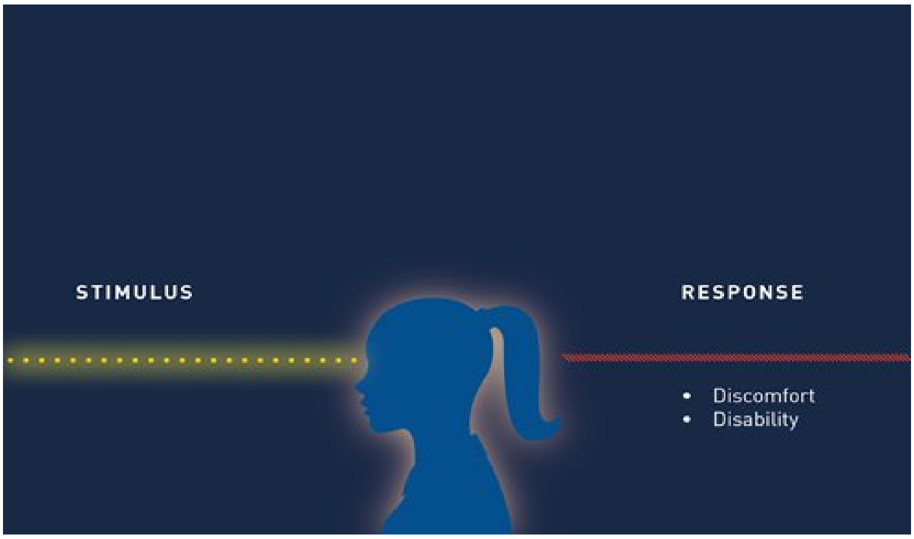
There are numerous instruments available to objectively measure the luminance of street lighting based on defined calculations. However, there are two issues with this.

1. The calculations were originally developed for older technology, favoring certain lamp types over others. These methods do not work well for most LED luminaires, the prevalent light source used in street lighting.
2. A street light installation may meet the current criteria for glare, but the user still experiences glare. This is because the impact assessment does not consider how the human eye and brain work together.

The main physical parameters that influence discomfort glare include the luminous flux (lumens) of the glare source, its size, the background surrounding the glare source, and its position within the field of view. Let’s consider this in more detail using the photometry element of street lighting as an example.

Today’s LED Street lighting uses modern lenses and multiple, smaller light sources - yet the metrics have not changed. It is obvious that LEDs, made up of multiple points of light, and the angles between the luminaires would provide a different experience when compared to older technologies. Think about the equipment used to measure the even spread of light, there are a number of issues with this, including:

- The equipment uses standard calculations that do not consider the interdependency of the luminaire with the environment - bright city backgrounds or darker countryside.
- The photometry sensor measures a horizontal line running perpendicular at a fixed height. Yet the human eye is rarely if ever static.
- The eye starts to see direct light at 65° from the nadir of a streetlight yet the luminaire visual comfort level - the glare - is evaluated at 70°, which is normally most of the roadway optic peak intensity.



Stimulus & Response

The issue with street lighting metrics and the urgent need to reassess street lighting standards

The issue with existing street lighting is that there is a clear mismatch between LED lighting technology, people's experiences, and the current metrics. Calculations to determine the positioning and efficacy of a LED luminaire may deliver as per the metrics on paper, however, when humans are reporting concerns, and we know that the metrics are based on historical technology, then it is a fair assumption that the metrics and the supporting calculations need to be updated. In addition, most lighting standards do not specify design targets for discomfort glare and those that do are not used universally, and they tend to be based on subjective ratings, which favour older technologies.

Three methods currently exist in the main for predicting and controlling glare of street lighting applications within European standards EN 13201.

- TI (Threshold Increment)
- G* Luminous intensity classes
- D* Disability Glare Index

In addition, there is also

- CIE 112 Glare Rating Index - GR is also adopted for other outdoor purposes
- IES TM-155 G rating is one of the most used methods to measure glare for outdoor lighting

As discussed, each presents a problem for modern technologies given that the calculation was based on research long before LED existed as a light source.

There are ongoing studies into creating standard, LED-appropriate metrics that consider glare in a contemporary manner. Notice must be taken of the initial studies by the CIE Technical Committee and by the DGONE5 Committee to create a generic discomfort glare sensation model. A change in standards will encourage the specification of sustainable lighting products that make living with LEDs more aesthetically pleasing and more comfortable.

The desire to reassess lighting standards is not new; neither is the need to improve comfort levels, remove unhealthy glare and unwanted light. An ever-growing body of experts - including lighting engineers, The Dark Skies movement, wildlife experts and medical professionals - are calling for a change and demand is building. As we increasingly consider sustainability as important as the mental and physical comfort of humans and the environment around us, we are amplifying this call.

5 Discomfort Glare in Outdoor Nighttime Environments

The urgent need to reassess street lighting standards