TAC Guide for the Design of Roadway Lighting

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Today's Presentation Goals

- Provide overview of the document
- Review new design concepts and principals
- Review Roadway and Intersection Lighting Design Process

Consultant Team

- The principal authors of the new Guide were:
  - Don McLean ,DMD, Surrey, BC;
  - Dr. Ian Lewin, LSI, Scottsdale, Arizona;
  - Paul Lutkevich, Parsons Brinckerhoff, Boston.
- Principals had worldwide expertise included lighting standards in Europe, Australia and North America
- All active members of IESNA Roadway Lighting Committee

Project Scope / Goals

- Research standards worldwide
- Create a new, standalone document based on current research and proven industry practices
- Make document easy to use by including examples and pictures
- Write for a varied audience (novice to expert)
- Provide publication-ready document
- Link with other TAC documents (ie; Geometric Design, MUTCDC, etc)

Chapters

- **Volume 1 – Fundamentals of Roadway Lighting**
  - Chapter 1 – Introduction
  - Chapter 2 – Vision and Fundamental Concepts
  - Chapter 3 – Obtrusive Light
  - Chapter 4 – The Planning and Design Process
  - Chapter 5 – System Components and Common Design Elements
  - Chapter 6 – Standards and Codes
  - Chapter 7 – Computer Applications
  - Chapter 8 – Maintenance

Chapters

- **Volume 2 – Design**
  - Chapter 9 – Roadways and Interchanges
  - Chapter 10 – Intersections
  - Chapter 11 – Roundabouts
  - Chapter 12 – Mid-Block Crosswalks
  - Chapter 13 – Railway Crossings
  - Chapter 14 – Tunnels
  - Chapter 15 – Toll Plazas
  - Chapter 16 – Off-Roadway Facilities
  - Chapter 17 – Roadway Signs
  - Chapter 18 – Streetscapes
  - Chapter 19 – Temporary Lighting and Work Zones

Research

- Undertook a review of standards and research from around the world
- Standards from Canadian governments and Cities were obtained
- Included were International Commission on Illumination (CIE Europe), Illuminating Engineering Society (IES), AASHTO, FHWA, CSA, Institute of Lighting Engineers (England)
- IES Roadway Lighting Committee members were consulted

Features

- Luminance Design Approach for Roadways
- Each Application Treated in its Own Chapter
- Criteria for Increased Visibility in Crosswalks (Vertical Illuminance) leading to improved safety
- Design for Roundabouts and Toll Booths
- Lighting Warrants Integrated with Other TAC Standards
- Computer-Aided Design Approach
- Design Examples Provided

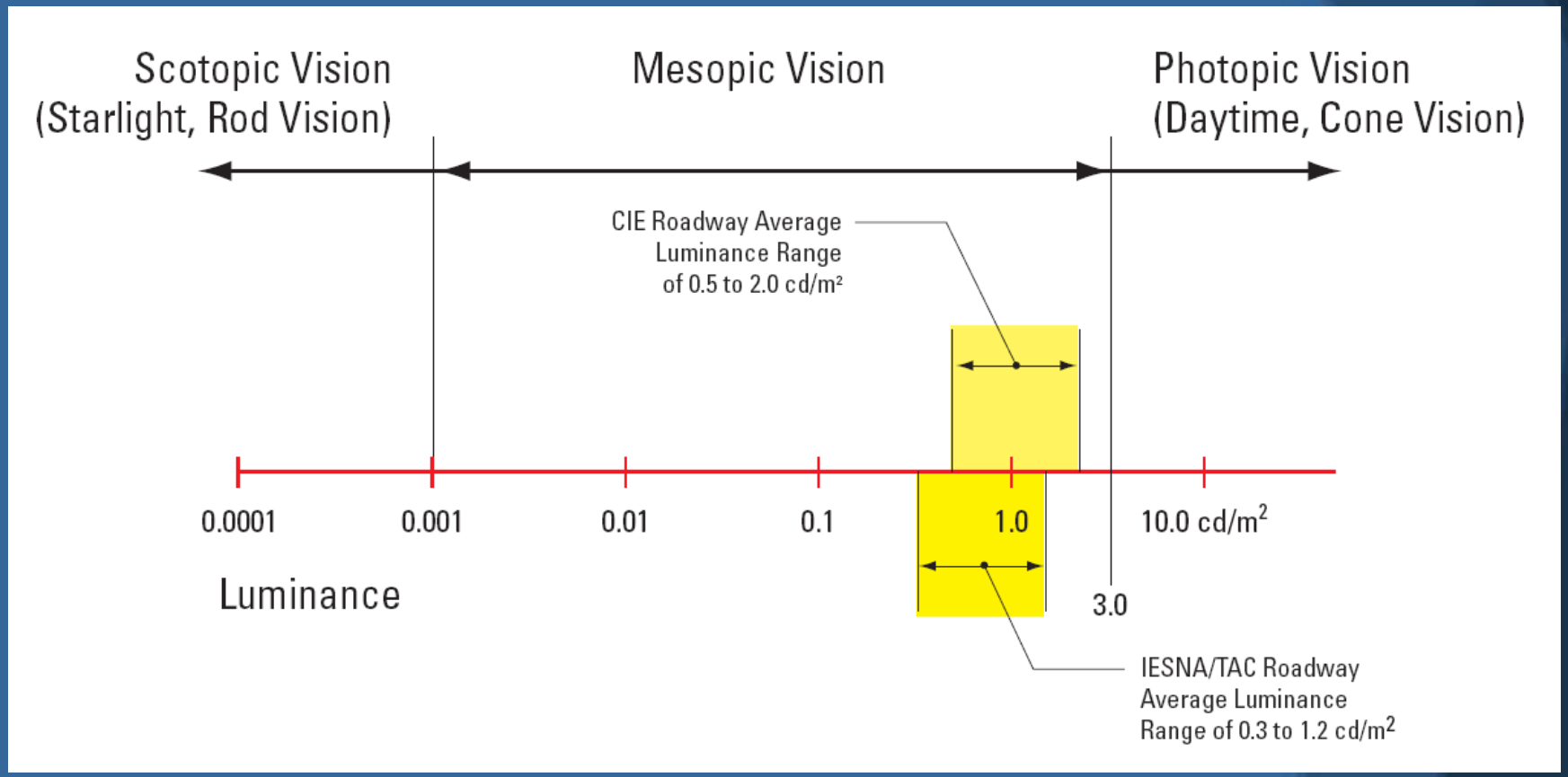
Why Light

- Reduces glare effects from oncoming vehicle headlamps
- Improves visibility for drivers
- Improves visibility for pedestrians and cyclists
- Provides a level of comfort and feeling of security

Benefits of Lighting

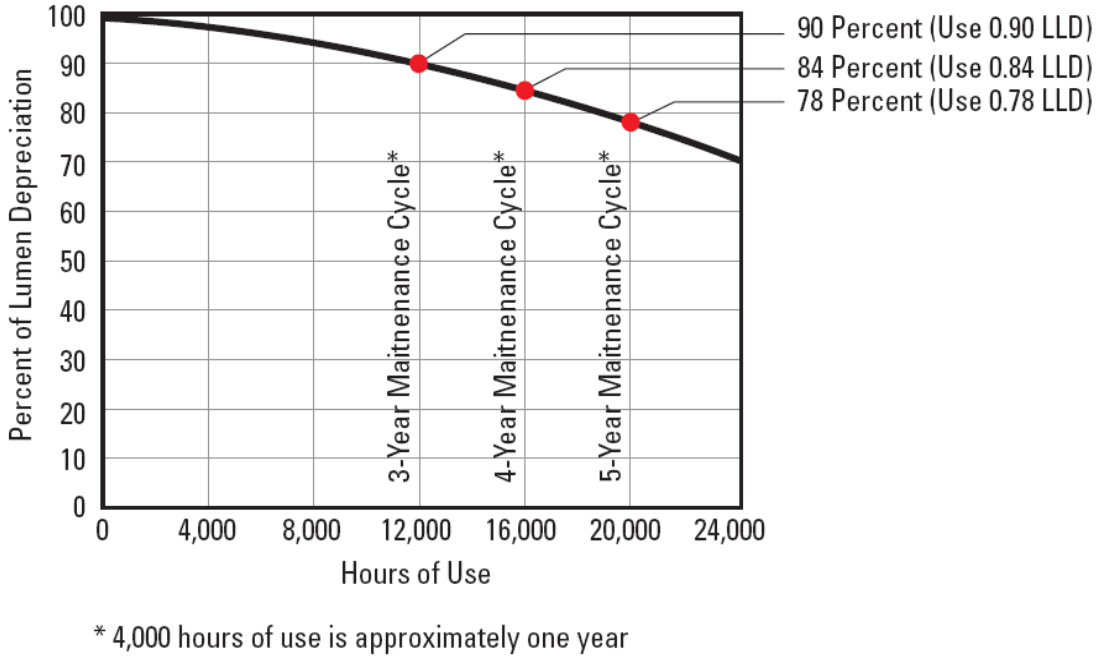
- 20 year FHWA study showed lighting had the highest $ benefit for each $ spent
- Studies show lighting reduces collisions up to 40%
- Studies show lighting reduces pedestrian fatalities 45% to 80%

Comparison IESNA - CIE



Light Loss Factor (LLF)

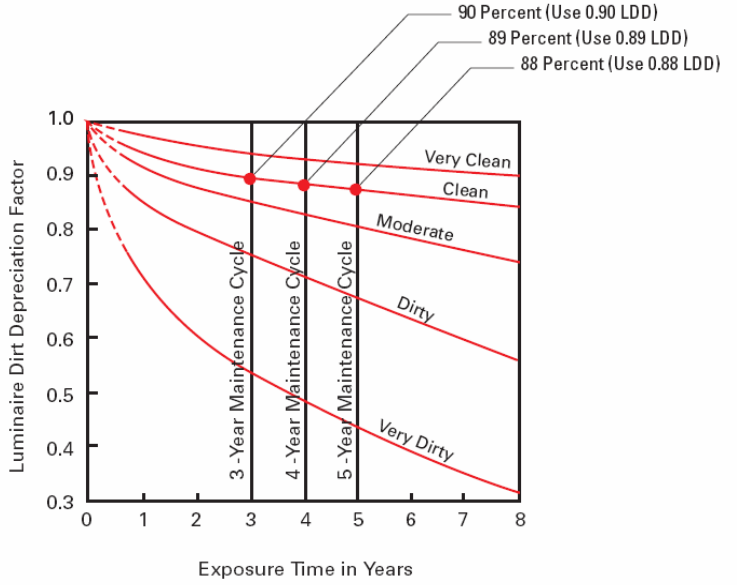
Design is based on end of lamp life LLF = LLD x LDD x EF



Lamp Lumen Depreciation (LLD)

Light Loss Factor (LLF)

Design is based on end of lamp life LLF = LLD x LDD x EF



Very Clean – No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per m^3.

Clean – No nearby smoke or dust generating activities and a low ambient contaminant level. Moderate to heavy traffic. The ambient particulate level is no more than 300 micrograms per m^3.

Moderate– Moderate smoke or dust generating activities and a low ambient contaminant level. Moderate to heavy traffic. The ambient particulate level is no more than 600 micrograms per m^3.

Dirty – Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.

Very Dirty – As above, but the luminaires are commonly enveloped by smoke or dust plumes.

Luminaire Dirt Depreciation (LDD)

Light Loss Factor (LLF)

Design is based on end of lamp life
LLF = LLD x LDD x EF

Equipment Factor fixed at 0.95 includes:
- Manufacturing Tolerance
- Luminaire Degradation
- Varying input voltages

Light Loss Factor (LLF)

Design is based on end of lamp life

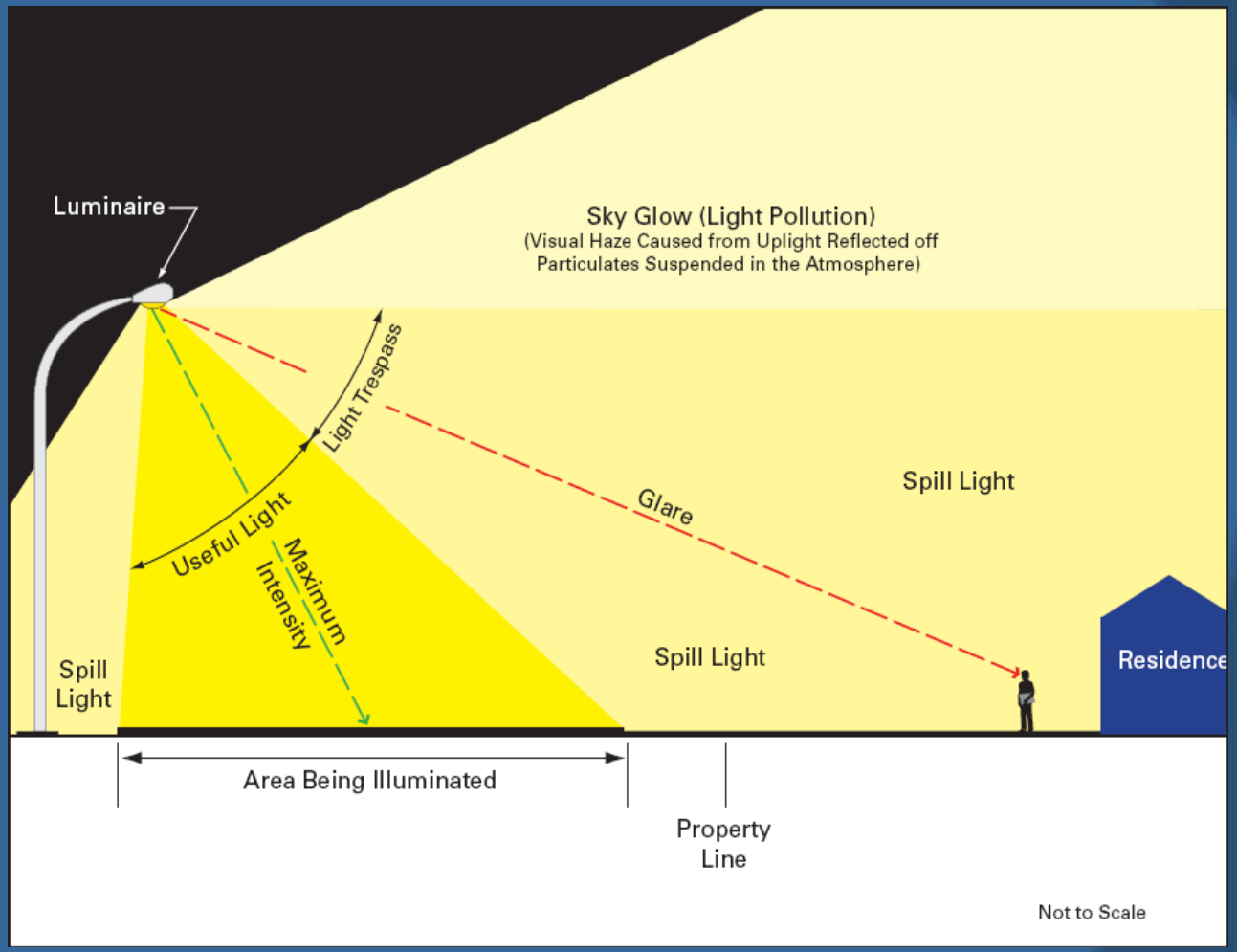
LLF = LLD x LDD x EF

3 Year Maintenance Cycle – 0.9 LLD x 0.9 LDD x 0.95 EF = 0.77 LLF

4 Year Maintenance Cycle – 0.84 LLD x 0.89 LDD x 0.95 EF = 0.71 LLF

5 Year Maintenance Cycle – 0.65 LLD x 0.88 LDD x 0.95 EF = 0.65 LLF

Obtrusive Lighting



Spill Light Definitions

Designation	Description
LZ 1	These are very rural areas outside a city with little or no ambient lighting, no commercial development and no outdoor public nighttime pedestrian activity. Where lighting is required in an LZ1 area, the spill light measurements would be taken at the place being inhabited by humans as opposed to the property boundary line or edge of road allowance.
LZ 2	These are rural areas outside of a city with very low population density, no commercial development, minimal outdoor nighttime pedestrian activity and no security issues or concerns. Where lighting is required in an LZ2 area, the spill light measurements would be taken at the place being inhabited by humans as opposed to the property boundary line or edge of road allowance.,
LZ 3	These are areas within a city, with low to medium population density, some outdoor pedestrian nighttime activity and no security issues or concerns. Potential traffic conflicts between vehicles, pedestrians and cyclists are inevitable but mild. Such areas include residential subdivisions, townhouse developments on local and collector roads, as well as highways and freeways. Where lighting is required in an LZ3 area, the spill light measurements would be taken at the property boundary line or edge of road allowance.
LZ 4	These are areas within a city with medium to high population density, or areas intended for heavy public and commercial activities. Potential traffic conflicts between vehicles, pedestrian and cyclists are inevitable and intense. Normally these are urban areas having both commercial and residential development that experience a high level of nighttime activities. Such areas include those with multifamily housing (apartments), those in a downtown core, as well as areas of commercial and industrial development on local, collector and arterial roads, as well as highways and freeways. Where lighting is required in an LZ4 area, the spill light measurements would be taken at the property boundary line or edge of road allowance.

Spill Light levels

Designation	Recommended Maximum Illuminance Level (Ee)	
	Pre-Curfew	Post-Curfew (Not Applicable to Roadway Lighting)
LZ 1	1.0 lux	0.0 lux
LZ 2	3.0 lux	1.0 lux
LZ 3	8.0 lux	3.0 lux
LZ 4	15.0 lux	6.0 lux

Skyglow and Glare

Urban Sky glow

Glare

- Disability
- Discomfort
- Nuisance

For more info www.darksky.org

Lighting Software Comparison

Roadway Calculation Types and Complex Layouts	Software Package						
	Visual Professional Edition v 2.03	Visual Roadway Tool	Genesysll v 2000.1.7	AutoLUX v 7.69	AGI32 v 1.66	LumenMicro 2000 v 2000.2	Simply Roadway Lighting v 2002.1.8
Illuminating Engineering Society of North America (IESNA)**	Y	Y	Y	Y	Y	Y	Y
Commission Internationale de l'Eclairage (CIE)	Y	Y	N	Y	Y	N	Y
Commission Internationale de l'Eclairage (CIE)-Australian	N	N	N	N	Y	N	N
Complex Layouts (Curves)*	2	1	3	4*	4*	3	1

Key

Y = Yes
N = No
1 = Straight Section Only
2 = Illuminance only for Complex Layouts
3 = Illuminance, Pavement luminance, Lv Ratio for Complex Layouts
4* = Illuminance, Pavement Luminance, Veiling Luminance for Complex Layouts (Curves)

*Feature Required for Luminance Calculations on Curves
**Feature Required to do a Roadway Lighting Calculation

Basic Lighting Design Process

Step 1 – Warrant Analysis
Based on a point-score analysis, full intersection lighting will be required.
Step 2 – Roadway Features
- Road Type
- Pedestrian Conflict
- Pavement type
- Overhead power line conflicts
- Crosswalks - Vertical illuminance levels required

Step 3 – Selecting Criteria (from table)
Step 4 – Equipment Selection
Step 5 – Undertake Computer Calculations
Step 6 – Adjust and Recalculate

Roadway Lighting Warrants

Road Name_____
From_____ to_____
City_____
Warrant Undertaken by_____
Company name_____
Date_____

Warrants for Lighting Arterial, Collector and Local Roads

Item No.	Classification Factor	Rating Factor 'R' 1	2	3	4	5	Weight 'W'	Enter 'R' Here	Score 'R' x 'W'	
	Geometric Factors (See Note 6)									
1	Number of Lanes	≤ 4	5	6	7	≥ 8	0.15			
2	Lane Width (m)	>3.6	3.4 to 3.6	3.2 to 3.4	3.0 to 3.2	<3.0	0.35			
3	Median Openings/km	<2.5 or 1-Way	2.5 to 5.0	5.0 to 7.2	7.2 to 9.0	>9.0 or No Median	1.40			
4	Driveways and Entrances/km	<20	20 to 40	40 to 60	60 to 80	>80	1.40			
5	Horizontal Curve Radius (m)	>600	450 to 600	225 to 450	175 to 225	<175	5.90			
6	Vertical Grades (%)	<3	3 to 4	4 to 5	5 to 7	>7	0.35			
7	Sight Distance (m)	>210	150 to 210	90 to 150	60 to 90	<60	0.15			
8	Parking	Prohibited	Loading	Off Peak	One Side	Both Sides	0.10			
						Subtotal Geometric Factors				G
	Operational Factors									
9	Signalized Intersections (%)	80 to 100	70 to 80	60 to 70	50 to 60	0 to 50	0.15			
10	Left Turn Lane	All Major Intersections or 1-Way	Substantial Number of Major Intersections	Most Major Intersections	Half of Major Intersections	Infrequent Number or TWTL (See Notes 1 & 3)	0.70			
11	Median Width (m)	>10	6 to 10	3 to 6	1.2 to 3	0 to 1.2	0.35			
12	Operating or Posted Speed (km/h) (See Note 5)	≤ 40	50	60	70	≥ 80	0.60			
13	Pedestrian Activity Level (See Note 2)			Low	Medium	High	3.15			
						Subtotal Operational Factors				O
	Environmental Factors									
14	Percentage of Development Adjacent to Road (%) (See Note 4)	nil	nil to 30	30 to 60	60 to 90	>90	0.15			
15	Area Classification	Rural	Industrial	Residential	Commercial	Downtown	0.15			
16	Distance from Development to Roadway (m) (See Note 4)	>60	45 to 60	30 to 45	15 to 30	<15	0.15			
17	Ambient (off Roadway) Lighting	Nil	Sparse	Moderate	Distracting	Intense	1.38			
18	Raised Curb Median	None	Continuous	At All Intersections (100%)	At Most Intersections (51% to 99%)	At Few Intersections (≤ 50%) (See Note 7)	0.35			
						Subtotal Environmental Factors				E
	Collision Factors									
19	Night-to-Day Collision Ratio	<1.0	1.0 to 1.2	1.2 to 1.5	1.5 to 2.0	>2.0 (See Note1)	5.55			
						Subtotal Collision Factors				A
						G + O + E + A = Total Warranting Points				
						Warranting Condition			60.00	
						Difference –			-60.00	D

Notes:

1 Lighting Warranted
2 Pedestrian Activity Level (Refer to 9.1.3 - Pedestrian Related Definitions)
3 Two-Way Left Turn Lane
4 Development Defined as Commercial, Industrial or Residential Buildings
5 85th Percentile Night Speed Should Be Used if Available, Otherwise Posted Speed Shall Be Used
6 Worst Case Geometric Factors for a Segment of Roadway Shall Apply
7 Also Includes Isolated Medians (Non-Continuous) Between Intersections.

Typical Pole Layouts

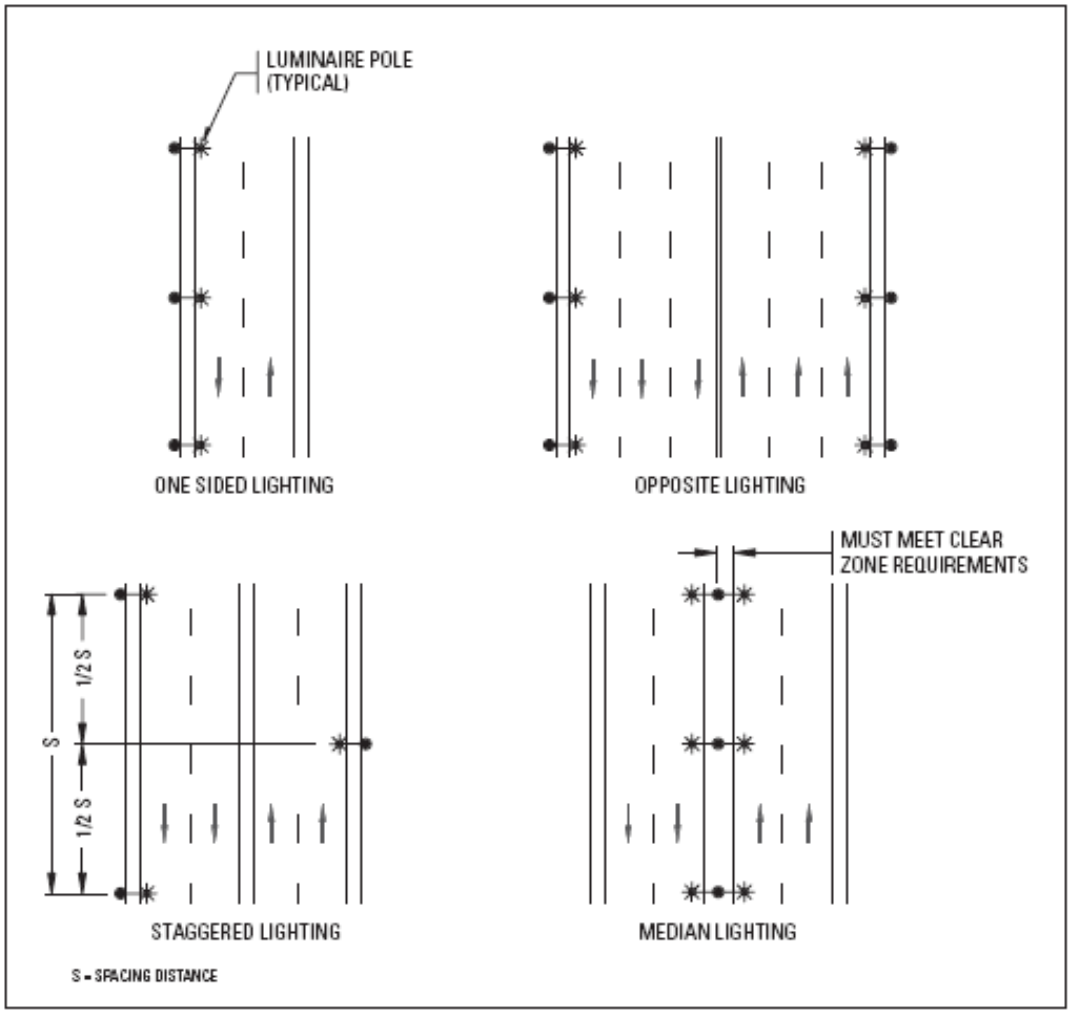


Figure 9-5 – Standard Pole Spacing Definitions

Roadway Luminance Levels

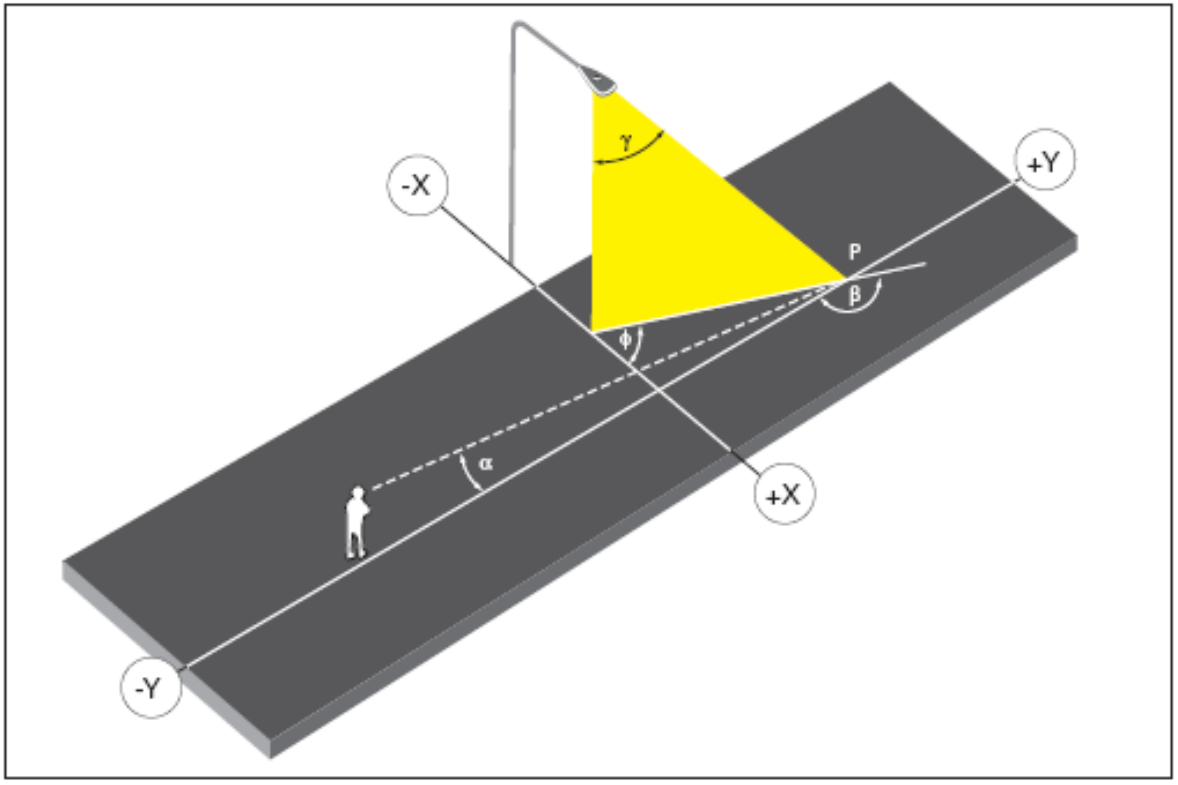
Road Area and Pedestrian Activity		Average Luminance cd/m^2	Average-to-Minimum Uniformity Ratio	Maximum-to-Minimum Uniformity Ratio	Maximum-to-Average Veiling Luminance Ratio
Road Type	Pedestrian Activity				
Freeway	--	≧ 0.6	≦ 3.5	≦ 6.0	≦ 0.3
Partial Lighting of Interchange On-Ramps/ Off-Ramps	--	≧ 0.6	≦ 3.5	≦ 6.0	≦ 0.3
Expressway-Highway	High	≧ 1.0	≦ 3.0	≦ 5.0	≦ 0.3
	Medium	≧ 0.8	≦ 3.0	≦ 5.0	≦ 0.3
	Low	≧ 0.6	≦ 3.5	≦ 6.0	≦ 0.3
Arterial	High	≧ 1.2	≦ 3.0	≦ 5.0	≦ 0.3
	Medium	≧ 0.9	≦ 3.0	≦ 5.0	≦ 0.3
	Low	≧ 0.6	≦ 3.5	≦ 6.0	≦ 0.3
Collector	High	≧ 0.8	≦ 3.0	≦ 5.0	≦ 0.4
	Medium	≧ 0.6	≦ 3.5	≦ 6.0	≦ 0.4
	Low	≧ 0.4	≦ 4.0	≦ 8.0	≦ 0.4
Local/Alleyway	High	≧ 0.6	≦ 6.0	≦ 10.0	≦ 0.4
	Medium	≧ 0.5	≦ 6.0	≦ 10.0	≦ 0.4
	Low	≧ 0.3	≦ 6.0	≦ 10.0	≦ 0.4

Luminance Design Method

Direction of View - 1 degree angle (a)

Distance - 83.07m

Height – 1.45m



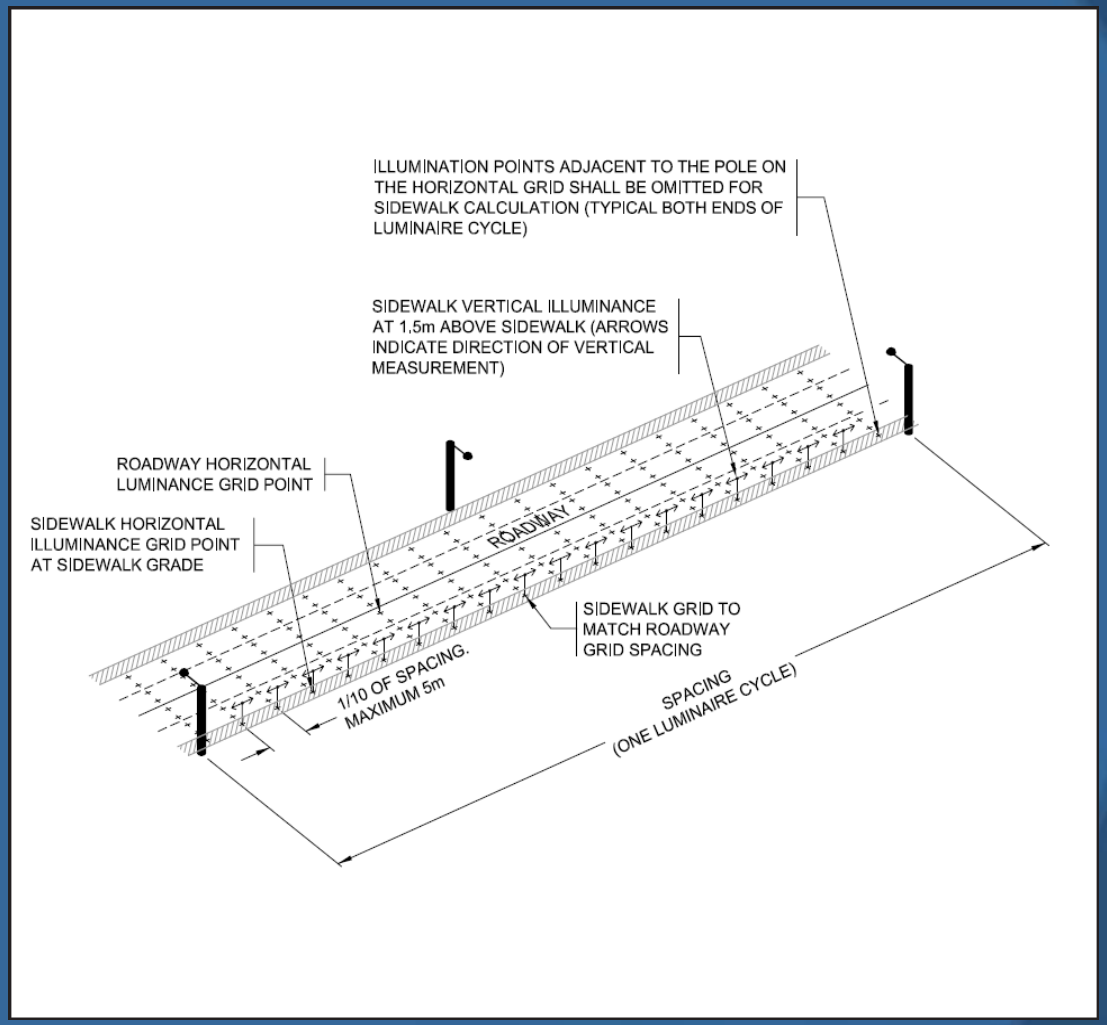
Graphic Reproduced with Permission of the IESNA

Figure 2-22 – Luminance Calculation Geometry

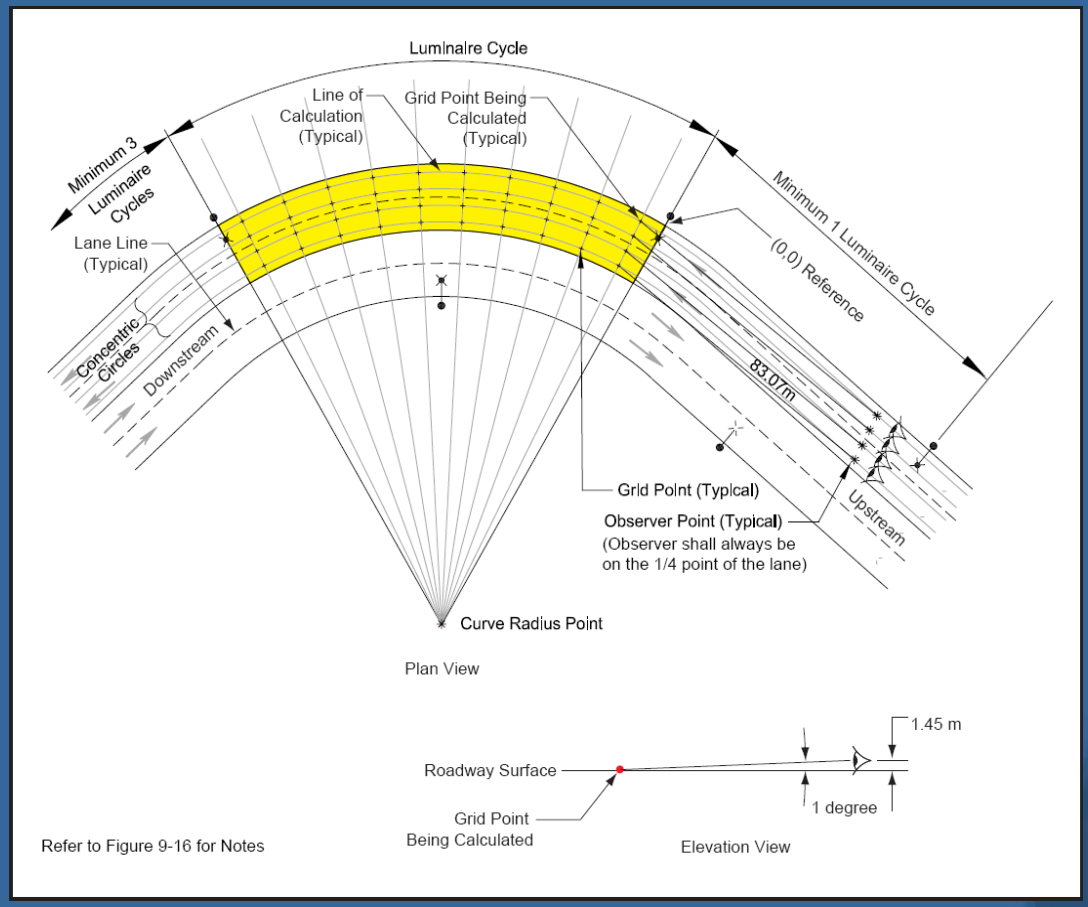
Roadway Pedestrian Illuminance Levels (Sidewalks)

Pedestrian Activity	Maintained Average Horizontal Illuminance (lux)	Average-to - Minimum Horizontal Uniformity Ratio	Minimum Maintained Vertical Illuminance (lux)
High	≧ 20.0	≦ 4.0	≧ 10.0
Medium	≧ 5.0	≦ 4.0	≧ 2.0
Low	≧ 3.0	≦ 6.0	≧ 0.8

Roadway Calculation Grids



Calculation Grid on Curves with 600m > Radius



Roadway Calculation Example

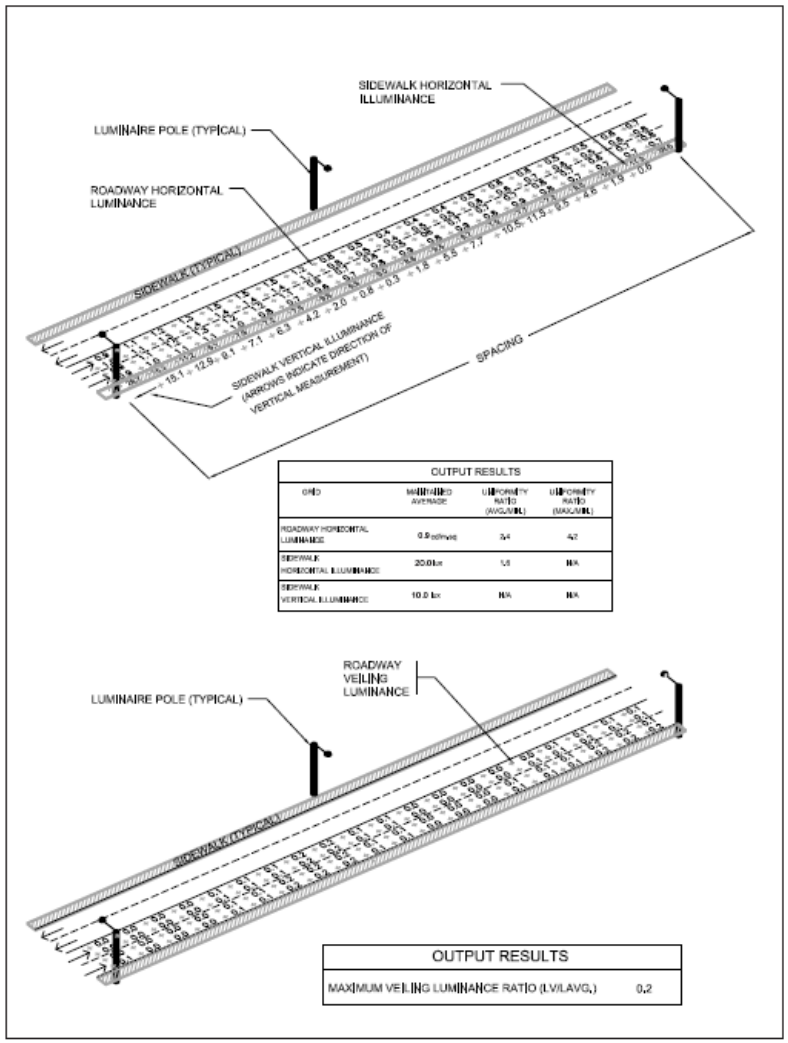
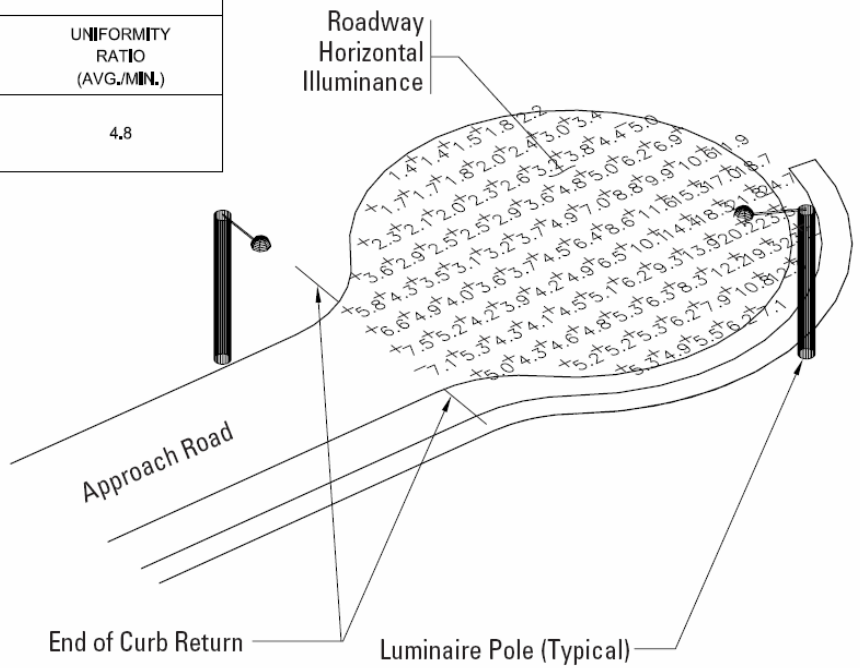


Figure 9-21 – Sample Roadway Calculation, Example No. 2, Arterial Roadway

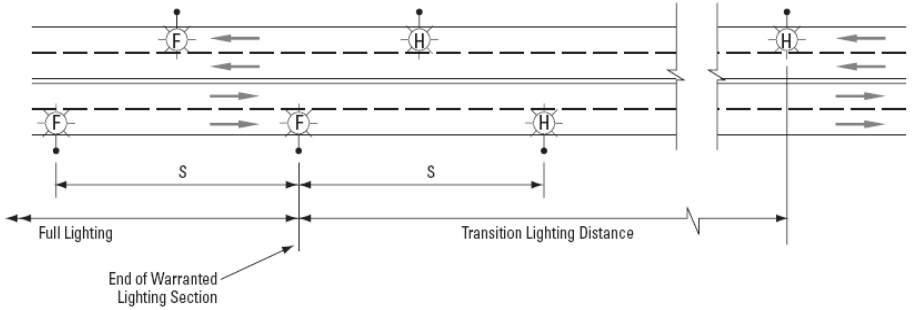
Cul-de-sac Lighting

OUTPUT RESULTS		
GRID	MAINTAINED AVERAGE	UNIFORMITY RATIO (AVG./MIN.)
C-D-S HORIZONTAL ILLUMINANCE	6.8 LUX	4.8

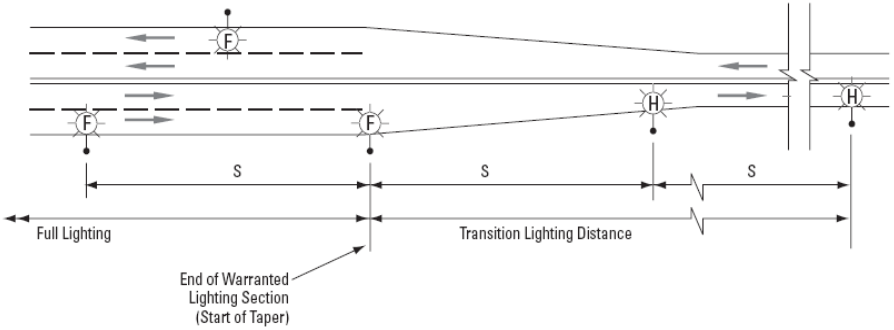


Transition Lighting

Transition Lighting on Consistent Road Width



Transition Lighting on Tapering Road Width



Notes

1. H Luminaires have approximately half the lumen output of F Luminaires.
2. Spacing, "S," shall be constant for the length of the transition and meet the uniformity requirements for the given road type and pedestrian activity.

Transition Lighting Distances

Design Speed (km/h)	Minimum Transition Distance (m)
50	210
60	250
70	295
80	335
90	375
100	420
110	460

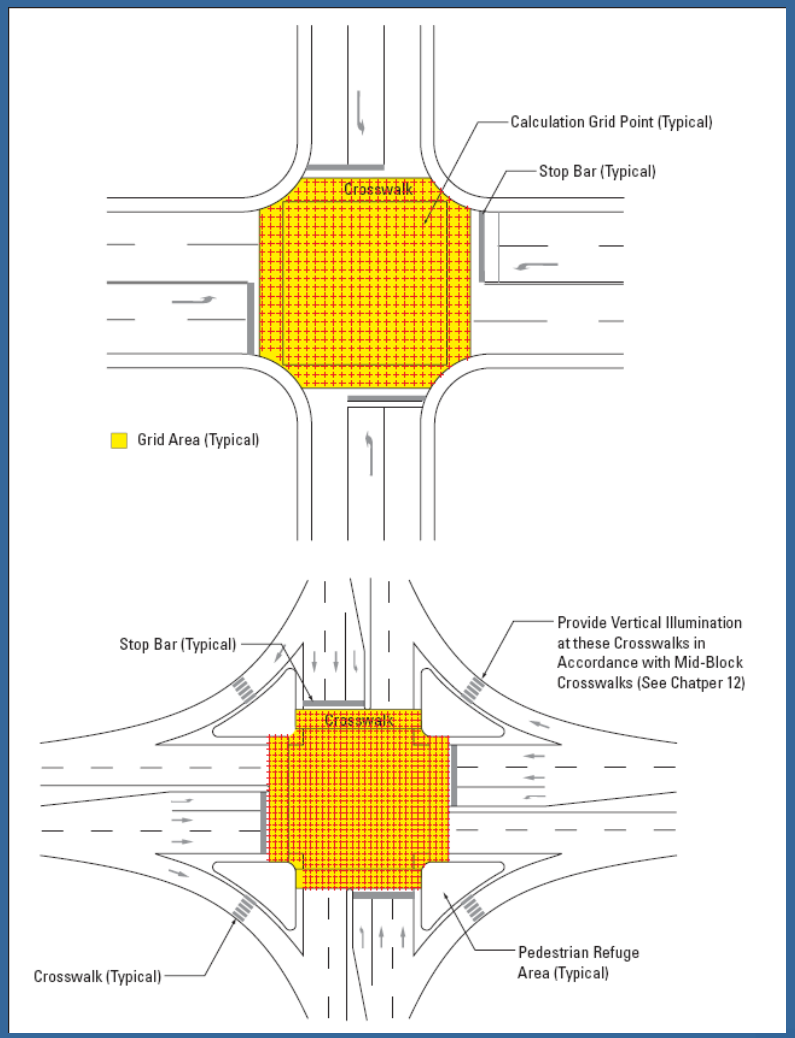
Intersection Lighting Warrants

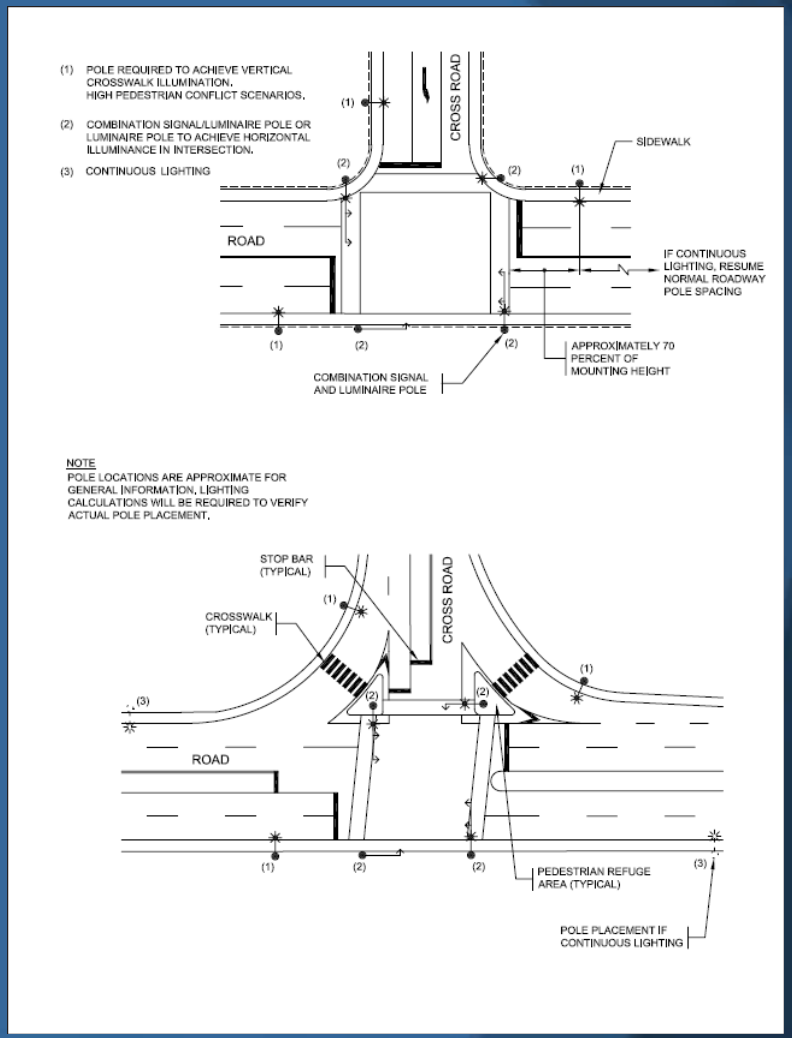
Item No.	Classification Factor	Rating Factor 'R'					Weight 'W'	Enter 'R' Here	Score 'R' x 'W'	
		1	2	3	4	5				
	Geometric Factors (See Note 6)									
1	Number of Lanes	≦ 4	5	6	7	≧ 8	0.15			
2	Lane Width (m)	>3.6	3.4 to 3.6	3.2 to 3.4	3.0 to 3.2	<3.0	0.35			
3	Median Openings/km	<2.5 or 1-Way	2.5 to 5.0	5.0 to 7.2	7.2 to 9.0	>9.0 or No Median	1.40			
4	Driveways and Entrances/km	<20	20 to 40	40 to 60	60 to 80	>80	1.40			
5	Horizontal Curve Radius (m)	>600	450 to 600	225 to 450	175 to 225	<175	5.90			
6	Vertical Grades (%)	<3	3 to 4	4 to 5	5 to 7	>7	0.35			
7	Sight Distance (m)	>210	150 to 210	90 to 150	60 to 90	<60	0.15			
8	Parking	Prohibited	Loading	Off Peak	One Side	Both Sides	0.10			
						Subtotal Geometric Factors				G
	Operational Factors									
9	Signalized Intersections (%)	80 to 100	70 to 80	60 to 70	50 to 60	0 to 50	0.15			
10	Left Turn Lane	All Major Intersections or 1-Way	Substantial Number of Major Intersections	Most Major Intersections	Half of Major Intersections	Infrequent Number or TWTL (See Notes 1 & 3)	0.70			
11	Median Width (m)	>10	6 to 10	3 to 6	1.2 to 3	0 to 1.2	0.35			
12	Operating or Posted Speed (km/h) (See Note 5)	≦ 40	50	60	70	≧ 80	0.60			
13	Pedestrian Activity Level (See Note 2)			Low	Medium	High	3.15			
						Subtotal Operational Factors				O
	Environmental Factors									
14	Percentage of Development Adjacent to Road (%) (See Note 4)	nil	nil to 30	30 to 60	60 to 90	>90	0.15			
15	Area Classification	Rural	Industrial	Residential	Commercial	Downtown	0.15			
16	Distance from Development to Roadway (m) (See Note 4)	>60	45 to 60	30 to 45	15 to 30	<15	0.15			
17	Ambient (off Roadway) Lighting	Nil	Sparse	Moderate	Distracting	Intense	1.38			
18	Raised Curb Median	None	Continuous	At All Intersections (100%)	At Most Intersections (51% to 99%)	At Few Intersections (≦ 50%) (See Note 7)	0.35			
						Subtotal Environmental Factors				E
	Collision Factors									
19	Night-to-Day Collision Ratio	<1.0	1.0 to 1.2	1.2 to 1.5	1.5 to 2.0	>2.0 (See Note1)	5.55			
						Subtotal Collision Factors				A
						G + O + E + A = Total Warranting Points				
						Warranting Condition			60.00	
						Difference –			-60.00	D

Intersection Lighting

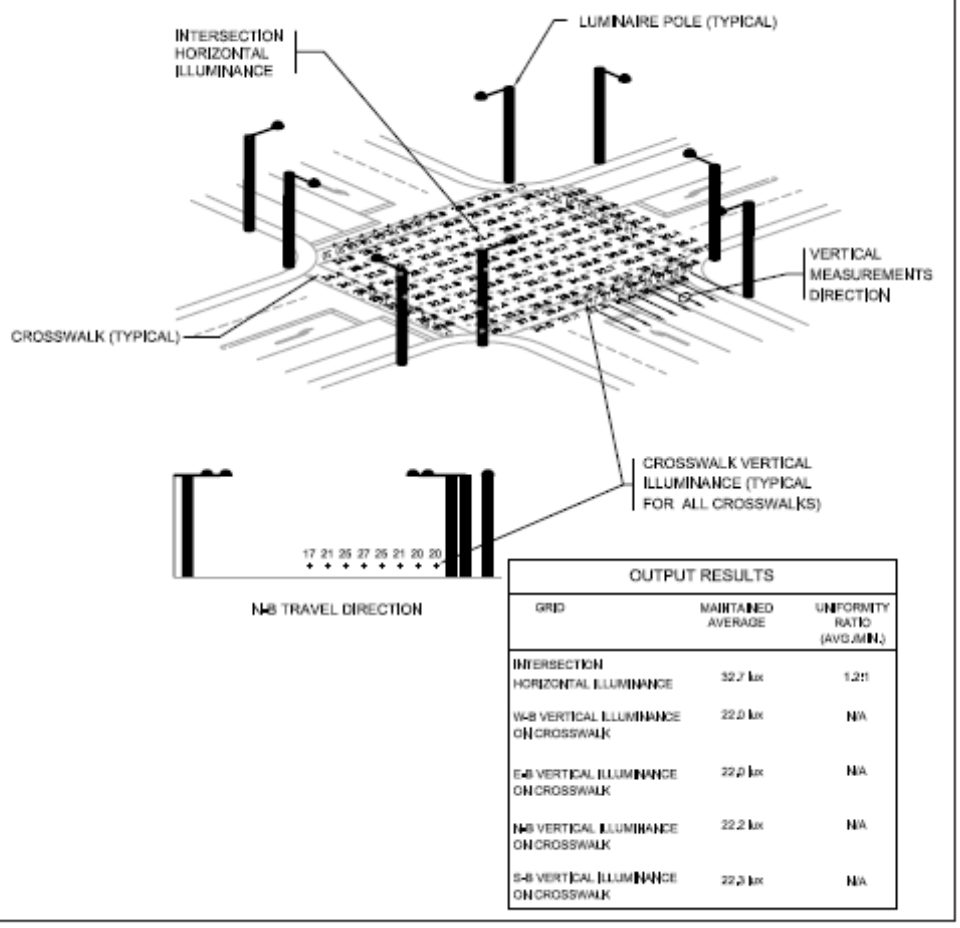
Roadway Classification	Average Maintained Illuminance at Pavement by Pedestrian Conflict (lux)			Average-to-Minimum Uniformity Ratio
	High	Medium	Low	
Arterial/Arterial	34.0	26.0	18.0	≦ 3.0
Arterial/Collector	29.0	22.0	15.0	≦ 3.0
Arterial/Local	26.0	20.0	13.0	≦ 3.0
Expressway-Highway/Arterial	31.0	25.0	18.0	≦ 3.0
Expressway-Highway/ Expressway-Highway/	28.0	24.0	18.0	≦ 3.0
Expressway-Highway/Collector	26.0	21.0	15.0	≦ 3.0
Expressway-Highway/Local	23.0	19.0	13.0	≦ 3.0
Collector/Collector	24.0	18.0	12.0	≦ 4.0
Collector/Local	21.0	16.0	10.0	≦ 4.0
Local/Local	18.0	14.0	8.0	≦ 6.0

Intersection Lighting





Intersection Calculation Example

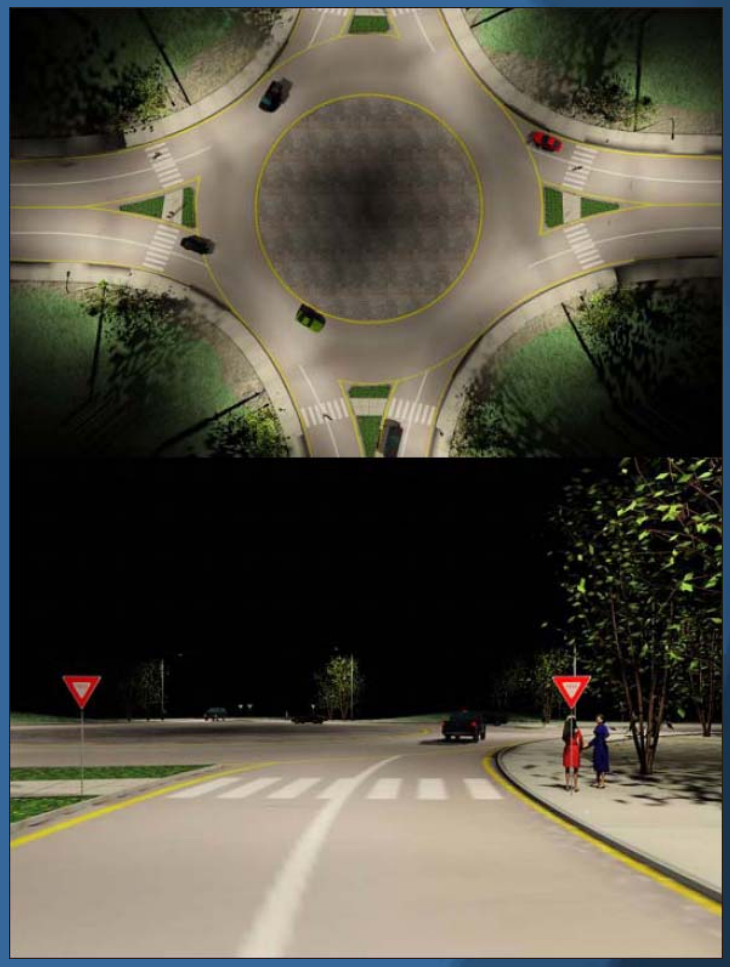


OUTPUT RESULTS

GRID	MAINTAINED AVERAGE	UNIFORMITY RATIO (AVG./MIN.)
INTERSECTION HORIZONTAL ILLUMINANCE	32.7 lux	1.21
W-B VERTICAL ILLUMINANCE ON CROSSWALK	22.0 lux	N/A
E-B VERTICAL ILLUMINANCE ON CROSSWALK	22.0 lux	N/A
N-B VERTICAL ILLUMINANCE ON CROSSWALK	22.2 lux	N/A
S-B VERTICAL ILLUMINANCE ON CROSSWALK	22.3 lux	N/A

Figure 10-9 – Intersection Design Example

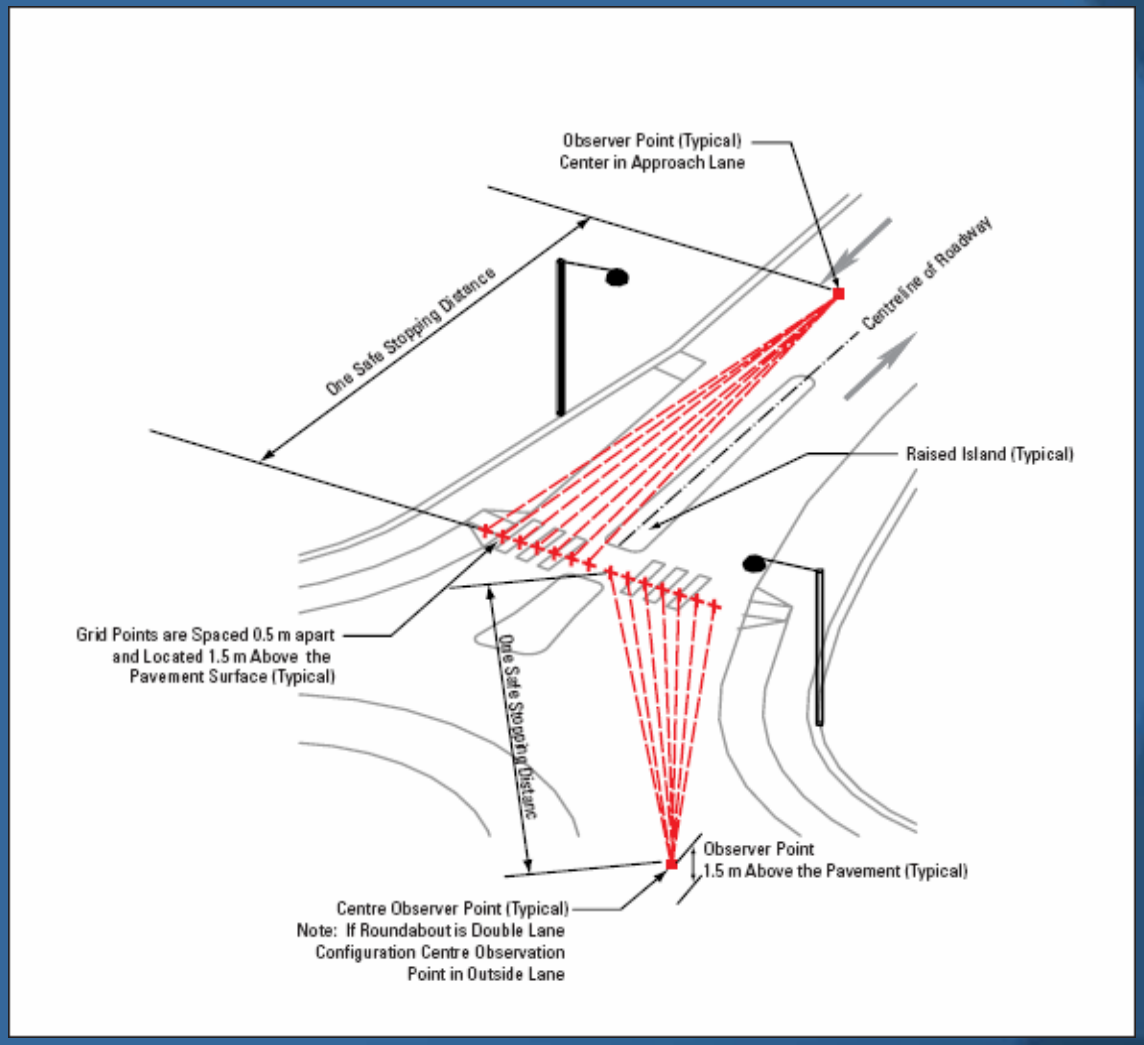
Roundabout Lighting



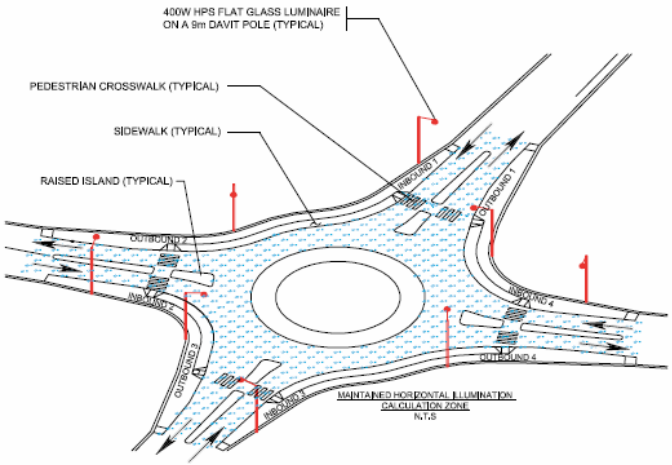
Contrast

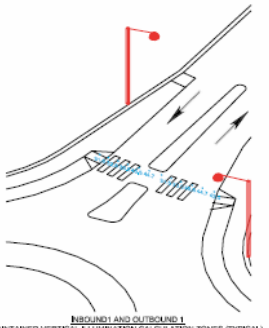
Figure 2-14 – Examples of Negative and Postive Contrast.

Roundabout Lighting



Roundabout Lighting



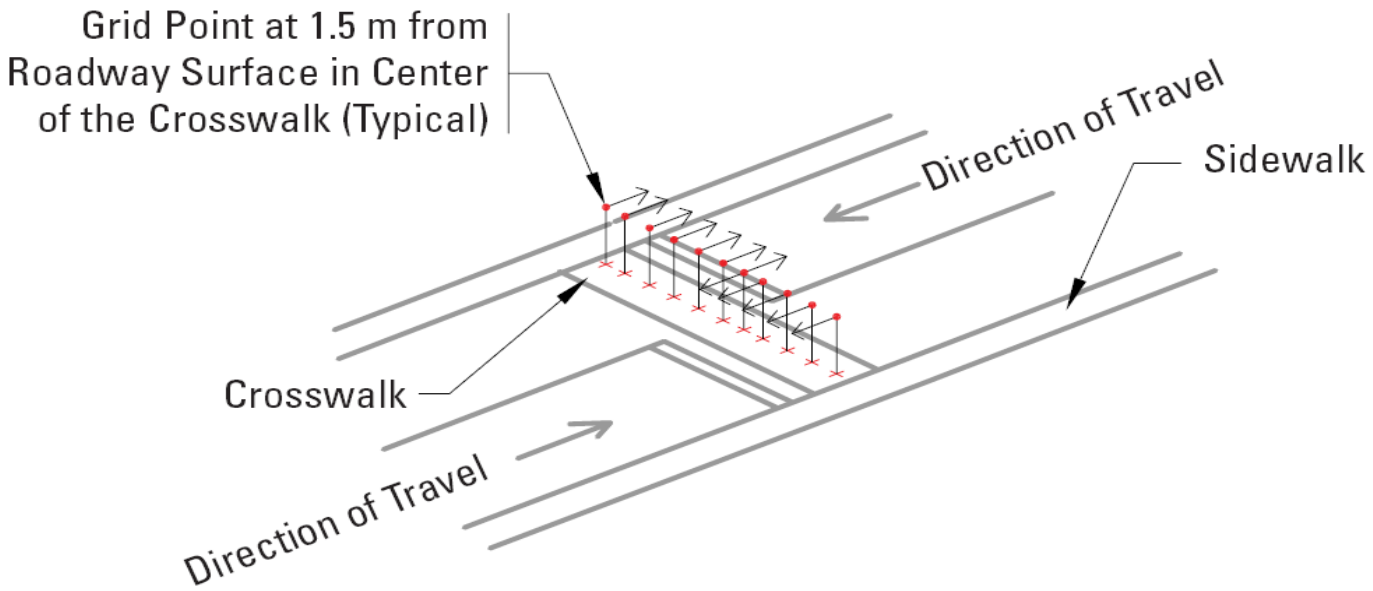


INBOUND1 AND OUTBOUND 1
MAINTAINED VERTICAL ILLUMINATION CALCULATION ZONES (TYPICAL)
N.T.S.

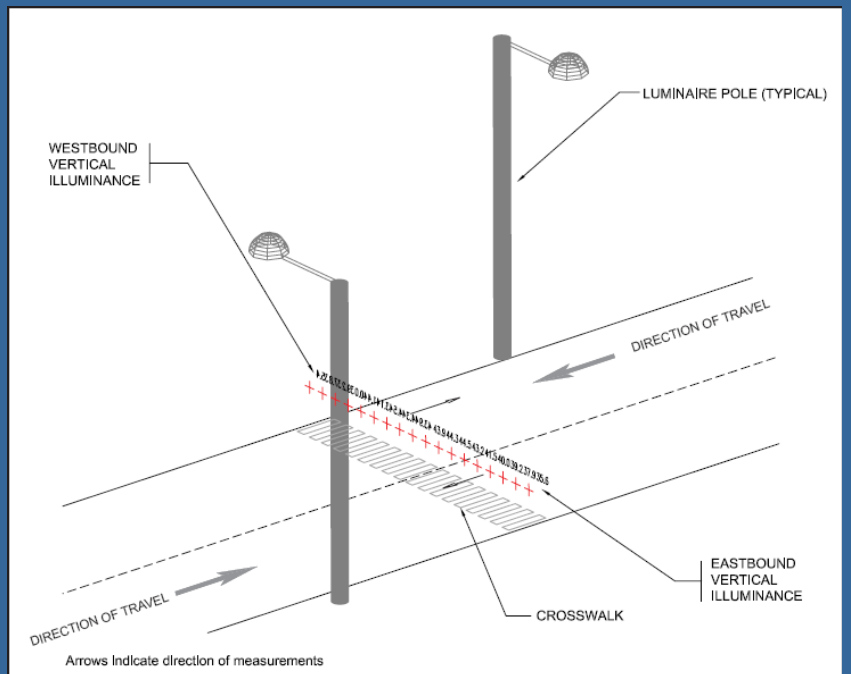
STATISTICS

Description	Symbol	avg	Max	Min	Max/Min	Avg/Min
Inbound 1 (Vertical)	+	43 lux	47 lux	35 lux	1.3:1	1.2:1
Outbound 2 (Vertical)	+	41 lux	48 lux	32 lux	1.5:1	1.3:1
Inbound 2 (Vertical)	+	40 lux	45 lux	33 lux	1.4:1	1.2:1
Outbound 3 (Vertical)	+	41 lux	46 lux	33 lux	1.4:1	1.2:1
Outbound 1 (Vertical)	+	41 lux	47 lux	31 lux	1.5:1	1.3:1
Inbound 2 (Vertical)	+	41 lux	44 lux	34 lux	1.3:1	1.2:1
Outbound 4 (Vertical)	+	40 lux	46 lux	30 lux	1.5:1	1.3:1
Inbound 4 (Vertical)	+	40 lux	45 lux	34 lux	1.3:1	1.2:1
Roundabout (Horizontal)	+	42 lux	82 lux	14 lux	5.8:1	3.0:1

Mid Block Crosswalk Lighting

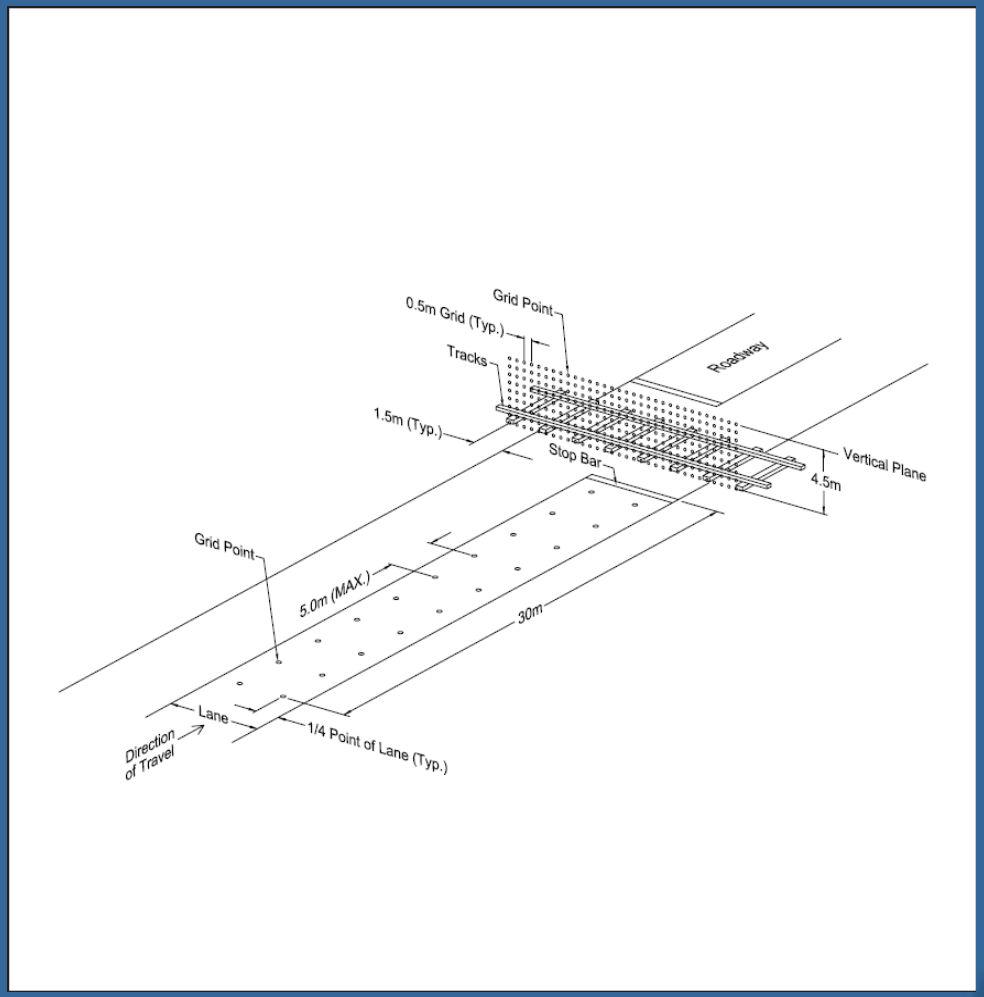


Mid Block Crosswalk Lighting



OUTPUT RESULTS	
GRID	MAINTAINED AVERAGE
W-B VERTICAL ILLUMINANCE	41.1 lux
E-B VERTICAL ILLUMINANCE	41.1 lux

Railway Crossing Lighting



Railway Crossing Lighting

Based Transport Canada RTD-10

Warrants

- Railway Crossing is unrestricted
- No signals
- Posted Speed on Roadway 50 km/h or greater
- Trains running at speeds less than 24 km/h (spur type line)

Walkways and Bikeways

Description	Maintained Average Horizontal Illuminance	Maintained Average Vertical Illuminance
Walkways and Bikeways for Security	NA	≧ 5.0 lux
Walkways and Bikeways for Guidance	≧ 5.0 lux	NA
Pedestrian Stairways for Security	NA	≧ 5.0 lux
Pedestrian Stairways for Guidance	≧ 5.0 lux	NA
Pedestrian and Cyclist Tunnels for Security	NA	≧ 54.0
Pedestrian and Cyclist Tunnels for Guidance	≧ 43 lux	NA

Parking Lot Lighting

Description	Maintained Average Horizontal Illuminance	Average to Minimum Uniformity Ratio
Basic Parking Lot Illumination Level	10.0 lux	5.0:1
Enhanced Parking Lot Illumination	25.0 lux	5.0:1

Streetscape Lighting

Streetscape Lighting

- Obtrusive Lighting
- Surrounds
- Color
- Vertical Surface Illumination
- Grazing Light
- Accent Lighting

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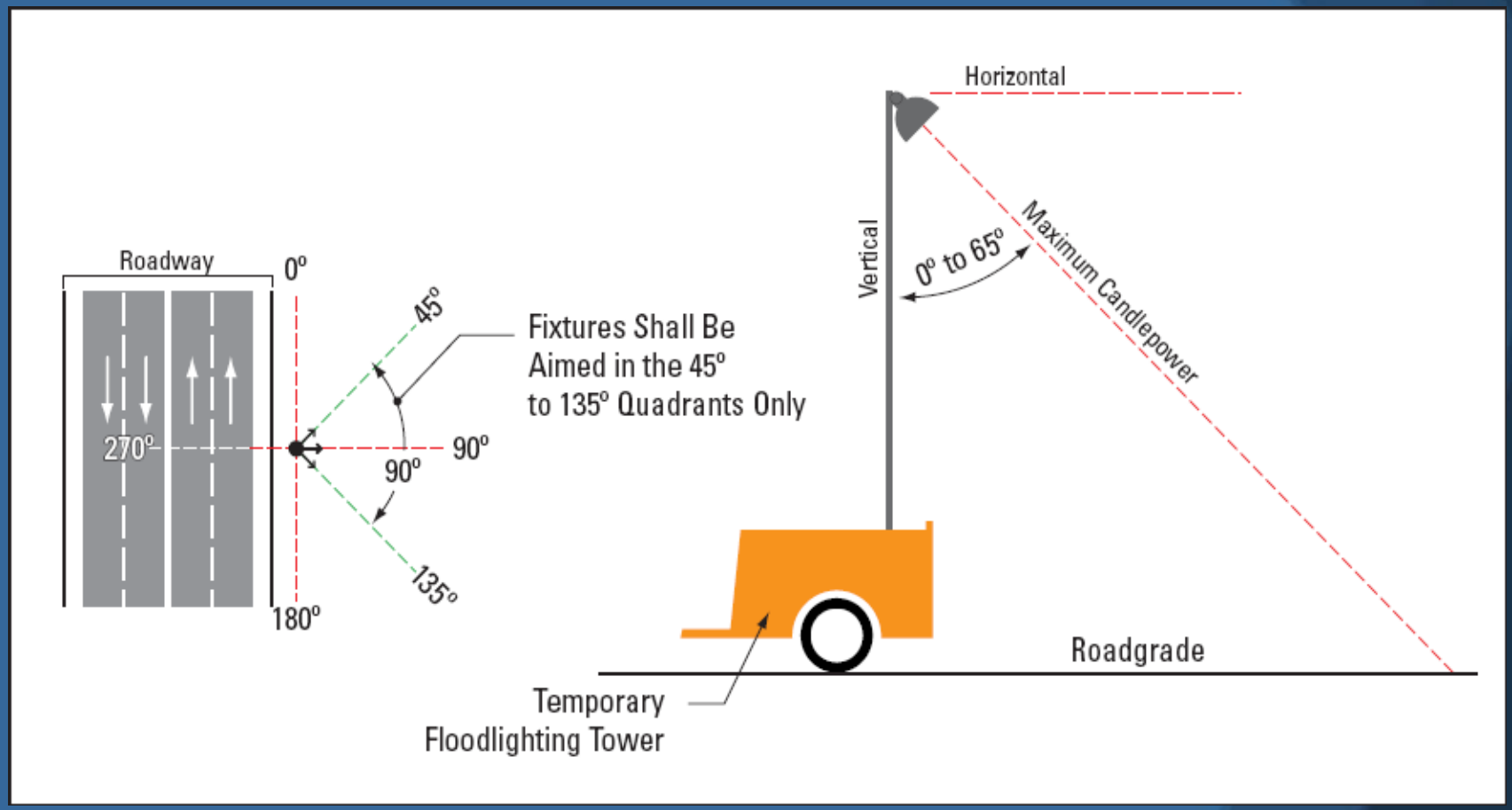
Work Zone Lighting

Category	Minimum Illuminance Level	Area of Illumination	Application	Example Areas and Activities for Illumination
1	54 lux	General illumination through spaces	Large size visual task; low accuracy; general safety requirements	Excavation; sweeping and cleaning; movement areas in work zones; movement between tasks
2	108 lux	General illumination of tasks around equipment	Medium size visual task; low to medium contrast; medium accuracy; safety on around equipment	Paving; milling; concrete work around paver, miller and other construction equipment
3	216 lux	Illumination on task	High size visual task; low contrast; high accuracy and fine finish	Crack filling; pot filling; signalization or similar work requiring extreme caution and attention

Work Zone Lighting



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Questions and Answers