REALTERM
ENERGY

How Photometric Design Enhances Energy Savings and Asset Management

WHITE PAPER

This paper shows how photometric design should be included in any streetlight upgrade as good design provides optimal energy savings while providing safe streets.

PHOTOMETRIC DESIGN WHITE PAPER

We all experience design in our everyday lives in some fashion or another without giving it much thought. We know what we like and we often presume that good design is subjective. But design must move beyond merely personal taste to address tested, universal principles if it is to be most effective. The same is true for lighting design for streetlights.

Street lighting is first and foremost about safety. Good lighting can prevent accidents by serving drivers and offering protection to otherwise unprotected pedestrians and cyclists. Lighting levels on roads at night need to provide adequate visual acuity for the driver of a vehicle and pedestrians. This enables an individual to detect movement of other vehicles and pedestrians. Good lighting on streets and sidewalks also enhances the feeling of personal safety for pedestrians. Street lighting in newer neighbourhoods was likely designed with this in mind—but in older neighbourhoods and rural areas this is usually not the case as lights would have been put on existing utility poles.

DID YOU KNOW?

Utility poles are an inexpensive way to keep electric wires insulated from the ground and out of the way of people and vehicles. Utility poles can be made of wood, metal, concrete, or composites like fiberglass.

The governing code for utility pole spacing is the law of gravity. The limiting factors are the type of conductor used and the maximum sag allowed, required clearances, their ability to support their own weight along with the necessary tension required and the need to avoid breaking the dead end pole that will have to take the load.

There is no universal formula for pole spacing as they are conservatively engineered factoring in local conditions such as soil types and weather patterns.

The **ANSI/IES RP-8-14** Roadway Lighting guide distinguishes between roadway lighting (freeways and major roads without pedestrians) meant to help motorists remain on the road by "detecting obstacles within and beyond the range of their headlights" and street lighting (majors, collectors, locals) meant to help the motorist "identify obstacles, provide adequate visibility of pedestrians and cyclists, and assist in visual search tasks, both on and adjacent to the street. Design is driven by the classification of the particular roadway, the geometric position and frequency of the luminaires with respect to the roadway, and the unique distribution pattern of a prospective fixture. Good lighting for both roadways and streets means reducing back light and up light while delivering the required light to the targeted surfaces.

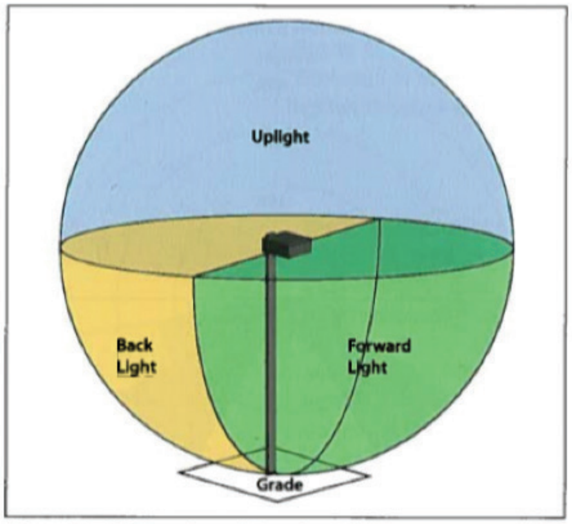

Figure 2a: LCS main solid angles. (© Illuminating Engineering Society of North America)

Good lighting necessitates photometric design based on all of these inputs:

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WHAT IS PHOTOMETRIC DESIGN?

Photometry is the science of the measurement of visible light, especially luminous intensity. Our eyes cannot see all wavelengths of visible light so photometry tackles this by weighing the measured power at each wavelength with a factor that represents how sensitive the eye is at that wavelength. The result is a model of the eye's response, called luminosity function, to light conditions (photopic vision) and dark conditions (scotopic vision). Photometric design for lighting focuses on the eye's photopic response. *The Illuminating Engineering Society of North America* (IESNA) provides guidance in this area, including standards, recommended software, and file types. Lighting designers use these IES files, which are fixture measurements conducted by third party equipment independent of the manufacturer, to complete their designs. While this science continues to evolve, sometimes rapidly, one of the most important considerations for photometric designers at this time is luminance.

Table 3. **LIGHTING DESIGN CRITERIA FOR STREETS** ANSI/IES RP-8-14

Street Classification	Pedestrian Area Classification	Avg. Luminance L_{avg} (cd/m²)	Avg. Uniformity L_{avg}/L_{min}	Max. Uniformity Ration L_{max}/L_{min}	Max. Veiling Luminance Ration LV_{max}/L_{avg}
MAJOR	High	1.2	3.0	5.0	0.3
	Medium	0.9	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
COLLECTOR	High	0.8	3.0	5.0	0.4
	Medium	0.6	3.5	6.0	0.4
	Low	0.4	4.0	8.0	0.4
LOCAL	High	0.6	6.0	10.0	0.4
	Medium	0.5	6.0	10.0	0.4
	Low	0.3	6.0	10.0	0.4

L_{avg} Minimum maintained average pavement luminance
L_{min} Minimum pavement luminance
LV_{max} Maximum veiling luminance

Luminance is the "photometric quantity most closely associated with one's perception of brightness. It usually refers to the amount of light that reaches the eye of the observer measured in units of luminous intensity (candelas) per unit area (m2)." In other words, it is the measure of surface brightness or reflected light that we can see. Here's where it starts to get confusing. A second important consideration, especially for intersections, crosswalks, walkways and sidewalks, is called illuminance. **Illuminance** is the amount of light striking a surface calculated as the density of lumens per unit area, stated as footcandles (lumens/square foot) or lux (lumens/ square meter). In its simplest, illuminance is the light that hits a surface whereas luminance is the light that is reflected or 'bounced' off a surface.

Good photometric design must also consider uniformity. **Uniformity** addresses how evenly light spreads over a task area. Uniformity is measured as a ratio between road surface illumination levels: max. to min. or max to average. Light levels along roadways and streets vary according to mounting height, luminaire spacing, and luminaire output. Designers generally seek to maximize uniformity to minimize the contrast drivers have to deal with. Fortunately, the **RP-8-14** guide provides direction on luminance, illuminance, and uniformity measures according to three different street classifications: Major, Collector, and Local.

OTHER FACTORS TO CONSIDER

When providing roadway and street lighting, planners must balance the benefits of lighting against potential drawbacks such as "engineering, capital, and maintenance costs, energy use, appearance, added fixed object hazard of poles, plus spill light on adjacent residential or commercial property and into the sky,". The RP-8-14 guide adds that "lighting is 'good' when it is economical in equipment, energy and maintenance costs, and meets a proven or reasonably predictable need, with a minimum of adverse effect." Lighting designs thus must also consider both the initial installation cost and the subsequent operating (maintenance and energy) costs.

One of the biggest benefits of an LED lighting retrofit is increased lifespan. For some municipalities and utilities the maintenance cost savings can be even more valuable than the energy savings of a streetlight retrofit. As a result, a good design must also create a lighting system that performs well to the end of the fixtures expected life. This involves accounting for light loss factors such as LED depreciation. The standard here is the L70 rating which is an IES standard for rating the relative output (70%) after X number of hours. The 70% figure is significant because it is generally when the difference in light output is noticeable by the human eye. The difference between a fixture's initial and end of life brightness is referred to as lumen maintenance.

A FURTHER CONSIDERATION

Those communities with observatories or sensitive natural heritage features sometimes also wish to incorporate the Model Lighting Ordinance (MLO) into their lighting design. The MLO is the result of extensive efforts by the International Dark Sky Association (IDA) and the Illuminating Engineering Society of North America (IES). The MLO enables communities to drastically reduce light pollution and glare and lower excessive light levels. The recommended practices of the IES can be met using readily available, reasonably priced lighting equipment. Among its features is the use of lighting zones (LZ0-4) which allow each governing body to vary the stringency of lighting restrictions according to the sensitivity of the area as well as accommodating community intent. In this way, communities can fine-tune the impact of the MLO without having to customize the MLO. The MLO also incorporates the Backlight-Uplight Glare (BUG) rating system for luminaires, which provides more effective control of unwanted light.

WHY SHOULD I CARE ABOUT GOOD DESIGN?

In addition to the range of safety considerations addressed above (and the inherent liability concerns in not addressing them), good design results in significant upfront and ongoing cost savings. Good design means addressing areas that are under or over lit. Good design means moving beyond a simple one for one fixture replacement to one tailored to your local infrastructure—which often results in selecting lower wattage fixtures than a simple one for one would suggest. The cost savings are both immediate, in terms of selecting lower wattage fixtures that tend to cost less, and long-term as the operating costs for the life of that fixture are lower because lower wattage lights use less energy. The design team at RealTerm Energy has found that good design nets an average of an additional 12% of savings over one-for-one type replacement for most (not underlit) communities.

HOW DOES REALTERM ENERGY'S DESIGN PROCESS WORK?

RealTerm Energy prides itself on its excellent design processes that are supported by an accurate inventory of the actual assets and based on recognized roadway classifications and recommended practices for design.

DID YOU KNOW?

Both municipal and utility inventories are often wrong—meaning neither match what actually exists on the streets. In 100% of the communities in which we have completed an asset map both inventories have been incorrect, sometimes dramatically. Accidents, weather incidents, failures, additions of streets and/or fixtures, quality concerns related to previous mapping, as well as discrepancies over who owns what are common causes of inaccuracies in existing data.

The first step in our design process is to accurately verify and map the streetlight assets via our Roadway Survey Data collection. Our GIS Engineering Department collects the following critical metadata using a custom-designed smartphone App: Fixture Type, Wattage, Mounting Height, Road Width, Pole Setback, Arm Length, Road Classification, and XY Coordinate. Each fixture is assigned a unique ID# and mapped in ESRI GIS software.

Roadway illumination design is driven by the classification of the particular roadway, the geometric position and frequency of the luminaires with respect to the roadway, and the unique distribution pattern of a prospective fixture. Roadway classifications have two components. **1.** Vehicular traffic volumes, which are determined by the National Roadway Network (NRN) and the data presented terms of Local/Collector/Major naming conventions. **2.** Pedestrian conflict, or volumes determined by the land use within 200m of the roadway in question and IES prescribed naming conventions, which are as follows for average nighttime activity: **a.** Low: less than 10, **b.** Med: less than 100, **c.** High: more than 100 pedestrians per hour.

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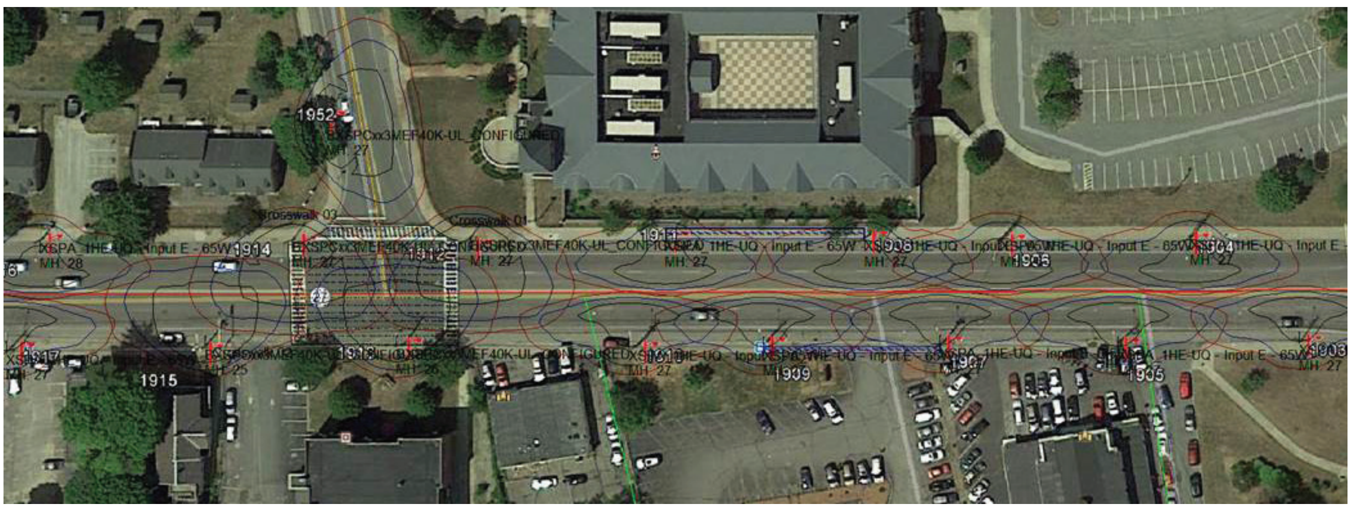
Photometric Models are created with an industry leading software. The inputs to those models are taken from RTE's Roadway Survey Data and the photometric performance of selected fixtures. The outputs from these models are compared to industry recommended practice prescribed by the IES. The unique distribution pattern of a luminaire is fixed intrinsically by the model of fixtures used. The photometric performance of these are measured, verified and published by a 3rd party laboratory in the form of luminous intensity tables that can be fed into a photometric calculation by means of an .ies file. The Photometric Models are evaluated by comparing the results to **RP-8-14** design criteria.



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Numerous iterations are performed in each design to yield average luminance values that meet or marginally exceed the target design criteria. If the output calculation of Photometric Model meets, or exceeds **RP-8-14** average luminance design criteria, the process moves onto Fixture Specification.

Base designs for representative streets are determined and then carefully applied to other, streets with the same parameters until each street that supports the design is specified. This process is repeated for each unique set of street conditions where unique designs can be applied.