New CIE and ANSI/IES Recommendations for Vehicular Tunnel Lighting

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In 1987 and 1988, two important documents were developed concerning the lighting recommendations for vehicular tunnels. These were CIE's *Guide for the Lighting of Road Tunnels and Underpasses* (CIE 26/2) (draft), and the ANSI/IES *American National Standard Practice for Tunnel Lighting* (ANSI/IES RP-22). Although these organizations kept a close liaison throughout the preparation of these documents, the photometric values in tunnel threshold zone and the length of supplementary lighting recommended in the documents differ considerably.

In 1987 and 1988, two important documents were prepared by the Commisson Internationale de l'Eclairage (CIE) (*1*) and the Illuminating Engineering Society of North America (IESNA) (*2*), offering recommendations for vehicular tunnel lighting design.

The CIE document was prepared by the TC-4-08 Committee on Tunnel Lighting. This committee consists of 15 members and 3 consultants, representing 11 member countries. The ANSI/IES *Standard Practice* was prepared by the Subcommittee on Tunnels and Underpasses of the Roadway Lighting Committee (IESNA).

A close liaison was maintained between the CIE Committee on Tunnel Lighting and the IES Subcommittee on Tunnels and Underpasses, and four IES members (R. N. Schwab, R. E. Stark, A. Ketvirtis, and Dr. W. Adrian) served on both IES and CIE committees. However, the photometric values recommended for a tunnel threshold and its interior, as well as the procedures used to arrive at these values, differed considerably between these documents.

To assist those who will study these documents, particularly the practicing engineers and highway administrators who may attempt to use one or both of them in practice, a brief discussion of their differences is presented.

ANSI/IES RECOMMENDATIONS FOR TUNNEL THRESHOLD AND TRANSITION ZONE LUMINANCE VALUES

The ANSI/IES recommendations for threshold and transition zones are based on the following factors:

- Tunnel characteristics and immediate surroundings,
- Traffic speed and safe stopping site distance (SSSD), and
- Traffic volume.

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Table 1 (reproduced from the ANSI/IES publication) shows the recommended values for threshold zone luminance, ranging from 60 cd/m^2 for low-speed, low-volume tunnels to 330 cd/m^2 for high-speed, high-volume structures.

In the ANSI/IES document, the length of threshold and transition zones are related to SSSD; the length of one SSSD, counting from the adaptation point, is recommended for the threshold zone. In other words, the threshold zone length should be one SSSD minus the distance from the adaptation point (approximately 15 m) to the tunnel portal. A total of one SSSD is also recommended for the transition and adaptation zones, in order to achieve a gradual reduction of luminance level.

ANSI/IES RECOMMENDATIONS FOR LIGHT SOURCE SELECTION

The ANSI/IES document stipulates that the following factors should be used in selecting a light source for tunnel lighting: efficacy, color renditions and their effect on sign and traffic signals, wattages or lumen output available, life, lamp lumen depreciation, ambient temperature, cost, restrike time, ability to control the light distribution, dimming capability, physical size, and physical durability. No further advice, recommendations, or preferences are offered regarding selection of the light sources, light distribution methods, or lighting system geometric arrangements.

CIE ACCESS ZONE LUMINANCE, L_{20} CONCEPT

According to the CIE document, "the correlation between equivalent veiling luminance and access zone luminance, L_{20}, indicates that the simpler of the two, the access zone luminance, can be used for practical tunnel lighting purpose. For this reason the luminance value required at the beginning of the threshold zone is based on the access zone luminance, L_{20}, measured one stopping distance in front of the portal."

The CIE document also provides a method for calculating L_{20} values. In the assessment of L_{20} values, sky, road surroundings, and the tunnel entrance (in percentages) are taken into account. In the case of new tunnel design, where these factors cannot be determined by field measurements, a table for L_{20} values is included (see Table 2, reproduced from CIE Table 5.1). The L_{20} value can be selected from this table.

TABLE 1 RECOMMENDED MAINTAINED THRESHOLD ZONE AVERAGE PAVEMENT LUMINANCE VALUES FOR TUNNEL ROADWAYS (*2*)

Characteristics of Tunnel	Traffic Speed		Traffic Volume AADT*			
	Kilometers per Hour	Miles per Hour	< 25,000	25-89,999	90-150,000	> 150,000
			Candelas per Square Meter+			
Mountain tunnels, gradual slopes where snow can accumulate or river tunnels with few surrounding buildings. East/west tunnel orientation.	⩾ 81	50	210	250	290	330
	61-80	38-49	180	220	260	300
	⩽ 60	37	140	185	230	270
Mountain tunnels with steep, dark slopes or climate conditions where snow cannot accumulate. Portal surroundings have medium brightness year round.	⩾ 81	50	145	175	205	235
	61-80	38-49	130	160	190	220
	⩽ 60	37	105	140	170	200
Concealed portals, dark surfaces, or buildings surrounding entrance. Artificial measures taken to reduce exterior brightnesses. North/south orientation.	⩾ 81	50	80	100	115	130
	61-80	38-49	70	90	105	120
	⩽ 60	37	60	80	95	110

* Average Annual Daily Traffic in both directions.
\+ For approximate values in candelas per square foot, multiply by 0.1.

TABLE 2 TABLE OF L_{20} (cd/m^2) (*1*)

Percentage of sky (%) in the 20° conical field of view (%)								
	35%		25%		10%		0%	
brightness situation in field of view	normal low high (1)	snow low high (1)	normal low high (1)	snow low high (1)	normal low high (2)	snow low high (3)	normal low high (2)	snow low high (3)
stopping distance 60 m	(4)	(4)	4000 5000	4000 5000	2500 3500	3000 3500	1500 3000	1500 4000
stopping distance 100 m and 160 m	5000 7500	5000 7000	4500 6000	5000 5000	3000 4500	3000 5000	2000 4000	2000 5000

Table 3 (CIE Table 5.4) recommends the ratio that should exist between L_{th} (luminance in the threshold zone) and L_{20}.

It should be noted that the CIE recommendations make a significant distinction between a symmetrical lighting system and a counterbeam lighting system. If the latter system is used, a reduction of 30 percent of the luminance level in the threshold zone is permitted.

CIE RECOMMENDATIONS FOR LENGTH OF THE THRESHOLD ZONE

CIE recommendations stipulate that "the total length of the threshold zone must be at least equal to the stopping distance." The reduction of the luminance level is permitted to begin from "half of the stopping distance onwards."

According to the CIE document, if stepwise reduction is made, the ratio between the steps should not exceed 3:1. The reduction of light in the transition zones using CIE recommendations would occur much more slowly than under IES recommendations. For example, the total length of the threshold zone recommended for a tunnel with a speed of 100 km/hr is on the order of 500 m (or approximately 20 sec of travel).

TABLE 3 RECOMMENDED RATIOS BETWEEN THRESHOLD ZONE LUMINANCE AND ACCESS ZONE LUMINANCE (*1*)

	L_{th}/L_{20}	
Stopping Distance (m)	Symmetrical Lighting System ($L/E_v < 0.2$)	Counterbeam Lighting System ($L/E_v > 0.6$)
60	0.05	0.04
100	0.06	0.05
160	0.10	0.07

ASYMMETRY IN LIGHT CONTROL (L_b/E_v)

According to the CIE guide, a lighting system which produces high road surface luminance (L_b) and low vertical illuminance (E_v) (i.e., high values of the ratio L_b/E_v) gives relatively high contrast values for most objects on the road. A system featuring such characteristics is often referred to as counterbeam lighting.

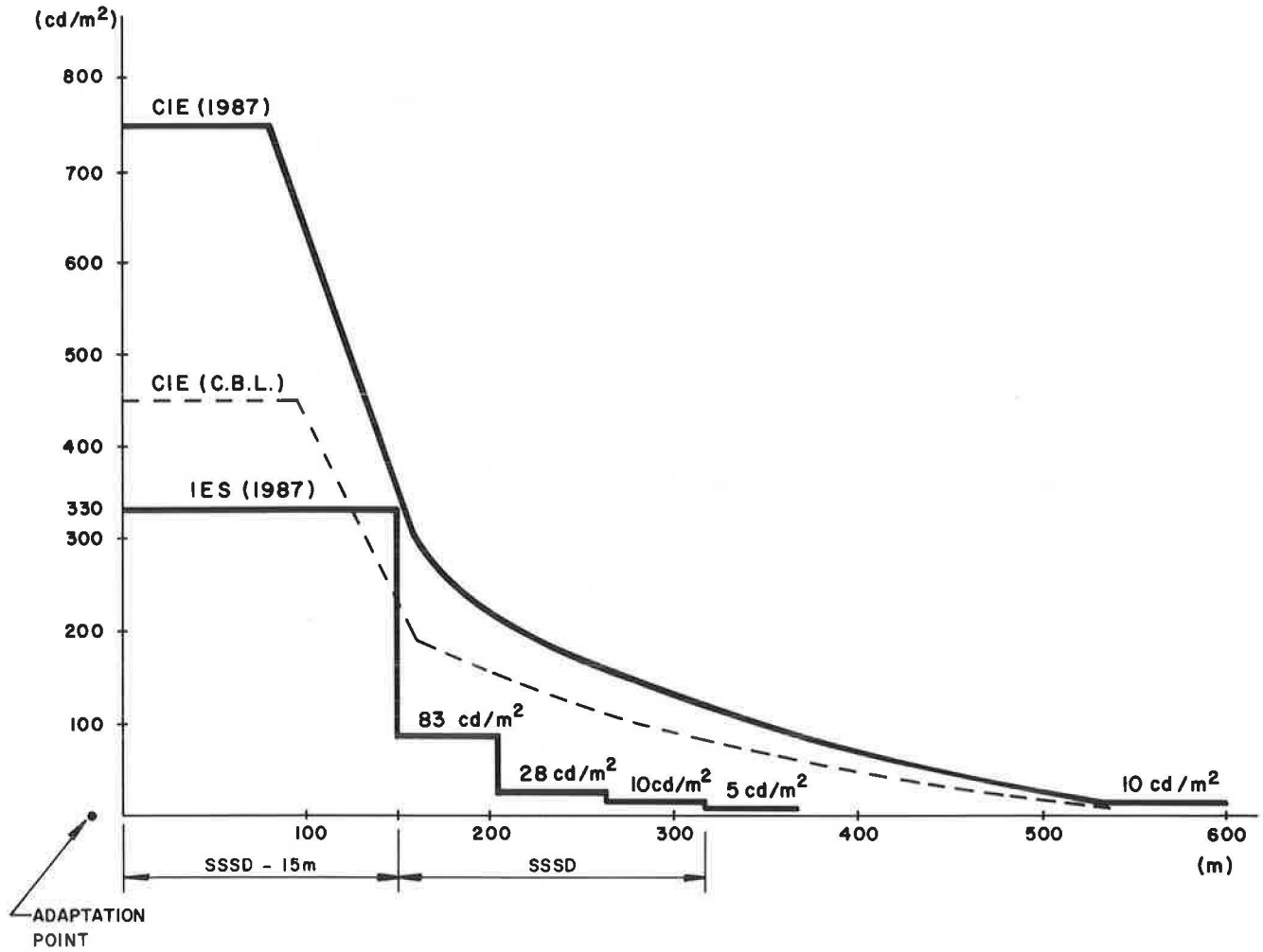

FIGURE 1 IES and CIE recommended luminance levels for threshold and transition zones.

CIE AND ANSI/IES RECOMMENDATION SUMMARY AND COMPARISON

Figure 1 compares the suggested threshold and transition zone luminance values from the CIE and the ANSI/IES documents. From this figure, it is evident that using CIE recommendations will result in considerably higher luminance levels in the tunnel threshold and transition zones.

Total supplementary lighting length using ANSI/IES recommendations is equal to two SSSDs minus 15 m, or approximately 320 m; according to the CIE, the length of threshold and transition zones may reach 550 m.

A conclusion can be drawn that the CIE recommended practice will result in higher capital investment and higher maintenance and operation costs.

REFERENCES

1. *Guide for the Lighting of Road Tunnels and Underpasses* (draft). CIE 26/2. Commisson Internationale de l'Eclairage, 1988.
2. *American National Standard Practice for Tunnel Lighting*. ANSI/IES RP-22. American National Standards Institute/Illuminating Engineering Society, 1987.