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LIGHTING FOR TRAFFIC SAFETY

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Overview

Lighting plays a crucial role in enhancing nighttime visibility. While measures such as vehicle headlights and the retroreflective properties of signs and pavement markings assist drivers, roadway lighting offers a distinct advantage—it improves visibility independently of the vehicle or driver.

Lighting is important for safety, security, and comfort. Safety is provided by illuminating pedestrian routes and crossing locations, and locations which could otherwise be prone to driver error at night. It can also be provided for busier roadways, interchanges and intersections where drivers may need to see angles that are not illuminated by the vehicle. The added illumination provides a safety factor by making these locations more visible. Lighting increases security by illuminating areas that could be prone to trespass by unauthorized individuals, such as near entry control facilities or near buildings, thereby making it easier for authorities to see these areas and serving as a deterrent to people with suspicious intent. Lighting provides convenience simply by illuminating areas to make drivers and pedestrians feel more comfortable at night. Locations may include neighborhood streets, parking lots, and walkways.

There have been major advancements in lighting technology and the understanding of uniformity, contrast, glare and the color of the light and how they affect nighttime visibility. UFC 3-530-01, entitled *Interior and Exterior Lighting Systems*, incorporates current design concepts. As a result, installations should:

☑ Use the most effective, energy-efficient light source available.

☑ Avoid over lighting and ensure that lights are only on during the hours they are needed.

☑ Promote dark skies and reduce light trespass onto adjacent properties by using cutoff luminaires.

The proper design of the lighting system will increase safety and efficiency, aid security forces, and enhance appearance. A qualified lighting engineer should develop a lighting plan that satisfies applicable illumination standards while accounting for site-specific constraints and design parameters.

The following resources are available for roadway lighting design:

- ☑ Unified Facilities Guide (UFC) 3-530-01 *Interior and Exterior Lighting Systems*
- ☑ American Association of State Highway and Transportation Officials (AASHTO) *Roadway Lighting Design Guide*
- ☑ Federal Highway Administration (FHWA) *Lighting Handbook* and *Pedestrian Lighting Primer*
- ☑ Illuminating Engineering Society (IES) *Recommended Practice: Lighting Roadway and Parking Facilities (RP-8-22)*
- ☑ State Departments of Transportation (DOTs)

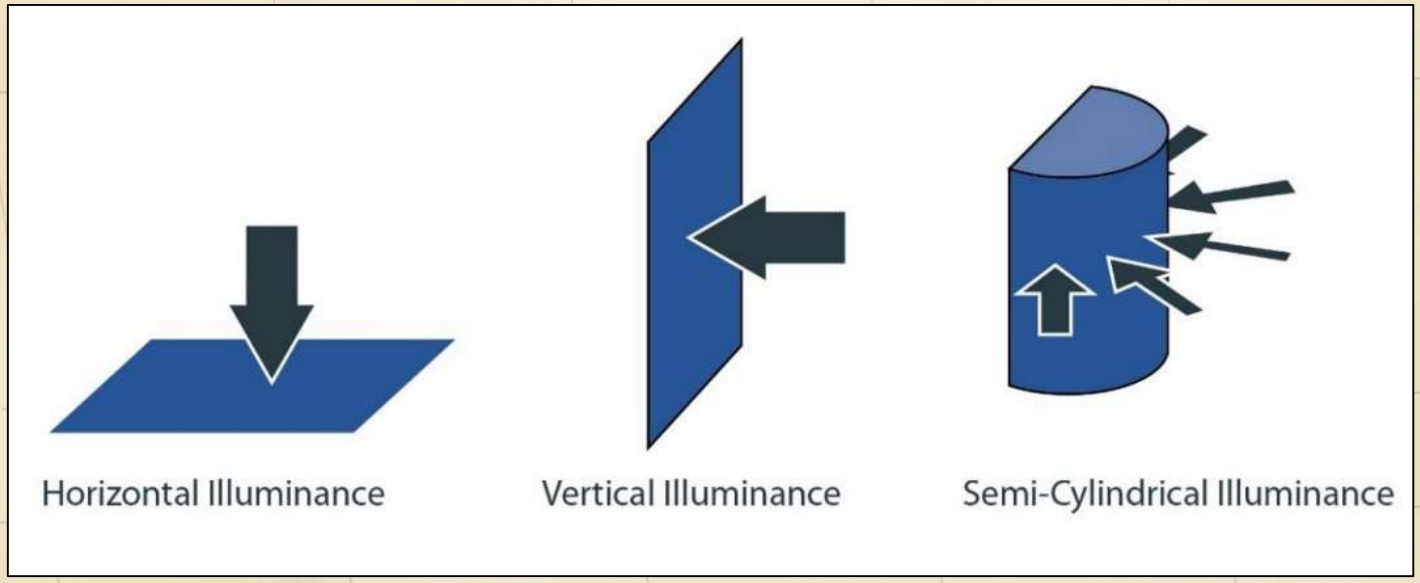
Illuminance

Illuminance is a measure of the intensity of light on a surface. A foot-candle is the U.S. customary unit of measure, equal to one lumen per square foot, and was originally defined as the amount of light from a typical candle burning at a distance of one foot from the surface. The table to the right shows a range of some relative illumination levels.

Lighting Source	Level of Illuminance (Foot-Candles)
Full Moon	0.02
Gas Station Canopy	10-20
Office	20-50
Overcast Day	100
Large Football Stadium	300
Direct Bright Sunlight	10,000

Horizontal illuminance is the density of light that falls on a horizontal surface and measured at a location 6 inches above the ground. Although illuminance is typically measured on a horizontal surface, the term “vertical illuminance” is used in the ID check areas, parking lots, pedestrian areas, and perimeter lighting. Vertical illuminance is the application of light on upright objects such as people, rather than horizontal surfaces like roadways and parking lots. For security purposes, the need to illuminate people, especially their face, for identification purposes is more important than illuminating horizontal surfaces. Vertical illuminance is generally measured at a height of 5 feet above the grade. Semi-cylindrical illuminance considers the amount of light falling on a semi-cylinder, which more accurately represents the visibility of pedestrians.

Methods of Calculating Illuminance. Source: Pedestrian Lighting Primer, FHWA.



Minimum Illuminance. Source: SDDCTEA Pamphlet 55-15

Location	Minimum Illuminance (footcandles)	Notes
ECFs Near the ID Check Area ✓ Approach & response zones ✓ Search area parking and roadways	✓ 3 [4 for Air Force at primary gates]*	✓ Illuminance on the pavement and sidewalks ✓ Average-to-minimum uniformity levels shall not exceed 4:1
ECFs at the ID Check Area ✓ Access control zones ✓ Search areas	✓ 5 in general areas* ✓ 10 or twice the immediate surrounding areas at the ID checking area [Air Force is 20 under the canopy and 30 at the point of contact]*	✓ Average-to-minimum uniformity levels shall not exceed 3:1 ✓ In immediate area where ID and inspection occur, vertical illuminance is 25% of horizontal illuminance at driver level
Parking Lots	✓ 1 – 2**	✓ The maximum-to-minimum uniformity ratio should be not greater than 15
Pedestrian Areas	✓ 0.5**	✓ By using shorter poles with illuminance from multiple directions, adequate vertical illuminance should be provided to light individuals and their faces
Perimeter Lighting	✓ 0.2 - 0.4 vertical illuminance**	✓ See Table 6-1 in UFC 3-530-01

* minimum illuminance at location 6 inches above the ground level
** average illuminance

Light Temperature

The apparent color of a light source is measured as its correlated color temperature (CCT) of the light source, measured in degrees kelvin (K). Luminaires manufactured for use in roadway and pedestrian applications are tested for color temperature. CCT represents the relative warmth of the emitted light. Lower values (e.g., 2700K) indicate a warm, yellow tone of light; higher values (e.g., 5000K or more) indicate a cool, blue tone of light; a neutral white is around 4000K. Per the Pedestrian Lighting Primer, a neutral color is preferred for lighting to maintain accurate color visibility.

Glare

The difficulty or discomfort associated with a light source in direct view of the observer is referred to as glare. Veiling luminance is a common measure of glare used to guide the lighting design process. As described in the FHWA *Lighting Handbook*, there are two types of glare that may occur due to the presence of a light source.

- ☑ Disability glare is the intensity from a light source that limits a road user's ability to see.
- ☑ Discomfort glare occurs when light from a light source causes discomfort to a road user.

It is important for both types of glare to be minimized. Glare can be a greater concern with pedestrian scale lighting (20 feet in height or lower).

Types of Lamps

Solid state lighting (SSL), primarily in the form of light-emitting diodes (LEDs), has become the dominant lighting technology due to its high energy efficiency, long lifespan, and broad applicability. SSL systems use semiconductor-based light sources such as LEDs rather than traditional filaments, plasma, or gas-discharge mechanisms. LED luminaires are widely available as replacements for conventional fixtures, including cobrahead-style streetlights, and are commonly installed in new lighting systems. Unlike older technologies, LEDs achieve full brightness instantly and consume significantly less power.

Although LED reliability has improved, gradual lumen depreciation over time can lead to unnoticed reductions in light output, raising concerns for maintenance planning. Additionally, because LEDs emit minimal forward-directed radiant heat, snow and ice accumulation can occur on exposed surfaces—most notably on LED traffic signals—though this is typically less problematic for downward-facing street luminaires.

Snow Buildup in LED Signal Heads

Several traditional lamp types, though largely replaced by modern technologies, remain in use and may be appropriate in specific applications:

- ☑ High-pressure sodium (HPS) lamps are high intensity discharge (HID) lamps in which light is produced by radiation from sodium vapor. These traditionally have been the most common lamp but they do not have the best efficiency, longevity, or color.
- ☑ Pulse-start metal halide (MH) lamps were traditionally preferred for most external lighting due to their excellent color and high efficiency. These are HID lamps in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors such as mercury. However, because of long restrike and warm-up periods, when used for security purposes they always require backup lights. (Note: Standard MH lamps are not as efficient or durable as the pulse-start types.)
- ☑ Quartz-halogen lamps are inefficient, but provide excellent color and a quick start.
- ☑ Incandescent lamps have excellent color, but poor energy efficiency.
- ☑ Fluorescent lamps can offer good color rendering and rapid start options, but are generally unsuitable for outdoor use in cold environments

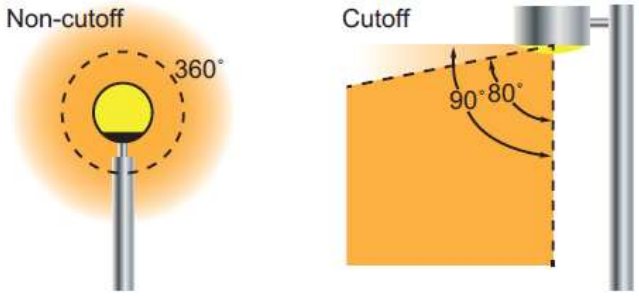
Per UFC 3-530-01, LED lighting should be used for all exterior lighting applications. Some of the advantages of LEDs include:

- ☑ Reduce energy consumption
- ☑ Reduce maintenance costs
- ☑ Provide more uniform illuminance
- ☑ Attract fewer insects to the lights
- ☑ Faster restrike time, or time to gain full intensity, than traditional luminaire types.

Light Trespass. Light trespass is unwanted light spilling beyond the intended area, such as into nearby windows. To reduce light trespass and support dark-sky goals, use full cutoff luminaires when possible, as shown below.

Cutoff Classifications. Source: SDDCTEA Pamphlet 55-17

CLASSIFICATION	MAXIMUM INTENSITY (% LAMP LUMENS)	
	ABOVE HORIZONTAL	80° ABOVE VERTICAL
Full Cutoff	0	10
Cutoff	2.5	10
Semi-Cutoff	5	20
Non-Cutoff	n/a	n/a



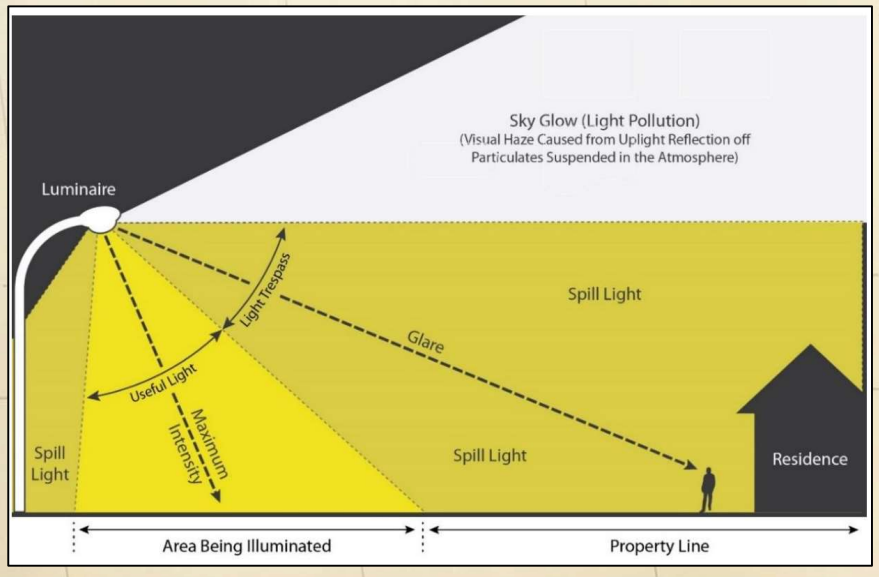
It is generally possible to classify the type of cutoff by visual observation. For example, if the lens is not visible when viewed from the side, it is a full cutoff lamp, whereas a low-hanging, globe-like lens is a semi-cutoff lamp.

The primary issue with full cutoff lamps is the fact that more poles and lamps may be required to provide proper illuminance. The angle of the cutoff may vary by application. For roadway lighting, a cutoff angle of 80 degrees, as shown in the figure above may be appropriate. For other applications, such as building entrances or exits, it may be more appropriate to use lower cutoff angles to limit light trespass.

A canopy over an ECF will also reduce light trespass. In addition, special shields can be used to further reduce light trespass.

The following figure illustrates light trespass and glare with respect to locations of desired light.

Light Trespass, Glare, and Sky Glow. Source: FHWA.



Intersection and Pedestrian Lighting

Lighting is used frequently at intersections and for pedestrian facilities. Most State Departments of Transportation (DOTs), as well as the Illuminating Engineering Society (IES) have established warrants for the implementation of lighting and illumination requirements based on pedestrian and vehicular traffic volumes, roadway classification, as well as other environmental and operational factors. When designing lighting, the following factors should be considered; luminaire type, light source type, wattage, mounting height, distribution pattern, and pole location. The need for intersection lighting should be professionally evaluated.

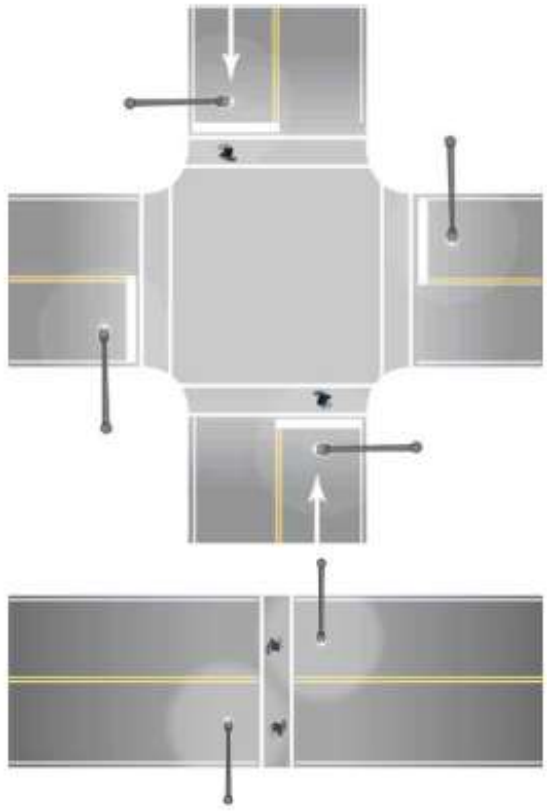
Intersection lighting, when designed and operating correctly, increases motorist and pedestrian visibility and reduces crash potential. Although the Manual on Uniform Traffic Control (MUTCD) does not address warrants, it suggests implementing roadway lighting if a disproportionate number of crashes occur at night. Lighting should be installed at those locations where a lighting engineer has determined that lighting will contribute to the efficiency, safety, and/or comfort of motorists and pedestrians.

It is common to install luminaire arms for lighting on mast arms. The design is variable, all dependent on the intensity of the luminaire, location of the post as compared to the crossing and width of the roadway crossing. Existing poles should be structurally evaluated for increased loading before adding any mast arms.

Pedestrians are the most vulnerable road users at night. Based on average crash data, pedestrians are between three and seven times more vulnerable in the dark than during daylight hours. According to the *Pedestrian Lighting Primer* by FHWA, for years 2016 to 2019, there were approximately 4500 pedestrian fatalities per year in dark conditions, which represents 75 percent of all pedestrian fatalities.

Per the TEA Crosswalk Warrant and Guidelines, all crosswalks spanning uncontrolled (no stop, yield, or signal control) approaches at intersections and midblock locations are required to have lighting. Crosswalks spanning uncontrolled approaches are especially critical since traffic is not required to stop or slow if a pedestrian is not present, which reinforces the importance of pedestrian visibility to drivers. Lighting should also be used for controlled crossing locations. In an effort to improve visibility of pedestrians, the preferred location of the luminaire for intersection and midblock crosswalks is as illustrated in the figure to the right.

Recommended Location for Luminaires at Intersections and Midblock Crosswalks. Source: FHWA



Note that with this configuration, the lighting is between the vehicle and the pedestrian in a crosswalk, thereby illuminating the front of the pedestrian as seen by the approaching driver of a vehicle. It is undesirable to have the opposite configuration, where the pedestrian is between the vehicle and the light source, because only the silhouette of the pedestrian is visible to the driver.

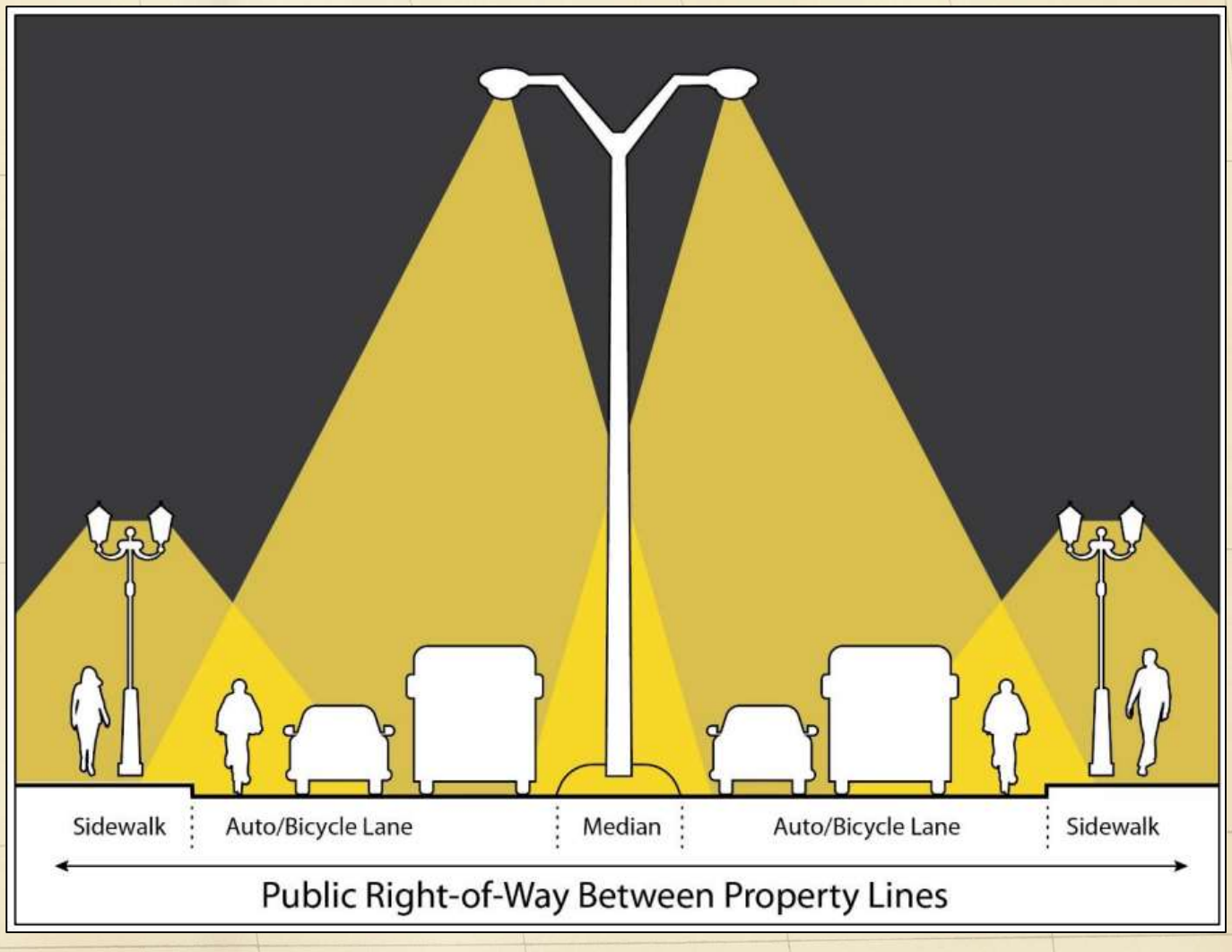
In the absence of mast arms, lighting is often installed on utility poles, or on exclusive light poles. All poles, including signal mast arms, light poles, or utility poles should be located outside of the clear zone, shielded by a barrier, or be breakaway. Common mistakes

include locating non-breakaway pole bases too close to the roadway, or setting the concrete foundation elevation too high such that it becomes a roadside hazard.

For continuous roadway lighting, light poles can be installed in redundant runs parallel to the roadway. Continuous lighting should avoid shadowing effects from too wide of spacing. The conical shape of the lighted area from one luminaire should have a slight overlap with the lighted area of the next luminaire. The exact spacing can vary depending on the height and wattage of the luminaires, as well as the angle of lighting cone. It is especially important in retrofit projects to make sure that the angle of the lighting cone is the same as what the original lighting system was designed for.

When pedestrian walkways are illuminated, consider using pedestrian scale lighting, or luminaires with lower mounting heights. These might often have decorative properties. Pedestrian-scale lighting enhances pedestrian visibility by increasing driver detection distances. That said, disadvantages of pedestrian scale lighting are the need for more luminaires, and an increased glare produced by the light source since the light source is closer to the driver eye height. The combination of pedestrian scale lighting and roadway lighting is shown in the figure on the following page. If a median is not available for lighting, a light pole for roadway lighting can be installed on each road edge.

Variable Lighting Mounting Heights Within Public Right-of-Way. Source: FHWA



The FHWA *Lighting Handbook* identifies geometric factors and operational factors that should be considered in determining if lighting should be used in collector, major, and local streets.

Geometric factors include:

- ☑ Number of lanes
- ☑ Lane width
- ☑ Number of median openings per kilometer
- ☑ Driveways and entrances per kilometer
- ☑ Horizontal curve radius
- ☑ Vertical grade
- ☑ Sight distance
- ☑ Parking

Operational factors include:

- ☑ Signalized intersections
- ☑ Left turn lanes
- ☑ Median width
- ☑ Operating or posted speed
- ☑ Pedestrian activity

Environmental factors are also considered. These include:

- ☑ Amount of development adjacent to the roadway
- ☑ Distance from development to roadway
- ☑ Ambient Lighting
- ☑ Raised median curb

Crash history is also considered.

The same publication cites warrants for intersections. These include:

- ☑ Traffic volumes (particularly on the cross street).
- ☑ The presence of crosswalks.
- ☑ Nighttime crashes that may be attributed to the lack of illumination.
- ☑ The extent of raised medians.

If an intersection is signalized, lighting is generally warranted.

Parking Lot Lighting

Parking lot lighting plays a critical role in maximizing visibility between motorists and pedestrians. In large exchange and commissary parking lots, lighting is also helpful as shoppers transfer goods from shopping carts to their vehicles. Lighting also gives pedestrians accessing their vehicles greater convenience of seeing their vehicles and reduces safety and security concerns involved with walking in dark areas.

Mounting height and spacing of luminaires should be sufficient to distribute the desired lighting intensity to the entire parking area. Pole heights range from 20 to 50 feet or more. A normal lighting level is from 1 to 2 foot-candles, and the maximum-to-minimum uniformity ratio should be no greater than 20:1. The following illuminance requirements should be met for all parking lot lighting zones:

Parking Lot Performance Requirements. Source: UFC 3-530-01

Target Criteria	All Lighting Zones
Minimum Horizontal Illuminance	0.2 (2 lux) at grade
Minimum Vertical Illuminance in center of drive lane, in direction of traffic flow	0.1 (1 lux) at 5'-0" (1524 mm) AFF
Horizontal Illuminance Uniformity	20:1 maximum to minimum

Locate light fixtures away from traffic aisles and parking stalls wherever possible. Light poles are ideally located in islands and protected by raised curbs. When light poles are within parking rows, locate the poles at the junctions of adjacent stalls, and install them on top of a 3-foot high concrete base to avoid accidental knockdowns. While this practice is acceptable in parking lots, high concrete bases should not be used on open roadways due to the need to provide breakaway designs in areas with higher travel speeds. Nor should high concrete bases be used if the pole is located beyond the edge of a parking lot or within a curbed island since that area is not prone to vehicular traffic. Poles and fixtures should be in scale and accommodating to the setting and surrounding area, while providing adequate illuminance of the parking lot. Luminaires should direct the light downward and within the desired lighting area with visors to minimize light trespass.

ECF Lighting

Entry Control Facilities (ECFs) have stringent lighting requirements, and the lighting in these areas is extremely important for the proper execution of necessary functions. UFC 4-022-01 discusses ECF lighting, while UFC 3-530-01 provides more specific requirements. ECFs are especially critical since lighting serves multiple needs:

- ☑ Security requirements for ID checks and inspections
- ☑ Perimeter security
- ☑ Safety of guards sometimes working within travel ways
- ☑ Multiple decisions needed by the driver due to increased signage and multiple options for driver actions
- ☑ Likelihood of slow or stopped traffic
- ☑ Likelihood for confused motorists
- ☑ Presence of pedestrians

UFC 3-530-01 has lighting requirements for several areas within an ECF, including:

- ☑ Access Control Zone Outside Canopy: Provide recessed or surface-mounted downlights in canopy to reduce glare to approaching drivers. Provide a low-brightness surface luminaire behind and to the side of inspection personnel to light the approaching vehicle and driver.
- ☑ Access Control Zone Beneath Canopy: Locate low-brightness luminaire behind and to the side of the inspection personnel to light the approaching vehicle and driver. This also eliminates glare for the guard.
- ☑ Response Zone: Locate pole-mounted luminaires to prevent glare to the overwatch guards. The luminaire should be shielded to block glare toward the overwatch.
- ☑ Under-Vehicle Inspection Areas: LED luminaire should light the underside of incoming vehicles.

Transitional lighting is necessary on approach to and departure from the ECF to minimize blinding effects as drivers travel into and out of a brightly illuminated ECF. Standard conventional lighting is mounted at 30 to 60 feet. When standard conventional lighting is used, transitional lighting is to be provided to allow the driver's eyes to adjust to the change in lighting levels on arrival or departure.

Departure lighting is more critical since the eye has greater difficulty adjusting from light to dark than from dark to light. Provide gradual change in lighting levels using the minimum number (typically three or more) of lighting poles possible, with an approximate 33 percent or less change between poles. Actual lighting locations and spacing must be determined by an engineering assessment and will depend on luminaire height, light source type, and lens distribution.

High mast lighting in the range of 60 to 120 feet high is practical, because it provides broader and more natural light distribution. It also requires fewer poles than standard conventional lighting and may reduce or limit the need for transitional lighting.

High mast lighting in the range of 120 to 180 feet does not require transitional lighting since it provides its own transition through distance; however, high mast lighting exceeding 120 feet typically requires stronger luminaries of 1,000 watts and may create light pollution on neighboring properties. The final determination of the lighting type selected should consider the life-cycle cost of each system. Although one high mast light can often replace six conventional lights, the cost of high mast lights is often five times more than conventional lights not including power requirements.

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Reference List

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- ☑ TEA Pamphlet 55-17, *Better Military Traffic Engineering* (2016)
- ☑ TEA Pamphlet 55-15, *Traffic and Safety Engineering for Better Entry Control Facilities (2019)*
- ☑ DOD UFC 3-530-01 *Interior and Exterior Lighting Systems* (15 December 2023)
- ☑ DOD UFC 4-022-01 *Entry Control Facilities/Access Control Points* (27 July 2017)
- ☑ FHWA *Pedestrian Lighting Primer* (2022)
- ☑ FHWA Lighting Handbook (2023)
- ☑ IES RP-8-22 Recommended Practice: Lighting Roadway and Parking Facilities (2022)