Street Lighting Analysis Standards & Specifications for the City of Portland, Oregon

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Volume 1

Recommended Lighting Standards

Industrial Testing Laboratories

BERKELEY, CALIFORNIA

RECOMMENDED STREET LIGHTING STANDARDS FOR THE CITY OF PORTLAND

The City of Portland initiated an Arterial Conversion Project in 1979 to reduce the energy cost of operating the City's street lighting system by converting street lights along commercial arterials from mercury vapor to high pressure sodium vapor. In September 1979, a contract was awarded to Industrial Testing Laboratories for an engineering study to recommend appropriate street lighting standards; to identify commercially available equipment, including high pressure sodium vapor sources, that satisfactorily meet the recommended standards, and to compare the energy efficiencies of the alternatives with other qualities of the equipment; and to develop material specifications and bid documents for the City to use in purchasing equipment for its conversion project.

This report summarizes the findings and recommendations on street lighting standards. Detailed information on this part of the study is documented in Volume 2, Technical Report. Additional supplementary data is given in Volume 3, Technical Appendix.

Recommended Standards

In cooperation with the City's Street Lighting Division, Industrial Testing Laboratories recommends five classifications of streets for the purpose of establishing street lighting standards. The recommended standards on the following pages establish requirements for horizontal illumination, luminance, and glare for each of these five street classifications, as well as setting luminance and glare requirements for intersections.

In deriving the recommended standards, consideration was given to the driver's requirements for visual perception in terms of (1) the luminances in the field of view; (2) the visual adaptation; (3) the size, shape, color, and pattern of objects; (4) motion; (5) time available; and (6) age, physiology, and psychology of the driver. In addition, the physical parameters relating to the functional use of the streets and the research and experience of other regulatory agencies were considered.

Recommended Street Lighting Standard for the City of Portland

Class	Portland Street Classification	Horizontal Illumination E_h			Luminance L				Glare		
		$E_{h(ave)}$ fc	Ave / Min	Max / Min	L_{ave} fL	Ave / Min (Overall)	Max / Min (Overall)	Max / Min (Longitudinal)	GM	TI	L_v
1	Regional Trafficway	⩾1.2	⩽3	⩽9	⩾0.30	⩽2.5	⩽5	⩽2.5	⩾6	⩽20	⩽.05
2	Major Traffic – Major Transit	⩾1.0	⩽3	⩽9	⩾0.24	⩽2.5	⩽5	⩽2.5	⩾6	⩽20	⩽.04
3	Neighborhood Collector – Major Transit	⩾0.7	⩽3	⩽9	⩾0.18	⩽2.5	⩽5	⩽2.5	⩾6	⩽20	⩽.03
4	Neighborhood Collector – Minor Transit	⩾0.5	⩽3	⩽9	⩾0.12	⩽2.5	⩽5	⩽2.5	⩾6	⩽20	⩽.02
5	Local Service	⩾0.2	⩽6	⩽20	⩾0.06	⩽5	⩽10	None	⩾4	⩽25	⩽.05
6	Intersections				$L_{ave(i)} \geqslant 1.5\, L_{ave(r)}$ Unif. $\frac{L_{ave(i)}}{L_{min\,(i)}} \leqslant 2.5$				⩾7	⩽10	⩽.05

Explanatory notes on following page.

Horizontal Illumination, E_h:

a. The value of average horizontal illumination, $E_{h(ave)}$, is measured in footcandles (fc) and calculated as the average over the area of the traffic lanes including the center median and bike lanes, if any. The area for $E_{h(ave)}$ does not include parking lanes, sidewalks, berm, or other areas outside of the vehicular traffic lanes. A parking lane will be assigned 7 ft of width.

b. For design calculations, the end-of life lamp lumens will be used together with an appropriate luminaire maintenance factor.

c. $E'_{h(ave)}$: The $E'_{h(ave)}$ is for areas out to 15 ft to each side of the outside traffic lane and shall be lighted to $\geqslant$0.2 fc(ave) if such areas are used for parking or pedestrian traffic. No ratios are specified for the side areas.

d. Ave/Min values of horizontal illumination are related to twin-beam luminaires at 30-40 foot mounting heights.

Luminance, L:

a. L_{ave}, measured in footlamberts (fL), is the average luminance within the traffic lanes from a transverse line 100 ft ahead to about 400 ft ahead of the observation point. The lateral boundaries shall include the area of the traffic lanes. At least 20 points shall be used to calculate L_{ave} with at least 5 points along the centerline of the outside lane.

   The individual luminance points shall be calculated or measured from a point 4.5 ft above the roadway located approximately in the center of the outside lane and at a longitudinal point along the centerline spaced to include the maximum longitudinal variations in road luminance.

   For 2-way traffic roadways, the luminances shall be determined for each direction of traffic if the luminance pattern is assymetric.

b. Field measurements will be made with a suitable telephotometer using an acceptance aperature with a 2 arc minute vertical angle. At least 20 points will be measured on the roadway within the prescribed area at approximately equal angular increments.

c. The L_{ave}/L_{min} ratios shall be calculated for each observer location and shall consider all of the individual luminances within the area. The ratio of L_{ave}/L_{min} shall be met for all observer locations.

d. The L_{max}/L_{min} ratios shall be calculated overall and along the centerline of the outside lane for each direction of traffic.

Glare:

Glare will be evaluated by two criteria: (1) discomfort glare and (b) disability glare.

a. Discomfort Glare

   The discomfort from glare is described by a Glare Control Mark, GM, which expresses on an ordinal scale the subjective appraisal of the degree of discomfort experienced. The value of GM is associated to different glare sensations as follows:

GM-1 "Unbearable"
GM-2 "Disturbing"
GM-5 "Just admissible"
GM-7 "Satisfactory restriction"
GM-9 "Unnoticeable"

The wordings are not intended to indicate an absolute level of glare. They are listed here as used in the International Commission on Illumination (CIE) experiments.

The subjective appraisal of the glare and the associated value of the Glare Control Mark depend on the photometric and geometric characteristics of the lighting installation.

b. Disability Glare

The method for evaluation of disability glare is based on the Holladay formula. According to the formula, the effect of glare is quantified by an equivalent uniform luminance which describes the effect of the stray light in the eye: lowering the contrast. The relative threshold increment, TI, is expressed as the difference between the threshold under glare condition and its value without glare, expressed in percent of the value without glare.

The veiling luminance, L_v, represents the illumination at the eye due to glare sources and is the equivalent uniform luminance, in footlamberts, superimposed over the entire visual field.

c. Recommendations on Glare

The recommendations concerning the restriction of glare in road lighting installations have been given in terms of GM and TI. These values should be considered as minimum requirements. If higher values for G and lower values for TI are economically feasible, preference should be given to such an improvement of the glare restrictions.

Field measurements of glare should be made using a telephotometer located at the luminance observation location. The photometer should use a 6 arc minute aperture (approx. 2-inch circle at 100 ft) and should have a mount that can give vertical and horizontal angles with respect to a reference line of sight. All sources within the normal field of view of a driver that are greater than about 20 times the average road luminance should be measured for maximum luminance within a 6′ cone angle. The approximate field of view will be $\pm 30^\circ$ horizontal, $+20^\circ$ vertical to -5° vertical. The location and magnitude of each source should be recorded. If the sources subtend a solid angle greater than 0.0002 steradians (2 ft^2 at 100 ft), separate measurements should be made in each incremental solid angle.

Intersections:

a. The area used to determine L_{ave} will be that roadway area within the traveled lanes extending from the centroid of the intersection along each lane to a transverse line 10 ft beyond the point of entry.

b. $L_{ave(i)}$ is the average luminance in the intersection, $L_{ave(r)}$ is the average luminance of the intersecting road with the highest value, and $L_{min(i)}$ is the minimum luminance in the intersection.

Existing Lighting Standards and Conditions

Three agencies have established guidelines for street and highway illumination which have, in turn, been accepted by many state and local governments responsible for providing street lighting. The most widely accepted guidelines are set by the American National Standards Institute/Illuminating Engineering Society (ANSI/IES) in its publication *American National Standard Practice for Roadway Lighting* (RP-8, 1977). The International Commission on Illumination (CIE) has recommended guidelines for lighting, as presented in its publication *Recommendations for the Lighting of Roads for Motorized Traffic* (12/2, 1975), which are widely accepted in Europe, Australia, and Japan. The American Association for State Highway Transportation Officials (AASHTO) publishes a guide for roadway lighting that is mainly concerned with high speed roadways.

In developing the Recommended Street Lighting Standards for the City of Portland, Oregon, Industrial Testing Laboratories reviewed the ANSI/IES, CIE, and AASHTO guidelines for lighting, and drew the following conclusions:

ANSI/IES. The ANSI/IES standard (RP-8, 1977) is concerned mainly with one aspect of outdoor traffic lighting, viz., pavement illumination, and does not stress the importance of visual effects such as pavement luminance, luminance contrasts, luminaire beacon effects (optical guidance), accent lighting, and so on.

By contrast, RP-8, 1977, plays down the importance of pavement brightness. In fact, Appendix E, titled "Pavement Luminance," primarily contains reasons for not using pavement luminance criteria.

Probably the greatest deficiency of RP-8, 1977, is that it does not emphasize the special need for the lighting of traffic conflict and other hazardous areas on public traffic routes. The only reference to this problem is in section 3.10 where it is stated that intersecting, converging, or diverging roadway areas require higher illumination.

RP-8, 1977 thus stresses the continuous lighting of public traffic routes and does not recognize that the lighting of traffic conflict areas may in some instances be the only lighting that is warranted.

The standard is now up for review and will probably be revised in line with the recommendations of this report when RP-8 is reissued in 1982.

A more detailed critique of the ANSI/IES standards is provided in Volume 2.

CIE. The visual orientation of the CIE document (12/2) puts it on a much more solid basis than IES RP-8, 1977. The luminance criteria given for roadway lighting are completely independent of the lighting technique that might be used, whereas RP-8, 1977, presents illumination criteria that are appropriate only when standard street lights are used at conventional spacings on roadways.

Another strength of CIE 12/2 is that luminaire glare is quantified and limits on that glare are recommended. Two other noteworthy features of CIE 12/2 are (1) the emphasis on the need for luminaire beacon effects to show the direction of the roadway and (2) the need to reveal the direction of the traffic route by virtue of its luminance in contrast to the surrounding area.

Where RP-8, 1977, focuses on simplistic illumination criteria that apply only to the continuous lighting of traffic routes by "standard" twin-beam street lights, CIE 12/2 emphasizes the visual aspects of outdoor traffic lighting. Where RP-8, 1977, gives reasons for not using pavement luminance criteria, the CIE document emphasizes the importance of pavement luminance along with other visual needs, such as roadway delineation and beacon effects. The strength of the CIE document lies in the fact that true visual criteria are independent of the lighting technique that may be used. That is, if certain levels and uniformity of pavement luminance are specified, it does not matter what type of lighting technique is used as long as the specified criteria are met.

In CIE 12/2 glare control is emphasized and glare value limitations are given.

In the recommendations concerning disability glare the Holladay formula is used and it applies to the glare from all of the luminaires adjacent to a given line of sight. The Holladay formula is the most generally applicable method of evaluating glare. The relative threshold increment, or TI, given in the CIE document, relates the Holladay veiling luminance created by glare sources to the pavement luminance.

Discomfort glare is evaluated by another relationship among the luminance and geometric parameter and is given the name "Glare Mark" (GM).

In both methods of glare evaluation the glare created by luminaires is related to the pavement luminance. Thus, it is important to note that in the evaluation of glare from roadway lighting systems, the importance of road pavement luminance is stressed.

CIE 12/2 contains some excellent recommendations regarding visual and optical guidance. The visual guidance referred to in this document is often called a beacon effect in this country and simply refers to the delineation of traffic routes provided by the brightness of the luminaires themselves. In effect, therefore, a luminaire can function to some extent like a beacon or traffic signal.

One deficiency of CIE 12/2 is that it ignores the possible existence and benefits of roadway lighting limited to critical traffic areas.

AASHTO. Earlier editions of the AASHTO guide were concerned mainly with the lighting of high speed roadways (freeways and limited access highways). However, Federal legislation now requires that this guide cover all types of roadway lighting. Furthermore, this guide now covers rest-area lighting, sign lighting, and tunnel and underpass lighting.

One of the unique features of the AASHTO guides has been that they recognize this existence and benefits of limiting roadway lighting to critical traffic areas.

AASHTO has never been convinced that very high levels of average illumination are necessary. It still considers that an average maintained roadway pavement illumination of only 0.6 fc is adequate for freeways, and it does not recommend higher illumination levels for critical traffic areas. AASHTO also believes that a minimum level of only 0.2 fc is adequate on freeways.

Illumination and luminance measurements were made at representative locations to evaluate the existing street lighting conditions in the City of Portland. Complete results of these tests are provided in Volume 3, Technical Appendix. The data show that the lighting on these typical streets is essentially in accord with the recommended levels for quantity ($E_{h(ave)}$ and L_{ave}) but is generally below recommended values for quality (the average/minimum and maximum/minimum ratios for both E_h and L).

Projected Impact of Recommended Street Lighting Standards

Modernization of the entire City of Portland street lighting system to the recommended standards would have the following impacts:

Energy Savings. The present connected load can be reduced by approximately 50% if the recommended standards are applied city-wide and modern arc-discharge lamps and luminaires are used to replace existing mercury-vapor and incandescent equipment.

Traffic Safety. This is an intangible factor. Many studies[1] show accident reductions up to 30% overall in selected test areas with pedestrian accidents reduced the most, by 45%. Serious accidents were reduced by 33%; minor accidents by 27%.

Pedestrian Safety. The safety of pedestrians is of vital importance on city streets. Good quality background lighting, even at a relatively low level, has been shown to be very effective in reducing vehicle-pedestrian accidents[2].

Adjacent Property Security. The spill light from street lights may provide benefits in terms of higher adaptation levels of drivers, orientation and guidance information for drivers and pedestrians, a feeling of security for residents and pedestrians along the road, and enhanced civic pride in the area[3]. However, other studies have failed to determine a definitive relationship between lighting levels and adjacent property security[4]. Furthermore, there may be some objections to spill light on the grounds of light trespass and the degradation of astronomy observations.

REFERENCES

1. Fisher, A., *A Review of Street Lighting in Relation to Road Safety*, Australian Dept. of Transport, 1971, p. 23-24.

2. Tanner, J., "Reduction of Accidents by Improved Street Lighting," *Light and Lighting*, Vol. 51, No. 11, p. 353.

3. Walton and Rowan, *Warrants for Highway Lighting*, Texas Transportation Inst., 1973, p. 24 and references 18, 19, 20, 21, 22, 23.

4. *Effectiveness of Highway Arterial Lighting*, Final Report, Federal Hwy. Adm., July, 1977. p. 41-42.

ORDINANCE NO. **149210**

An Ordinance adopting street lighting standards, directing the Street Lighting Division of the Bureau of Street and Structural Engineering to apply those standards, authorizing the City Engineer to make exceptions to those standards subject to approval of the Commissioner in charge, and declaring an emergency.

The City of Portland ordains:

Section 1. The Council finds:

1. The City of Portland has no adopted policy on the level and quality of street illumination. As a result, street lighting services are not uniformly provided throughout the City.

2. As part of the Arterial Street Light Conversion Project, the City Council authorized a contract with Industrial Testing Laboratories, Inc. (Ordinance No. 148454) for preliminary engineering, including recommendation of street lighting standards. Industrial Testing Laboratories, Inc., has submitted Street Lighting Analysis, Standards and Specifications for the City of Portland, Oregon, Volume 1: "Recommended Lighting Standards" in partial fulfillment of that contract. This report is attached as Exhibit "A."

3. The City Engineer and the Commissioner of Public Works have reviewed the standards recommended by Industrial Testing Laboratories, Inc., and have filed reports to the City Council recommending adoption of these standards.

4. The street lighting standards contained in Exhibit "A" should be applied to all new installations of street lights within, or lighting, the public right-of-way in the City of Portland, whether construction by the City, other public agencies, or private parties. The street lighting standards contained in Exhibit "A" should also be applied to all projects involving the removal, relocation, or conversion of existing street lights, whether funded by the City, other public agencies, or private parties.

5. Subject to approval of the Commissioner in charge, the City Engineer should have authority to approve minor exceptions to these street lighting standards when individual circumstances render the standards unreasonable.

149210

ORDINANCE No.

NOW, THEREFORE, the Council directs:

a. Effective immediately, the City Council adopts Exhibit "A" as street lighting standards for the City of Portland.

b. The Street Lighting Division of the Bureau of Street and Structural Engineering is directed to apply the street lighting standards in Exhibit "A" to all new street lighting installations within or lighting the public right-of-way for which the City accepts ownership and provides maintenance and energy, on or after passage of this Ordinance by the City Council.

c. The Street Lighting Division is directed to apply the street lighting standards in Exhibit "A" to all projects involving the removal, relocation, or conversion of street lights within the City of Portland street lighting system on or after the date or passage of this Ordinance by the City Council.

d. The City Engineer is authorized to make exceptions to the street lighting standards in Exhibit "A" when individual circumstances render the standards unreasonable, subject to approval of the Commissioner in charge.

Section 2. The Council declares that an emergency exists because delay in enactment of this Ordinance will unnecessarily delay application of the street lighting standards; therefore, this Ordinance shall be in force and effect from and after its passage by the Council.

Passed by the Council, FEB 28 1980

Commissioner Mike Lindberg
M.T. Nolan:mmv
February 20, 1980

Connie McCready
Mayor of the City of Portland

Attest:

Auditor of the City of Portland

THE COMMISSIONERS VOTED AS FOLLOWS:		
	Yeas	Nays
Ivancie	1	
Jordan	1	
Lindberg	1	
Schwab	1	
McCready	1	

FOUR-FIFTHS CALENDAR	
Ivancie	
Jordan	
Lindberg	
Schwab	
McCready	

Calendar No. 692

ORDINANCE No. 149210

Title

An Ordinance adopting street lighting standards, directing the Street Lighting Division of the Bureau of Street and Structural Engineering to apply those standards, authorizing the City Engineer to make exceptions to those standards subject to approval of the Commissioner in charge, and declaring an emergency.

1+7

Filed FEB 22 1980

GEORGE YERKOVICH
Auditor of the CITY OF PORTLAND

By Gordon Crowell
Deputy

INTRODUCED BY
Commissioner Mike Lindberg

NOTED BY THE COMMISSIONER
Affairs
Finance and Administration
Safety
Utilities
Works ML/SA

BUREAU APPROVAL
Bureau: Street & Structural Engineering
Prepared By: M.T. Nolan:mmv — Date: 2-20-80
Budget Impact Review: ☑ Completed ☐ Not required
Bureau Head: Vargas — David J. Vargas, Acting Chief

NOTED BY
City Attorney
City Auditor
City Engineer: Approved — John M. Lang, Acting Head
By: