

# Roadway Lighting

## Design Guide

October 2005



**American Association  
of State Highway and  
Transportation Officials**

# Roadway Lighting

## Design Guide

October 2005



**American Association  
of State Highway and  
Transportation Officials**



American Association of State Highway and Transportation Officials  
444 North Capitol Street, NW, Suite 249  
Washington, DC 20001  
P: 202-624-5800, F: 202-624-5806 fax  
[www.transportation.org](http://www.transportation.org)

© 2005 by the American Association of State Highway and Transportation Officials.  
All rights reserved. Duplication is a violation of applicable law.

ISBN: 1-56051-325-X

Publication Code: GL-6

© 2005 by the American Association of State Highway and Transportation Officials.  
All rights reserved. Duplication is a violation of applicable law.

# AASHTO 2004–2005 Executive Committee

## **Voting Members**

### ***Officers:***

President: Harold E. Linnenkohl, Georgia

Vice President: David Sprynczynatyk, North Dakota

Secretary-Treasurer: Larry M. King, Pennsylvania

### ***Regional Representatives:***

REGION I: Dan Tangherlini, District of Columbia, One-Year Term  
Jim Capaldi, Rhode Island, Two-Year Term

REGION II: Harold Linnenkohl, Georgia, One-Year Term  
Joe McInnes, Alabama, Two-Year Term

REGION III: Frank Busalacchi, Wisconsin, One-Year Term  
Carol Malnau, Minnesota, Two-Year Term

REGION IV: David Sprynczynatyk, North Dakota, One-Year Term  
Victor Mendez, Arizona, Two-Year Term

## **Nonvoting Members**

Immediate Past President: Jack Lettiere, New Jersey

AASHTO Executive Director: John Horsley, Washington, DC

# Technical Committee on Highway Lighting

**Chairman:** Karl A. Burkett, P.E., Texas

**Secretary:** Balu Ananthanarayanan, P.E., Wisconsin

Carl Andersen, FHWA

Stanley C. Biddick, P.E., Alabama

Mike DeAngelo, New Jersey

Jon Dickinson, Nevada

Ernest Kim, P.E., Oregon

Susan Lodahl, P.E., Minnesota

Jeff Unick, P.E., Pennsylvania

# AASHTO Highway Subcommittee on Traffic Engineering

**Chair:** Delbert McOmie  
Wyoming

**Chair:** Vacant

**Vice Chair:** Thomas Hicks  
Maryland

**Secretary:** Regina McElroy  
FHWA

**Liaison:** Ken Kobetsky  
AASHTO

## State Member

<b>Alabama</b>	Timothy C. Taylor, P.E.
<b>Alaska</b>	Kurtis J. Smith, P.E.
<b>Arizona</b>	Mike Manthey, P.E. Richard C. Moeur, P.E.
<b>Arkansas</b>	Eric Phillips Tony Sullivan
<b>California</b>	Asif J. Haq Karla Sutliff
<b>Colorado</b>	Gabriela Vidal
<b>Connecticut</b>	John F. Carey, P.E.
<b>Delaware</b>	Donald D. Weber, P.E.
<b>District of Columbia</b>	Douglas E. Noble, P.E.
<b>Florida</b>	Lap Thong Hoang, P.E.
<b>Georgia</b>	Keith Golden, P.E.
<b>Hawaii</b>	Alvin Takeshita
<b>Idaho</b>	Lance Johnson
<b>Illinois</b>	Joseph S. Hill
<b>Indiana</b>	Jim Poturalski Carl T. Tuttle
<b>Iowa</b>	Timothy D. Crouch
<b>Kansas</b>	David A. Church, P.E. Kenneth F. Hurst, P.E.
<b>Kentucky</b>	Duane H. Thomas, P.E.
<b>Louisiana</b>	Charles Adams, P.E., PTOE
<b>Maine</b>	Bruce A. Ibarguen, III, P.E.
<b>Maryland</b>	Thomas Hicks, P.E.
<b>Massachusetts</b>	William Bent
<b>Michigan</b>	Vacant

<b>Minnesota</b>	Bernard J. Arseneau
<b>Mississippi</b>	Wes Dean
<b>Missouri</b>	Eileen Rackers
<b>Montana</b>	Duane Williams, P.E.
<b>Nebraska</b>	Randall D. Peters
<b>Nevada</b>	Scott L. Thorson
<b>New Hampshire</b>	William Lambert
<b>New Jersey</b>	Douglas R. Bartlett Timothy J. Szvedo
<b>New Mexico</b>	Vacant
<b>New York</b>	Bruce W. Smith, P.E.
<b>North Carolina</b>	J. Kevin Lacy, P.E., CPM
<b>North Dakota</b>	Al Covlin
<b>Ohio</b>	Dave Holstein
<b>Oklahoma</b>	Harold Smart
<b>Oregon</b>	Edward L. Fischer, P.E., PTOE
<b>Pennsylvania</b>	Glenn Rowe
<b>Puerto Rico</b>	Samuel Forestier
<b>Rhode Island</b>	Robert Rocchio, P.E.
<b>South Carolina</b>	Richard B. Werts
<b>South Dakota</b>	John Adler, P.E.
<b>Tennessee</b>	Don L. Dahlinger Gerald Gregory Michael L. Tugwell
<b>Texas</b>	Margaret (Meg) A. Moore
<b>Utah</b>	Robert E. Hull
<b>Vermont</b>	Vacant
<b>Virginia</b>	Raymond J. Khoury, P.E.
<b>Washington</b>	Theodore Trepanier, P.E.
<b>West Virginia</b>	Barry Warhoftig, P.E.
<b>Wisconsin</b>	David I. Vieth
<b>Wyoming</b>	Michael N. Gostovich

**Associate Member—Bridge, Port, and Toll**

**N.J. Turnpike Authority**      Robert F. Dale

**Associate Member—Cities and Counties**

**City of Minneapolis**      Jon Wertjes

**Associate Member—Federal**

**USDA Forest Service**      John W. Bell

**Associate Member—International**

**Manitoba**                      Ben Rogers

**Nova Scotia**                  Ralph Hessian

**Saskatchewan**                Sukhy Kent

# AASHTO Highway Subcommittee on Design

**Chair:** Allen D. Biehler  
Pennsylvania

**Vice Chair:** Robert L. Walters  
Arkansas

**Secretary:** Dwight A. Horne  
FHWA

**Liaison:** Jim McDonnell  
AASHTO

## State Member

**Alabama** Don T. Arkle, P.E.  
Steven E. Walker, P.E.

**Alaska** Gary Hogins, P.E.

**Arizona** Mary Viparina

**Arkansas** Phillip L. McConnell, P.E.  
Charles D. Clements, P.E.

**California** Mark Leja, P.E.

**Colorado** Mithilesh “Mitch” Kumar  
Gary W. Meacham

**Connecticut** Arthur W. Gruhn  
Michael W. Lonergan  
James H. Norman

**Delaware** Michael H. Simmons  
Michael F. Balbierer  
James M. Satterfield

**District of Columbia** Kathleen Penney  
Zahra Dorriz  
Allen Miller

**Florida** Brian A. Blanchard, P.E.  
Robert Greer  
Jim Mills, P.E.

**Georgia** James “Ben” Buchan, P.E.  
Babs Abubakari, P.E.  
Brent Story, P.E.

**Hawaii** Gary C.P. Choy  
Julius Fronda

**Idaho** Loren D. Thomas  
Steven C. Hutchinson

**Illinois** Michael Hine

**Indiana** Gary Mrocza, P.E.  
Jeff Clanton, P.E.

**Iowa** Michael J. Kennerly  
David L. Little  
Deanna Maifield

<b>Kansas</b>	James O. Brewer, P.E. Richard G. Adams, P.E. LaMonte C. Armstrong, P.E.
<b>Kentucky</b>	Kenneth Sperry, P.E. David Jones
<b>Louisiana</b>	N. Kent Israel Nicholas Kalivoda, III Lloyd E. Porta, Jr.
<b>Maine</b>	Jerome A. Casey, P.E.
<b>Maryland</b>	Kirk G. McClelland Robert D. Douglass
<b>Massachusetts</b>	John Blundo, P.E. Stanley Wood, Jr.
<b>Michigan</b>	Mark A. Van Port Fleet, P.E.
<b>Minnesota</b>	Mukhtar Thakur, P.E.
<b>Mississippi</b>	David Foster John B. Pickering, P.E. C. Keith Purvis, P.E.
<b>Missouri</b>	David B. Nichols
<b>Montana</b>	Paul R. Ferry Lesly Tribelhorn
<b>Nebraska</b>	Don Turek Dawn Allyn James J. Knott
<b>Nevada</b>	Frank Csiga, Jr., P.E. Ruedy Edgington Rand Pollard, P.E. Paul K. Sinnott, P.E.
<b>New Hampshire</b>	Craig A. Green
<b>New Jersey</b>	Kiran B. Patel Brian Strizki
<b>New Mexico</b>	Roy Maestas, P.E. Dennis Peralta, P.E. Max E. Valerio, P.E.
<b>New York</b>	Philip J. Clark, P.E. Daniel D'Angelo, P.E. Richard W. Lee, P.E.
<b>North Carolina</b>	Jay A. Bennett, P.E. Deborah M. Barbour Art McMillan
<b>North Dakota</b>	Mark Gaydos
<b>Ohio</b>	Cash Misel Dirk Gross Timothy McDonald

<b>Oklahoma</b>	Christine M. Senkowski, P.E. Bruce E. Taylor
<b>Oregon</b>	Thomas Lauer
<b>Pennsylvania</b>	Dean A. Schreiber, P.E. Brian D. Hare, P.E.
<b>Puerto Rico</b>	Ariel Pérez José E. Santana-Pimentel
<b>Rhode Island</b>	J. Michael Bennett, P.E.
<b>South Carolina</b>	Robert I. Pratt, P.E. Rocque L. Kneece, P.E. John V. Walsh, P.E.
<b>South Dakota</b>	Joel Gengler Joe J. Feller
<b>Tennessee</b>	Jeff C. Jones Mark Holloran
<b>Texas</b>	Mark A. Marek
<b>Utah</b>	Stan Burns, P.E.
<b>Vermont</b>	Kevin Marshia, P.E.
<b>Virginia</b>	Mohammad Mirshahi, P.E. Barton A. Thrasher, P.E.
<b>Washington</b>	Harold Peterfeso, P.E. Richard Albin, P.E. Ken L. Smith, P.E., CVS
<b>West Virginia</b>	Jason C. Foster Randolph T. Epperly, Jr.
<b>Wisconsin</b>	Beth Cannestra
<b>Wyoming</b>	Paul P. Bercich Tony Laird

**U.S. DOT Member**

**FAA** Rick Marinelli, P.E.

**Associate Member—Bridge, Port and Toll**

**N.J. Turnpike Authority** J. Lawrence Williams

**Penn. Turnpike Commission** Barry L. Troup, P.E.

**Associate Member—Bridge, Port and Toll**

**Port Authority of NY and NJ** Scott D. Murrell

**Associate Member—Cities and Counties**

**City of Minneapolis** Fred Abadi

**Associate Member—Federal**

**USDA Forest Service** Ellen G. LaFayette

**Associate Member—International**

<b>Alberta</b>	Allan Kwan
<b>British Columbia</b>	Richard Voyer
<b>Ontario</b>	Joe Bucik
<b>Ontario</b>	Joe Bucik
<b>Saskatchewan</b>	Sukhy Kent



# Table of Contents

<b>Chapter 1: Introduction .....</b>	<b>1</b>
Overview .....	1
Need for Engineering Expertise .....	1
Necessary Expertise .....	1
Recommended Design Methods.....	2
Modern Controls and Master Lighting Plans .....	2
<b>Chapter 2: Master Lighting Plans.....</b>	<b>3</b>
<b>2.1 Overview .....</b>	<b>3</b>
Introduction .....	3
Definition.....	3
Benefits.....	3
<b>2.2 Plan Development .....</b>	<b>3</b>
Introduction .....	3
Participants .....	4
Groups Having Concerns About Lighting.....	4
<b>2.3 Goals of a Master Lighting Plan.....</b>	<b>5</b>
Introduction .....	5
Improved Safety .....	5
Environmentally Judicious Use of Resources .....	5
Energy Use .....	6
Tourists, Businesses, and Nighttime Activities.....	6
Planned Maintenance .....	6
<b>2.4 Lighting Curfews.....</b>	<b>6</b>
Introduction .....	6
Reasons for Curfews .....	7
Considerations Before Implementation.....	7
<b>2.5 Electrical and Lighting Management Systems.....</b>	<b>8</b>
Introduction .....	8
Cost.....	8
Benefits.....	9
Benefits of ELMS Standardization.....	10
<b>2.6 Conducting Studies.....</b>	<b>10</b>
Introduction .....	10
Electrical System.....	11
Benefits and Effects of Curfews and Dimming.....	11
Traffic Studies .....	11
Community Goals.....	11
Budget .....	11
<b>Chapter 3: Techniques of Lighting Design.....</b>	<b>13</b>
<b>3.1 Overview .....</b>	<b>13</b>
Introduction .....	13
Level and Uniformity of Illuminance and Luminance .....	13
Illuminance Considerations.....	14

	Luminance Considerations .....	14
	Visibility-Based Design Methods .....	16
<b>3.2</b>	<b>Warranting Conditions.....</b>	<b>17</b>
	General.....	17
	Benefits of Lighting.....	17
	Rural Interchanges.....	17
	Warranting Conditions.....	17
	Continuous Freeway Lighting .....	18
	Partial Interchange Lighting .....	19
	Special Considerations.....	20
	Bridges.....	20
<b>3.3</b>	<b>Design Values for Freeways.....</b>	<b>20</b>
	General.....	20
	Design Considerations .....	20
	Lighting Levels on Crossroads .....	20
	Partial Interchange Lighting .....	21
	Adaptation (Transition) Lighting.....	22
	Bridges and Overpasses.....	22
	Other Considerations .....	22
	Area Classifications .....	22
<b>3.4</b>	<b>Streets and Highways Other Than Freeways (Including Walkways and Bicycle Ways) .....</b>	<b>23</b>
	General.....	23
	Warranting Conditions.....	23
	Lighting Design Levels.....	23
	Other Considerations .....	23
<b>3.5</b>	<b>Pole Placement Guidelines .....</b>	<b>26</b>
	Introduction.....	26
	Obstruction of View .....	26
	Height Restrictions .....	26
	Medians.....	26
	Gore Areas.....	26
	Maintenance Considerations.....	26
	Adjacent to Deflecting Barriers .....	27
	General Safety Concerns .....	27
	Design Options .....	27
	Option 1: Remove the Obstacle.....	27
	Option 2: Redesign the Obstacle .....	27
	Option 3: Relocate the Obstacle .....	28
	Option 4: Use Appropriate Breakaway Device .....	28
	Option 5: Shield the Obstacle.....	29
	Option 6: Delineate the Obstacle.....	29
<b>3.6</b>	<b>References.....</b>	<b>29</b>
<b>Chapter 4:</b>	<b>Techniques of Lighting Design.....</b>	<b>31</b>
<b>Chapter 5:</b>	<b>Tunnels and Underpasses.....</b>	<b>33</b>
<b>5.1</b>	<b>Overview .....</b>	<b>33</b>

5.2	Underpasses.....	33
	General Scope and Guide Application .....	33
	Warrants for Nighttime Underpass Lighting.....	33
	Design Values for Underpass Lighting .....	34
	Selection and Placement of Underpass Luminaires .....	34
5.3	Vehicular Tunnels .....	34
	General Scope and Guide Application .....	34
	Short Tunnels .....	35
	Long Tunnels.....	35
	Warrants for Tunnel Lighting.....	35
	Visibility Optimization of the Tunnel and Approach Features .....	36
5.4	Daytime Lighting of Tunnel Interiors .....	37
	Short Tunnels—Silhouette Visibility .....	37
	Entrance Portal Lighting .....	37
	Lighting Beyond the Entrance Zone .....	37
	Nighttime Tunnel Lighting.....	38
	Selection and Placement of Tunnel Luminaires.....	38
	Tunnel Lighting Control Systems .....	38
	Maintenance Factor for Tunnel Lighting Design .....	38
<b>Chapter 6:</b>	<b>Work Zone Lighting and Temporary Roadway Lighting.....</b>	<b>39</b>
	Introduction .....	39
	Cost.....	39
	Types .....	39
	Design Values .....	39
	Safety.....	39
	Work Area Lighting .....	40
<b>Chapter 7:</b>	<b>Roundabouts.....</b>	<b>41</b>
	Introduction .....	41
	Warrant Conditions.....	41
	Recommended Lighting Level .....	41
<b>Chapter 8:</b>	<b>Electrical Systems Requirements.....</b>	<b>43</b>
	Disconnects.....	43
	Guidelines Available .....	43
	Grounding.....	43
	Voltage Drop .....	43
<b>Chapter 9:</b>	<b>Safety Rest Areas.....</b>	<b>45</b>
	Overview .....	45
	Warrant.....	45
	Design Values.....	45
	Entrance and Exit .....	45
	Interior Roadways .....	46
	Parking Areas .....	47
	Activity Areas.....	47
	Main Lanes .....	47

<b>Chapter 10: Roadway Sign Lighting</b> .....	<b>49</b>
<b>10.1</b> Overview .....	49
Introduction .....	49
Key Elements of Roadway Sign Lighting.....	49
<b>10.2</b> Sign Lighting Warrants .....	50
<b>10.3</b> Illuminated Sign Types .....	51
Ambient Luminance Classifications .....	51
<b>10.4</b> Sign Lighting Recommendations .....	52
Lighting Uniformity .....	53
Sign Color Standards.....	53
Placement of Lighting Units.....	53
<b>10.5</b> References .....	54
<b>Chapter 11: Maintenance Considerations in Roadway Lighting Design</b> .....	<b>55</b>
General.....	55
Maintenance Factors .....	55
Luminaire Dirt Depreciation (LDD).....	55
Lamp Lumen Depreciation (LLD).....	55
Equipment Factor (EF) .....	56
Support Structure Maintenance .....	56
Electrical Distribution and Control System Maintenance .....	56
External Factors .....	57
<b>Chapter 12: Sky Glow and Light Trespass</b> .....	<b>59</b>
<b>12.1</b> Overview .....	59
Introduction .....	59
Types of Objectionable Roadway Lighting.....	59
<b>12.2</b> Mitigating Sky Glow and Light Trespass.....	60
<b>Glossary</b> .....	<b>61</b>



---

# Chapter 1

## Introduction

### Overview

This guide replaces the 1984 publication entitled, *An Informational Guide for Roadway Lighting*. It has been revised and brought up to date to reflect current practices in roadway lighting. The guide provides a general overview of lighting systems from the point of view of the transportation departments and recommends minimum levels of quality. The guide incorporates the illuminance and luminance design methods, but does not include the small target visibility (STV) method.

Two appendices to this document are located online for reference purposes at <http://downloads.transportation.org/lighting.pdf>. Appendix A is entitled *Literature Review and References*, and contains information on research studies related to accidents and highway lighting, driver parameters, pavement parameters, and a summary of further references. Appendix B contains an overview of *Lighting Basics*, including background information on the various issues related to effective highway lighting.

### Need for Engineering Expertise

Most states require that final design documents be signed and sealed by a registered professional engineer. The registrant is normally required to only sign and seal documents that the registrant prepared, or documents for which the registrant was responsible for the direction and control of the work. Documents include specifications, reports, drawings, plans, design information, and calculations. Lighting designs, as described in this guide, meet the criteria for requirement of an engineering seal. This is necessary because the public interest is at stake. In addition, the designs integrated with other aspects of the transportation facility that have engineering features. These other aspects include support structures, break-away devices, pavement characteristics, electrical characteristics, traffic engineering features, traffic management features, and the relative priority of lighting with respect to other safety features on the facility. Proper engineering judgment must be used in the integration of the various aspects of the facility, as well as in the consideration of maintenance and life-cycle costs.

Many of the current problems in outdoor lighting are due to poor lighting designs. These problems include less than optimal benefits from the lighting systems, excessive glare and visual clutter at night, the use of improper depreciation factors and photometric distributions, excessive sky glow and light trespass, and excessive maintenance and energy costs. The primary cause of poor lighting designs is a lack of proper lighting and electrical education.

### Necessary Expertise

Departments of transportation (DOTs) that hire consultant engineers are paying for engineering expertise. This expertise is available in the area of roadway lighting and associated electrical systems. The expertise required for DOT lighting designs includes:

- lamp types and characteristics, including depreciation factors
- ballast types and characteristics
- fixture mechanical characteristics

- lens types
- photometric performance of luminaires and factors impacting such performance
- fixture mounting types
- pole mechanical and electrical characteristics
- breakaway device options and when appropriate to use
- clear zone criteria
- pole types, mounting options, and loading considerations
- foundation and support details
- pavement reflection factors
- mounting height and spacing options
- light trespass and sky glow issues including laws and ordinances
- lighting quality requirements, such as illuminance, luminance, veiling luminance, and visibility
- maintenance considerations for individual components and the lighting system as a whole
- energy and life-cycle costs
- coordination with master lighting plans.

Consultants accepting payment for lighting system design should perform that work in an engineering manner. This includes exercising engineering judgement when balancing all of the above characteristics. Training courses are available for engineers wishing to learn how to design lighting systems.

### **Recommended Design Methods**

This guide recommends only the luminance and illuminance design methods but recognizes efforts to turn lighting designs toward visibility-based design methods. A discussion of visibility-based methods is included. The fact that this guide does not recommend the small target visibility (STV) design method should not be interpreted as non-support for visibility based methods and associated research. The STV method is not recommended as standard practice because the increased benefits of using this design method have not been adequately demonstrated and confidence in the ability to achieve design values and better visibility is low. Accurate visibility calculations require the input of all light sources, including off-roadway sources and headlamps from multiple vehicles. Such data are not easily obtained on roadways under even moderate traffic conditions. The fact that lighting is installed on roadways based on, among other things, high traffic volumes lends further uncertainty to the value of visibility calculations. STV or other visibility criteria may be applied as an additional quality criteria in order to gain experience with those methods and to determine the value of such criteria.

### **Modern Controls and Master Lighting Plans**

This guide also addresses modern control methods for lighting systems and encourages the use of a master lighting plan incorporated into the traffic management centers, emergency management centers, or other central locations. Better use of resources can be achieved through innovative strategies such as lighting curfews, special event and weather situation control, and maintenance automation. Curfews can create energy savings. Energy cost savings on one particular lighting system may allow additional lighting systems to be installed and operated in peak traffic times, thereby improving safety of the entire area under the jurisdiction of the master lighting plan.

Maintenance inventory and management can be improved by remotely monitoring percentage of lights burning, diagnosing problems prior to sending out maintenance crews, tracking life-cycle costs, and monitoring the performance level of maintenance contractors.

---

# Chapter 2

## Master Lighting Plans

### 2.1 OVERVIEW

#### Introduction

The commitment to lighting roadway facilities is a large responsibility. A master lighting plan can help in the fulfillment of this responsibility. This chapter provides general guidelines for implementing a master lighting plan when local authorities determine that such a plan is desirable for their community.

#### Definition

A master lighting plan is a formal arrangement between local governments and other entities within a regional area to coordinate and standardize the design, operation, and maintenance of public lighting. Master lighting plans can include lighting curfews and sophisticated monitoring systems (described in Sections 2.4 and 2.5, respectively).

#### Benefits

The basic benefits of lighting include safety, beautification, and security for people and property. Additional benefits derived from a master lighting plan include:

- improved safety through the maximizing of resources
- a consistent image, reflecting the local culture and tastes
- nighttime linking of various sections of the city
- systems that better identify the nature of the site (residential versus “restaurant row,” for example)
- better management of energy use
- tighter control of sky glow and light trespass
- aid in implementing lighting curfews
- increased public security (other concerns may warrant immediate turning on or off)
- coordinated maintenance
- easier coordination of maintenance specifications, such as poles, breakaway devices, and luminaires.

### 2.2 PLAN DEVELOPMENT

#### Introduction

The master lighting plan development process can proceed as shown in the following table.