Oregon Department of Transportation

Traffic Lighting Design Manual

Delivery & Operations Division | Traffic Section

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Oregon Department of Transportation

Engineering & Technical Services Branch

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1.0 – Introduction

The purpose of the **Traffic Lighting Design Manual** is to assist in the lighting design of future construction and reconstruction projects on state highways. It is not intended that existing lighting systems be modified as a result of this manual. For policy practices, please refer to the Lighting Policy and Guidelines.

This design manual draws from several sources, cited in the Additional Resources section of this manual. This manual addresses items not included in the **AASHTO Roadway Lighting Design Guide** or provides clarification on included items.

The material herein is for informational purposes only and may aid new employees and those unfamiliar with ODOT traffic engineering and design practices. The state illumination engineer is responsible for maintaining ODOT's Traffic Lighting Design Manual.

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1.1 – Availability

This manual is a web-only document. You may access and print in its entirety from the ODOT website:

https://www.oregon.gov/ODOT/Engineering/Documents_TrafficStandards/Lighting-Design-Manual.pdf

1.2 – Updates

The state illumination engineer updates this manual continually; revisions will be made as necessary. The revised manual becomes effective on the official revision date (month/year format). All design work prior to final plans should follow the requirements of the current version of this manual.

2.0 – Starting the Design

Before starting the design, gather the following information:

- Standards applied to the project.
- Applicable project background information, such as roadway, bridge and signal installation.
- Illumination project scope.

2.1 – What Standards will be Used?

Designers must answer the question "what standards will I use" before starting the design and specifications. Investigating and gathering applicable standards for the assigned project are essential part of successful outcome. Regardless of the jurisdiction, illumination installation must meet the current National Electrical Code.

2.1.1 – Full ODOT Design Standards and Specifications

Full ODOT standard consists of the ODOT Lighting Policy and the ODOT Traffic Lighting Design Manual. The full standard is typically required for any project on the state highway system outside of city limits. If ODOT will maintain and operate the illumination system, the full standard is always required.

2.1.2 – Local Agency Design Standards and Specifications

The local agency standard applies to local agency owned and maintained illumination system on the state highways. If the local agency will maintain and operate the state-owned illumination system, then ODOT may allow local agency standards.

2.2 – Background Information to Gather

2.2.1 – As-Built Drawing Archive (FileNet)

As-built plan sheets will be available from ODOT traffic or illumination designer, or electrical crew. Also, they are available from FileNet in ODOT website. There is a Traffic Plan Search Guide available on FileNet for help using the database.

2.2.2 – Electronic Information

Prior to field verification, it is good to get familiar with the project area using available electronic sources, such as ODOT digital video logs and Google maps. These tools can help identify issues to address during the field verification.

2.2.3 – Field Verification

Field verification is an important step in the process of designing illumination.

Making a field visit during the design phase and verifying the existing conditions could save a lot of cost and effort during the construction phase of the project. It provides the designer accurate and complete information of existing conditions.

The designer may ask the electrical crew for assistance accessing certain portions of the existing illumination system.

2.3 – Background Information from Others

2.3.1 – Base Map and Survey Information

For new pole installations, illumination design requires a full survey information and a geotechnical report. Collect the following data within the survey area:

- Underground utilities less than 10 ft. deep in project area.
- Above ground utilities and wires with existing heights.
- Power poles with transformers for power sources.
- All pavement markings within the survey area.
- Any illumination and electrical wiring on bridges and wall structures.
- Any other existing illumination within the survey area.

2.3.2 – Roadway Design

If the project involves rebuilding or modifying the roadway, there will be a roadway base map showing the final roadway layout. It is critical that the illumination design is based on what the crew will build in the field.

The illumination designer must communicate with the roadway designer from the start of design through final plans. The roadway designer's final product, including bridges and wall structures, is the base for the illumination design.

2.3.3 – Geotechnical Report

If new poles are proposed, then a geotechnical report is required to determine the foundation depths. Contact the region geo/hydro manager for a foundation investigation of the proposed site as soon as the pole locations are defined.

2.3.4 – Utility Hook-ups

New illumination systems require a connection to a commercial power source. It may involve moving existing utilities.

The illumination designer needs to coordinate with the region utility specialist and utility company when locating the power supply and requesting any new connections early in the design process.

2.4 – Illumination Design Project File

Use ProjectWise to store the project files for the illumination design. It should contain the supporting documents, calculations and decisions related to the illumination design and construction. The items listed below, if applicable, are typically included in the files:

- Project narratives with project scope.
- Photometric data file of the luminaires.
- Project plan sheets and comments log.
- Calculations for:
    - Electrical load.
    - Wire sizes.
    - Illumination light levels.
    - Voltage drop.
    - Typical energy usage.
- Cost estimates (itemized breakdown for each bid item, total bid item cost, and anticipated item cost).
- Emails and memos related to illumination design decisions.
- Photos.
- Field verification information.
- Geotechnical report.
- Pole submittals and shop drawings.
- Manufacturer's cut-sheets and submittals of electrical materials.
- Correspondence between project managers, consultants or contractors.
- Existing "As-builts."

3.0 – Lighting Analysis

It is ODOT's practice to provide adequate illumination levels on the roadway according to the national standards, listed in Chapter 18.

3.1 – Standard Calculations

ODOT uses the illuminance method for light level calculation. The lighting design and its calculations are necessary to meet the required average illuminance levels and uniformity ratios in Table 1, below.

Table 1: Lighting Design Levels for Roadways

Street Classification	RP-8 Average Luminance* (cd/m^2)	Average Illuminance (fc)	Average Uniformity Ratio (E_{avg}/E_{min})	Maximum Veiling Luminance Ratio ($L_{v,max}/L_{avg}$)
Freeway	0.4~0.6	0.6~0.9	3.5:1	0.3
Expressway	1.0	1.5	3.0:1	0.3
Major	0.6~1.2	0.9~1.8	3.0:1~3.5:1	0.3
Collector	0.4~0.8	0.6~1.2	3.0:1~4.0:1	0.4
Local	0.3~0.6	0.45~0.9	6.0:1	0.4

*Table Note: * Luminance converts $1cd/m^2$ to 1.5 fc in R3 pavement.*

The lighting analysis should include the following information:

A. Provide average illuminance level in foot-candle (fc) or lux
B. Check minimum point.
C. Check maximum point.
D. Check illuminance uniformity ratios.
    a. Average to minimum.
    b. Maximum to minimum (10:1 or less is desirable).
E. Uniformity of illumination using mean deviation (for sign lighting only).

Provide increased illumination levels at critical decision points of the roadway. Some examples of critical decision points are:

A. Gore areas - 1.0 to 1.5 fc.
B. Weaving lanes - 0.8 to 1.0 fc average.
C. Intersections (see Chapter 11).

D. Underpasses (1 to 1.5 times of adjacent roadway illuminance level).

Glare and veiling luminance at critical decision points of the roadways should also be checked to satisfy design requirements.

On ODOT plans, include the average maintained illuminance and average to minimum uniformity on the first page of the illumination plans.

3.2 – Optional Calculations

As appropriate, use the luminance method for light level calculation when designing illumination system for a corridor. The unit is candela per square meters (cd/m^2). See Table 1 in 3.1.

Check average maintained luminance level with:

A. Uniformity of luminance (average to minimum).

B. Veiling luminance ratio (maximum to average).

4.0 – Illumination Plan

4.1 – Pole Placement

Use engineering analysis and judgement to minimize the number of poles needed to meet the lighting requirements of the project. All equipment (including foundations) must be located within the right of way or permanent easements.

When working on illumination located near airports, there is the possibility of height restrictions, which can have an impact on pole locations and parameters.

Also, consider permitted high loads and oversized truck routes. Check with the airport regarding flight paths and any height restrictions and with the ODOT trucking industry representative regarding permitted route issues.

Always check for possible conflicts with overhead and underground utilities when placing illumination poles. Address conflicts with overhead and underground utilities during the design phase.

Designs must meet a minimum clearance requirement from overhead high voltage lines, per OAR 437-002-0047, National Electrical Safety Code and other regulations. If there are known conflicts with utilities, contact the region utility specialist for assistance. Address and resolve utility conflicts before the design is complete.

Slip base poles are installed mainly for freeway environment. The designer should investigate traffic condition and frequency of pedestrians of the project area to ensure traffic safety. Slip base pole installation is not recommended around sidewalks, commercially developed area or intersections.

Fixed base poles should be installed outside of "clear-zone distance" required per AASHTO's "Roadside Design Guide." With appropriate protection in front of fixed pole location such as barriers, walls or guardrails, fixed base poles can be installed closer to the roadway and traffic area.

4.2 – Standard Lamps

It is ODOT's standard to use light emitting diode (LED) lamps on all new installations owned and maintained by ODOT maintenance. Access specifications for LED luminaires installed on "Cobrahead" style poles in standard specifications 00970.45 and 02926.54. Coordinate with the state illumination engineer and maintenance crew to select the appropriate LED luminaires when designing illumination mounted on structures other than standard poles.

4.3 – Standard Luminaires

Standard luminaires for ODOT projects are LED luminaires along state highways and bridges, including tunnels and underpass installation. Exceptions may occur when a region traffic engineer allows the use of other light sources such as high pressure sodium (HPS) or metal halide luminaires.

Establish the pole spacing by evaluating the luminaire's photometric performance, wattages and other parameters, such as mounting height, hang-over distance etc. You may determine these luminaire wattage and pole parameters with the lighting analysis described in Chapter 3.

The high-mast luminaire may be used for interchange lighting. Use the cut-off style of luminaire in these applications to control light trespass. LED luminaires, which are up to 500 watt each, can be used and the weight of each luminaire should be equal to or less than 50 lb. In the past, ODOT has used 400- to 1000-watt HPS lamps for these applications, and the illumination designer can replace existing luminaires with the same kind, if necessary.

Mount underpass luminaires on bridge structures. When the luminaire is recessed into the box girder, use an underdeck style luminaire with 70- to 100-watt HPS or 40- to 70-watt LED. When the luminaire is located on the open beam or girder type structures, use a pendant mount style luminaires with integral ballast. When the luminaire is on a rigid frame, or overcrossing bents, use the wall mount style luminaire with glare shield. Even though HPS fixtures have been used for these applications, the designer should coordinate with the maintaining agency to determine if LED luminaires are preferable.

Typically, ODOT uses the boxy style LED luminaire for bikeway and pedestrian paths. The recommended minimum mounting height is 30 feet. Lower mounting heights are subject to vandalism. Vandal resistant types of lighting installations are preferred. Since local agencies generally maintain and operate bikeway and pedestrian path lighting, the designer should coordinate with the local agency for its preferences.

5.0 – Poles and Towers

Choose poles and tower locations to provide traffic safety as well as required light levels and uniformities. Use ODOT-approved poles and towers when installing illumination on the state highway system.

For typical "cobra-head" installations, use galvanized steel poles with slip or fixed base. Slip base steel poles can be installed within the clear zone. Fixed base poles must be outside the clear zone or behind a protective barrier.

The general recommendation for pole placement on highways is 30 ft. from the edge of the travel lane where no barriers are installed. When a barrier is present, place poles 5 ft. behind the face of the barrier.

Typically, ODOT uses a mounting height of 40 ft. However, designers may consider other mounting heights depending on the project site and results of the illumination analysis. When determining the mounting height, consider the following factors:

- Highways in urban area.
- Controlling trespass light.
- Interference with the view of property owners (when poles located near property line between owners).
- Effecting greenhouses, mink farms, etc.
- Overhead conflict with utility lines or structure.
- Up to 50-foot mounting height can be used where needed in case of replacing existing pole or covering wider roadways.

ODOT typically surveys illumination poles into place during construction. Designers need a finished cross section at each pole location in order to have a realistic estimate of the attachment height and base height of the pole. If the construction schedule does not allow the necessary lead time (approximately six months) to order the poles, crews may pre-order the poles using the base height and attachment height. The designer should coordinate with the project leader and the construction project manager if it is necessary to pre-order poles.

When installing high-mast tower illumination, use galvanized steel towers. Traffic Standards Unit must approve all high mast illumination installations. Contact and coordinate with the state illumination engineer prior to DAP design.

For lighting outside ODOT jurisdiction: Check with city, county and related utility company for their design requirements or preferences.

6.0 – Power Supply

ODOT powers all highway illumination systems with commercial power. Select the nearest power source location with available utility's information. Illumination system needs to tap power from a transformer. If illumination design requires a new transformer installation, check and coordinate with utility company.

It is important to investigate what type of power is available and where the power source is located. Typically, 120/240 volts single phase power is used, but 240/480-volt three phase power can be used on larger electrical system (such as interchange illumination system) and tunnel lighting. If the existing power source is inadequate, inform the region utility specialist so they can work with the utility company to upgrade the power source.

Sometimes a project requires moving the existing power source to a new location. If this is the case, illumination designer must work with utility company in advance and show this change in the illumination plans.

For new installations, the wiring from the power source should enter the service cabinet via a conduit (aerial connections are not recommended for permanent illumination system). The design and installation of the conduit and wiring from the power source to the service cabinet is according to the requirements of the power company. The plan sheets should include a reference to the conduit and wiring indicating this requirement.

Generally, the contractor is responsible for installing the conduit and a pull-line from the service cabinet to the power source. The power company is responsible for installing and terminating the wiring from the power source to the service cabinet.

The cost of the power hook-up is included as an "Anticipated Item" in the project.

7.0 – Power Distribution System

Electrical power is distributed to the illumination system via conduit and conductors. Locate the control cabinet near the center of the system. Use the simplest layout to minimize conduit/conductors length and voltage drop occurring to the farthest location of the electrical circuit from the cabinet.

The maximum system voltage drop is under 5% per National Electrical Code (NEC). For ODOT illumination systems, the recommended value of the maximum voltage drop on the branch circuits is 4% and the maximum voltage drop between the utility transformer and service cabinet is 1%.

The typical formula for voltage drop (using NEC Table 9) is:

$$V_d = \frac{(2 \times A \times L \times R)}{1{,}000}$$

Where:

V_d = Voltage drop (single phase AC system).

2 = Power goes out and back using two wires.

A = Load being drawn (amperes).

L = Wire distance (ft.).

R = Resistance per 1,000 feet (ohms).

Determine the load, A, by dividing the total wattages connected down the stream, by the voltage serving the load. Calculate the percentage drop by dividing total voltage drop in a circuit by service voltage, and then multiplying them by 100.

Calculate voltage drop in three phase AC system with:

$$V_{d,\ 3\,phase} = \frac{(1.732 \times A \times L \times R)}{1{,}000}$$

On ODOT installations, the minimum wire size is #10 AWG copper.

Junction boxes provide pull point and secure splicing room for circuits coming from the service cabinet to the poles. Provide a concrete junction box at each illumination pole and provide a conduit sweep into the pole with smaller conductors.

Space junction boxes a maximum of 300 ft. apart on a conduit run. The total conduit diameter contained within the junction box determines the size of the junction box. Use polymer concrete for the illumination junction box lids.

It is also important to consider the type of surface on which the crew will install a junction box. The ”A” in the junction box designation denotes a 12-inch wide concrete apron surrounding a

precast concrete junction box. The concrete apron provides support to the fragile sides of the box. Use a type "A" boxes in non-paved areas, where maintenance vehicles may be present.

Do not use a precast concrete junction box within a travel lane or any access area, exposed to traffic. Avoid placing a junction box within a travel lane or where it is exposed to traffic at all costs. However, designers must use an approved cast iron junction box, rated for traffic, for locations where we cannot avoid traffic exposure. Do not place junction boxes in the slope or the landing area of an ADA ramp. Standard detail DET4320 shows illumination junction boxes and the installation guidelines.

A pad mounted control cabinet shown in standard drawings TM302 and TM303 are the standard for new illumination installations. The main circuit breaker must be rated 600 volts (except for 120-volt system use circuit breaker rated 480 volts). Branch circuit breaker ratings are as follows:

1. For 120-volt system, use 277-volt rated circuit breakers.
2. For 240-volt system, use 480-volt rated circuit breakers.
3. For 480-volt system, use 480-volt rated circuit breakers.

Short circuit interrupt rating: All service equipment and circuit breakers must have equal or higher ratings than available fault currents of the system.

Provide separate circuit(s) for sign illumination, navigation lights and aviation lights, as required. Permits are required for conduit on railroad right-of-way; avoid such installation as much as possible due to the expense and time involved.

The photo electronic control relay (photocell) is a device used for turning on and off the power on the connected luminaires, based on ambient lighting conditions. Place the photocell on the control cabinet. Use lighting contactors and a main photo electronic control relay to control electrical circuits with loads over 1000 watts. Provide a test switch for daytime maintenance.

The size of each branch circuit breaker is usually 20 Amp. And maximum lighting load on 20-amp circuit should not exceed 16 Amp.

When designing illumination on bridge structures, it is important to coordinate with the bridge designer on all electrical conduit and equipment installed on the bridge. The illumination designer must provide the bridge designer with the details of the distribution system.

Use rigid nonmetallic (PVC schedule 40) conduit where traffic is not present. Use rigid metallic (GRC) conduit where traffic is present or the conduit is exposed. Fiberglass conduit or PVC schedule 80 conduit can substitute GRC on underground installation. High density polyethylene (HDPE) conduit may be used for horizontal directional drilling (HDD) applications.

7.1 – Protection Against Wire Theft and Vandalism

Aluminum conductors as substitute of standard copper conductors may be installed in illumination circuits to provide protection against theft and vandalism as shown in the plans.

Install aluminum conductors where applicable as follows:

(a) Use "AA-8000 series" aluminum alloy conductors. Do not use conductors made with conventional aluminum alloys, such as "AA1350."

(b) Use following termination methods:

  (1) Always use torque wrench specifically designed for aluminum conductors to provide proper tightening at connections. Submit torque specification to PM office for approval.

  (2) Clean all wire connection points thoroughly to remove oxide buildup before termination.

  (3) Apply antioxidant joint compound to keep the oxide layer from forming.

  (4) Use connectors rated for aluminum wire or rated for both aluminum and copper wires.

(c) Use XHHW type of wires in illumination circuits, which is listed for aluminum conductors or as specified in the plans.

(d) Use appropriate sizes of aluminum conductors according to the NEC considering current carrying capacity. Minimum size for ODOT illumination circuits is No. 8 AWG. For multiple circuits in the distribution conduit system, use appropriate size of conduit and junction boxes.

(e) Check voltage drop of the illumination circuits as higher resistance values of the aluminum conductors are involved in calculations. And it should be within the ranges as recommended in NEC and ODOT Traffic Lighting Design manual. (See section 7.0)

(f) Provide protection against moisture to prevent corrosion at connections with heat-shrink tubes or as specified.

(g) When pulling aluminum conductors, use appropriate tension as recommended by the manufacturer to avoid damage to the wires and cables.

(h) After installation, perform thorough inspection of all connections to verify proper torque and tightness.

Illumination junction boxes, hand holes at illumination poles, and illumination cabinets may be required additional protection against theft as ODOT electrical crew or illumination designers specify in the plans. Coordinate with region electrical crew to show required protection method in the plans.

8.0 – Temporary Lighting

Project construction crew may install temporary lighting to provide necessary lighting to the travelling public. It is important the illumination designer coordinates with traffic control plans designer to provide an adequate temporary illumination plan.

The main goal of temporary illumination system is to provide illumination for the traffic conflict area at night during project construction. The illumination designer should work with region traffic and project manager for the need of temporary illumination.

Similar to permanent installations, illumination designer provides a lighting analysis for the designated project area using a computer program. The lighting analysis should demonstrate the following requirements are met:

- Average illuminance = 0.8 fc minimum.
- Minimum point = 0.2 fc.
- Uniformity patio.
    - Average to minimum = 4:1 to 6:1.
    - Maximum to minimum = 15:1 or less.
- Critical (decision points) areas of roadway = 1.2 fc.
- Maintenance factor = (luminaire dirt depreciation factor) times (lamp lumen depreciation factor).
- Luminaire dirt depreciation factor (for HPS luminaire).
    - New equipment = 0.95.
    - Used equipment = 0.8.
- Lamp lumen depreciation factor (for HPS luminaire).
    - Temporary lighting life 1 year and less = 0.95.
    - Temporary lighting life 1 year to 2 years = 0.90.
    - Temporary lighting life over 2 years = 0.73.

Use the minimum amount of equipment necessary to provide temporary illumination. Consider all construction stages when placing the temporary poles. Avoid pole relocations when possible. However, relocation may be necessary if the traffic control design moves traffic significantly from a stage to another stage. Since the illumination system is temporary, use an aerial power distribution system, unless the nature of construction requires underground distribution.

Wood poles are the standard for temporary illumination. When the temporary installation is for construction lasting over one year, treatment on the wood poles is required.

Place poles 30 feet set-back from edge of travel lane and 5 feet behind face of barrier/guardrail with a 6-foot minimum luminaire arm (luminaire should be hanging in front of barrier face). Set-back limits may vary for urban area installation.

9.0 – Partial Interchange Lighting

Partial Interchange Lighting design method is ODOT's standard for interchange lighting installations. It provides roadway lighting on only the essential parts of an interchange – gore points, weaving lanes, ramps and terminals. The recommended coverage at ramps and terminals are as follows:

- **On-Ramps –** Standard of two or three poles at merging sections. Ramps in urban or suburban areas and ramps with high truck traffic may need more coverage. Ramps with longer acceleration lanes or complex alignment may need more coverage.
- **Off-Ramps –** Standard of three poles to cover gore area. Ramps with complex alignment or roadside features may need additional coverage or pull through light.
- **Ramp Terminals –** Standard of two poles at the intersection without a traffic signal. One pole may be sufficient in rural area or T-shape intersections without a traffic signal. A wide intersection with crosswalk, a raised island, or a crossroad with median channelization may need more coverage.

If a project team considers "full interchange lighting" design method or "continuous lighting" sections, consult with state traffic engineer for review and approval.

10.0 – Underpass and Tunnel Lighting

10.1 – Underpass Lighting

Underpass illumination is not part of ODOT's standard coverage. However, ODOT may consider underpass illumination in special situations. Such as when:

- Pedestrian and bicycle path are under a structure.
- Highway merge and diverge areas are under a structure.
- A structure is 70 ft. or more in width.
- Requested by a local jurisdiction.

Coordinate with the maintaining agency to determine what type of luminaire should be used. Mount luminaires flush with the ceiling surface or on surface off the travel lanes.

10.2 – Tunnel Lighting

When designing tunnel lighting, conduct a site-specific engineering study on the tunnel to determine the appropriate lighting levels. Region traffic and illumination designer may replace an existing tunnel lighting system with an upgraded system with light levels below IES RP-8 design levels, if there is justification with traffic investigation.

The daytime entrance zone light level depends upon the brightness features within the motorist's view on the portal approach. Utilize 2-3 light level switching to provide proper amount of lighting according to different ambient lighting conditions.

Conduct research and use engineering judgement when selecting luminaire types, sizes, locations, orientations, and so on. Equipment for tunnel lighting may include propriety items, as required. Use LED luminaires and remote control system for energy savings and public safety in tunnels on state highways.

11.0 – Lighting for Intersections, Crosswalks and Roundabouts

The planning and installation of new lighting at intersections and crosswalks require a traffic investigation by the responding region traffic on the project site. Illumination designer must work with the responding project team and responding region traffic investigation unit to determine the illumination scope and prepare the illumination plans.

For illumination installation on new marked crosswalks, visit ODOT's illumination webpage to access the Crosswalk Illumination Worksheet, which provides a scoping recommendation.

11.1 – Intersections

11.1.1 – Full Intersection Lighting

To design a new intersection lighting, "Full intersection lighting" is applicable to an intersection with continuous lighting on all approaching roadways. The recommended illuminance values on traffic conflict areas, including marked crosswalks, are below.

Table 2: Illuminance for Full Intersection Lighting

Crossing Roads Classes	Average Illuminance	Uniformity (E_{avg}/E_{min})
Major/Major	1.7 ~ 3.2 fc	3:1
Major/Collector	1.4 ~ 2.7 fc	3:1
Major/Local	1.2 ~ 2.4 fc	3:1
Collector/Collector	1.1 ~ 2.2 fc	4:1
Collector/Local	0.9 ~ 2.0 fc	4:1
Local/Local	0.7 ~ 1.7 fc	6:1

11.1.2 – Intersection with One-way Illumination

If only one roadway of two crossing roadways has continuous lighting, design a new intersection lighting to provide 30-50% higher illuminance than the light level of the continuously lighted roadway. Refer to the table below for recommended illuminance values of an intersection with one-way illumination.

Table 3: Illuminance for Intersections with One-way Illumination

Road class of the main roadway	RP-8 reference on Roadway luminance* (cd/m^2)	Average Illuminance for intersections w/ 1-way illumination	Uniformity (E_{avg}/E_{min})
Expressway	1.0	1.9 fc ~ 2.2 fc	3.0:1
Major	0.6 ~ 1.2	1.2 fc ~ 2.7 fc	3.0:1
Collector	0.4 ~ 0.8	0.8 fc ~ 1.8 fc	3.5:1
Local	0.3 ~ 0.6	0.6 fc ~ 1.3 fc	6.0:1

*Table Note: * Roadway luminance converts 1 cd/m^2 to 1.5 fc in R3 pavement.*

11.1.3 – Isolated Intersection Lighting

Use "Partial intersection lighting" to design a new isolated or rural intersection lighting. The recommended illuminance values are below.

Table 4: Illuminance for Partial Intersection Lighting

Road class of the main roadway	Average Illuminance for partial intersection lighting	Uniformity (E_{avg}/E_{min})
Expressway	1.1 fc ~ 2 fc	3.0:1
Major	0.8 fc ~ 1.5 fc	3.0:1
Collector	0.6 fc ~ 1.2 fc	4.0:1
Local	0.4 fc ~ 0.8 fc	6.0:1

11.2 – Marked Crosswalks at Intersection

Include all marked crosswalks and traffic conflict area in the lighting calculation when installing new lighting at an intersection. See Section 11.1 for recommended light levels for intersection lighting design. Intersection lighting design, which meets the recommended light levels, will cover entire intersection area including the marked crosswalks within the intersection.

For un-signalized intersections with marked crosswalks, RP-8 and national research results recommend new lighting installation using frontal lighting and positive contrast technique to increase vertical illuminance on pedestrians at crosswalks. Where feasible, use frontal pole locations and check the vertical illuminance at the marked crosswalks. Recommended vertical illuminance at the crosswalks is equal or higher than the values of Section 11.1. See Section 11.3 for vertical illumination calculation details.

For signalized intersections and intersections with traffic control devices, desirable vertical illuminance at the marked crosswalks may not be obtainable due to the locations of signal-

illumination joint poles. With the region traffic engineer's approval, lighting designer can use alternative back-lighting or top-lighting design technique for the intersection without providing the vertical illumination calculation. Without vertical illumination calculation, include all crosswalks within the intersection in lighting calculation to meet the values of Section 11.1.

11.3 – Marked Midblock Crosswalks

11.3.1 – Marked Midblock Crosswalks without Traffic Control Device

For a new illumination installation at marked midblock crosswalk, the responding ODOT region traffic section must conduct a traffic investigation. A worksheet is available on ODOT's illumination webpage to provide a recommendation.

When designing new illumination for a marked crosswalk, meet the recommended light levels for horizontal luminance or illuminance levels on the crosswalk, based on the street classifications below.

Table 5: Light Levels for Marked Midblock Crosswalks w/o Traffic Control Device

Street Classification	Average Luminance* (cd/m^2)	Uniformity Ratio (L_{avg}/L_{min})	Average Illuminance (fc)	Uniformity Ratio (E_{avg}/E_{min})
Expressway	1.0~1.5	3.0:1	1.5~2	3.0:1
Major	0.6~1.2	3.0:1~3.5:1	0.9~1.8	3.0:1~3.5:1
Collector	0.4~0.8	3.0:1~4.0:1	0.6~1.2	3.0:1~4.0:1
Local	0.3~0.6	6.0:1	0.45~0.9	6.0:1

*Table Note: * Luminance converts 1 cd/m^2 to 1.5 fc in R3 pavement. Illumination designer may use luminance or illuminance for light level calculation.*

RP-8 and national research results recommend frontal pole locations to increase vertical illuminance on pedestrians at crosswalks. Where feasible, use frontal pole locations and check the vertical illuminance at the marked crosswalks. Place light poles 15-30 feet in front of crosswalk, typically using a 40-foot mounting. For mounting heights of 30 feet, use spacing of 12-25 feet. Luminaire wattages may vary for the recommended light levels.

Set vertical illuminance grid at 5 feet above roadway surface and 1.5 feet apart for entire crosswalk on centerline of the crosswalk. (This grid setting is for lighting design calculation.) The light meter window must face the approaching driver.

The recommended light level for vertical illuminance is min. 1.5 fc. Provide higher vertical illuminance for the area with high pedestrian conflict.

When project site condition does not permit frontal lighting to meet the recommended vertical illuminance levels, designers may use back-lighting and top-lighting methods without vertical illuminance calculation with approval from responding region traffic engineer.

Use full-cutoff style luminaires with flat-glass lens to reduce potential glares.

With approval from responding region traffic engineer, a continuously lighted roadway section around a new crosswalk may be redeemed to be adequate lighting condition for the crosswalk.

11.3.2 – Marked Midblock Crosswalks with Beacons

If a project involves installation of a new lighting at a marked midblock crosswalk with rectangular rapid flash beacon (RRFB) or pedestrian hybrid beacon (PHB), refer to the recommended light levels, shown in the table of Section 11.3.1 above, with minimum 1.0 fc vertical illuminance. Provide higher vertical illuminance level, for the crosswalks with high ambient light conditions or high pedestrian conflicts.

Designers may use back-lighting or top-lighting methods without vertical illuminance calculation with approval from the responding region traffic engineer.

With overhead RRFB/PHB installations, combine the illumination with the signal pole, as appropriate. ODOT recommends a minimum of 10-foot clearance for the luminaire from the mast arm or signal heads.

11.4 – Evaluation of Existing Lighting

For new crosswalk illumination installation, traffic investigation on project site is necessary. As part of the traffic investigation, evaluation of existing lighting may be important to obtain a background information for project planning.

Using evaluation process and considering available project budget, region traffic unit and project team can determine project scope and provide illumination plans to improve lighting of project area. Illumination plans may include:

- New illumination installation.
- Relocation of existing illumination.
- Cleaning fixtures and replacing bulbs, or changing luminaires.

Use one or both of the evaluation methods of existing lighting explained below.

11.4.1 – Computer Analysis

Gathering Information on Existing Lighting System

Obtain information of all existing light sources within three times of typical mounting height or 150 feet from the project target area, such as:

- Mounting heights.

- Lateral distance from light pole to the project area.
- Luminaire wattages and types, including brand names and models.

For a rough estimate, use a typical luminaire of the same kind (such as 400 w HPS or 135 w LED).

Calculation of Light Level

Use a commercially available computer software, such as Agi32, to calculate average illuminance on the project target area and its uniformity (average to minimum) by using gathered information. Where applicable, calculate vertical illuminance and uniformity. See Section 11.3 above for vertical illuminance calculation details.

Comparing Light Levels to the Standards

Compare the calculated light levels to the recommended illuminance values above in Section 11.0 to provide an engineering decision on illumination installation for the project.

11.4.2 – Field Measurement

Visiting Project Site

Obtain the proposed roadway plans of the project area. Find the location of the crosswalks or intersections of the project. Ensure the safety of the crew conducting the light-measurements with necessary traffic control set-up. Coordinate with ODOT maintenance office/crew.

Schedule the site visit during the night when traffic volume is lower around the project site – minimum two hours after sunset or before sunrise. Taking measurements during these hours helps to avoid excessive vehicle-headlight contribution on measurement values. Avoid foggy or rainy weather for accurate measurement.

Illuminance Light Meter

Use an illuminance light meter, such as Konica-Minolta T10A, to measure light levels for the project area. (ODOT provides necessary equipment for all region traffic units, as shown below.)

Figure 1: Example Light Meter, K-M T10A

Figure 2: Example Light Meter, K-M T10A with Detached Head Option

Measuring Illuminance

A. Intersections and crosswalks at intersections –

Select area for horizontal illuminance measurement, which includes the entire intersection and all crosswalks. Measuring grid should be 10' X 10'. See the examples in the figures below. Record measurement values for an evaluation.

If further crosswalk lighting investigation is needed, see section B below for guidance.

B. Mid-block crosswalks –

For horizontal illuminance, measure entire crosswalk area using 5'x5' grid, curb to curb, between marked crosswalk edge lines. See the examples in the figures below. Record measurement values for evaluation.

For vertical illuminance, measure every three feet along the centerline of the crosswalk, curb to curb. Record measurement values for evaluation.

When measuring horizontal illuminance, place the light meter receptor window to be flat on the ground looking upward.

For vertical illuminance measurement, place the light meter five feet above the grid points with the meter receptor window turned 90 degrees to face approaching driver. See examples in the figures below. It will take two different directional readings on a two-way street crosswalk to gather the vertical illuminance measurement.

Calculate average horizontal illuminance values and uniformities (average to minimum) from field measurement data, and vertical illuminance data, as needed.

Comparing to the Standards

Compare the calculated light levels with the recommended illuminance values above in Section 11.0 to provide an engineering decision on illumination installation for the project.

Examples for Grid and Direction Setting for Field Measuring

Note: Grid set-ups shown below are only for field measurement on existing illumination. These are not intended to show grid set-ups for new illumination design and calculations.)

Figure 3: 10′ x 10′ grid at Intersection

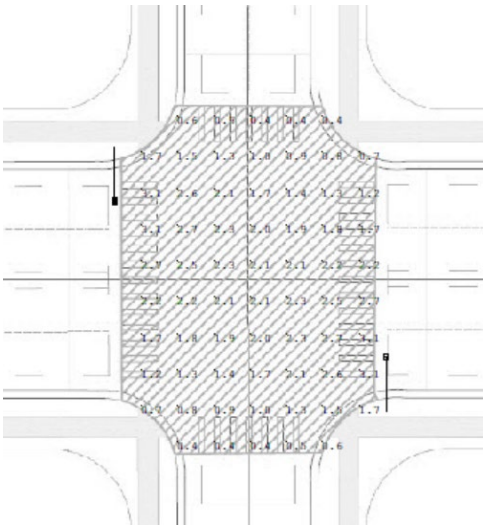


Figure 4: 5′ x 5′ Grid at Crosswalk for Horizontal Illuminance

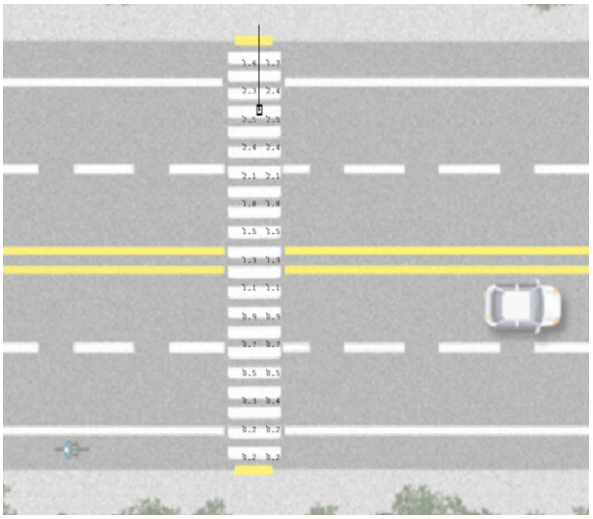
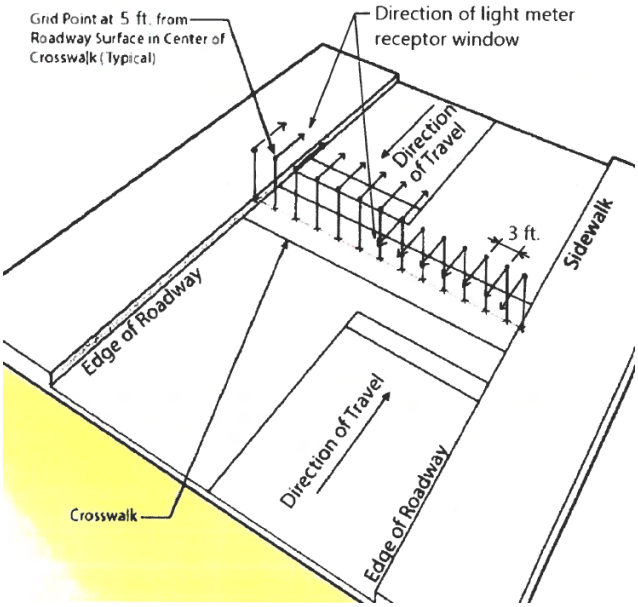


Figure 5: Vertical Illuminance measuring Grid at Mid-block Crosswalk



11.5 – Roundabout Illumination

Illuminating roundabouts on state highways is recommended for informational navigation and pedestrian safety, as stated in ODOT Lighting Policy and Guidelines 2.1.1.

It should cover the following, while excluding center circle area:

- All roadway lanes and sidewalks of the roundabout.
- All approach roadways with raised/channelized sections.
- Pedestrian crosswalks of the roundabout.

Coverage should extend to the start of the splitting approach roadways or up to 400 ft along the approach roadways from the center of the roundabout.

11.5.1 – Recommended Lighting Levels

For circular lanes, pedestrian crosswalks, and splitting approach roadway sections, use the recommended horizontal illuminance levels below. The calculation grid should be 6 ft X 6 ft or less.

1. Roundabout with continuous lighting on all approach roadways – Use "Full Intersection Lighting" values (Chapter 11.1.1, Table 2).
2. Roundabout with continuous lighting on only two approach roadways – Use "Intersection with One-way illumination" values (Chapter 11.1.2, Table 3).

3. Roundabouts without continuous lighting on approach roadways – Use "Isolated Intersection Lighting" values (Chapter 11.1.3, Table 4).

For the recommended illuminance levels of approach roadways, see Chapter 3.1, Table 1.

11.5.2 – Vertical Illuminance for Pedestrian Crosswalks

Provide positive contrast pedestrians on the crosswalks by placing light poles 10 to 30 ft before the crosswalks (vehicle approaching direction).

Vertical illuminance check is recommended for pedestrian crosswalks, per 11.2 Marked Crosswalks at Intersection.

11.5.3 – Adaptive Lighting Control for Future Installation

Illumination designers should select luminaires and electrical equipment, such as service cabinet, conduit and wiring to consider future installation of adaptive lighting control on new roundabout lighting system.

11.5.4 – Light Pole Locations at Roundabouts

1. Per Roadside Design Guide (2011, AASHTO), low speed (less than 40mph) section has 15-foot "Clear Zone" requirement. Within the "Clear Zone" from the vehicle travel area at roundabouts, use slip-base/breakaway type of light poles.
2. Provide minimum 5-foot clearance behind concrete barrier/guardrail. Fixed base illumination poles may be installed.
3. Recommending a clear distance from the curb would not be effective for pole placement since a curb does not stop vehicles that veer off the road, including unmountable and mountable curbs. Clear distance at roundabouts may be set from the edge of vehicle travel way, including lanes and shoulder. A minimum 6 feet from the edge of roadway is considered adequate for slip-base/breakaway illumination poles.
4. Roadway Section plans to study this further, considering upcoming national standards and other states practice.

12.0 – Sign Lighting

Signs constructed with retroreflective sheeting are not illuminated.

Pole locations on highway illumination system can be adjusted to provide some lighting in front of the sign structures (70 feet or further off the structure).

Check with the project's sign designer whether a special need for sign lighting installation exists.

13.0 – Aviation and Navigation Lighting

13.1 – Navigation Lighting

When designing navigation lighting, design the lighting system to the bridge lighting requirements stated in the Coast Guard permit. If a permit is not required, then provide lighting that is equal to the existing system.

Design and install a navigation lighting on a separate circuit from any other lighting on the bridge. Use engineering judgement to select equipment that is simple and requires the least amount of maintenance. Coordinate with region maintenance office on selection of equipment.

13.2 – Aviation Lighting

When designing a project in or near navigable airspace, the project team should coordinate with the Federal Aviation Administration (FAA) prior to finalizing the DAP design.

If the FAA review determines the project requires aviation lighting, use FAA approved equipment. Some examples of aviation lighting equipment may include:

- Obstruction lights.
- Beacon lights.
- Photo electronic control.

14.0 – Monthly System Energy Utilization

On ODOT illumination plans, calculate the project's monthly energy utilization of each illumination system and include it on the first sheet of the illumination plans.

The formula for the monthly system energy utilization is:

$$E = W \times N \times T$$

Where:

E = Monthly system energy utilization (KWH).

W = Wattage of lamp (KW).

N = Number of luminaires connected for the electrical cabinet.

T = 351 hours / month.

If more than one type of luminaire is used, add the energy usage for all different types of luminaires to calculate a total amount of energy utilization for the electrical system.

15.0 – Standard Drawings and Details

15.1 – Standard Drawings

Standard drawings provide micro details for construction information on typical installations. The contract plans, via the illumination plans, reference these drawings. The designer is responsible for selecting and including the standard drawings applicable to the project.

The first sheet of the illumination plan set lists all the standard drawings applicable to illumination. The main index shows the entire set of applicable standard drawings for the whole project. The standard drawings applicable to illumination design are available in the TM300 series (illumination design) and TM600 series (traffic structures).

Designers cannot modify standard drawings. However, if a standard drawing does not quite work for a particular project due to a non-typical condition, the standard drawing content can be used to create a modified illumination detail in the project plan sheet, then signed and sealed by the engineer of record.

Each standard drawing has an effective date. The bid date of the project should be within the range of the effective date. This assists with identifying the correct drawing for the project. The standard drawings used on this project are valid for the life of the construction.

The Traffic-Roadway Section maintains the standard drawings, which it updates twice a year, once in January and once in July.

An ODOT engineer of record signs and seals each standard drawing, backed by engineering analysis, calculations, and/ or other justification to support the content contained within.

15.2 – Standard Details

Standard details typically contain construction installation information that is:

- Used infrequently.
- Used on non-state highway roadways.
- Requires modification based on the project specific location.
- New or unproven technology, needing refinement prior to becoming a standard drawing.

Use standard details to create a project-specific details plan sheet for inclusion in the project contract plans set and stamped by the engineer of record. Designers may modify the standard detail to fit the unique requirements of a given project. Often standard details include notes to the designer containing further information on the appropriate use and modification of the detail.

The Traffic Section maintains and updates the standard details. Designer should always download standard details from the website to ensure they work from the most current copy, as details may update at any time.

The standard details applicable to illumination design include DET4300 to DET4350.

16.0 – Specifications, Bid Items and Cost Estimate

Two separate documents are needed to complete the specifications for a project:

- Oregon Standard Specifications for Construction.
- Project-specific special provisions.

The Oregon Standard Specifications for Construction remain static for three to five years. The special provisions add, modify and/or delete portions of the standard specifications, based on project-specific needs.

The following specifications directly relate to illumination:

- 00950 – Removal of Electrical Systems.
- 00960 – Common Provisions for Electrical Systems.
- 00962 – Metal Illumination and Traffic Signal Supports.
- 00970 – Highway Illumination.
- 02920 – Common Electrical Materials.
- 02926 – Highway Illumination Materials.

16.1 – Review and Approval of the Special Provisions

When designers modify special provisions according to the instructions provided within the boilerplate (information in orange italics within parenthesis), additional review and approval from the illumination engineer isn't required. However, the state illumination engineer will do a courtesy review, if requested.

When designers modify a special provision beyond the instructions provided within the boilerplate, the state illumination engineer and state specifications engineer must review and provide concurrence, per technical bulletin TSB12-01(B).

16.2 – Bid Items

Standard specifications and special provisions define the bid items and are the means by which contract work is paid. The specifications define the title of bid item, the unit of measurement, and what work is included in the bid item. The following sections are used:

- 00970.90 contains the list for all permanent illumination bid items.
- 00950.90 contains the list for removal of electrical systems.
- 00227.90 contains the list for all temporary illumination items.

These bid item lists are explained in more detail below and can be found on the specifications website. The vast majority of project work should fit within these existing, standard bid items. If the standard bid item lists do not meet the needs of the project, contact the illumination engineer for guidance. The solution may involve use of an existing, standard bid item or creation of a new bid item.

The illumination engineer and specifications engineer must approve the use of new, unique bid items. New, unique bid items are discouraged, but are sometimes necessary in illumination design.

16.2.1 – Permanent Illumination Bid Items (00970.90)

The standard bid items available in section 00970.90 of the specifications applies to permanent illumination installations:

- Pole Foundations – Lump sum includes all concrete foundations for lighting poles.
- Lighting Poles and Arms – Lump sum includes all metal poles and arms for lighting poles.
- Luminaires, Lamps, and Ballasts – Lump sum.
- Switching, Conduit, and Wiring – Lump sum includes all switches, conduit, cabinets, wiring, delineators, junction boxes, and other items required to construct the lighting system as specified.
- Refurbishing and Reinstalling Existing Illumination Systems – Lump sum includes all refurbishing, reinstalling, and other work as specified and not included in the removal of existing illumination.

Include the cost of illumination items encased within concrete bridges and retaining walls as part of the respective bridge or wall bid items. Such items may include:

- Foundations.
- Conduit.
- Junction boxes.
- Cabinets.

16.2.2 – Removal of Electrical Systems Bid Items (00950.90)

The standard bid items available in section 00950.90 of the specifications applies to removal of illumination equipment:

- **Incidental to Installation Bid Item –** If the removal work meets the criteria for "Method A," which occurs when existing electrical systems are removed and replaced with new electrical systems, no separate bid item for removal is used. The removal work is inclusive to the new electrical system bid item.

- **Removal of Electrical Systems – Lump sum.** By definition in the specifications, use this bid item when the removal work meets the criteria for "Method B," which occurs when existing electrical systems are removed and are not replaced with new electrical systems.

16.2.3 – Temporary Illumination Bid Items

The standard bid items available in section 00225.94 of the specifications applies to temporary illumination installations:

- **Temporary Illumination – Lump sum.** This bid items includes all required materials called for by the plans. The illumination designer needs to work with traffic control designer to include the amount to the project.

16.3 – Cost Estimate

Once selected, complete a cost estimate for each bid item. Base bid item estimates on historical data, available industry data, manufacturer quotes and project specific research.

For ODOT illumination designers, download the excel spreadsheet to assist in cost estimating efforts. ODOT internal estimating tools are not available to external staff.

16.3.1 – Anticipated Items

ODOT uses anticipated items to provide a funding mechanism for non-biddable elements of work that may be necessary to complete a project. Do not list work items for competitive bidding as anticipated items. Anticipated items are included with the cost estimate.

For illumination work, power hookups are the most common anticipated item. This item should include the cost of conduit installation, trenching, and wiring from the power source to the illumination cabinet. Coordinate with the region utility specialist and utility company to determine a reasonable cost estimate.

17.0 – Construction Support

Once the project has been let, the illumination designer provides assistance to the office administering the contract during the advertisement and construction phases.

This typically consists of:

- Clarifying and interpreting information shown in the plans and specifications.
- Assisting the project manager and staff to provide solutions for illumination installation issues of the project.
- Adding, modifying or deleting information in the plans and specifications as necessary.
- Providing a cost estimate for your expected amount of construction support.
- Reviewing and approving illumination submittals.
- Attending meetings, as requested.
- Periodic inspection of work, as requested.

18.0 – Additional Resources

When designing illumination systems, reference the following sources along with this manual.

Roadway Lighting Design Guide. American Association of State Highway and Transportation Officials (AASHTO), Washington D.C., 2018.

Recommended Practice for Lighting Roadway and Parking Facilities (IES-RP-8-18). Illuminating Engineering Society of North America (IESNA), New York, N.Y., 2018.

Roadside Design Guide, 4th Edition. American Association of State Highway and Transportation Officials (AASHTO), Washington D.C., 2011.

NFPA70: National Electrical Code, 2020 Edition. National Fire Protection Association (NFPA), 2020.

The National Electrical Safety Code, 2017. Institute of Electrical and Electronic Engineers (IEEE), 2017.

Oregon Revised Statues, Title 59 810.010 "*Road Authorities (Jurisdiction)*" State of Oregon, 1999 Edition.

Federal Highway Administration Rules and Guidelines Code of Federal Regulation – Title 23 Sub-Chapter "G."

"Obstruction Marking and Lighting," Federal Aviation Administration, advisory circular.

"Proposed Construction or Alteration of Objects that May Affect the Navigable Airspace," Federal Aviation Administration, advisory circular.

Oregon Standard Specifications for Construction. Oregon Department of Transportation (ODOT), Salem, OR., 2021.

ODOT Standard Drawings Manufacturer's Catalogs and Cutsheets.

Local Agency Agreements, League of Oregon Cities and Association of Oregon Counties.

"Guidelines and Working Agreements for Local Government Programs" (p.p. 32-33) Local Officials Advisory Committee (local design standards).

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www.oregon.gov/ODOT