Roadway Lighting Design Guide

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American Association of State Highway and Transportation Officials

AASHTO

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1

1.1 Overview 1
1.2 Need for Engineering Expertise 2
1.3 Safety Research and Application 3
1.4 Recommended Roadway Lighting Design Methods 3
1.5 Master Roadway Lighting Plans 4
1.6 Modern Roadway Lighting Controls 4
1.7 Emerging Roadway Lighting Technologies 4
1.8 References 5

CHAPTER 2: MASTER LIGHTING PLANS 6

2.1 Overview 6
- 2.1.1 Introduction 6
- 2.1.2 Definition 6
- 2.1.3 Benefits 6

2.2 Plan Development 7
- 2.2.1 Introduction 7
- 2.2.2 Participants 7
- 2.2.3 Gropus Having Concerns About Lighting 8

2.3 Goals of a Master Lighting Plan 8
- 2.3.1 Introduction 8
- 2.3.2 Improve Roadway Safety 8
- 2.3.3 Increase Personal Security 9
- 2.3.4 Provide Nighttime Aesthetics 9
- 2.3.5 Consider Environmental Issues 9
- 2.3.6 Use Energy Efficiently 10
- 2.3.7 Plan Maintenance 10

2.4 Lighting Curfews 10
- 2.4.1 Introduction 10
- 2.4.2 Reasons for Curfews 11
- 2.4.3 Considerations before Implementation 11

2.5 Electrical and Lighting Management Systems 12
- 2.5.1 Introduction 12
- 2.5.2 Cost 13
- 2.5.3 Benefits 13
- 2.5.4 Benefits of ELMS Standardization 13

2.6 Conducting Studies 14
- 2.6.1 Introduction 14
- 2.6.2 Lighting Justification Criteria 15
- 2.6.3 Electrical System 15
- 2.6.4 Benefits and Effects of Curfews and Dimming 15

2.6.5 Traffic Studies 15
2.6.6 Community Goals 15
2.6.7 Budget 15

2.7 References 16

CHAPTER 3: TECHNIQUES OF LIGHTING DESIGN 17

3.1 OVERVIEW 17
3.1.1 Introduction 17
3.1.2 Level and Uniformity of Illuminance and Luminance 17
3.1.3 Illuminance Considerations 18
3.1.4 Luminance Considerations 18
3.1.5 Visibility-Based Design Methods 20

3.2 Warranting Conditions 20
3.2.1 General 20
3.2.2 Benefits of Lighting 20
3.2.3 Rural Interchanges 20
3.2.4 Warranting Conditions for Lighting on Freeways 21
3.2.5 Continuous Freeway Lighting 21
3.2.6 Complete Interchange Lighting 21
3.2.7 Partial Interchange Lighting 22
3.2.8 Special Considerations 23
3.2.9 Bridges 23

3.3 Design Values for Freeways 23
3.3.1 General 23
3.3.2 Design Considerations 23
3.3.3 Lighting Levels on Crossroads 24
3.3.4 Partial Interchange Lighting 24
3.3.5 Adaptation (Transition) Lighting 26
3.3.6 Bridges and Overpasses 26
3.3.7 Other Considerations 26
3.3.7.1 Aesthetics 26
3.3.7.2 Future Lighting 26
3.3.8 Area Classifications 26
3.3.8.1 Commercial 26
3.3.8.2 Intermediate 26
3.3.8.3 Residential 26

3.4 Streets and Highways Other Than Freeways (Including Walkways and Bicycle Ways) 27
3.4.1 General 27
3.4.2 Warranting Conditions 27
3.4.3 Lighting Design Levels 27
3.4.4 Other Considerations 27

3.5 Pole Placement Guidelines 31
3.5.1 Introduction 31
3.5.2 Obstruction of View 31
3.5.3 Height Restrictions 31
3.5.4 Center Medians 31
3.5.5 Gore Areas 32

3.5.6 Intersections 32
3.5.7 Adjacent to Deflecting Barriers 34
3.5.8 General Safety Concerns 34
3.5.9 Design Options 34
3.5.9.1 Option 1: Remove the Obstacle 34
3.5.9.2 Option 2: Redesign the Obstacle 34
3.5.9.3 Option 3: Relocate the Obstacle 35
3.5.9.4 Option 4: Use Appropriate Breakaway Device 35
3.5.9.5 Option 5: Sheild Obstackle 36
3.5.9.6 Option 8: Delineate the Obstacle 36

3.6 References 37

CHAPTER 4: TUNNELS AND UNDERPASSES 38

4.1 Overview 38
4.1.1 Introduction 38

4.2 Underpasses 38
4.2.1 General Scope and Guide Application 38
4.2.2 Warrans for Night-Time Underpass Lighting 38
4.2.3 Design Values for Underpass Lighting 39
4.2.4 Selection and Placement of Underpass Luminaires 39

4.3 Vehicular Tunnels 39
4.3.1 General Scope and Guide Application 39
4.3.2 Short Tunnels 40
4.3.3 Long Tunnels 40
4.3.4 Warrants for Tunnel Lighting 40
4.3.5 Visibility Optimization of the Tunnel and Approach Features 41
4.3.5.1 Reduction of Ambient Daytime Brightness 41
4.3.5.2 Portal Design Factors 41
4.3.5.3 Visibility Optimization of Tunnel Interiors 41
4.3.5.4 Types of Pavement Surfaces 41

4.4 Daytime Lighting of Tunnel Interiors 42
4.4.1 Short Tunnels—Silhouette Visibility 42
4.4.2 Tunnel Approach at Entrance Portal 42
4.4.3 Interior Tunnel Lighting 42
4.4.4 Nighttime Tunnel Lighting 43
4.4.5 Emergency and Egress Lighting Systems 43
4.4.6 Selection and Placement of Tunnel Luminaires 43
4.4.7 Tunnel Lighting Control Systems 43
4.4.8 Maintenance Factor for Tunnel Lighting Design 43

4.5 References 43

CHAPTER 5: WORK ZONE LIGHTING AND TEMPORARY ROADWAY LIGHTING 45

5.1 Overview 45
5.1.1 Introduction 45

5.2 Considerations 45
5.2.1 Cost 45
5.2.2 Types 45
5.2.3 Design Values 46
5.2.4 Safety 46
5.2.5 Work Area Lighting 46
5.3 References 46

CHAPTER 6: ROUNDABOUTS 47
6.1 Overview 47
6.1.1 Introduction 47
6.2 Warranting Conditions 47
6.3 Recommended Lighting Level 48
6.4 References 48

CHAPTER 7: ELECTRICAL SYSTEMS REQUIREMENTS 49
7.1 Overview 49
7.1.1 Introduction 49
7.2 Electrical Systems 49
7.2.1 Disconnects 49
7.2.2 Grounding 49
7.2.3 Voltage Drop 50
7.2.4 Lighting System Control 50
7.2.5 Ground-Fault and Overcurrent Protection 50
7.3 References 50

CHAPTER 8: REST AREAS, WELCOME CENTERS, AND PARK-AND-RIDE LOTS 51
8.1 Overview 51
8.1.1 Introduction 51
8.2 Warrants 51
8.3 Design Values 51
8.4 Entrance and Exit 52
8.5 Interior Roadways 53
8.6 Parking Areas 53
8.7 Activity Areas 53
8.8 Main Line Lanes 53
8.9 Other References 53

CHAPTER 9: OVERHEAD LIGHTING 55

9.1 Overview 55
- 9.1.1 Introduction 55
- 9.1.2 Key Visibility Considerations for Overhead Sign Lighting 55

9.2 Guidelines for Overhead Sign Visibility 56
- 9.2.1 Introduction 56
- 9.2.2 Visual Complexity Levels for Overhead Guide Signs 57
- 9.2.3 Visual Complexity Levels for Overhead Street Name Signs 58

9.3 Illuminated Sign Types 60

9.4 Sign Lighting Recommendations 60
- 9.4.1 Introduction 60
- 9.4.2 Lighting Uniformity 60
- 9.4.3 Light Source Selection 61
- 9.4.4 Placement of Lighting Units 61

9.5 References 62

CHAPTER 10: MAINTENANCE CONSIDERATIONS IN ROADWAY LIGHTING DESIGN 63

10.1 Overview 63
- 10.1.1 Introduction 63

10.2 Luminaire Maintenance Factors 63
- 10.2.1 Luminaire Dirt Depreciation (LDD) 63
- 10.2.2 Lamp Lumen Depreciation (LLD) 64
- 10.2.3 Equipment Factor (EF) 64
- 10.2.4 Light Loss Factor (LLF) 64

10.3 Support Structure Maintenance 64

10.4 Electrical Distribution and Control System Maintenance 65

10.5 External Factors 65
- 10.5.1 Introduction 65
- 10.5.2 Suggestions for Reducing Wire Theft 66

10.6 Resources 66

CHAPTER 11: SKY GLOW AND LIGHT TRESPASS 67

11.1 Overview 67
- 11.1.1 Introduction 67
- 11.1.2 Types of Objectionable Roadway Lighting 67
  - *11.1.2.1 Sky Glow* 67
  - *11.1.2.2 Light Trespass* 68
  - *11.1.2.3 Glare* 68
  - *11.1.2.4 Visual Clutter* 68

11.2 Mitigating Sky Glow and Light Trespass 68

11.3 Luminaire Rating and Light Zones 68

11.4 Light Trespass 70
11.5 References 71

GLOSSARY 72

LIST OF TABLES

Table 1-1. Resources for Lighting Engineering Guidelines 2
Table 2-1. Master Lighting Plan Development Process 7
Table 2-2. Benefits of Electrical and Lighting Management Systems (ELMS) 13
Table 2-3. Benefits of ELMS Standardization 14
Table 3-1. Road Surface Classifications 19
Table 3-2. Warranting Conditions for Continuous Freeway Lighting (CFL) 21
Table 3-3. Warranting Conditions for Complete Interchange Lighting (CIL) 22
Table 3-4. Warranting Conditions for Partial Interchange Lighting (PIL) 22
Table 3-5a. Illuminance and Luminance Design Values (U.S. Customary) 29
Table 3-5b. Illuminance and Luminance Design Values (Metric) 30
Table 8-1. Recommended Maintained Average Lighting Levels for Rest Areas—Illuminance 52
Table 8-2. Recommended Maintained Lighting Levels for Rest Areas—Luminance 52
Table 9-1. Luminance Levels for Overhead Signs 56
Table 11-1. Maximum Values of Lighting Zones 71

LIST OF FIGURES

Figure 3-1. Calculation Points for Luminance and Illuminance Design Methods 18
Figure 3-2. Typical Luminaire Locations—Partial Interchange Lighting (A–D) 24–25
Figure 3-3. A) Plan View for Conflict Points; B) Positive Contrast for Pedestrians 33
Figure 4-1. Example of a Vehicular Tunnel 40
Figure 6-1. Typical Light Pole Locations 48
Figure 9-1. Five Levels of Visual Complexity for Overhead Guide Signs 57–58
Figure 9-2. Five Levels of Visual Complexity for Overhead Street Name Signs 59
Figure 9-3. Types of Sign Lighting 61
Figure 11-1. Spherical Lighting Zones of a Luminaire (based on Addendum of IES TM-15-11) 70

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

This is the seventh edition of the AASHTO *Roadway Lighting Design Guide*, with the sixth edition having been published in October 2005. This seventh edition has been revised to reflect current practices in roadway lighting and ultimately replaces the 1984 publication entitled An Informational Guide for Roadway Lighting. This guide provides a general overview of lighting systems from the point-of-view of state transportation departments and recommends minimum design parameters.

This guide may be used by agencies to warrant and design roadway lighting systems within their jurisdiction. Additionally, agencies can incorporate this information into their own roadway lighting policies. Agency-specific policy may also include types of lighting equipment and technologies, lighting calculation preferences, or maintenance issues.

Significant changes in the seventh edition of this guide include the following:

- additional information on roadway lighting safety research,
- commentary on emerging technologies,
- Revised goals of master lighting plans,
- additional information on coordination with the Federal Aviation Administration,
- additional information about pedestrians at intersections,
- new criteria and methods for determining the need for overhead sign lighting, and
- new information on sky glow and light trespass.

Please note, however, that one of the key components of the sixth edition of the AASHTO *Roadway Lighting Design Guide*, i.e., the Illuminance and Luminance Design Value tables in Chapter 3, has not changed significantly. No reduced lighting levels are recommended regardless of the color temperature of the luminaire.

Beyond the information included in the seventh edition of this guide, various guidelines of national and international lighting engineering and architectural groups may be consulted for reasonable limits and strategies to optimize lighting designs while limiting any negative effects. Table 1-1 lists some of these groups.

Table 1-1. Resources for Lighting Engineering Guidelines

Organization	Internet Address
The Illuminating Engineering Society (IES)	http://www.ies.org
The International Commission on Illumination (CIE)	http://www.cie.co.at
The European Committee for Standardization (CEN)	http://www.cenorm.be
The Transportation Association of Canada (TAC)	http://www.tac-atc.ca

1.2 NEED FOR ENGINEERING EXPERTISE

Most states require final design documents to be signed and sealed by a registered professional engineer. Roadway lighting designs, as described in this guide, meet the criteria for requirement of an engineering seal. An engineer's seal is necessary primarily because the public's interest is at stake. In addition, roadway lighting designs often integrate other aspects of transportation engineering that cannot be overlooked by the designer.

These other aspects may include support structures, breakaway devices, pavement designs, electrical standards, traffic operations and traffic engineering, or safety factors. Engineering economics must also be utilized when determining various aspects of the facility, including the consideration of construction costs, maintenance programs and life-cycle analysis.

The engineering expertise necessary for developing quality roadway lighting designs includes, but is not limited to the following:

- light source types and characteristics, including depreciation factors and efficacy;
- ballast types and characteristics;
- luminaire mechanical characteristics;
- lens types;
- photometric performance of luminaires and factors impacting such performance;
- luminaire mounting types;
- pole mechanical and electrical characteristics;
- breakaway device options and when appropriate to use;
- clear zone criteria;
- overhead utility clearance factors;
- pole types, luminaire mounting options, and loading considerations;
- foundation and support details;
- road surface classification;
- luminaire mounting height and spacing options;
- light trespass and sky glow issues including local laws and ordinances;
- lighting quality measures, such as illuminance, luminance, veiling luminance, visibility, and color spectrum;
- lighting technology options (such as LED);
- maintenance considerations for individual components and the lighting system as a whole;
- electrical distribution and wiring systems;
- energy and life-cycle costs;
- coordination with master lighting plans; and
- right-of-way considerations and public involvement.

Lighting system design should be performed in an engineering manner. This includes exercising engineering judgment when balancing all of the above characteristics.

Many of the current problems in roadway lighting are due to poor lighting designs. Excessive glare, poor uniformity, visual clutter, sky glow, and light trespass are all noticeable disadvantages of poor designs. Excessive maintenance and energy costs are just two of the hidden expenses resulting from less-than-optimal roadway lighting systems. The use of improper depreciation factors and inaccurate photometric distributions may magnify these issues. A relatively new issue arises when some agencies convert to LED lighting based solely on energy cost saving criteria, with no consideration of the resulting light levels, uniformity, or glare. Fortunately, the quality of roadway lighting designs can be improved with education and experience.

1.3 SAFETY RESEARCH AND APPLICATION

The *Highway Safety Manual* (HSM) *(1)* was released by AASHTO in 2010 as a tool to quantitatively predict and evaluate changes in crash rates given the presence or modification of a specific feature for roadway segments and intersections.

A major component of the HSM with regard to quantitative crash prediction involves the use of Crash Modification Factors (CMFs). A CMF is a value which represents the predicted change in number of crashes when a specific treatment is added or removed. This value is then multiplied by existing crash data to achieve the predicted number of crashes at the location.

CMFs involving the installation of roadway lighting are available for roadway segments as well as intersections. According to the HSM, the installation of lighting along roadway segments of all types is predicted to reduce nighttime crashes of all severities by 20 percent. Nighttime injury and non-injury crashes are predicted to decrease by 28 percent and 17 percent, respectively.

The HSM includes CMFs for the installation of roadway lighting at intersections as well; however, the CMFs provided reflect injury crashes only. When lighting is installed at intersections, nighttime injury crashes are predicted to be reduced by 38 percent while nighttime pedestrian injury crashes are predicted to be reduced by 42 percent.

When existing crash data is not available, predicted crashes can be calculated through the use of Safety Performance Functions (SPFs). SPFs are pre-determined equations for roadway segments and intersections used to predict the number of crashes. Coefficients are included as elements within the SPF to reflect the roadway segment or intersection's conditions (turn lanes, lane width, presence of lighting, etc.). CMFs can then be applied to estimate the affect of a change in conditions, such as the installation of roadway lighting. The end result is a predicted number of crashes based on those characteristics.

1.4 RECOMMENDED ROADWAY LIGHTING DESIGN METHODS

AASHTO strongly recommends the luminance or illuminance design methods. Several popular lighting design software packages utilize these methods, allowing many designs to be analyzed in a time-efficient manner.

AASHTO previously supported research for visibility-based methods, but increased benefits have not been adequately demonstrated. Accurate small target visibility (STV) calculations require the input of all light sources, including vehicle headlamps and off-roadway contributions. Such data are not easily obtained on roadways during moderate traffic conditions, let alone high-volume conditions typically characterized by roadways requiring lighting.

Although the STV design method has made significant contributions to roadway lighting, it is generally not recommended by AASHTO as standard practice. However, STV or other visibility factors may be considered during roadway lighting design as a comparative method or as a complement to the primary method.

1.5 MASTER ROADWAY LIGHTING PLANS

AASHTO encourages the use of master roadway lighting plans for implementation by traffic management centers, emergency management agencies, or other central control facilities. Better use of resources (and subsequent energy savings) may be achieved through innovative strategies such as lighting curfews, special event adjustments, weather adaptation, or maintenance automation.

1.6 MODERN ROADWAY LIGHTING CONTROLS

Modern lighting controls (also termed Electrical and Lighting Management Systems) offer significant benefits for master roadway lighting plans that agencies may determine provide enough benefit to warrant the additional expense of modern controls Lighting control systems that allow agencies to monitor or adjust, or both, lighting systems from a remote location are now available. While maintenance tasks are still necessary, modern roadway lighting controls can inventory assets, observe power usage, compute life-cycle costs, and monitor the performance of individual systems. This provides a more effective means of identifying and diagnosing lighting issues than methods previously used.

1.7 EMERGING ROADWAY LIGHTING TECHNOLOGIES

New roadway lighting technologies have inundated the market and are being promoted as having advantages over traditional lighting sources. Solid-state lighting (SSL)—principally light emitting diodes (LEDs), but also light emitting plasma (LEP), and other technologies—is being promoted as improving safety, conserving natural resources, reducing energy consumption, and reducing life-cycle costs of roadway lighting operations. Until recently, the majority of roadway lighting was comprised of high-intensity discharge (HID) lighting, specifically high-pressure sodium (HPS). There are many differences between SSL and HID beyond the physical equipment differences. Examples include the following:

- light distribution,
- lighting output control (dimmability),
- spectral power distribution (SPD), and
- efficiency of lighting production suitable for human perception (luminous efficacy).

Research comparing the use of SSL to HID for roadway lighting has established some benefits in terms of energy consumption, luminous efficacy, color rendering, and adaptability.

The NCHRP technical report *Analysis of New Highway Lighting Technologies* (Project No. 20-7/305, published in 2013) *(2)* documents and presents the results from a study of roadway lighting technologies including the use of LED sources and other light source types. A review of published research and case studies of new lighting technologies, as well as a comparison of roadway luminaire photometric performance, suggests that LED technologies, while still rapidly developing, are viable for specifying energy efficient and visually effective roadway lighting systems. New metrics such as luminaire system application efficacy can allow engineers to make informed decisions about the roadway lighting system configurations (including luminaire selection, spacing, and mounting height) that will lead to the most economical system performance. Research also suggests that a number of other metrics such as mesopic photometry, brightness perception, and spectral sensitivity for discomfort glare could assist the designer in selecting among new lighting technologies, most of which have greater short-wavelength spectral output than conventional high-pressure sodium lighting. Evaluations of visual performance and visibility coverage areas from roadway lighting may also be of use in identifying appropriate adaptive control strategies for roadway lighting.

When considering any new technology, it is appropriate to carefully evaluate the benefit and potential risk associated with that product. In the case of LED highway lighting, great improvements have been made during the past few years. Manufacturers have developed creative solutions to concerns such as heat dissipation, light output, photometrics, and durability. For roadway lighting, the industry-wide trend appears to be away from HPS and towards LED systems. While light levels and distributions of LED roadway lighting luminaires are now similar or in some cases better than traditional luminaires, some of the unanswered questions include:

- Does the higher color temperature of LED luminaries result in the need for less overall illumination?
- Will LED luminaires last as long in the field as predicted by manufacturers? Does the higher color temperature of LED luminaires create any health concerns related to the effect of melatonin levels on sleep and alertness?
- Does the higher color temperature of LED luminaires create any environmental concerns related to negative impacts on fauna and flora?

National Cooperative Highway Research Project (NCHRP 05-22), *Guidelines for Solid-State Roadway Lighting*, is currently underway, with an expected completion date in 2019. Further updates to this Guide may occur after that report is published. Other research efforts related to health concerns are also underway. Regarding SSL/LED lighting, a list of items that still need research includes the following:

- metrics for assessing the effectiveness of roadway lighting, with and without headlights, to achieve adequate contrast;
- standardization and asset management for SSL replacement to simplify maintenance;
- potential revenue streams from data collection and barriers to their implementation;
- real-time asset management within the context of ITS framework;
- metrics to characterize the environmental and health effects of roadway light spectrum, amount, distribution, and timing;
- metrics for assessing light depreciation and means of determining end of useful life; and
- light and adverse weather.

1.8 REFERENCES

1. AASHTO. *Highway Safety Manual*, First Edition, with 2014 supplement, HSM-1-M. American Association of State Highway and Transportation Officials,
Washington, DC, 2010.
2. Bullough, J. D. and L. C. Radetsky. *National Cooperative Highway Research Report 20-7/305: Analysis of New Highway Lighting Technologies*. NCHRP, Transportation Research Board, Washington, DC, 2013.