New TAC Roadway Lighting Research

Introduction

As noted in the ***Methodology and Specific Research Requirements*** Section of the RFP "The consultant will be required to research documents and guidelines published by the international transportation and electrical/lighting agencies". Documents listed in the RFP and additional documents referenced are listed below.

It is important to note we have not listed all documents and information as that list would be overwhelming in itself. Given the over 100 year of collective roadway lighting design experience of the three main authors Don McLean, Dr. Ian Lewin and Paul Lutkevich much of the information which will be contained within the new guide is based on the expertise of these industry experts.

The purpose of this document is to show the TAC Roadway Lighting Committee we have undertaken the required investigation and are proposing reasonable and current design practice and standards. It is important to note as this assignment is not a research project we can't be expected to create new standards as part of our scope. It is our goal to source out and apply what we believe to the most suitable standards for the Canadian market. The information listed below is intended to show of the material which we have reviewed for this project.

In addition we will be working with numerous lighting suppliers such as GE, Phillips, Lumec, American Electric, Hubbell, Holophane, Cooper, Advance Ballasts, West Coast Engineering and Valmont (poles) in order to keep up with advancements in systems component and new technologies. A draft of ***Chapter 6 – System Components and Common Design Elements*** will be submitted to this select group of supplier's engineers for comment. We will of course follow up a assess information provided the by the suppliers and only apply suitable information which not proprietary to a given supplier.

This report should also be read in conjunction with our teams technical power point presentation from the 2003 TAC St Johns Conference. A copy of which can be found on the DMD TAC web site. In addition information under the Learning Center on the DMD web site (www.dmdeng.com) from a fall BC Chapter IESNA Outdoor Lighting presentation by Bill Smelser, PEng, Dr Ian Lewin and Don McLean would also form part of this document.

We have assembled a list of reference documents assembled during the preparation of the new TAC Design Guide. This documents are posted in PDF on TAC Project Page the DMD web site.

Trends

The use of artificial lighting to aid in the undertaking of night-time tasks is a necessity of modern society. This lighting requires electricity to operate. Recent blackouts in North America and over demand have opened all our eyes to what we often take for granted – reliable electricity and lighting. Power outages result in nearly all lighting being unavailable, creating conditions that compromise security, safety and economic well being. Unfortunately we can't go on using electricity at will without considering conservation. This is why we must seek out new innovative ways to reduce power demand. Past lighting standards typically specify the minimum amount of illumination with no thought to maximums. As a result precious power is wasted. This is where unit power density (watts/area) standards such as those developed as part of California's "Title 24" are useful.

At the same time we are now much more aware of the environment. Special interest groups such as the International Dark Sky Association (IDA) have really come into prominence with the aim being to reduce wasted light and preserve the night sky for all to enjoy.

The trend in outdoor is towards new visibility standards rather than the old method of simply specifying illumination levels and/or pole height and spacing. This is largely driven by the desire to reduce power and improve visibility. Reductions in stray light falling away from its intended area and reductions in sky glow are positive side effects to this desire.

This move to research-based standards is the result of modern computing power that allows the complex calculations to be undertaken that can verify theoretical assumptions. Previously these calculations were not possible. Lighting design and standards are destined to become more complex as visibility becomes the issue. Simply put research shows more light is not always better in terms of visibility.

New lighting controls are being developed to improve efficiency and reduce power.

Illuminating Engineering Society of North America (IESNA)

IESNA RP-8 American National Standard Practice for Roadway Lighting
This document is the most used in North America for the design of roadway lighting. New version being worked on by the IESNA Roadway Lighting Committee and should be published in 3 to 5 years. Presently there are no plans for significant changes to lighting specifications, although issues of peripheral vision (that are likely to include spectral effects) are under early stages of discussion.

The IESNA is also developing a new luminaire light distribution classification system to replace the old cut-off, full cut-off, non cut-off and semi cut-off designations. The current standard is very limited in its effectiveness. The new standard will define max candelas/ lamp lumens or less at various angles relative to the fixture.

IESNA RP-22 American National Standard Practice for Tunnel Lighting

Is a very comprehensive tunnel lighting design standard document. The document has been updated and will soon be re-issued by the IESNA. Paul Lutkevich of our team has undertaken edits so we have current information

IESNA DG-5 Recommended Lighting for Walkways and Class 1 Bikeways
This document (1994) is relatively current and quite comprehensive in detail. As a Design Guide is meant to complement IESNA RP-6. It deals with both vertical and horizontal illuminance for walkways and bikeways, pedestrian tunnels, overpasses and stairways.

IESNA RP-19 Recommended Practice for Roadway Sign Lighting
The document deals with the illumination of highway signs. Dr Ian Lewin of the DMD was the lead on this committee and was the main author of the current publication. This guide is current and the subcommittee has been suspended for the next 3 to 4 years.

IESNA CP-38 Lighting Roadway Safety Rest Areas
The sub-committee are working to revise the current document. The existing document is quite old and levels will need to be looked in more detail. We will talk to the sub-committee to confirm what changes are being proposed

IESNA RP-20 Recommended Practice for Lighting for Parking Facilities
The document was revised and republished in 1998. The document defines minimum maintained horizontal illuminance levels as well as vertical levels for both “basic” conditions and “enhanced security” condition.

IESNA RP-17 Recommended Practice for Airport Road and Automobile Parking Area Lighting
IESNA RP-17 RP for Airport Roads and Auto Parking Guide is old, but we believe the IESNA aviation lighting committee is working on an update. We are covering this lighting application in the TAC document.

IESNA RP-33 Recommended Practice on Lighting Exterior Environments
Published in 1999 and as such is quite current. Document is a comprehensive guide to all types of outdoor lighting. It deals mainly with visual issues such as glare luminance, visual acuity, and illuminance; Community responsive design and design guidelines; security lighting; stray light; lighting ordinances; luminaire types and classifications; energy conservation and maintenance; lighting structures. It touches very briefly on soft and hard landscape lighting; roadway and street lighting; pedestrian mall, plaza and park lighting; parking lot lighting; sports lighting; outdoor retail lighting and security lighting.

IESNA LM-69 Interpretation of Roadway Luminaire Photometric Reports
We believe this document is current.

IESNA LM-50 Photometric Measurements of Roadway Lighting Installations
We believe this document is current.

IESNA LM-71 Photometric Measurements of Tunnel Lighting Installations

We believe this document is current.

IESNA LM-64 Photometric Measurements of Parking Areas
We believe this document is current.

IESNA LM-52 Photometric Measurements of Roadway Sign Installations
We believe this document is current..

IESNA TM-11 Light Trespass: Research, Results and Recommendations and IESNA TM-10 Addressing Obtrusive Light in Conjunction with Roadway Lighting
Document is recent and current. The document is based on research undertaken by Dr Ian Lewin. The subcommittee is working on a design practice on this subject. The International Dark-Sky Association has developed a model ordinance.

IESNA DG-4 Design Guide for Roadway Lighting Maintenance
This document has been refined republished as Dec 2003 and is therefore very current. Don McLean of the team is on the committee with developed this document.

European Committee for Standardization (CEN)

Based in Brussels, Belgium, the European Committee for Standardization (CEN) is responsible for standardization in areas other than the electrotechnical and telecommunications fields. In the fast-moving domain of information and communications technologies, CEN has created the Information Society Standardization System (CEN/ISSS). In addition to the traditional CEN Technical Committees, this makes use of open Workshops, which are standards committees created whenever there is an identified need for consensus. They are open to all interested parties and their deliverables are published by CEN as CEN Workshop Agreements (CWAs).

We could find no information with pertains directly to roadway lighting.

International Commission on Illumination (CIE)

A detailed comparison of CIE and IESNA standards is listed below. The main CIE documents are as follows:

CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic
CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic
CIE 92 – 1992	Guide to the Lighting of Urban Areas
CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic

The CIE documents are very complete and comprehensive in detail.

Association of American State Highway and Transportation Officials (AASHTO)

AASHTO are developing a comprehensive *Roadway Lighting Design Guide.* The document is currently in "draft" state and its date of publish is unknown. The guide will cover Master Lighting Plans; Techniques of Lighting design; High mast Lighting; Work Zone Lighting and Temporary Roadway Lighting; Roundabout Lighting; Electrical Systems; Safety Rest Areas and Maintenance Considerations.
We have reviewed this document and find some of this information will be useful. Information in the document based on current IESNA practice.

Transportation Research Board (TRB)

The TRB has a number of research papers which are available on-line at http://arrow.win.ecn.uiowa.edu/symposium/DraftPapers/ . Three papers which relate to lighting are:

- TRB VIS 2002-21 Fixed Lighting to Benefit Older Drivers
- TRB VIS 2002-23 Improved Visibility via Fixed lighting
- TRB VIS 2002-28 Crosswalk Lighting

Selected information from these documents will be included within the document

Australia and New Zealand

Australia and New Zealand have very comprehensive roadway lighting standards. These standards include:

AS/NZS 1158.0:1997 Road Lighting Part 0 – Introduction
Lighting categories include Category V – Roads where visual requirements are driver dominant, Category B – Road where visual requirements are pedestrian dominant and Category C – Outdoor areas other than roads where visual requirements are pedestrian dominant.

Insert 1

AS/NZS 1158.1.1:1997 Road Lighting Part 1.1: Vehicular traffic (Category V) Lighting – Performance and installation design requirements
The standards used a combination of luminance and illuminance design methods for road types V1 to V5. In general levels are slightly higher than the IESNA however lower than CIE. The standards more closer reflect CIE however the levels are slightly lower than CIE. Surround illuminance (*Es)* ratio is also used which defines a ratio of average illumination on a 3m wide strip on the off

roadway side of the curb to a 3m wide strip of illumination on the roadway. Intersections have specific illumination requirement. Uniformity is:

- Overall luminance uniformity (*Uo)* ratio of minimum luminance to average roadway luminance within a given area viewed from a specific observer point
- Longitudinal luminance uniformity (*UL)* the ratio of minimum luminance to the maximum illuminance within a specified area along the longitudinal line which passes along the observer point

Insert 2

AS/NZS 1158.1.3:1997 Roadway Lighting Part 1.3 Vehicular Traffic (Category V) lighting – Guide to design, installation, operation and maintenance

Most interesting are the warrants under section 4. Warrants are defined for:

- Traffic Route Lighting – Criteria for whether to light a road (excluding freeways) includes minimum traffic volume of 5000AADT, a high accident rate, a day / night accident ratio greater than 1.3:1 and 2 or more lanes in one direction
- Isolated Intersections – AADT over 1000, Day night accident ratio greater than 1.3:1 and economic cost benefit
- Continuous freeway Lighting in Urban Areas – AADT of 40,000 or greater, on unlit sections less than 2km between lit sections, reduce geometric standards, if high night accident rate and if adjacent class V roads impact visibility of those using the freeway
- Full interchange Lighting in Urban Areas – Greater 10,000 AADT, connecting roads are category V with lighting and if continuous freeway lighting warrant is met.
- Partial Lighting in Urban Areas – AADT on freeway is greater than 25,000, AADT on ramp is great than 5000, ramp design standard are less than those on approaches, significant nighttime accident ratios and if adjacent class V roads impact visibility of those using the freeway.
- Lighting of Off Ramp Intersections in Urban Areas – If continuous freeway or complicated interchange lighting is provided, if crossroad approaches are illuminated, if crossroad has raised island and if AADT through the intersection is 3600 or greater

- Rural Freeways – High accident history, reduced geometric design standards and where background illumination off the freeway may be distracting to those on the freeway.
- Pedestrian Crossings – shall be illuminated when AADT exceeds 1000. Where pedestrian crossing is isolated and category V4 or V% roadway then the lighting shall extend 2 to 3 pole spacings beyond the crosswalk. Special circumstances also include poor road location geometry, background lighting and poor weather (such as fog).

Their primary light source is HPS. They define a comprehensive design process some which we may adopt. They use the term “aeroscreen luminaire” for those which restrict uplight (similar to IESNA full cutoff)

They define the mounting height (*H*) based on road (*Wk*). They note when using single sided spacing *H* should not be less than *WK*. For staggered they define H as not less than Wk/1.25 of Wk/1.75 for areoscreen luminaires. For opposite H should not be less than Wk/2.25. They use pole height and wattages of 9m – 100W, 10.5m – 150W and 250W, 12m – 400W, 13.5m – 400W and 15m – 400W.

AS/NZS 1158.3.1:1999 Road lighting Part 3.1: Pedestrian area (Category P) lighting – Performance and installation design requirements

This lighting applies to lighting of collector and local roads as pathways and public areas. They focus on average horizontal illuminance at ground level (*Eh),* horizontal uniformity, max to average ratio (*Up)* and vertical illumination 1.5 above ground level (*Ev).* Lighting is defined by category (P1 to P12) and pedestrian/cyclist volume, risk of crime and need to enhance prestige (high, medium or low)

Levels are very low (maintained average horizontal level of 1.75 lux and 0.85 lux for collector roads in P3/P4 category’s in rural areas and very high (21 lux) in high pedestrian volume areas P6. The uniformity is always 10:1 (max to average) and would therefore in most cases be the criteria which would drive the design. The standard is somewhat hard to follow.

Insert 3

AS 4282-1997 Australian Stand – Control of obtrusive effects of outdoor lighting

They provide interesting methods of measuring offsite light source luminance as opposed to illuminance at the off site boundary line. We may be able to apply some information the high mast lighting.

Institute of Transportation Engineers (ITE)

We know of no ITE standards which apply to roadway lighting.

United States Federal Highway Administration (FHWA)

The information from two documents has been used extensively through the new TAC document. They are the FHWA-PL-01-034 European Road Lighting Technologies as well and FHWA Crosswalk Lighting. The European Lighting Technologies was authored by Paul Lutkevich of our team. Must of the knowledge gained has been used in the development of the new TAC Guide.
Again Paul Lutkevich of our team was involved in the study aimed improving pedestrian visibility at crosswalks. This and further research has formed the basis for visibility based crosswalk lighting standards defined in Chapter 8.

National Cooperative Highway Research Program

Research Results Digest #216 defines Illumination levels for Nighttime Highway Work. It is brief and based on the finding of HCHRP Project 5-13. The document notes illumination levels for various work activities. This will be used a the basis for Chapter 12 Temporary Lighting and Work Zone Lighting

Lighting Research Board (LRB)

List of LRB have many document providing lighting education and information. The Transportation Lighting Group at the Lighting Research Center is committed to explore lighting and visibility issues associated with transportation. This includes research and educational programs in such disciplines as optical design, photometry, human factors, vision, product testing, and market assessment.

Currently, the transportation lighting group's main focus is the roadway visibility system. The LRC takes a unique approach to examining roadway visibility by considering all elements; vehicle lighting, fixed roadway lighting, and signal and marking devices, separately and as an interactive system. Documents are available at http://www.lrc.rpi.edu/programs/transportation/index.asp.

Must of the research from the LRB parallel's that undertaken by Dr Ian Lewin of our team.

International Municipal Signal Association (IMSA)

They have a street lighting standard which is mainly aimed at workers as opposed to designers. Design information is based on the IESNA. No information has been used from the IMSA.

Transportation Association Of Canada (TAC)

RTAC/ARTC Guide for the Design of Roadway Lighting
Published in 1983. The TAC guide does contain some useful information however is very out of date and not well organized. The levels in the current TAC document are defined in Table 3.1 on page 45 of the old guide. Under Sub-Chapter 3.1 of the old guide it notes "The recommended criteria are shown in Table 3.1 and are taken from a consensus of current North American Practice with adaptation to Canadian Conditions". From the actual levels and uniformity defined in Table 3.1 we believe the IESNA RP-8 -83 was the basis for these numbers and in some cases were increased to accommodate the so called "Canadian Conditions".

TAC Illumination of Isolated Rural Intersections
This document is very current and defines warrants for lighting rural intersections. We would apply it to urban intersections also

Transport Canada

TC – RTD 10 Transport Canada Road/Railway Grade Crossing Technical Manual :Guide for the Design of Roadway Lighting Transportation Association of Canada 3
Could not find and information on roadway lighting in document referenced.

Governments

Roadway Lighting Guides/Manuals from Canadian Road Jurisdictions:

- British Columbia – The Electrical and Lighting Design Manual has been updated and has been re-issued in draft form by the Ministry of Transportation. It follows IESNA and references their documents
- Alberta Transportation – The Alberta Transportation Lighting Design Guide was produced and issued in 2003. It is very similar to British Columbia and also follows IESNA and references their documents.
- Saskatchewan – Unable to obtain any Standards. We believe they follow IESNA
- Manitoba - Unable to obtain any Standards. We believe they follow IESNA
- Ontario – Unable to obtain standards. Also copyright issues with publisher. We did obtain a copy of the ***Ministry Policy for Highway Illumination*** dated May 8th, 2002 which contains a detailed warrant system
- Quebec – Could not obtain documents in English
- New Brunswick - Follow partial lighting per TAC 1983. At interchanges, they locate two lamps at the exit ramps and one lamp on the minor roadway for the on ramp. It is a rare occasion when we use full lighting, but when we do, we follow TAC. They follow the Illumination of Isolated Rural Intersection -TAC Supplement, for isolated intersections. The province does not provide intersection lighting inside municipalities. This matter is a municipal responsibility. So, in their case, at least, rural is truly rural.
- Ottawa – Ottawa have construction standard drawings and specifications and a Residential Street Lighting Policy

Comparison between IESNA and CIE documents

The two most common standards used for outdoor lighting throughout the world are those of the IESNA and CIE. The IESNA is primarily used throughout North America whereas the CIE is used in Europe.

General Roadway Lighting

The two standards governing roadway lighting for the CIE and IESNA are:

ANSI/IESNA RP-8-2000	Recommended Practice for Roadway Lighting
CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic

The IESNA gives three methods for the lighting of roadways. They include illuminance, luminance and STV (small target visibility). The document recommends that the designer consider meet at least one of the methods and consider meeting 2 or all 3 of the methods. The values for luminance are given in the following table.

Table 3: Luminance Method - Recommended Values

Road and Pedestrian Conflict Area		Average Luminance	Uniformity Ratio	Uniformity Ratio	Veiling Luminance Ratio
Road	Pedestrian Conflict Area	L_{avg} (cd/m^2)	L_{avg}/L_{min} (Maximum Allowed)	L_{max}/L_{min} (Maximum Allowed)	L_{Vmax}/L_{avg} (Maximum Allowed)
Freeway Class A		0.6	3.5	6.0	0.3
Freeway Class B		0.4	3.5	6.0	0.3
Expressway	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
Major	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	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

(*Refer to* ***Section 3.6*** *for Intersection Lighting*)

The CIE uses the luminance method for roadway lighting. STV values are included in the CIE document in the annex but are not part of the recommendation. It is given so that countries may use it if they so choose. The description of roadway types and luminance values given in CIE are given in the following tables:

Table 5.1 Lighting Classes for different road types.

DESCRIPTION OF ROAD	LIGHTING CLASS
High speed roads with separate carriageways, free of crossings at grade and with complete access control; motorways, express roads. Traffic density and complexity of road layout *(Note 1)*: High Medium Low	 M1 M2 M3
High speed roads, dual carriageway roads. Traffic control *(Note 2)* and separation *(Note 3)* of different types of road user *(Note 4)*: Poor Good	 M1 M2
Important urban traffic routes, radial roads, district distributor roads. Traffic control and separation of different types of road user: Poor Good	 M2 M3
Connecting less important roads, local distributor roads, residential major access roads. Roads which provide direct access to property and lead to connecting roads. Traffic control and separation of different types of road user: Poor Good	 M4 M5

Table 6.1: Lighting requirements for motor traffic, based on road surface luminance (NR is no requirement)

LIGHTING CLASS	EXTENT OF APPLICATION				
	All Roads	All Roads	All Roads	Roads with few or no Intersections	Roads with Footways not lit to Classes P1 to P4 in Clause 9.4
	$\bar{L}$ (cd.m^{-2}) Minimum Maintained *Clause 6.1*	U_o Minimum *Clause 6.2*	TI (%) Maximum Initial *Clause 6.3*	U_l Minimum *Clause 6.4*	SR Minimum *Clause 6.5*
M1	2,0	0,4	10	0,7	0,5
M2	1,5	0,4	10	0,7	0,5
M3	1,0	0,4	10	0,5	0,5
M4	0,75	0,4	15	NR	NR
M5	0,5	0,4	15	NR	NR

The levels used in the CIE are higher than those used by the IESNA. The CIE uses luminance levels of 0.5cd/m^2 to 2.0 cd/m^2. The IESNA uses values of 0.3 cd/m^2 to 1.2 cd/m^2 .

Other areas where the CIE and IESNA differ for roadways is in the required uniformity. The CIE uses a value of 0.4 Lmin/Lavg. This is equal to a uniformity ratio of 2.5 Lavg/Lmin. The IESNA uses levels of 3.5 to 6.0 depending on the roadway type. The

CIE uses glare criteria called Threshold Increment (TI) which is the percent increase in luminance needed to make an object visible in the presence of glare. The IESNA uses a glare criteria called Veiling Luminance Ratio which is the ratio of the maximum veiling luminance (generally the brightness of the closest luminaire) to the average pavement luminance. There is no direct correlation between the two methods but in general using the TI values included in the CIE document would require the use of lower veiling luminance ratios (i.e. the lighting systems would be required to produce much less glare).

Again the need for greater uniformity and less glare than that recommended by the IESNA has not been proved by studies to reduce accidents and the addition resulting cost does not seem warranted.

Other recommendations used by the CIE and not adopted by the IESNA include Surround Ratio (SR). The SR is a value to which the area adjacent to the roadway is lit. In general for higher classes of roadways the area of 5 meters adjacent to the road would be lit to a value of half the roadway levels. The CIE document also discusses wet pavement design and discomfort glare criteria using Glare Control Mark. These additional lighting requirements and associated design and calculation time are not seen as justified at this point in time.

Research does not seem to bear out the increase in traffic safety related to the increase in light levels.

In many urban areas in Europe the roads are very well lit and uniform but the TAC document is recommending minimum values for lighting. For that reason the values recommended in IESNA were used.

Pedestrian Lighting Adjacent to Roadways

The standards governing pedestrian lighting adjacent to roadways for the CIE and IESNA are:

ANSI/IESNA RP-8-2000	Recommended Practice for Roadway Lighting
CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic
CIE 92 – 1992	Guide to the Lighting of Urban Areas

The IESNA method for the lighting for pedestrian areas when adjacent to roadways is given in terms of average horizontal illuminance and minimum vertical illuminance, as well as uniformity. The values are included in the following tables.

Table 5: Recommended Values for High Pedestrian Conflict Areas

Maintained Illuminance Values for Walkways/Bikeways			
	E_H lux/fc	E_{vmin} lux/fc	E_{avg}/E_{min}*
Mixed Vehicle and Pedestrian**	20.0/2.0	10.0/1.0	4.0
Pedestrian Only	10.0/1.0	5.0/0.5	4.0

* Horizontal only

Mixed vehicle and pedestrian refers to those areas where the pedestrians are immediately adjacent to vehicular traffic without barriers or separation. Does not apply to mid-block crossings. (See **Section 3.5.1.4.)

E_H = average horizontal illuminance at walkway/bikeway

E_{vmin} = minimum vertical illuminance at 1.5 m (4.9 ft.) above walkway/bikeway measured in both directions parallel to the main pedestrian flow

Table 6: Recommended Values for Medium Pedestrian Conflict Areas

Maintained Illuminance Values for Walkways/Bikeways			
	E_H lux/fc	E_{vmin} lux/fc	E_{avg}/E_{min}*
Pedestrian Areas	5.0/0.5	2.0/0.2	4.0

* Horizontal only

Table 7: Recommended Values for Low Pedestrian Conflict Areas

Maintained Illuminance Values for Walkways/Bikeways			
	E_H lux/fc	E_{vmin} lux/fc	E_{avg}/E_{min}*
Rural/Semi-Rural Areas	2.0/0.2	0.6/0.06	10.0
Low Density Residential	3.0/0.3	0.8/0.08	6.0
Medium Density Residential	4.0/0.4	1.0/0.1	4.0

* Horizontal only

Table 8: Recommended Values for the Pedestrian Portion of Pedestrian Vehicular Underpasses and Exclusive Pedestrian Underpasses

Maintained Illuminance Values for Walkways/Bikeways			
	E_H lux/fc	E_{Vmin} lux/fc	E_{ave}/E_{min} *
Day	100.0/10.0	50.0/5.0	3.0
Night	40.0/4.0	20.0/2.0	3.0

* Horizontal only

These values are somewhat similar to those given in the CIE 92 – 1992 document with the exception of the use of semi-cylindrical illuminance (Esc). Prior studies had shown the useful value of Esc to be approximately equal to Ev and because of the ease of calculation Ev was used. The values contained in CIE 92 are as follows:

Table 2.3
Lighting Requirements on walkways (maintained values)

	City or Town Centres			
	E_H Ave	E_H min	E_{SC} min	$LA^{0.25}$ max
Mixed vehicle and pedestrian	25 lux	10 lux	10 lux	(a) 6 000 (b) 8 000 (c) 10 000
Wholly pedestrian	15 lux	5 lux	5 lux	

	Suburban Shopping Streets			
	E_H Ave	E_H min	E_{SC} min	$LA^{0.25}$ max
Mixed vehicle and pedestrian	20 lux	8 lux	8 lux	(a) 6 000 (b) 8 000 (c) 10 000
Wholly pedestrian	10 lux	3 lux	4 lux	

	Village Centres			
	E_H Ave	E_H min	E_{SC} min	$LA^{0.25}$ max
Mixed vehicle and pedestrian	10 lux	4 lux	4 lux	(a) 6 000 (b) 8 000 (c) 10 000
Wholly pedestrian	8 lux	2 lux	3 lux	

Table 2.4
Lighting Requirements for specialised residential areas (maintained values)

	E_H Ave	E_H min	E_{SC} min	$LA^{0,25}$
High usage areas	8 lux	4 lux	3 lux	
Medium usage areas	5 lux	2 lux	2 lux	(a) 6 000 (b) 8 000 (c) 10 000
Low usage areas	3 lux	1 lux	1 lux	

Table 2.12
Lighting Requirements for pedestrian and cycle underpasses (maintained values)

	E_H Ave	E_H min	E_{SC} min	$LA^{0,25}$
Pedestrians and cycles only - Day: Night:	100 lux 40 lux	50 lux 20 lux	25 lux 10 lux	6 000 max

CIE 115-1995 also has lighting requirements for pedestrians and the tables of values are as follows.

Table 9.1 Lighting Classes for different road types in pedestrian areas.

DESCRIPTION OF ROAD	LIGHTING CLASS
High prestige roads	P1
Heavy night-time use by pedestrians or pedal cyclists	P2
Moderate night-time use by pedal cyclists or pedestrians	P3
Minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties	P4
Minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties. Important to preserve village or architectural character of environment	P5
Very minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties. Important to preserve village or architectural character of environment	P6
Roads where only visual guidance provided by the direct light from the luminaires is required	P7

Table 9.2 Lighting requirements for pedestrian traffic

LIGHTING CLASS	HORIZONTAL ILLUMINANCE (lx) on whole of used surface Maintained	
	AVERAGE *Sub-clause 9.3.1*	MINIMUM *Sub-clause 9.3.1*
P1	20	7,5
P2	10	3
P3	7,5	1,5
P4	5	1
P5	3	0,6
P6	1,5	0,2
P7	Not applicable	Not applicable

Any of these values or methods is reasonable for the lighting of pedestrian areas adjacent to roadways. It is our opinion that vertical illuminance is very important to the visibility of pedestrians as well as their sense of security. Semi-cylindrical illuminance, although a more complete way of determining vertical illuminance, is difficult to calculate and not included in most lighting software. For these reasons it was determined that the IESNA recommendations were the most reasonable ones to include in the TAC document.

Intersection Lighting or Conflict Area Lighting

The two standards governing intersection lighting for the CIE and IESNA are:

ANSI/IESNA RP-8-2000	Recommended Practice for Roadway Lighting
CIE 115 – 1995	Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic

The IESNA and the CIE both use horizontal illuminance and uniformity as the method of intersection lighting design. The IESNA arrived at the values for intersection lighting by using the sum of the recommended lighting levels for the approach roads and developed this table.

Table 9. Recommended Illuminance for the Intersection of Continuously Lighted Urban Streets
(Based on the values in Table 2 for R2 and R3 pavement classifications)

Illuminance for Intersections				
Functional Classification	**Average Maintained Illumination at Pavement by Pedestrian Area Classification** lux/fc			E_{avg}/E_{min}
	High	Medium	Low	
Major/Major	34.0/3.4	26.0/2.6	18.0/1.8	3.0
Major/Collector	29.0/2.9	22.0/2.2	15.0/1.5	3.0
Major/Local	26.0/2.6	20.0/2.0	13.0/1.3	3.0
Collector/Collector	24.0/2.4	18.0/1.8	12.0/1.2	4.0
Collector/Local	21.0/2.1	16.0/1.6	10.0/1.0	4.0
Local/Local	18.0/1.8	14.0/1.4	8.0/0.8	6.0

The CIE classifies the intersections (conflict areas) by complexity and some by the approach roads and gives the following recommendations.

Table 8.2 Examples of the application of Lighting Classes in conflict areas where luminance is not applicable

CONFLICT AREA	ILLUMINANCE LIGHTING CLASS
Underpasses	C(*N*) = M(*N*)
Junctions, gores, ramps, weaving sections, areas with restricted lane width	C(*N*) = M(*N*-1)
Railroad crossings: simple complex	 C(*N*) = M(*N*) C(*N*) = M(*N*-1)
Roundabouts with no signals: complex or large medium complexity simple or small	 C1 C2 C3
Queuing areas: complex or large medium complexity small or simple	 C1 C3 C5

Table 8.1 Lighting requirements for conflict areas

LIGHTING CLASS	$\bar{E}$ (lx) over whole of used surface Minimum Maintained	$U_0(\bar{E})$ Uniformity of Illuminance Minimum
C0	50	0,40
C1	30	0,40
C2	20	0,40
C3	15	0,40
C4	10	0,40
C5	7,5	0,40

In general the values would be higher than that given by the IESNA but is consistent with the higher level of roadway lighting recommended by the CIE. The uniformity ratio used is also 2.5 avg/min which is more stringent than that of the IESNA. This also is consistent with the roadway lighting requirements of the CIE. Although the higher levels may provide greater visibility at the conflict areas we found no scientific justification which used crash data to economically justify the increased values.

Tunnel Lighting
The new versions of the CIE document for Tunnel Lighting and the IESNA document for tunnel lighting are very similar in philosophy and criteria. Both methods use an equivalent veiling luminance model for determining the lighting required in the threshold of the tunnel as well as in the interior.

Summary

Both IESNA and CIE are well defined and excellent roadway lighting design methods and lighting levels which have extensive research to back them up. We would have no problem adopting either standard as the basis for the TAC document. We however believe that as the IESNA is more widely accepted throughout North America then it would make little sense to switch to the CIE.

As has been the case with the tunnel lighting standards member of the CIE and IESNA are interacting and trying to bring the two standards closer together. The trend in the further will be for groups like the CIE, IDA and the IES to share information and research with the goal being to develop uniform standards. This has been facilitated by the electronic age in which we live were documents can be exchanged by the push of a button.

The higher levels noted in the CIE go contrary to the trend within the industry to reduce power consumption. Introducing a new standard such as CIE to the Canadian market would incur expense for designers who would to design to new methods. The previous version of the TAC Roadway Lighting Design Guide pretty much followed IESNA with some higher levels for what where termed as “Canadian conditions”. From a lighting standpoint we see very little which would define a difference between lighting in Canada versus that in the United States. In the big picture roads are pretty much designed to similar standards. Being as much of population is in close proximity to the Canada/US border it makes sense to create some consistency between the two Country’s.

Lighting software such a Visual is now starting to link themselves up with IESNA required levels and criteria. We see this trend expanding to other suppliers.

The terms “rural and urban” though loose in definition are used throughout the roadway lighting and traffic worlds. Following discussion within our group we feel these terms should be used throughout the new TAC document. We would follow the previous TAC definitions with reference to pedestrian volumes. We will be presenting our proposed system to the committee at the upcoming TAC spring meeting in Ottawa. We will have developed a draft warranting system for discussion at the Spring meeting.