



# Roadway Lighting Manual

Division of Traffic Operations, First Edition, July 2021





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## Introduction

The Roadway Lighting Manual is the culmination of extensive research and effort by Caltrans staff to develop guidelines for roadway lighting designs. This publication does not constitute a standard, specification or regulation. Field and economic conditions may call for variation from this publication's requirements and may be subject to approval by designated levels of management in the district. This publication is neither a textbook nor a substitute for engineering knowledge, experience or judgment.

The information in this manual is written to assist Caltrans roadway lighting designers in preparing uniform and standard designs of roadway lighting systems.

The *Roadway Lighting Manual* supersedes all prior versions of the *Traffic Manual*, Chapter 9, Sections 9-06 through 9-12.

### Purpose

The purpose of this manual is to provide a comprehensive source of information concerning Caltrans policies for roadway lighting within the State Highway System and to develop uniformity in designing roadway lighting systems.

The illumination requirements are based on Federal Highway Administration (FHWA), the American National Standards Institute/Illuminating Engineering Society of North America Recommended Practice (ANSI/IES RP) 8-18 guidelines, and industry practices and recommendations.

The *Roadway Lighting Manual* provides guidance for the following:

- Installing uniform lighting for various applications within the State right-of-way (including freeways, highways, expressways, intersections, bicycle and pedestrian facilities, roundabouts, park and ride lots, bus stops, and railroad crossings).
- The standardization of lighting structures.
- Adjusting luminaire spacing and light fixture characteristics for a more uniform lighting distribution.
- Evaluating lighting levels using computer-based lighting software.
- Updating Caltrans' lighting practices and standards (plans and specifications).

The terms used in this manual are defined in Appendix D.



## Chapter 1 – Lighting Development Procedures

### Chapter 1.1 – Introduction

The design of freeway and highway lighting should comply with the most current version of the following publications:

- *Roadway Lighting Manual*
- *Construction Contract Standards*
- *Construction Contract Development Guide*
- *Highway Design Manual (HDM)*
- *Plans Preparation Manual*
- *Cooperative Agreement Handbook*
- *Project Development Procedures Manual*
- *Electrical Systems Design Manual*
- *California Manual on Uniform Traffic Control Devices (CA MUTCD)*
- *Highway Safety Improvement Program Guidelines*
- *Caltrans Standard Environmental Reference (SER)*

Lighting standards for installation on State highways will normally be one of the types shown in the Standard Plans. The exception is where a local agency uses a different type of lighting standard and either of the following:

- Has existing lighting that is being replaced due to State highway construction; or
- Desires the inclusion of their roadway lighting into a State highway project.

The types, applications and mast arm lengths of the roadway luminaires are as follows:

#### Luminaire Standards

##### Type 15

Type 15 and 15D standards are used:

- On highways and expressways.
- At intersections of freeway ramps with surface streets.
- On structures in lieu of a Type 21 standard where a lower mounting height is desired.

A 12 feet mast arm is normally used on Type 15 and 21 standards, but lengths of 6, 8, 10, and 15 feet are also available. A 15-foot mast arm is not available for Type 15D and 21D standards.

##### Type 21

Type 21 and 21D standards are used on structures and may be mounted on a barrier railing or a retaining wall.

##### Types 30, 31 and 32

Type 30, 31, and 32 standards are used on freeways and in freeway interchange areas.



A Type 30 standard is used where the standard cannot be located further than 18 feet from the edge of the traveled way. The normal mast arm length for Type 30 is 15 feet, but lengths of 6, 8, 10, and 12 feet are available.

A Type 31 standard is available only with a mast arm of 20 feet and should be located a minimum of 20 feet from the edge of the traveled way.

A Type 32 standard is available only with a 30-foot mast arm and without a slip base and should be located a minimum of 30 feet from the edge of the traveled way.

## Luminaire Placement

Placement of luminaire standards should comply with the latest Caltrans Highway Design Manual, Section 309.1, "Horizontal Clearances for Highways."

## Foundations

The foundation and installation details for each lighting standard are shown in the Standard Plans. Location of foundations are described in the following section:

### *Lateral (Set Back)*

In general, lighting standards should normally be set as far from the right or left edge of the pavement as conditions permit. Exceptions to this occur in cut or fill sections with slopes steeper than 4:1; foundation locations for these conditions are shown in the Standard Plans. On curved ramps, lighting standards should be located on the inside of the curve.

### *Longitudinal*

- Typical spacing for Type 21, 30, 31 and 32 standards is 180 feet. The typical spacing for a Type 15 is 150 feet.
- The typical location of standards for each application is shown in Appendix A. Designers should adjust the spacing to achieve required lighting levels in the conflict area using lighting software.

### *Structures*

On structures and retaining walls, lighting standards should be located at least five feet from the structure expansion joints or hinges. Care should be taken in locating standards on lower roadways or structures to avoid creating glare to vehicles on a higher structure.

Slip bases shall be installed with Type 30 and 31 standards and with Type 15 standards on freeways, expressways, and highways within the Clear Recovery Zone (CRZ) as defined in the Caltrans High Design Manual. Exceptions to this policy are that slip bases are not used under signal standards with lighting or under lighting standards located in the following areas:

- On or behind structures, retaining walls, or sound walls;
- Behind guard rail or barrier railing;
- In sidewalk areas;



- Where pedestrians would be close enough to be endangered by a pole knockdown;

## Chapter 1.2 – Project Report

General requirements for developing lighting projects are noted in the *Project Development Procedures Manual*. The cost of lighting on Federal Aid highway projects is eligible for federal participation under certain conditions.

The *FHWA Lighting Handbook* describes recommendations for roadway lighting and requirements for federal aid eligibility. This manual is in substantial conformance with the *FHWA Lighting Handbook* to ensure federal aid eligibility.

For scoping and programming purposes, the preparation of a Project Initiation Document is required for all projects that include lighting. The *Project Development Procedures Manual* and the corresponding Project Manager should be consulted to determine specific reporting requirements.

The following data is required to determine the need for highway lighting installation and shall be included in the Project Initiation Document.

**Traffic Counts**—Both pedestrian and vehicular traffic counts shall be shown for any single hour that may be in darkness during winter months. Traffic counts shall be shown on Figure 4C-101 (CA) and Figure 4C-102 (CA) of the CA MUTCD. For Figure 4C-101 and Figure 4C-102 the single-hour traffic count shall be measured during a period of darkness that shows the highest traffic count. Pedestrian traffic counts should be shown on each crosswalk for the same periods as the vehicular count.

**Vehicle Speed**—This shows the posted speed limit or 85th percentile speed of vehicles on approaches to the intersection.

**Electrical Service**—This is a statement on the availability of electrical service. Where the cost of establishing electrical service is excessively high due to line extension, consider alternate sources of power or deferring the installation.

**Other Data**—This includes the following documentation:

- a. Location map;
- b. Condition diagram showing existing conditions;
- c. Summary of accidents and the collision diagram;
- d. Figure 4C-101 (CA), Figure 4C-102 (CA), or Figure 4C-103 (CA) (Traffic Signal Warrants Sheet [sheets 1 to 5] from CA MUTCD);
- e. Applicable warrant in Table 4C-1, Table 4C-2, Table 4C-3, and Table 4C-4, and Figure 4C-102 (CA) from CA MUTCD;
- f. Improvement diagram showing existing and proposed lighting, channelization, and other proposed improvements. This may be combined with (b), (c), (d), and (e) on a single plan;
- g. Estimate of cost; and
- h. Explanation of confusing or unsatisfactory conditions to be improved by the lighting.





## **Chapter 1.3 – Utility Coordination**

During the design stage, the local electrical utility should be contacted to determine the location and type of service available.

## **Chapter 1.4 – Financing**

### **General Policy**

Caltrans participation in financing is based on the use of standard equipment in accordance with Caltrans standard plans and standard specifications. If local agencies plan to use more expensive equipment, the additional cost over the standard equipment shall be at 100 percent local agency expense except as noted below.

### **Freeways**

The cost of installing lighting on freeways is at 100 percent Caltrans expense. If other agencies desire to provide lighting between interchange areas, such lighting may be included in the State's project. However, Caltrans will not be responsible for installation costs. Caltrans will maintain and operate the lighting at 100 percent local agency expense.

On Federal Aid projects, federal participation will be requested when one or more of the traffic volume warrants in Chapter 2.2 are met.

At the intersections of freeway ramps with local streets, the installation cost of lighting shall be at 100 percent Caltrans expense if it is found to be warranted at any time within five years after the date the freeway is opened to traffic. Lighting that meets the warrants stated in Chapter 2.2 may be installed at Caltrans expense on new frontage roads and local streets constructed as part of a freeway project when such lighting will be owned by a local agency. Lighting design may conform to the established design standards of the local agency.

### **Existing Highway Intersections**

Highway lighting to be installed at existing intersections shall be financed jointly by Caltrans and the local agency in the same ratio as the number of legs under each jurisdiction bears to the total number of legs at the intersection.

The District Director may approve installing warranted utility-owned lighting without submitting a Project Initiation Document to Headquarters.

Normally, the monthly charges for utility-owned lighting installed at the request of Caltrans should be shared jointly with the local agency, as stated above or as indicated on the District Maintenance Agreement.

### **New Highway Intersections**

The installation cost of highway lighting at new intersections on a State highway because of a State highway project shall be at 100 percent Caltrans expense. The installation cost of highway



lighting at new intersections on a State highway because of a local agency project shall be at 100 percent local agency expense.

## **Railroad Grade Crossings**

The cost of installing and maintaining lighting at railroad grade crossings on State highways shall be at 100 percent Caltrans expense.

## **Chapter 1.5 – Lighting by Local Agencies and Others**

Where a local agency proposes to install lighting on a State highway, an encroachment permit is required. Lighting may also be installed at the intersection of a State highway and private driveway by a private property owner under an encroachment permit. However, the local agency should also obtain an encroachment permit agreeing to own and maintain the lighting installed by a private party. Such lighting shall in no way detract from the effectiveness of existing State lighting or in any way interfere with the safe movement of traffic. On existing roadways, except expressways or freeways, the lighting may be installed on wood poles with overhead wiring for temporary construction. On expressways and freeways, the equipment shall meet Caltrans standards, i.e., steel standards and underground wiring. Where a local agency proposes to install continuous lighting using luminaires of higher light output than the existing highway luminaires, the project should include replacing the existing units with new luminaires with the higher light output. Caltrans will review the design of such lighting. The installation may be performed by local agency forces, a contractor, or an electrical utility.

Caltrans will only be responsible for the costs of installing or upgrading, maintaining, and operating lighting as warranted in Chapter 2.2 and Chapter 3.2.

## **Chapter 1.6 – Reconstruction of Existing Facilities**

### **Freeways**

When affected by State freeway construction, existing street lighting facilities shall be replaced in kind at 100 percent Caltrans expense, using salvaged material where feasible, under the following conditions:

- a. Existing lighting was installed under permit; and
- b. Existing lighting was warranted for installation; and
- c. Existing lighting is owned by a local agency.

In the event the local agency requests to have the relocated lighting system owned by the local agency reconstructed to an improved standard as part of the State contract, the difference in cost between replacement in kind and the construction requested shall be estimated and the agency shall agree to reimburse the State for the additional cost.

The reconstruction of existing street lighting facilities owned by a private utility is the responsibility of the utility and will be handled by the Division of Right of Way (see Chapter 2.2 for more information).



## Highways

When affected by construction on a State highway, existing street lighting facilities owned by a city, county, or lighting district shall be reconstructed at the sole expense of the owner unless prior rights can be established.

In the event a local agency desires to have an existing continuous lighting system along a State highway reconstructed to an improved standard, or a new system built above Caltrans standards, the cost to Caltrans shall be limited to its share of the lighting at those locations where lighting is warranted.

## Chapter 1.7 – Lighting Levels

The level of illumination on freeways, expressways, and controlled intersections are dictated by the roadway classification and pedestrian volumes.

See appropriate tables A through G in Appendix B for information on Average Maintained Illuminance, Uniformity Ratio, and lighting levels for pedestrian crosswalks.

## Chapter 1.8 – Lighting Area

### *Freeway or Highway*

Critical points are the points in the highway or freeway where the driver will have to decide on which through lane to follow or where there is a conflict. The following are critical points:

- a. Decision point – location where the motorist must decide on which lane to follow.
  - (i) Example 1: The decision point is at the location where one through lane transitions into two through lanes or where one through lane transitions into one through lane and an exit ramp.
  - (ii) Example 2: The beginning of the exit ramp gore is the decision point.
- b. Merge point – location where two or more lanes merge into one. The merge point is where the merging lane becomes 9 feet wide.

Lateral means going along the direction of travel of the highway (parallel to the highway).

Longitudinal means going across the highway (perpendicular to the highway).

The minimum lighting areas for conventional highway, expressway, and freeway are defined as follows:

- a. Decision point:
  - i. Lateral boundary: Starts 90 feet upstream the merge point and ends 270 feet downstream the merge point.
  - ii. Longitudinal boundary: Starts at the right-side edge of travel way and ends at the left-side edge of travel way for a 4 or lower lane highway. For wider highways, the boundary starts at the right-side edge of travel way and ends 48 feet across the highway. The usual ending boundary is at the lane line between the 4th and 5th lane



- if the lane widths are the standard width of 12 feet. (The 48 feet is for 4 lanes:  $4 \times 12$  feet=48 feet.)
- b. Merge point:
    - i. Lateral boundary: Starts 90 feet upstream the merge point and ends 90 feet downstream the merge point.
    - ii. Longitudinal boundary: Starts at the right-side edge of travel way and ends at the left-side edge of travel way for a 4 or lower lane highway. For wider highways, the boundary starts at the right-side edge of travel way and ends 48 feet across the highway. The usual ending boundary is at the lane line between the 4th and 5th lane if the lane widths are the standard width of 12 feet. (The 48 feet is for 4 lanes:  $4 \times 12$  feet=48 feet.)

For examples, see Appendix A.

The lighting area lateral boundary is extended if ramp traffic meets the volumes shown in Appendix B, Table F, during one hour of darkness.

### *Intersection*

The lighting area for intersection is defined by the area bounded by the crosswalks. Where there are no crosswalks, the lighting area is defined by the area normally bounded by the crosswalks.

## **Chapter 1.9 – Plans, Coordination, and Processing**

General requirements for submitting plans, specifications, and estimates (PS&E) are noted in the *Project Development Procedures Manual* and the *Caltrans Construction Contract Development Guide*.

The designer should coordinate with the Division of Engineering Services, Office of Structure Design to coordinate with a structure engineer for the exact location of luminaires and pull boxes, foundation details, and conduit routes through the bridge structure to ensure proper design is included for all structures within the project limits.

## **Chapter 1.10 – Environmental Coordination**

Coordination between Design and Environmental should begin early in the project development process and continue through construction. The Project Development Team (PDT) should work together to identify potential lighting impacts or requirements related to environmental resources ensuring that the project complies with applicable state and federal laws and regulations. Potential lighting impacts can include disturbances to bird nestings or sensitive habitats, or work that is within a coastal zone or historic district. The designer should consult with their District Environmental / Biology offices and the Caltrans Standard Environmental Reference (SER) for potential lighting mitigation measures.

Some potential lighting mitigation measures may include:

- a. Utilizing roadway lighting analysis software to perform lighting level analysis in areas of concern such as Environmentally Sensitive Areas (ESA).



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- b. Reducing correlated color temperature (CCT) of proposed lighting fixtures. See Appendix D for definition. Current Caltrans Standard Specifications require a nominal CCT of 3000 K. Document changes in project design files.
- c. Lowering luminaire mounting heights. (Consult HQ Structures if non-standard lighting standards are used)
- d. Installation of luminaire glare shields.



## Chapter 2 – Freeway Lighting

### Chapter 2.1 – Introduction

In general, freeway lighting includes the following characteristics:

- Freeway lighting refers to lighting that is provided for freeways, expressways, and limited-access roadways.
- Freeway lighting consists of complete interchange lighting, including all ramps, mainlines, cross streets, gore areas, and intersections.
- Freeway lighting serves to illuminate areas of potential vehicle conflict and to delineate exit ramps, entrance ramps, and gore areas.
- The designer may consider extending the limits of the conflict area to include side-specific areas, such as intersections, points of access, means of egress, curves, and steep hills.
- Lighting shall be installed where unusual freeway geometrics exist and traffic volume warrants are met. Current enhanced conspicuity standards for signage, markings, and delineation make it feasible in such situations to defer the installation of lighting facilities until required by increased traffic.

### Chapter 2.2 – Warrants

#### Definitions

- a. Urban, Suburban, and Rural Conditions. Urban conditions exist in areas designated on maps approved by the FHWA. Suburban conditions exist in areas contiguous to the designated urban areas. Rural conditions exist in all other areas.
- b. Average daily traffic (ADT) is the average calculated for up to five years after the freeway is opened to traffic.
- c. Arterial<sup>1</sup> roadways provide a high level of mobility, often in the form of fully or partially controlled access highways, with no or very few intersecting roadways to hinder traffic flow.
- d. Collector<sup>1</sup> roadways provide a more balanced blend of mobility and access to land and residence. (Collectors “collect” traffic from local roads and connect traffic to arterial roadways.)
- e. Local<sup>1</sup> roadways provide a high level of accessibility, provide direct access to adjacent land (e.g. low-density residential, multiple properties) and higher systems (e.g., collector, arterial), and may carry no through traffic movement.

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<sup>1</sup> Road Definition (Arterial, Collector, Local) is defined in the FHWA: *Highway Functional Classification Concepts, Criteria and Procedures, 2013 Edition*.



## Freeway Interchange Lighting

Freeway Interchange lighting is warranted under either of the following conditions:

- a. Where the total sum of the ADT ramp traffic entering and leaving the freeway within the interchange area exceeds 5,000 under urban conditions, 3,000 under suburban conditions, and 1,000 under rural conditions. The above numbers refer to the total sum of the ADT for the normal four ramps at an interchange. Where the number of ramps connecting with the freeway is less than four, the above total sum of ADT may be reduced proportionately.
- b. Where the ADT on the freeway exceeds 25,000 for urban conditions, 20,000 for suburban conditions, and 10,000 for rural conditions.

## Freeway Interchange Lane Lighting

Freeway interchange lanes are the acceleration lane (entrance ramp), deceleration lanes (exit ramp), or any extra lane(s) that starts from an entrance ramp and ends at the next exit ramp. Lighting for freeway interchange lanes should be considered to illuminate the full-length of the lane if it is shorter than ½ mile.

## Freeway Ramp and Surface Street Intersection Lighting

Lighting at the intersection of a freeway ramp and a surface street is warranted if either of the conditions in Freeway Interchange Lighting (a) or (b) above are satisfied.

Typically, two luminaires are placed at each freeway exit ramp and one luminaire at each freeway entrance ramp. Typical locations are shown in Appendix A Figure A-1 and A-2. Typical locations for luminaires at the intersections of freeway ramps and surface streets are shown in Appendix A Figure A-2. One or more additional luminaires may be installed when justified by geometrics, traffic patterns, background ambient lighting and/or freeway ramp traffic volumes. This configuration should light the lighting area to the appropriate level shown in the Appendix B tables.

## Freeway Structures Lighting

Lighting on or under a freeway (underpass) structure is warranted under either of the following conditions:

- a. The lighting is illuminating acceleration lanes, deceleration lanes, weaving areas, or walkways.
- b. It is a part of local street lighting as stated in Chapter 2.5.

Provisions for future lighting may be installed in structures for freeway illumination only if there is a definite requirement to install lighting, as warranted above in Freeway Structures Lighting (a) or (b). Provisions for future lighting consist of conduits, pull boxes, foundations with anchor bolts, and flush soffit luminaires. The Project Engineer shall coordinate with the Division of Engineering Services, Office of Design and Technical Services.



Structures considered to be an underpass are those in which the length and physical configuration of the structure do not substantially limit the driver's ability to see objects ahead. No supplemental daytime lighting is required for these underpasses.

Short underpasses, such as those encountered where a roadway goes beneath two- or four-lane roadways, can generally be lighted with the standard luminaires for nighttime illumination only, if warranted.

Long underpasses, where overlapping of the lighting from the street luminaires cannot be accomplished, requires special treatment. When the lighting levels and uniformity on the roadway pavement are getting affected by the structure, then the underpass can be classified as "long" and will require additional daytime and nighttime lighting. And, if the pedestrian's lanes or sidewalks are included as part of the underpass then pedestrian lighting should be considered as per ANSI/IES RP-8-18 requirements.

## Chapter 2.3 – Entrance/Exit Ramps

This section includes general requirements for installing lighting on freeways.

Freeway entrance and exit ramps lighting includes:

- Freeway entrance and exit ramps (freeway ramps and connections)
- Freeway interchange
- Freeway ramps at single point interchange
- Freeway ramp meters

Typically, two luminaires are placed at each freeway exit ramp, starting at the full width of the exit lane, and a second luminaire placed at 180 feet downstream from it. This configuration should light the lighting area to the appropriate level shown in Appendix B tables. The luminaire position is to notify drivers of the decision point to exit the freeway.

Typically for each freeway entrance ramp, one luminaire is placed at the point where the on-ramp lane is tapered to nine feet wide and the adjoining freeway through lane is 12 feet. The luminaire position is to caution drivers of the merging freeway traffic to oncoming vehicles.

Typical locations for luminaires at the intersections of freeway ramps and surface streets are shown in Appendix A, Figure A-1 and A-2 (Partial Cloverleaf Interchange or Diamond Interchange). The lighting area can be increased when justified by geometrics, traffic patterns, background ambient lighting, or freeway ramp traffic volumes.

For metered freeway entrance ramps, a minimum of one luminaire should be placed at the limit line of metered-entrance ramp lanes.

The luminaire spacing and quantity of poles used for the entrance and exit ramps should be adjusted to achieve the lighting level shown in Appendix B.





## **Chapter 2.4 – Freeway to Freeway Connections**

Luminaires at freeway to freeway connections should be located as shown in Appendix A, Figure A-5. The typical advanced locations for luminaires at the diversion from one freeway to another is to warn drivers of the following:

- a. When additional lanes are added or reduced from the freeway or highway.
- b. Merging traffic between vehicles toward their destination routes.

## **Chapter 2.5 – Lighting of Local Streets Within Limits of Freeway Projects**

### **Chapter 2.5A – Lighting of Existing Local Streets Within Limits of Freeway Projects**

The lighting of existing local streets within the limits of a freeway project, including lighting on local streets over or under the freeway, is warranted if:

- The local street is lit to modern standards up to the freeway right of way and the local agency agrees to assume ownership and cost of maintenance; or
- The local street is not lit to modern standards and the local agency agrees to assume ownership and all costs of installation and maintenance.

If a local agency indicates that it proposes to install lighting on the local street within five years after construction is completed, the following should be installed on the project at 100 percent State expense:

- Conduits and other equipment in and under paved areas.
- Provisions for future structure lighting as stated in Chapter 2.2 under Freeway Structure Lighting.

### **Chapter 2.5B – Lighting of New Local Streets Within Limits of Freeway Projects**

Installing lighting on new local streets, including new frontage roads, that are constructed on a new alignment for a local agency shall be governed by the following:

- Lighting may be installed when requested by the local agency, only if there is existing lighting in the area and if that lighting is owned by the local agency. The lighting design and financing shall follow the guidelines in Chapter 1.5.
- Where the existing lighting is owned by a private utility, only equipment that will be in or under paved areas shall be installed by Caltrans (see Chapter 1.5).

If no lighting exists in the area, new lighting shall be installed only if the local agency agrees to finance the installation and to assume the cost of ownership and maintenance.



## Chapter 3 – Highway Lighting

### Chapter 3.1 – Introduction

The purpose of highway lighting is to promote the safe and orderly movement of traffic by illuminating certain permanent features or conditions that are unusual and require additional care and alertness to navigate.

When highway lighting is to be installed at an intersection, the “Basic” illumination requirements are provided as shown in Appendix B.

Lighting on highways and expressways shall be limited to lighting requirements at the intersection with traffic signals, flashing beacons, stop/yield controls, and locations where lighting is warranted, as shown in Chapter 3.2.

The existence of an intersection is not itself a justification for lighting.

A minimum of two luminaires should be placed on the downstream side of the intersection. The luminaire position is to notify drivers the perimeter of the intersection, past the approaching limit line, as well as the surrounding geometrics of the area (see Appendix A, Figure A-3, and A-4).

For each signalized intersection, a minimum of one luminaire should be placed at each corner to illuminate the pedestrian crosswalk. The lighting level emphasizes the middle of the intersection to all turning and oncoming vehicles.

### Chapter 3.2 – Warrants

#### 1. Existing Intersections.

Lighting may be provided at existing intersections on expressways and highways if one of the following conditions is fulfilled:

- a. Warrant 1, Condition A (Minimum Vehicular Volume) and Condition B (Interruption of Continuous Traffic) (See Figure 4C-101 (CA) Traffic Warrants Sheet Worksheet (Sheet 1 of 5)), or Warrant 4, Part 1, Section B (Pedestrian Volume) (See Figure 4C-101 (CA) Traffic Warrants Sheet Worksheet (Sheet 3 of 5) and Figures 4C-7 and 4C-8 from CA MUTCD) is satisfied for any single hour, which may be in darkness during winter Months.
- b. Four or more nighttime accidents in any recent consecutive 12-month interval or six or more nighttime accidents in any recent consecutive 24-month interval.
- c. Where a traffic signal or an intersection flashing beacon is installed.
- d. Where a controlled pedestrian crossing (e.g., Pedestrian Hybrid Beacon System) is installed.
- e. Where combinations of sight distance, horizontal or vertical curvature of the roadway, channelization, or other factors constitute a confusing or unsatisfactory condition that may be improved with lighting. The Project Initiation Document covering such lighting should include an explanation of the factors constituting the confusing or unsatisfactory condition.



## 2. New Intersections

- a. Lighting may be provided at new intersections on expressways or highways if there are indications that any of the warrants listed in 1(a) above will be fulfilled within five years after the opening of the project to traffic.

## 3. Replacement of Lighting Owned by Other Agencies (see Chapter 1).

## 4. Warrants for Continuous Highway Lighting

Continuous lighting may be provided with uniformity and average illuminance values in accordance with the current edition of ANSI/IES RP-8.

If one of the lighting warrants shown below is satisfied, then continuous lighting should be considered:

- Where a new pedestrian/bikeway is installed in an expressway
- If a crash analysis indicates that both the following conditions exist:
  - a. At least 30% of crashes occur at night over the last 5 years
  - b. High vehicle speed/volume sections with pedestrians/bikeway facilities



## Chapter 4 – Special Lighting Applications

### Chapter 4.1 – Introduction

Chapter 4 sets guidelines for special lighting applications used in projects. These applications entreat specific considerations that may differ depending on funding, available right of way, nearby electrical power, surrounding climate, etc. The special lighting applications include the following types:

- Bike paths
- Roundabouts
- Railroad grade crossings
- Park and ride lots
- Bus stops
- Signs
- Chain on/off areas
- Falseworks
- Tunnels
- High masts
- Temporary

### Chapter 4.2 – Bike Paths

The location of bike paths parallel to a freeway ramp and crossing and parallel to a roadway may warrant lighting.

This section covers the information needed for designing a lighting system that can be used for bike paths and/or pedestrian walkways and that are within the Caltrans right of way.

Roadway lighting improves the visibility for drivers, pedestrians and bicyclists near a freeway ramp or roadway. Lighting is considered warranted if a crash analysis indicates that at least 30% of crashes occur at night within last 5 years.

Lighting may be considered if either:

- a. A new pedestrian/bikeway is installed in an expressway
- b. High vehicle speed/volume sections exist with pedestrians/bikeway facilities

Light levels vary with the functional classification of the highway, the development of the adjacent area, and the level of nighttime activity.

Refer to Appendix B, Table B, C, and D.

### Chapter 4.3– Roundabouts

For a roundabout to work effectively, motorists should be able to enter the roundabout, move through the circulating traffic, and separate from the circulating stream in an efficient manner. To accomplish this, motorists should be able to see the general layout and operation of the



intersection in time to make the appropriate maneuvers. Adequate lighting should therefore be provided at all roundabouts.

When lighting a roundabout, key decision points and conflict areas should be illuminated. Crosswalks should be considered a part of the roundabout. Lighting poles should be placed in advance of a crosswalk to provide positive contrast for pedestrians. See Appendix A, Figure A-6 for the conflict area of a roundabout.

Roundabout lighting is also intended to identify:

- a. Central island parameters
- b. Splitter island nose radii and offsets
- c. Merging and diverging traffic

The advantage of providing positive contrast is that the vehicle headlights help increase contrast and improve the visibility of pedestrians in the crosswalk.

Additional lighting should be provided on the approach nose of the splitter islands at all conflict areas where traffic is entering the roundabout and all places where the traffic exits the roundabout.

The recommended lighting levels for roundabouts is shown in Appendix B, Table E.

## **Chapter 4.4 – Railroad Grade Crossings**

The purpose of railroad grade crossings lighting is to light the conflict area of the railroad crossings.

The conflict area includes the shoulders to 100 feet in front of the crossings in both directions.

Lighting poles should:

- a. Not be located closer than 33 feet from the railroad right of way.
- b. Be installed away from the tracks to avoid falling onto the tracks if knocked down.
- c. Not block visibility of the traffic signals used to warn drivers of approaching trains.

Designers should be familiar with road geometrics, including sidewalks, bikeways, signage, underground/overhead utilities, and railroad geometrics and crossing features.

Lighting may be provided at railroad grade crossings where a substantial amount of railroad operation is conducted at night, particularly where train speeds are low, where crossings are blocked for long periods, or a study indicates that motorists have trouble seeing trains or traffic control devices during the hours of darkness. For further information, see the CA MUTCD.

The recommended lighting levels for intersections with railroad crossings are shown in Appendix B, Tables A to G.



## Chapter 4.5 – Park and Ride Lots

Lighting for park and ride lots should be considered carefully. There may be several reasons why lighting is not provided, e.g., in a rural area where power line extension charges would be excessive.

The following guidelines should be used in determining the amount of lighting to be installed where it has been determined that providing lighting without excessive cost is feasible:

- Design the lighting to provide minimum 0.2 fc ( $E_{min}$ )
- Maximum uniformity ratio ( $E_{max}/E_{min}$ ) of 20:1
- Design for all-night illumination.

## Chapter 4.6 – Bus Stops

Bus stops qualify as major activity areas and are warranted for lighting. Particularly, bus stops within State highways, such as areas between Interchanges and at State-owned park & ride lots, should be lit. At locations within an interchange area where a special ramp for buses and a bus stop are provided, a minimum of one luminaire should be provided. Illumination should be provided at bus turn-outs, passenger loading areas, passenger benches, shelters, and crosswalks.

Lighting design should include bus turn-outs, passenger loading areas, passenger benches and shelters, and crosswalks.

The responsibility for lighting at bus stops may be shared with the local agency. The designer should consider illuminating bus stops with shelters as they usually result in higher passenger usage.

Illumination requirements are often a policy of individual local agencies; however, installing lighting that provides between 2 to 3 fc is the general recommendation.

A co-op agreement or maintenance agreement between Caltrans and the local Agency would ensure that operations and maintenance of lighting at bus stops are proportionally shared by the jurisdictions.

## Chapter 4.7 – Overhead Signs

In general, all new Overhead sign panels will come with ASTM Type XI retroreflective sheeting that will not require lighting. See Traffic Operations Policy Directive 14-02 Revision 1.

However, lighting for overhead signs may be needed if a location meets one of the following criteria:

- Signs skewed with angles greater than 25 degrees and are not legible when illuminated by vehicle headlights.
- Signs adjacent to other signs requiring or having sign lighting.
- Signs located along a horizontal curve with a radii of 880 feet or less in rural areas and radii of 2,500 feet or less in urban areas.



- Where vertical sag curves 1,000 feet or closer to overhead sign panels will limit vehicle headlight illumination of signs.

The sign lighting equipment, number of fixtures, and installation details are shown in the Standard Plans.

## Chapter 4.8 – Chain On/Off Areas

The purpose of lighting chain on/off areas is to improve safety for the travelling public when they are installing or removing chains. Lighting should illuminate pedestrians working along the roadside immediately adjacent to traffic. Increasing the lighting levels and lighting uniformity at chain on/off areas improves visibility for motorists.

- Design the lighting to provide minimum 3.0 fc ( $E_{avg}$ )
- Maximum uniformity of 3:1 ( $E_{avg}/E_{min}$ )

## Chapter 4.9 – Falsework

Falsework lighting should be considered for all passageways, including pedestrian openings through or under falsework. The faces of all falsework and forms located within or adjacent to the traveled way should be illuminated on the approach sides during the hours of darkness.

Refer to Standard Specification Section 48-2 for more details on falsework lighting.

The illumination levels for falsework during construction activities are shown in Appendix B, Table G.

## Chapter 4.10 – Tunnels

Tunnels should have sufficient illumination during the day so that vehicles inside the tunnel may be seen by approaching motorists. All interior walls and ceilings of tunnels to be lighted should be painted or tiled in a light color. All concrete surfaces to be painted should have a Class 1 finish. Tunnels less than 300 feet long normally do not require daytime lighting but interior walls and ceilings should be painted. Day and night lighting should be installed for tunnels that:

- Have vertical or horizontal curves in the road that may obstruct visibility;
- Are over 300 feet long; or
- Include walkways, pedestrians, or bicycle paths.

The recommended lighting level for tunnels is shown in Appendix B, Table C.

Designers should consult with the Division of Engineering Services, Office of Structure Design when designing non-standard poles and sign structures, modifying existing standards, and designing new traffic signal poles with special loading.

The Project Engineer should coordinate with the Office of Design and Technical Services to ensure that the proper structure design approach is included in the PS&E phase of the project.

To request the special design application, designers should complete and submit the “Signs and Overhead Structures” form to the Division of Engineering Services a minimum of three months



prior to the Ready to List phase of the project. Designers should also provide all required forms and supporting documents (layouts, cross sections, photos, etc.).

## Chapter 4.11 – High Masts

The use of high mast lighting systems may be considered where regular lighting standards are difficult to install and maintain. However, high mast lighting should not be applied in substantially developed residential areas to avoid lighting trespass.

Selection between conventional and high mast units should consider several factors: installation and maintenance costs, traffic volume, and possibility of lighting pollution.

Conventional lighting often requires lower installation costs on non-interchange roadway segments, while high mast lighting is less expensive for interchange areas because of reduced conduits and conductors, and requirements for fewer lighting fixtures and poles.

Maintaining high mast lighting also costs less because it involves less extensive lane closures.

Regardless of whether high mast or conventional lighting are used, the same lighting levels and uniformity ratios should be used.

## Chapter 4.12 – Temporary

A temporary lighting system may be used to light the work area and the adjacent roadway. These systems use existing or temporary poles to mount luminaires and may include high-mast lighting. Standard roadway luminaires are usually installed. Installing a temporary lighting system allows for uniform spacing of luminaires at high mounting heights, resulting in uniform lighting with low glare.

Temporary roadway lighting should be considered for the following circumstances:

- Abrupt changes in the roadway alignment, including lane reductions
- A medium or high pedestrian activity is present
- Locations with high traffic volumes
- Presence of a fixed roadway lighting system in the work area (existing light levels should be maintained, possibly augmented)
- The work area location is identified as having operational problems (e.g., a high nighttime crash rate)

Maintain required illumination during all construction activities, except when shutdown is permitted to allow for alterations or final removal of the system per the Project Engineer. Site preparation, widening, drainage, guardrail installation, or other work can easily impact existing conduit runs or luminaire locations. Also, changed conditions, such as merging, weaving, or unusual alignment due to traffic control, often require additional temporary illumination.

**Note:** The same lighting requirements apply whether a condition is temporary or permanent.





## Chapter 5 – Structure Lighting Facilities

### Chapter 5.1 – Introduction

Designers should consult with the Division of Engineering Services, Structure Design, Office of Electrical, Mechanical, Water & Wastewater (EMWW) for the following lighting applications.

These lighting applications are:

1. Road tunnels
2. Exclusive pedestrian facilities
  - 2.1. Undercrossings
  - 2.2. Overcrossings
3. Transportation-related facilities:
  - 3.1. Safety roadside rest areas
  - 3.2. Commercial vehicle enforcement facilities (truck inspections)
  - 3.3. Toll plazas
  - 3.4. Agriculture inspection facilities
  - 3.5. Maintenance stations
  - 3.6. Transportation labs

Conduit on structure should be run either parallel to or at right angles to the structure girders. A variation of  $\pm 15$  degrees is acceptable. Except for sidewalk joints, a conduit expansion fitting should be installed at each structure joint, hinge or abutment where a longitudinal movement of 0.5 inches or greater may occur. Where a lateral movement of 0.25 inches or greater may occur, an expansion-deflection fitting should be installed. Details for placement of expansion fittings and expansion-deflection fittings are shown in the Standard Plans.

### Chapter 5.2 – Road Tunnels

The new tunnel lighting systems should be designed and installed to comply with the following applicable codes:

1. California Electrical Code
2. ANSI/IES RP-8-18 (Chapter 14-Tunnels)

Lighting for new road tunnels located in rural areas and lighting upgrades to existing road tunnels will be evaluated on case-by-case basis to determine if meeting specific design features is feasible and cost effective.

The road tunnel lighting fixtures must comply with the following criteria:

1. LED type
2. Addressable for remote monitoring and control
3. Continuously dimmable (from 10 percent to maximum output)

Road tunnel lighting consists of lighting for the tunnel approach and roadway inside the tunnel. The tunnel lighting control system should also be upgraded. Road tunnel lighting levels shall be evaluated using lighting software.



### Chapter 5.3 – Exclusive Pedestrian Facilities

The lighting for exclusive pedestrian facilities within the freeway project is warranted at the following locations:

- a. Pedestrian undercrossings
- b. Pedestrian overcrossings

Lighting shall be provided on pedestrian undercrossings and overcrossings where the local agency agrees to assume ownership and cost of maintenance. Pedestrian undercrossings (no vehicular traffic) shall be provided with adequate daytime and nighttime illumination. The designer should coordinate with the Division of Engineering Services, Office of Design and Technical Services.

- a. Pedestrian Undercrossing

Lighting for long undercrossings should be considered carefully. The purpose of this lighting is for safety and security considerations. Undercrossings should also have daytime lighting.

The recommended maintained illuminance values for undercrossings are shown in table 5.1.

**Table 5.1: Maintained Illuminance Values for Pedestrian Undercrossing**

	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
Day	9.3	3.0
Night	3.7	3.0

- b. Pedestrian Overcrossings

This section provides information needed for designing lighting systems used for pedestrian overcrossings. Pedestrian overcrossings are facilities that provide a connection between pedestrian walkways as well as connecting the bike paths. Therefore, the use of pedestrian overcrossings is limited to pedestrians and bicyclists.

In general, lighting is required to be installed on pedestrian overcrossings within Caltrans right of ways.

The location of the proposed overcrossing requires special consideration for lighting levels due to environmentally sensitive areas, such as rivers, creeks, and wetlands. Lighting installed on the overcrossing may produce glare that should be shielded from spreading to the structure where light can be a distraction for motorists using the highway and frontage road.

The design criteria for pedestrian overcrossings are based on horizontal and vertical illuminance. The required minimum for maintained horizontal illuminance provides visibility of bikeways and walkways surfaces and their boundaries for their respective users.



**Table 5.2: Maintained Illuminance Values for Pedestrian Overcrossing**

Mixed Pedestrian and Bicyclist	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
	0.5	4.0

Consider limited hours of lighting or user-actuated lighting design to minimize unnecessary emissions when the bridge is not in use.

### Chapter 5.4 – Transportation-Related Facilities

Lighting design for new transportation-related facilities and major renovations should be designed and constructed to exceed 15 percent of the applicable version of Title 24, Part 6 Building Energy Efficiency Standards.

Lighting for the transportation-related facilities consists of interior building lighting and exterior walkway or parking lot lighting for these facilities. The foot-candle requirements for interior spaces within these facilities should be as listed in the Maintenance Station Design Manual. The exterior walkway or parking lot lighting should follow the guidelines listed in the ANSI/IES RP-8-18.

In addition, the controls for interior and exterior lighting should meet all the mandatory and perceptive requirements of Title 24, Part 6.



## Chapter 6 – Luminaires

### Chapter 6.1 – Roadway Luminaires

Utility-owned semi-cutoff type luminaires should be provided with glare shields in rural areas.

### Chapter 6.2 – Soffit Luminaires

Normally, the fixtures should not be located over the traveled way on freeways.

### Chapter 6.3 – Wall Luminaires

Wall luminaires are fixtures designed to be surface mounted on vertical surfaces. However, a simple right-angle bracket permits mounting them from a horizontal surface such as the bottom slab of a box girder. They are used with the same lamps as soffit luminaires.



## Chapter 7 – Lighting Software

### Chapter 7.1 – Introduction

With this manual, Caltrans introduces a new tool to assist designers with designing roadway lighting. Lighting software applications will replace the old technique of using the Isofootcandle templates. The lighting industry is using lighting design analysis software that allows the importing of roadway CAD files. These CAD files typically contain roadway properties on different layers (e.g. edge of pavement, road shoulder, stationing, structures, curbs, sidewalks). Designers will need to eliminate and combine the layers into one layer, confirming the scales and units used in the files.

### Chapter 7.2 – Lighting Design Using Software Applications

There are four basic steps to roadway lighting design using lighting analysis software applications:

1. Perform an initial assessment to become familiar with the project location and the specific design requirements;
2. Select the types of fixtures and poles to be used;
3. Determine lighting pole placements for constructability and maintainability; and
4. Perform appropriate lighting analysis to ensure conformance to design criteria and lighting levels.

Designers will utilize roadway CAD files and the lighting manufacturers' photometric files to calculate lighting levels for a roadway segment or an intersection. These photometric files are files with an IES file extension. The IES files include the photometric characteristics produced for each luminaire.

### Chapter 7.3 – Software Applications and Validation

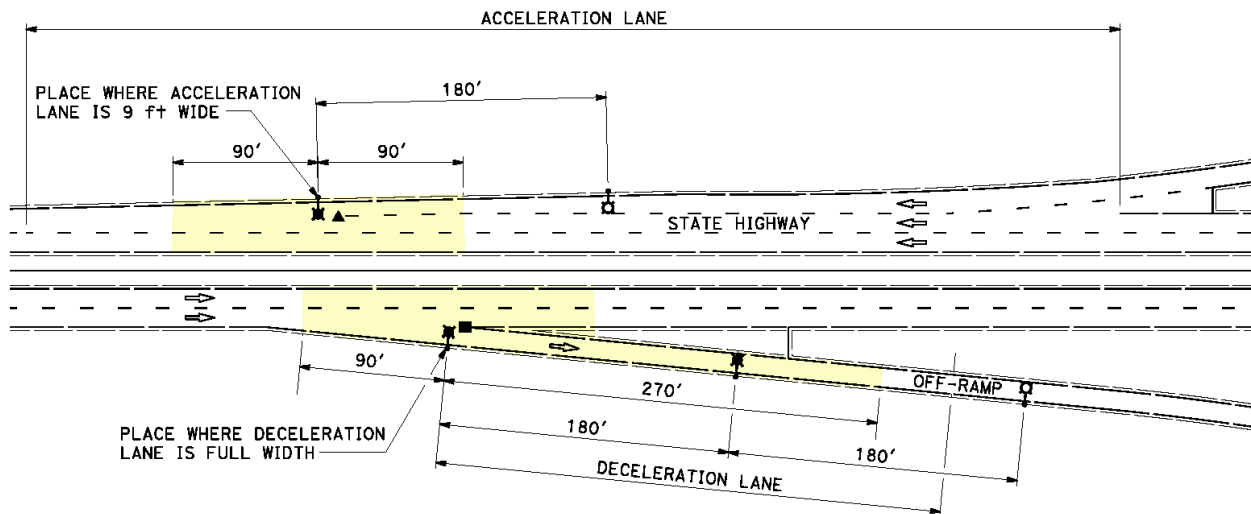
If time allows, field lighting measurements should be taken for a lighting project once it is installed and over time as the system ages. The Department should periodically validate luminaire photometrics, ensuring that the luminaires are providing the expected light output and distribution, and to confirm that lighting levels and lighting uniformity comply with recommended practice and design specifications.

ANSI/IES RP-8-18 “Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting,” provides detailed instruction on how lighting measurements should be conducted in the field.



## Appendix A – Figures and Diagrams (Typical)

Figure A - 1: Freeway Lighting



**NOTE:**

LUMINAIRE PLACEMENT IS TYPICAL. THE DESIGN ENGINEER SHOULD ADJUST THE LUMINAIRE LOCATIONS AND NUMBER TO MEET THE LIGHTING LEVELS SHOWN IN APPENDIX B.

**LEGEND:**

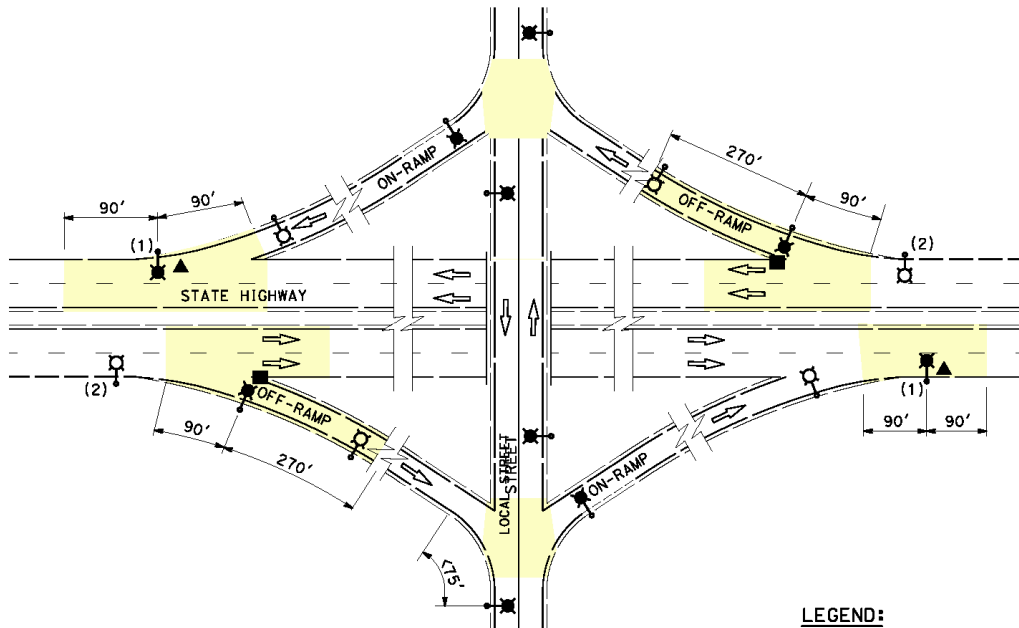
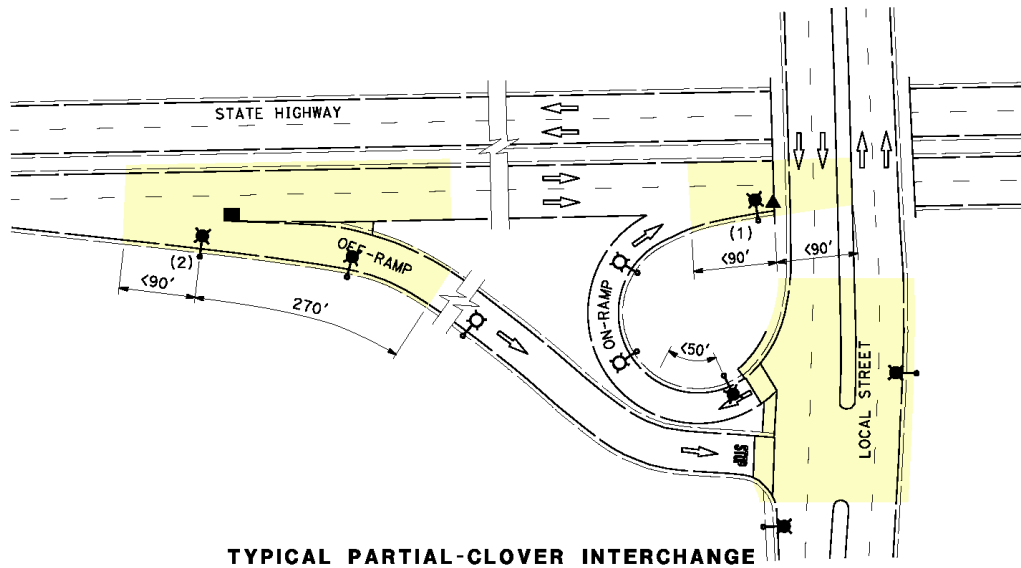
- BASIC ELECTROLIER
- ADDITIONAL ELECTROLIER (WHEN REQUIRED)
- CONFLICT AREA
- DECISION POINT
- MERGE POINT

**FIGURE A-1:  
FREEWAY LIGHTING**

NO SCALE



**Figure A - 2: Freeway Lighting**



**DIAMOND INTERCHANGE**  
**FIGURE A-2:**  
**FREEWAY LIGHTING**

**LEGEND:**

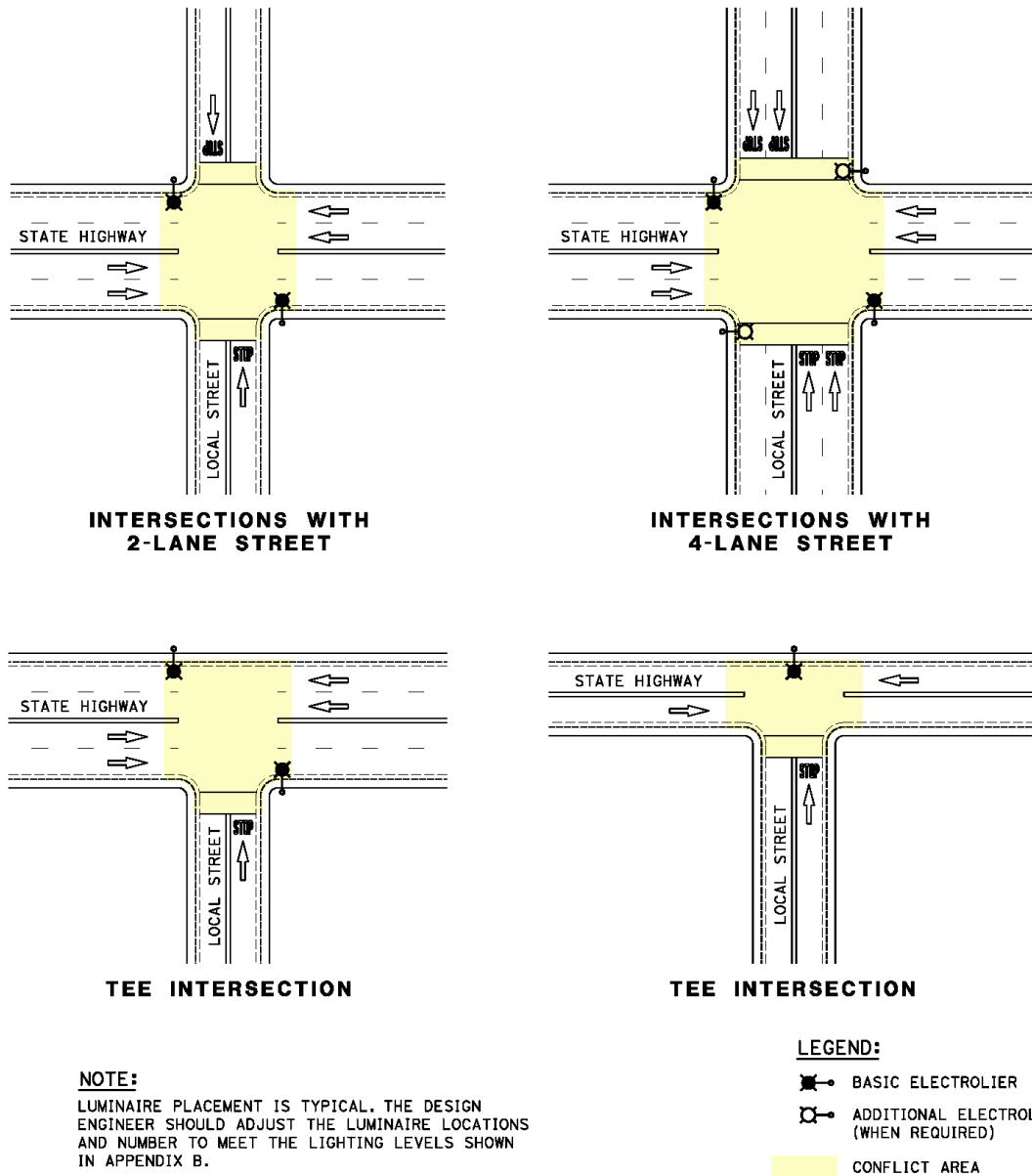
- BASIC ELECTROLIER
- ADDITIONAL ELECTROLIER (WHEN REQUIRED)
- CONFLICT AREA
- DECISION POINT
- MERGE POINT

**NOTES:**

- (1) PLACE WHERE ACCELERATION LANE IS 9 FT WIDE. NO SCALE
- (2) PLACE WHERE DECELERATION LANE IS FULL WIDTH.
- (3) LUMINAIRE PLACEMENT IS TYPICAL. THE DESIGN ENGINEER SHOULD ADJUST THE LUMINAIRE LOCATIONS AND NUMBER TO MEET THE LIGHTING LEVELS SHOWN IN APPENDIX B.



**Figure A - 3: Intersection Lighting**



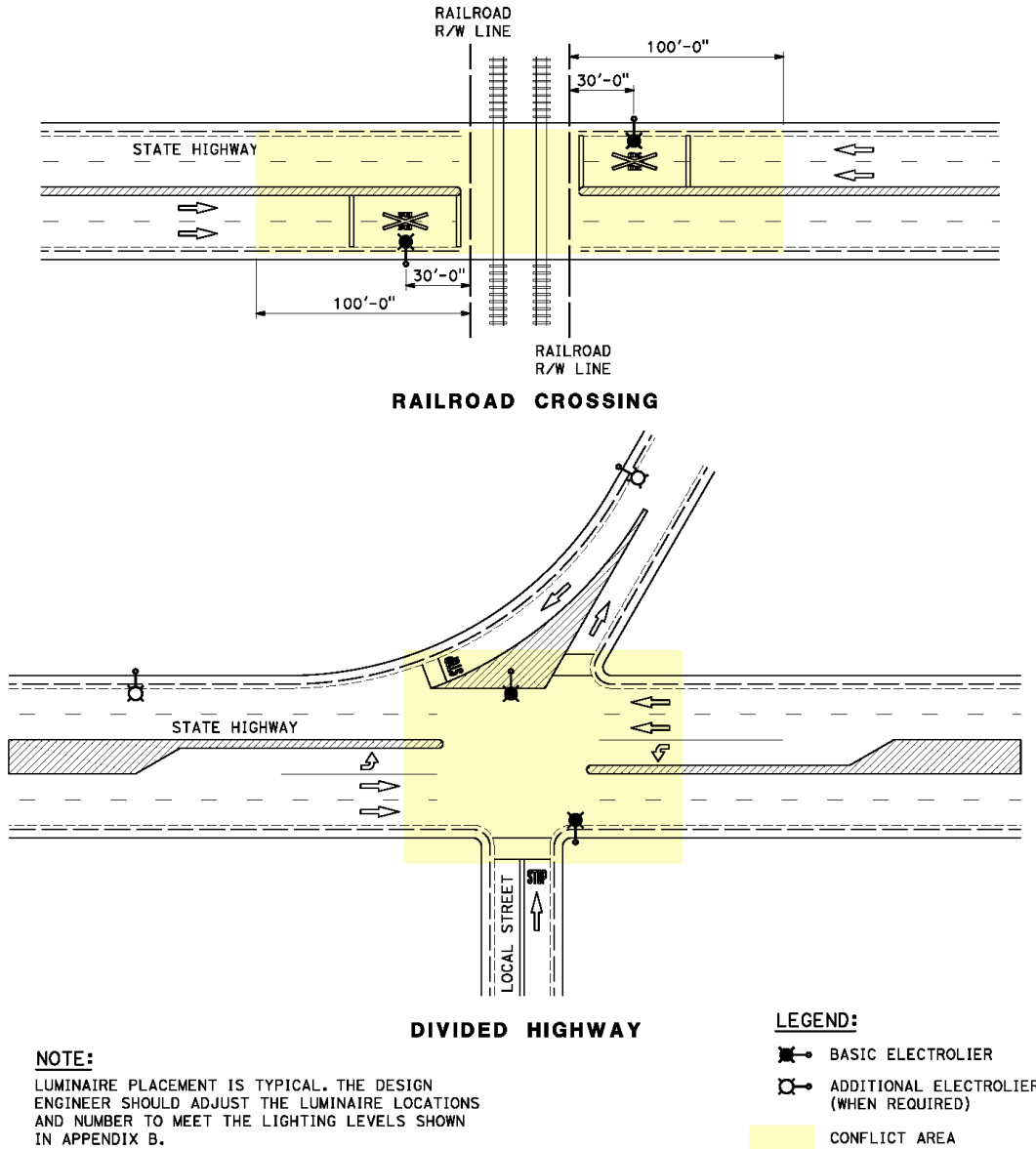
**FIGURE A-3:  
INTERSECTION LIGHTING**

NO SCALE





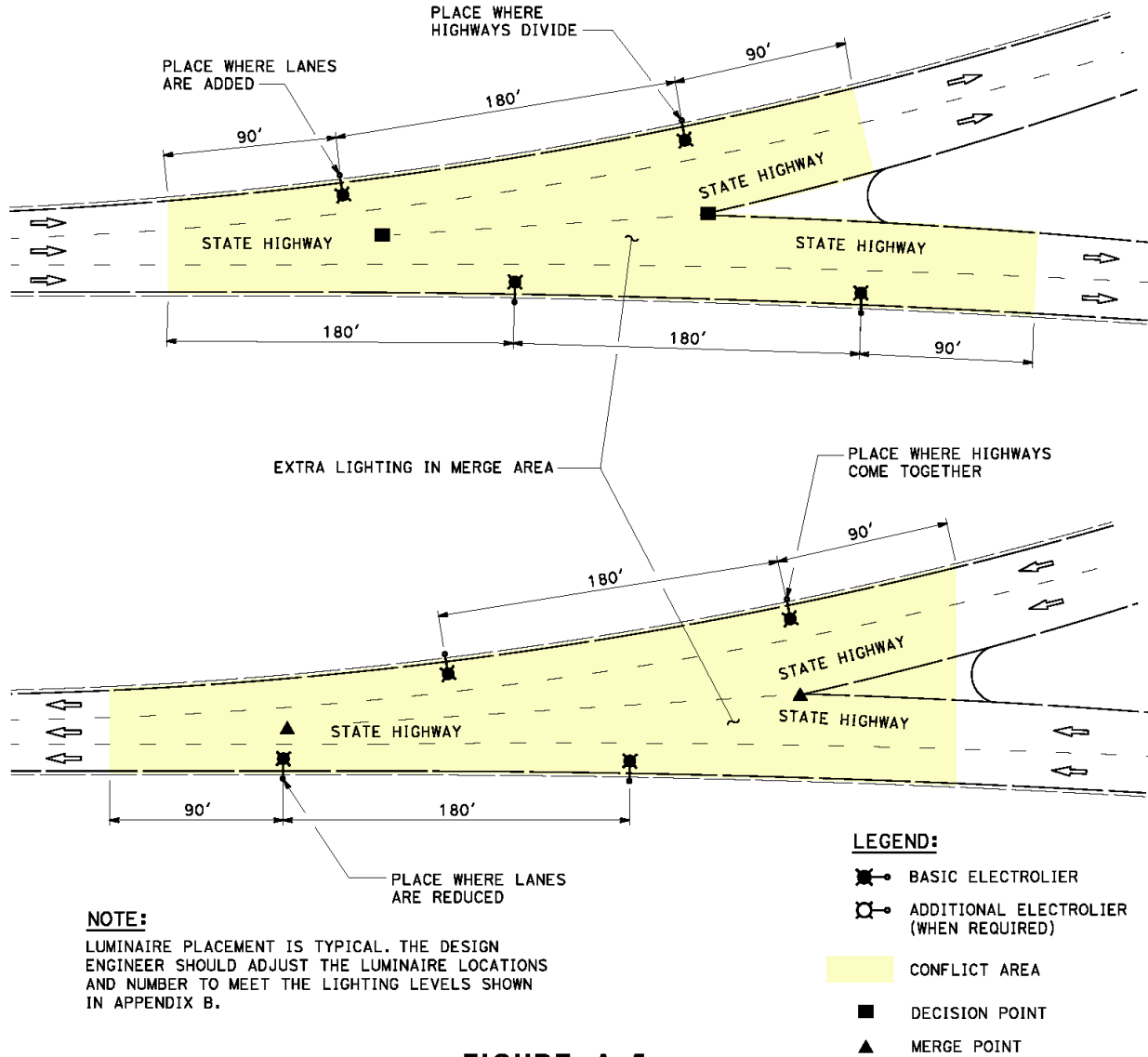
**Figure A - 4: Railroad Crossing and Intersection Lighting**



**FIGURE A-4:  
RAILROAD CROSSING AND  
INTERSECTION LIGHTING**  
NO SCALE



**Figure A - 5: Freeway to Freeway Connections**



**FIGURE A-5:  
FREEWAY TO FREEWAY CONNECTIONS**

NO SCALE



Figure A - 6: Roundabout Lighting



**Note:**

For Guidance on Luminaire Placement, See Chapter 4.3, Roundabouts

Drawing Source: ANSI/IES RP-8-18

**LEGEND**

 CONFLICT AREA

**FIGURE A - 6:  
ROUNDBOUT LIGHTING  
NO SCALE**



## Appendix B – Tables

### Lighting Design Criteria for Highways

Freeway lighting levels shown in Table A are based on roadways with limited access and low (or even no) significant pedestrian or bicyclist activity.

Expressway lighting levels are higher than freeway lighting levels. This is due to the increase in conflict points at intersections and driveways and a low level (less than 100 per hour) of pedestrian presence.

All lighting levels shown are in illuminance. The 2018 Illumination Engineering Society (IES)/ANSI RP8 recommends luminance for some values, but illuminance is chosen for Caltrans, since it is simpler to verify in the field. 2018 ANSI/IES RP8 chapter 3.2 gives luminance to illuminance conversion for R2 or R3 class roadway surface<sup>2</sup>. The conversion factor is 1 cd/m<sup>2</sup> to 1.39 fc. The calculation is shown below.

$$1 \frac{cd}{m^2} * \frac{15 lux}{1 \frac{cd}{m^2}} * \frac{1 fc}{10.76 lux} = 1.39 fc$$

Roadway 10 (R10) luminaires are typically mounted on Type 15 standards for conventional highway lighting.

Roadway 11 (R11) luminaires are typically mounted on Type 15 standards for expressways.

Roadway 12 (R12) luminaires are typically mounted on non-Type 15 standards for freeways.

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<sup>2</sup> R2 or R3 class roadway surfaces represent asphalt road surfaces. These are the worst-case scenario for light reflectance. For more information, see 2018 Illumination Engineering Society (IES)/ANSI RP8 publication 3.1.5 pavement classification.



Table A<sup>3</sup>: Design Criteria for Highways

Roadway Classification	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
Freeway	0.8	3.5
Expressway	1.4	3.0
Conventional	1.4	3.0

<sup>3</sup> Reference to 2018 Illumination Engineering Society (IES)/ANSI RP8 publication, table 10-1: Example: freeway and expressway, with no or low pedestrian (i.e. less than 10 pedestrians per hour at nighttime).



### Lighting Design Criteria for Isolated Intersection

Lighting may be required at an isolated intersection where continuous lighting does not exist. Lighting levels for isolated intersections should meet the light levels for the type of road where the intersection is located. The values included in Table B are based on R2 and R3 pavement classifications.

When the intersection roadways have different classification, the intersection is classified as the higher ADT classification.

Table B<sup>4</sup>: Lighting Design Criteria for Isolated Intersection Lighting

Roadway Classification	PED/hr	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
Major Intersection	< 100	0.8	3.0
Collector Intersection	< 100	0.6	4.0
Local Intersection	< 100	0.4	6.0

<sup>4</sup> Reference to 2018 IES/ANSI RP8 publication, table 12-2: Example: freeway and expressway, with low or medium pedestrian (i.e. less than 100 pedestrians per hour).



## Lighting Design Criteria for Streets

Street lighting is provided for roads where pedestrians and bicyclists are present. These roads can range from major to collector streets and require different lighting levels based on the expected pedestrian volumes. The recommended values for street lighting are shown in Table C.

**Table C<sup>5</sup>. Lighting Design Criteria for Streets**

Roadway Classification	PED/hr	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
Major	> 100	1.67	3.0
Collector	> 100	1.11	3.0

## Illumination for Intersections

The recommended lighting levels for intersections of continuously lit roadways are based on the functional classifications of the intersecting roadways and level of pedestrian use. The values are taken from Table 11-1 in ANSI/IES RP-8-18 “Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting.” The functional classifications of roadways are based on the Institute of Transportation Engineers (ITE) Guidelines for Residential Subdivision Street Design:

- Major – Over 3,500 ADT
- Collector – 1,501 to 3,500 ADT
- Local – 100 to 1,500 ADT

<sup>5</sup> Based on RP8, table 11-1: Use the table based on the number of pedestrians (medium or high).



**Table D<sup>6</sup>: Pavement Illuminance Criteria for Full Intersection Lighting**

Roadway Intersection Classification	PED/hr	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
<b>Major/Major or Major/Collector or Major/Local</b>	> 100	3.2	3.0
<b>Major/Major or Major/Collector or Major/Local</b>	< 100	2.4	3.0
<b>Collector/Collector or Collector/Local or Local/Local</b>	> 100	2.2	4.0
<b>Collector/Collector or Collector/Local or Local/Local</b>	< 100	1.7	4.0

Table D should be used for Full Intersections Lighting with high pedestrian level, e.g., community facilities; libraries; recreation centers; near major airport; truck, rail, or bus terminals; activity centers, such as a central business center to large town centers, shopping center, or malls; large colleges; medical complexes; military bases and large institutional facilities; major industrial or commerce centers; and major recreational areas.

<sup>6</sup> Based on RP8, table 12-1 for intersections with a high pedestrian level. For high pedestrian locations the pedestrian volumes are more than 100 pedestrians/hour at nighttime. For medium pedestrian locations the pedestrian volumes are within 11 to 100 pedestrians/hour at nighttime. For low pedestrian locations the pedestrian volumes are less than 10 pedestrians/hour at nighttime for isolated locations.





**Table E<sup>7</sup>: Recommended Pavement Illuminance for Roundabouts, Based on Pedestrian Activity Classification**

Roadway Classification	Ped/hr	Minimum $E_{avg}$ (fc)	Maximum Uniformity $E_{avg}/E_{min}$
Major/Major or Major/Local or Major/Collector	> 100	3.2	3.0
Major/Major or Major/Local or Major/Collector	< 100	2.4	3.0
Collector/Collector or Collector/Local or Local/Local	> 100	2.2	4.0
Collector/Collector or Collector/Local or Local/Local	< 100	1.7	4.0
Local/Local & Isolated	> 100	1.7	6.0
Local/Local & Isolated	< 100	1.3	6.0

**Table F – Criteria for Lighting Area Longitudinal Addition at Exit and Entrance Ramps**

Freeway ADT	Exit Ramp Volume		Entrance Ramp Volume	
	>75,000	>300 vph	+90 feet downstream	>300 vph
>150,000	>700 vph	+180 feet downstream	>700 vph	+180 feet upstream

<sup>7</sup> Based on the ANSI/IES RP8 Table 12-4. The lighting levels are recommended for continuously lighted streets. For roundabouts on roadways that are not continuously lighted, the values for the local/local classifications should be used.



**Table G – Falsework Illumination Levels**

The minimum average illumination levels for falsework during construction are shown in the following table:

**Minimum Average Illumination Levels**

<b>Illumination Area</b>	<b>Minimum <math>E_{avg}</math> (fc)</b>
Pavement	0.8
Portal	1.0
Pedestrian Walkway	2.0



**Table H – Relationship Between Older LED Luminaires and LED Newer Luminaires Usage**

<b>Roadway Intersection Classification</b>	<b>PED/hr</b>	<b>Typical Older Luminaire</b>	<b>Typical Newer Luminaire</b>
<b>Major/Major or Major/Local or Major/Collector</b>	> 100	Roadway 2	Int L – A or Int M – A
<b>Major/Major or Major/Local or Major/Collector</b>	< 100	Roadway 2	Int L – B or Int M – B
<b>Collector/Collector or Collector/Local or Local/Local</b>	> 100	Roadway 2	Int M – A
<b>Collector/Collector or Collector/Local or Local/Local</b>	< 100	Roadway 2	Int M – B
<b>Isolated Major Intersection</b>	< 100	Roadway 2	Int L – C
<b>Isolated Collector Intersection</b>	< 100	Roadway 2	Int M – C
<b>Isolated Local Intersection</b>	< 100	Roadway 2	Int S – C
<b>Conventional Highway</b>		Roadway 1	Roadway 11
<b>Expressway</b>		Roadway 1	Roadway 11
<b>Freeway</b>		Roadway 2	Roadway 12



## Appendix C – Application Policies

### Lighting policies

[Breakaway/Slip Base Under Standards Located Along Freeways, Expressways, and Conventional Highways](#) – 10/15/1987

[Nonstandard Lighting Poles on Conventional State Highway Installed and Maintained by Others](#)  
– 1/25/1991

[Catwalks on Overhead Sign Structures](#) – 8/16/1991

[Clarification on Lighting of Sag Vertical Curves with Nonstandard Stopping Sight Distance](#) –  
5/11/1993

[Lighting for Nonstandard Sag Vertical Curves](#) – 6/16/1993

[Updated Managed Lane Design TOPD](#) – 4/7/2011

[Overhead Guide Sign Policy on the State Highway System](#) – 12/11/2014: Revision 1 and  
Follow-up memo dated 8/24/2015 for Implementation of Retroreflective Sheeting (Types VIII, IX,  
or XI) for Fluorescent Orange



## Appendix D – Definition of Terms

**adaptation:** process by which the visual system becomes accustomed to different light intensity or different light colors than it was exposed to previously. It results in a change in the sensitivity of the eye to light.

**ambient lighting:** general lighting used to provide visibility in a built environment. Ambient lighting includes both artificial and natural lighting and does not include task lighting and accent lighting.

**arterial:** see Roadway Classification - Major

**ballast:** device used with an electric-discharge lamp to obtain the necessary circuit conditions (voltage, current, and waveform) for starting and operating.

**bikeway:** any road, street, path, or way that in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

**brightness:** see luminance and subjective brightness.

**conflict:** occurs whenever the paths followed by vehicles diverge, merge, or cross.

**conflict area:** area of a roadway where the motorist's special attention is required to interpret the functional features (e.g. bullnose) and/or activities (e.g. pedestrians, turning vehicles, railroad grade crossing) of the roadway, to decide on their driving routine. It is that area which encompasses all the conflict points.

**conflict point:** point at which conflicts can occur.

**continuous lighting:** fixed overhead lighting system designed to provide a specific level of illuminance, luminance and uniformity of light on the roadway throughout a highway complex.

**contrast:** see **luminance contrast**.

**correlated color temperature (CCT):** unlike the color rendering index (CRI), which describes how faithfully a light source represents other objects, the correlated color temperature (CCT) describes the color output of the lamp itself. Some common CCT values include:

- 2700K, with a warm tinge of yellow that creates appealing and relaxing environments
- 4000K, a neutral white tone that strikes just the right balance between relaxation and concentration
- 6500K, with a slight tinge of blue, which has an energizing effect

Although the correct technical term is correlated color temperature, it is often shortened to only color temperature. It is also important to note that the CCT is not the real operating temperature of a lamp; it is the temperature to which you would have to heat a black body to make it glow with the same color. For example, an LED bulb with a CCT of 5000K glows in the same color as a black body heated to a real temperature of 5000K, but the LED bulb itself does not reach that temperature.



**crosswalk:** see pedestrian crosswalk.

**darkness:** any time from one-half hour after sunset to one-half hour before sunrise and any other time when visibility is not sufficient to render clearly discernible any person or vehicle on the highway at a distance 1,000 feet.

**discomfort glare:** glare producing discomfort. It does not necessarily interfere with visual performance or visibility.

**expressway:** divided highway with partial control of access.

**footcandle, fc:** unit of illuminance when a foot is taken as the unit of length. It is the illuminance on a surface that is one square foot in area, on which there is a uniformly distributed flux of one lumen. Or, it is the illuminance produced on a surface of all points that are one foot from a directionally uniform point source of one candela.

**glare:** sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility. Visual impairment caused by a bright source of light, directly visible or reflected by a surface. There are two types of glare:

- Discomfort glare causes an instinctive reaction to close the eyes and look away. This is the type of glare felt when exposed to a potent HID light or when the sun is directly visible through a window.
- Disability glare impairs vision but does not cause the same reaction as discomfort glare. If a light source gets reflected on your laptop screen, for example, it does not bother your eyes but distinguishing objects on the screen may be impossible.

**high-intensity discharge (HID):** type of lighting often used for industrial and outdoor settings due to its powerful output. Some examples of HID lighting are mercury-vapor, metal-halide, xenon, high-pressure sodium, and low-pressure sodium lamps.

**high mast lighting:** illumination of a large area by means of a group of luminaires that are designed to be mounted in fixed orientation at the top of a high support or pole (generally 20 meters or higher).

**high-pressure sodium (HPS):** subtype of HID lighting where excited sodium vapor is the source of light. The lighting output of HPS lamps is characterized by its warm yellow hue, and are commonly used in cobra-head street lights.

**Illuminating Engineering Society of North America (IESNA):** technical authority in the lighting industry, with dozens of publications to its credit. IESNA has members and recognition throughout the world.



**illuminance:** density of luminous flux incident on a surface, measured in footcandles, or fc (or lux, lx). One footcandle is the illumination of a surface one square foot in area on which there is a uniformly distributed luminous flux of one lumen. One footcandle is 10.76 lux. The illuminance requirements of built environments are determined by their intended purpose, and there are two common units of measurement:

- Lux - Equivalent to one lumen per square meter.
- Footcandle - Equivalent to one lumen per square foot.

Higher illuminance levels make surfaces appear brighter to the human eye and improve visibility.

**interchange:** road junction that uses grade separation, and typically one or more ramps, to permit traffic on at least one highway to pass through the junction without interruption from other crossing traffic streams.

**intersection:** general area where two or more roadways (highways) join or cross, including the roadway and roadside facilities for traffic movement within it.

**isolated Interchange:** separated roadway crossing with one or more ramp connections between the crossing roadways, which is lighted and is not part of a continuous roadway system.

**isolated Intersection:** lighted area in which two or more non-continuously lighted roadways join or cross at the same level

**kelvin (K):** measurement unit for temperature, although in the lighting industry it is more commonly used to indicate the CCT of light sources.

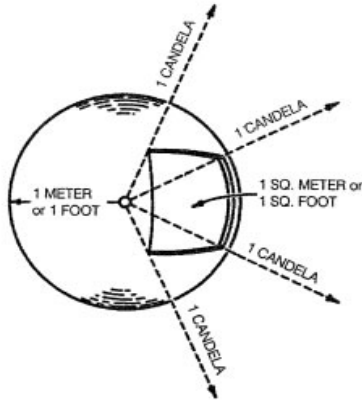
**kilowatt (kW):** measurement unit for electric power, equivalent to 1000 watts; thus, a 10kW light = 10,000 watts. This term should not be confused with kilowatt-hour. See watt.

**kilowatt-hour (kWh):** measurement unit for energy consumption. As implied by its name, it is equivalent to the amount of energy consumed by a one-kilowatt appliance running for one hour. Electric utility bills are often calculated based on kilowatt-hour consumption per month. This term should not be confused with kilowatt.

**L70:** extrapolated life in hours of the luminaire when the luminous output depreciates 30 percent from the initial values.



**lamp:** a generic term for an artificial source of light.



**Figure 2 – Relationship between candelas, lumens, lux, and footcandles:**

*A uniform point source (luminous intensity or candlepower = one candela) is shown at the center of a sphere of unit radius whose surface has a reflectance of zero. The illuminance at any point on the sphere is one lux (one lumen per square meter) when the radius is one meter, or one footcandle (one lumen per square foot) when the radius is one foot. The solid angle subtended by the area A, B, C, D is one steradian. The flux density is therefore one lumen per steradian, which corresponds to a luminous intensity of one candela as originally assumed. The sphere has a total area of 4 (or 12.57) square units (square meters or square feet), and there is a luminous flux of one lumen falling on each unit area. Thus, the source provides a total of 12.57 lumens.*

**lamp lumen depreciation factor (LLD):** multiplier to be used in calculations to relate the initial rated output of light sources to the anticipated minimum output based on the relamping program to be used.

**LED** (light-emitting diode): solid-state component that emits light when exposed to electric current. LED lighting represents the state-of-the-art in the industry, outclassing most other types of lighting in terms of energy efficiency, design flexibility, and colors of light available.

**light:** visually evaluated radiant energy.

**lighting standard:** pole and mast arm supporting the luminaire.

**lumen:** measurement unit for the lighting output of lamps or fixtures. The total lumens emitted and their spatial distribution are of paramount importance when creating appealing and luxurious indoor spaces. In lighting, lumens can be compared to miles traveled and watts can be compared to fuel consumption. Radiometrically, it is determined from the radiant power. Photometrically, it is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela.





**luminance, L (cd/m<sup>2</sup>):** quotient of the luminous flux at an element of the surface surrounding the point and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and area of the orthogonal projection of the element of the surface on a plane perpendicular to the given direction. The luminous flux may be leaving, passing through, and/or arriving at the surface. Note: In common usage the term "brightness" usually refers to the strength of sensation which results from viewing surfaces or spaces from which light comes to the eye. This sensation is determined in part by the measurable luminance defined above and in part by conditions of observation such as the state of adaptation of the eye.

**luminance (photometric brightness):** quantity of luminous flux emitted, reflected, or transmitted from a surface in a direction, measured in cd/feet<sup>2</sup> or cd/m<sup>2</sup>. This is the property of light we can visibly see with our eyes.

Term	Symbol	English Unit	Metric Unit	Relationship
Luminous Intensity	I	candela (cd)		$I = \phi/\omega$ , $\omega = A/r^2$
Luminous Flux	$\phi$	lumens (lm)		$\phi = I \omega$
Luminous Exitance	M	lm/ft <sup>2</sup>	lm/m <sup>2</sup>	$M = \phi'/A$
Illuminance	E	fc = lm/ft <sup>2</sup>	lx = lm/m <sup>2</sup>	$E = \phi/A$ 1 fc=10.76 lx
Luminance	L	cd/ft <sup>2</sup>	cd/m <sup>2</sup>	$L = I/A \cos \theta$

**luminaire:** includes the lamp, the ballast or driver, internal wiring, reflectors, lens and any additional components required to deliver light. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply. Sometimes includes ballasts and photocells. Assembly that houses the light source and controls the light emitted from the light source.

**luminaire cycle:** distance between two luminaires along one side of the roadway. Note: this may not be the same as luminaire spacing along the centerline considering both sides of the road. (See spacing.)

**luminous flux:** luminous flux is the measure of the total amount of energy radiated per second from a light source in all directions. It is measured in lumens. One lumen is defined as the luminous flux of the uniform point light source having a luminous intensity of 1 candela

**luminous flux density at a surface:** luminous flux per unit area at a point on a surface. Note: this need not be a physical surface; it may equally well be a mathematical plane.

**luminous intensity:** lighting emission in a specific direction, measured in candelas. Luminous intensity changes depending on the viewing angle. Not to be confused with luminous flux.

**lux:** SI unit for illuminance, or lumens per unit of area. One lux is equivalent to one lumen per square meter. A key component of lighting designed is achieving a suitable illuminance level depending on the application at hand. It is the illuminance on a surface one square meter in area on which there is a uniformly distributed flux of one lumen, or the illuminance produced at a surface all points that are at a distance of one meter from a uniform point source of one candela. Conversion Formula: fc x 10.8 = Lux.



**mercury lamp:** subtype of HID lamp that produces its lighting output by stimulating mercury vapor, hence its name. Mercury lamps may use a phosphor coating to enhance lighting performance and are commonly used in outdoor and industrial lighting applications.

**mounting height:** vertical distance between the roadway surface and the center of the apparent light source of the luminaire.

**overcrossings** (For pedestrians/Bikeway): overcrossing is a facility that provides a connection between pedestrian walkways/bikeways or roads open to pedestrian walkways/bicycling.

#### **pedestrian classification:**

**high:** areas with significant numbers of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals.

**medium:** areas where lesser numbers of pedestrians use the streets at night. Typical are downtown office areas blocks with libraries, apartments, neighborhood shopping, industrial, older city areas, and streets with transit lines.

**low:** areas with very low volumes of night pedestrian usage. These can occur in any of the cited roadway classifications but may be typified by suburban single-family streets, very low-density residential developments, and rural or semi-rural areas.

**pedestrian crosswalk:** area designated by markings for pedestrians to cross the roadway.

**pull box:** box with a cover that is installed in an accessible place in a conduit run to facilitate pulling in wires or cables.

#### **roadway classification:**

**major:** part of the roadway system that serves as the principal network for through-traffic flow. The routes connect areas of principal traffic generation and important rural roadways leaving the city. Also, often known as “arterials,” “thoroughfares,” or “preferential.”

**collector:** roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial, and industrial areas. They do not handle long, through trips.

**local:** local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property.

**spacing:** distance between successive luminaires measured along the center line of the street. See luminaire cycle.

**subjective brightness:** subjective attribute of any light sensation given rise to the perception of luminous intensity, including the whole scale of qualities of being bright, lightness, brilliant, dim, or dark.

**surface street:** street that is not a freeway and has at-grade intersections with other surface streets.



**tunnel:** as defined by the American Association of State Highway and Transportation Officials (AASHTO) Technical Committee for Tunnels (T-20) are enclosed roadways with vehicle access that is restricted to portals regardless of the structure type or construction method. The committee further defines road tunnels not to include enclosed roadways created by highway bridges, railroad bridges, or other bridges. This definition applies to all types of tunnel structures and tunnels, mined and bored tunnels in rock and soft ground, and immersed tunnels.

**undercrossing** (pedestrians crossing/bikeway): pedestrian undercrossing and bicycle undercrossing are facilities that provide a connection between pedestrian walkways/bikeways or roads open to pedestrian walkways/bicycling.

**visibility:** quality or state of being perceivable by the eye. In many outdoor applications, visibility is sometimes defined in terms of the distance at which an object can be just perceived by the eye. In indoor and outdoor applications, it is usually defined in terms of the contrast or size of a standard test object, observed under standardized viewing conditions, having the same threshold as the given object.

**walkway:** sidewalk or pedestrian way.

**warrant:** threshold condition based upon average or normal conditions that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control device or other improvement is justified. Warrants are not a substitute for engineering judgment. The fact that a warrant for a traffic control device is met is not conclusive justification for the installation of the device.

**watt:** measurement unit for the electric power consumption of lighting fixtures, or any other appliance that runs with electricity. In lighting, lumens can be compared to miles traveled and watts can be compared to fuel consumption.



## Appendix E – References

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