Visual Data on Roadway Lighting

CHARLES H. REX, Roadway Lighting Engineer, Outdoor Lighting Department, General Electric Co., Hendersonville, N. C.

This paper presents additional data on seeing factor effectiveness ratings for roadway lighting. Such ratings provide an essential basis for highway engineering evaluation of traffic, economic, and human benefits.

Field measurements for different roadway lighting systems are continuing, are significant, and should be reported for the guidance of highway engineers interested in improving night motor vehicle transportation.

Preliminary tests show that about twice as much pavement brightness is required for equivalent L-M visibility when the target is dynamic (0.1- to 0.2-sec exposure) instead of static. This is based on ratings by eight observers.

Measurements made with the new Blackwell portable visual task evaluator are reported and compared with those obtained with the Finch visibility meter. Experience gained at Hendersonville using the first prototype model of this meter retarded measurements earlier this year. More extensive data are now available and are presented.

•MORE GENERAL USE of available visual data in prescribing roadway lighting is one of the greatest opportunities in the improvement of night motor vehicle transportation in the United States. Urgency is involved because the livelihood, general welfare, and economic progress of millions of citizens is dependent on efficient after-dark movement of people and goods. When data are not interpreted and used to meet challenges such as the Highway Safety Study (7) progress is retarded.

The Illuminating Engineering Society has an obligation to provide a recommended practice for American roadway lighting based on the available visual research data which its leading members know about and have sponsored.

There is a need for extending the improvement of night motor vehicle transportation. One is obliged to consider statements such as:

> The U.S.A. is lagging behind British and Continental European practice in the use of high quality roadway lighting.... Poor lighting may as well be omitted.

These comments by R. J. Smeed, Deputy Director of the British Road Research Laboratory, were supplemented by similar remarks from other leading European road engineers at the World Traffic Engineering Conference, held in Washington in August 1961.

Americans visiting Europe bring back similar reports of progress abroad in providing the quantity and quality of roadway lighting appropriate for progress in night transportation. European progress is based on implementing and using visual data to benefit the public (see Appendix B).

Those who attended the World Traffic Engineering Conference, anyone who reads the literature featuring world-wide traffic engineering and the illuminating engineering use of available visual data and roadway lighting is likely to get the impression that

European highway engineers are more interested than American engineers in night visibility and in efficient night motor vehicle transportation.

The United States is producing the most efficient roadway lighting luminaires providing a high degree of seeing effectiveness. This effectiveness can be measured (8, 17), computed (14, 18, 24), and hence predicted in terms of visual data such as relative visibility, relative visual comfort, and pavement brightness. Also through industry interest and invention, the cost of providing this seeing effectiveness, or even light lumens or foot-candles on the roadway has gone steadily downward—it is 20 percent less than in 1940.

There is no question that to meet the needs in the United States it is necessary to (a) implement and use available knowledge, (b) provide appropriate visual effectiveness, and (c) continue to increase public value to increase use.

IMPLEMENTATION AND USE OF AVAILABLE KNOWLEDGE

Visual data and requirements (1) have already been presented extensively in technical reports and made generally available for study and action during 1961, 1960, 1959, and earlier. A report by Fletcher Platt (4) presenting studies by Bruce Greenshields of the University of Michigan emphasizes that visual is the driver's most important sensory process. This fact applies to night as well as daytime driving. Additional study should be devoted to night transportation which produces sizeable Federal and State motor fuel tax revenue and increases the value of automobiles and roads.

In H. R. Blackwell's report (1) on "Illumination Requirements for Roadway Visual Tasks," (1), foot-candle illumination recommendations based on visual data were reported as the result of studies of roadway lighting. Included is a figure of slightly more than 2.4 ft-c for the medium reflectiveness asphalt pavement (his Table IV) and 1.2 ft-c for the high reflectiveness concrete pavement, based on a concrete vs asphalt factor of about 0.5 (his Table III).

Table 1 compares the recommendations by Blackwell (Col. C) with the 1940 recommended practice (Col. A) and the present-day 1953 ASA practice (5, 26) (Col. B) recommendations for high reflectiveness pavement surfaces.

TABLE 1

COMPARISON OF RECOMMENDED PRACTICES FOR HIGH REFLECTIVENESS LIGHT CONCRETE OR LIGHT FINISHED ASPHALT ROADWAYS[a]

Roadway[b]	Recommended Practice (avg. ft-c)		
	I. E. S. 1940	A. S. A. 1953[c]	Blackwell 1960
	(A)	(B)	(C)
Expressway and freeway:			
Continuous urban	1.2	0.6	1.2 - 2.4[d]
Continuous rural	0.8	0.6	1.2 - 2.4[d]
Interchange urban	2.4	1.2	
Interchange rural	1.6	1.2	
Other:			
Major	0.8	0.75 - 1.0[d]	1.2 - 2.4[d]
Collector	0.6	0.6 - 0.8[d]	1.2 - 2.4[d]
Local or minor	0.4	0.45 - 0.6[d]	1.2 - 2.4[d]

[a]Reflectance 20 percent or more, except where noted.
[b]Urban intermediate area classification.
[c]In use January 1962.
[d]Medium reflectiveness pavement surface, such as 10 percent reflectance.

Blackwell's foot-candle recommendations based on visual data are about double the illumination (Col. B) currently recommended by the 1953 ASA practice, still in use January 1962. This statement applies to roadways other than expressways or freeways in areas classified as urban intermediate.

For continuous expressways and freeways, Blackwell's recommendations are two to four times that shown in present-day ASA practice, depending on the reflectiveness of the pavement surface being lighted. The comparative foot-candles are based on the brightness obtained on high reflectiveness light concrete or light finished asphalt pavements.

Blackwell and other vision researchers point out that the foot-candles that he finds required should not by any exaggeration be considered optimum. Optimum for roadway lighting may be higher than the illumination levels specified for interiors.

For lighted limited access highways 1953 ASA practice for street and highway lighting is 0.6 ft-c. This figure can also be derived from the 0.8 ft-c shown in the 1953 practice Table IV modified by the footnote factor for high reflectance pavement.

Column A in Table 1 shows that 21 years ago the Illuminating Engineering Society recommended practice for foot-candles on urban intermediate area streets was about the same as ASA practice, January 1962. Moreover, for express freeways and viaducts carrying what was then considered to be heavy to very heavy traffic the 1940 I.E.S. recommendation was 0.8 to 1.2 ft-c. This highway lighting recommendation ranges from one-third more, to twice that recommended by ASA practice in 1962.

Blackwell's recommendations (1) in Column C are for the dog visual task. This target is quite similar in size and in visibility measurements to the 1-ft diameter 8 percent reflectance disc used in several other roadway lighting studies (8) in the U.S. The lighting system on which the foot-candles are based includes modern, semicutoff-controlled, filament lamp luminaires spaced 100 ft staggered. The layout and measurements are shown in Figures 4 and 6 of (8).

In addition, Blackwell reported his roadway lighting studies to the 1960 Research Symposium sponsored by the Illuminating Engineering Research Institute (2), the 1959 I.E.S. Annual Technical Conference, the I.E.S. Committee on Roadway Lighting, and in mid-June 1961 to a group including Ohio State Highway Engineers as well as David Solomon and W. P. Walker of the U.S. Bureau of Public Roads.

Blackwell, commenting on a paper he is now preparing on roadway lighting in which he includes pavement brightness and relative visibility data, said:

> It is my firm intention to include the pavement luminance data in the paper which I will submit to "Illuminating Engineering." In addition, I will include the supra-threshold factors and other items of data analysis which you have heard me present from time to time.

His comments (1) regarding optimum foot-candles for roadway lighting include:

> Preliminary measurements indicate that there are more difficult roadway visual tasks than these, which will require even higher levels of illumination.
>
> These data reveal that there are visual tasks in night driving of sufficient difficulty so that interior levels of illumination will be required if these tasks are to be adequately performed. Such results should not be surprising because the factors of small size, low contrast, and short viewing time will result in difficult visual tasks whether indoors or outdoors, and high illumination levels simply are required for adequate performance of such tasks. The present data do not suggest that impractical levels of roadway lighting are to be recommended for practical use, but they do provide a basis for evaluating what kinds of gains in visibility and hence improvements in the safety of night driving are to be expected with various increases in roadway illumination.

Also, as he states to HRB in describing "The Lighting Specification Method"

> A factor of 15 was used in adjusting the absolute values of the original data for the purposes of the lighting specification system.

The over-all factor of 15 is the same as that used by Blackwell in prescribing lighting levels for interior tasks.

Blackwell has pointed out that other I. E. S. committees are using his data. According to C. L. Crouch, I. E. S. Technical Director:

> The following I.E.S. Committees used the results of the Blackwell studies as a basis for their recommendations following the leadership of the R.Q.Q. Committee Report No. 1: Handbook; Industrial; Institutions; Merchandising; Offices; Progress; Recommendations for Quality and Quantity; Residence; School; and Sports and Recreational Areas (Interior).

However, the author feels that these interior activities do not involve a range of human capability factors that are as critical as those existing in the drivers on the highways at night.

Blackwell's moderate factor of 15 according to a study of his papers and presentations (1, 2, 3) multiplies two factors; i. e., 2. 5 times 6. Quoting in small part from one of his papers (3):

> [Pertaining to 2.5 multiplier]...we may wonder to what extent common sense seeing is equivalent to laboratory observing at an accuracy level of 99 percent. It would seem reasonable to suppose that the contrast threshold for common sense seeing would be still higher than the laboratory threshold even for 99 percent accuracy. It is, therefore, undoubtedly conservative to use a contrast multiplier of 2.5 to take account of the criterion difference between common sense seeing and laboratory performance with the forced choice method.

This 2. 5 factor is evidence that Blackwell's recommended foot-candles for roadway lighting may be low. There are many differences between trained normal young laboratory observers and the average daytime driver. With an awareness of human factors of drivers, 2. 5 is a very small safety factor for the wide range in night driver capability, especially in the light of fatigue, drugs, intoxication, distractions, etc., as well as vision, and 6,000,000 drivers 65 years of age or older.

When all factors are considered, Blackwell's required foot-candles seem low in the margin of protective seeing afforded the typical night motorist. However, his foot-candles are based on extensive visual data instead of personal opinion.

Platt writes in his paper (4):

> Also as a result of transient factors (fatigue, illness, drugs, alcohol) one person's ability-to-observe changes to a marked degree from time to time.

Actually, in night drivers there appears to be a large and critical range of variations in vision, distractions, perception and response, psychomotor functions, performance and skills, attitude, reaction time, and aging—typical of night drivers.

A discussion by Marsh (10) points up many of these factors, including that an estimated 6,000,000 drivers are 65 years of age and over.

A 100 to 1 estimated variation in driver capability was voiced at the National Conference on Driving Simulation March 1961 (11). James L. Malfetti of Columbia University pointed out that

> Roadhouses and suburban cocktail parties are generally accessible only by automobile. People will continue to drink and drive. The real effect of this activity is not really known. We must provide for this.

In reviewing Blackwell's (3) interior multiplier of 6, apparently, this part of the overall factor 1. 5 combines elements for consideration including

> Threshold measurements were made both with and without advance warning as to the moment of presentation of the target. It

> was found that the threshold contrast was 1.4 times higher when the observers were not given advance warning that a target was to be presented.
>
> ...With two locations each separated from the line of sight by three degrees or more, the threshold contrast was 1.31 times higher when the observer was not given advance knowledge of the target location...

The field task simulator (3) was also used by Blackwell to provide the interior search and scanning that he mentions in his HRB paper. Fifty moving targets of variable brightness were set up in the laboratory to rotate before the eyes of laboratory-trained observers at controlled rates of speed.

> ...On the average of 6.0 times as much contrast was needed in the Simulator as in the laboratory experiment...In this case, the informational content is considered to be 2.5 items per second...
>
> ...These data suggest that the overall field factor required to compensate for all the many differences existing between laboratory conditions and those of the Simulator varies between 6.0 and 7.25....The factor of 6, or 7.25, can be understood as due to a factor of perhaps 4.0 to provide a receptive psychological factors such as lack of knowledge as to when and where the target objects would appear.
>
> ....Section I[3] has the desirability of insuring that information assimilation can occur within a single fixational pause. To insure this level of performance we must provide a level of visual capacity sufficient to permit assimilation of at least five items of information per second...Selection of this level is surely conservative since it provides the capacity to assimilate only a single item of information per fixational pause...

Referring to Mr. Platt's paper (4):

> It is assumed that fundamental actions are taken by the driver only on decisions based upon focused observations. Experiments have demonstrated that the number of observations that a person can make is limited by time. Therefore the faster a vehicle is moving, the fewer observations can be made per mile traveled... There is a finite limitation (although it may vary) on the number of discrete events that can be observed at a given time. Finite limitations for observations in each important sense modality are estimates as follows: Seeing - 16/second.

For night drivers, 1/16-sec seeing will require much more light than Blackwell's foot-candle recommendations. Thus, in only one small detail, this confirms the fact that laboratory factors for dynamics may be submarginal for actual night driving conditions.

DOUBLE PAVEMENT BRIGHTNESS AND DYNAMIC VISIBILITY

As would be expected, split-second dynamic instead of static targets require twice as much pavement brightness and, consequently, foot-candles to produce equivalent visibility from similar lighting systems. This has been reaffirmed during the past few months under the full-scale roadway lighting conditions at Hendersonville, N. C.

Heretofore, a static target (8, 14, 18, 19, 20) has been used for the relative visibility rating of roadway lighting systems. The target is a 1-ft diameter, 8 percent reflectance disc, normal to the driver's line of sight and at a viewing distance of 180 ft. Visibility measurements on this basis have been reported using both the Luckiesh-Moss and Simmons-Finch meters.

A 1/6-sec exposure instead of steady, static exposure of a 1-ft diameter target at a known location only 200 ft in front of the observer requires twice as much pavement brightness. The 1/6-sec target exposure was interrupted for 4-sec intervals. No search or scan was involved. The observer's eyes were fixated at a known location, waiting with plenty of time allowed for the target to appear and reappear at fixed intervals. Dynamic target measurements with the Luckiesh-Moss visibility meter were followed by equally deliberate and attentive static target measurements.

Figure 1 shows the target used for this simulation of target dynamics. The split-second dynamic target exposure is automated so that the disc rotates through a 90° arc, from a position where it is parallel to the driver's line of sight (as shown at the left of Fig. 1) to the customary position normal to line of sight (shown at the right of the illustration), and then back to the position parallel to view.

The 1/6-sec time exposure includes the time of partial exposure indicated at the mid-portion of this figure. The target then remains parallel to the observer's line of sight for 4 sec. For the comparative static measurements the same target is used steadily exposed (as shown at the right of Fig. 1).

Obviously, during these outdoor tests, the observer (driver) is stationary, at fixed attention, rather than in motion traveling along a roadway. There is no discrimination between objects, no unexpected visual tasks, none of the other customary night motorist problems of attention, preoccupation, psychomotor skill, physiological, or pathological condition. This is merely one attempt, one step, toward simulation of the actual pursuit movement and avoidance maneuvers and other conditions experienced under actual night driving.

Also, in support of Blackwell's studies is the report by de Boer (12) involving field and laboratory tests to determine the pavement brightness required which is equivalent to 2 to 2.8 ft-c under certain simulated and actual driving conditions. The resulting Netherlands practice is discussed later.

Waldram of Great Britain joins de Boer in acknowledging the fact (14) that traffic deviations and situations must be seen and interpreted with split-second rapidity.

Blackwell explains (3) in further support of his over-all factor of 15:

> ...For the present it seems wise to base our standard performance curve upon a level of visual capacity which is surely the minimum required for all visual tasks...It was decided that a field factor of 15 would be recommended for use at the present time. ...Thus selection of a field factor of 15 must be considered a conservative estimate on the basis of our present knowledge.

Here, Blackwell uses the word conservative in the sense of low and moderate. After making a weighed average of two pavement surfaces and several lighting systems:

> The resulting values of requisite illumination are as follows: Dog 2.06 footcandles. Average Dog and Mannequin 1.9 footcandles. ...It is apparent that nearly 6 footcandles will be necessary in order to provide adequate visibility for all possible instances in which either the mannequin or Dog could occur at a 200 foot viewing distance.

A succinct quote from "Light for Safety on Streets and Highways": "The outside is a little tougher than the inside."

Two- to 3-ft-c illumination for a roadway lighting system cannot be considered overly protective from the standpoint of seeing safety factors provided for the night motorist.

Another factor is weather condition. It has been estimated that in the U. S. the pavements may be wet 15 percent of the time. The motorist welcomes the aid of roadway lighting most enthusiastically during wet, icy, or snow conditions.

PROVIDING APPROPRIATE VISUAL EFFECTIVENESS

During dry weather conditions twice as much light (foot-candles) is required on medium reflectiveness asphalt pavement to produce the pavement brightness equivalent

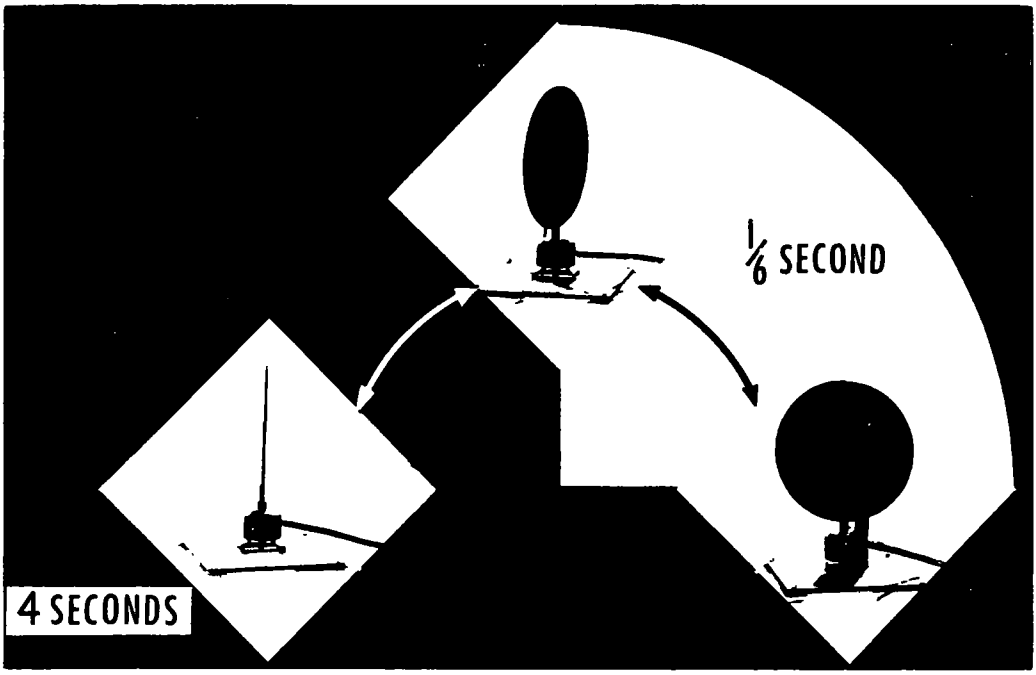

Figure 1. Exposure target (1/6-sec) used in simulation of some driving dynamics studies at Hendersonville, N.C.

to that obtained on high reflectiveness pavement surfaces. Pavement brightness is one of the principal factors in visibility.

Table 2 shows (2) Blackwell's conclusion as result of his Hendersonville studies (1) on the 100-ft staggered spaced lighting system and 5-year-old pavements. Table III, p. 124 (1), shows a concrete/asphalt factor of 0.519 in comparative foot-candles required. This pertains to the dog static target (similar to the 8 percent reflectance disc), which is revealed by negative contrast with the brighter background of pavement.

TABLE 2

RELATIVE INCREASE IN AVERAGE FOOT-CANDLE ILLUMINATION REQUIRED TO PRODUCE EQUIVALENT PAVEMENT BRIGHTNESS FOR DRIVERS' CONTRAST (VISIBILITY) OF TYPICAL DISC OR DOG TARGET

Lighting System[a]	Pavement Reflectiveness[b] (ft-L)		Approx. Increase in Illumination Req'd. from Same System
	Medium (Asphalt)	High (Concrete)	
15,000-L filament 100-ft staggered spacing	0.18	0.35	2:1
Blackwell 1960 recommendation	--	--	2:1
20,000-L mercury, 100-ft one-side spacing	0.46	0.72	1.5:1

[a]With semicutoff control.
[b]Roadway lighting systems (light distribution and geometry are the same).

As also shown in Table 2, the ratings from Figure 6 (8) showed that the average measured pavement brightness for the staggered lighting system used by Blackwell is 2 to 1 higher on the concrete pavement.

For the 100-ft one-side spaced mercury luminaire lighting system shown in Figure 12 (8) the ratio of pavement brightness measurements is approximately 1.5 to 1. The semicutoff luminaire light distributions are similar for both the filament (staggered) and mercury (one-side) lighting systems.

To assure equivalent pavement brightness for contrast visibility the foot-candles for medium reflectiveness pavement surface should be increased 50 to 100 percent over that required for high reflectiveness pavement depending on the system geometry. Also, the Luckiesh-Moss relative visibility ratings (8) are interesting in contrast.

Table 1 is based on high reflectiveness pavement surface (20 percent or more reflectance). For medium reflectiveness surfaces of the order of 10 percent, the 1953 ASA practice footnote under Table IV suggests a one-third increase, a factor of 1.33 to 1. It also suggests that for pavement having low reflectance of the order of 3 percent pavement the previous Table 1 foot-candles should be doubled by a factor of 2 to 1, or 100 percent.

As low as 4 percent reflectance has been measured on new asphalt pavements. The Hendersonville asphalt pavement is medium reflectiveness, of the order of 10 percent. The ASA practice factors appear to be low for future use.

As stated in 1961 (8),

> It is well known that the reflection characteristics of asphalt pavement can be made favorable by top surface treatment such as rolling-on a white or light gray aggregate. Also aging and traffic use may favorably affect the specular pavement reflection characteristics for raodway lighting.

An example is a section of Gratiot Avenue at Detroit shown in Figure 2 which has been recently described by Young and Wall of the Detroit Public Lighting Commission:

Figure 2. Gratiot Avenue, Detroit, Mich., mercury lighting; average illumination, 2 ft-c.

> We attribute this high ratio to the good directional reflectance of this particular kind of pavement consisting of worn asphalt with a light-colored, well-worn aggregate rolled into the surface.

The ratios referred to by Young are foot-Lamberts per foot-candle. For pavement brightness along the center of the curb lane from observer stations along the center of the same lane and directly in line with the luminaires, the Pritchard meter with 1° aperture measures the average pavement brightness at about 2 ft-L. However, transversely, across the pavement, the minimum brightness is about 0.7 ft-L when the observer-meter positions remained in the curb lane. This is consistent with the relative pavement brightness per 1,000 candlepower data shown in Figures 5 and 6 (14), also in Appendix B (8).

The calculated foot-candles, average about 2.0 for this 95-ft opposite spaced, 20,500-lumen mercury lighting system. The measured foot-candles are appreciably lower, bringing out the present-day instrumentation progress situation in which measurement of roadway lighting foot-candles is apparently less accurate than measurements of pavement brightness (foot-lamberts).

An abbreviated numerical tabulation of available pavement brightness visual data is shown in Appendix A. Specularity produces brightness along the 0 and 0.5 M.H. (driver-observer path) which is appreciably higher than that along the 1.0 M.H. and 1.5 M.H. L.R.L. (longitudinal roadway lines).

EUROPEAN PROGRESS

Continental European engineers are adopting recommendations (13, 20) based on their available visual data. Data have helped them provide the type of roadway lighting which they, and apparently the British, believe to be more adequate and higher quality than ours. For example, in May 1959, the Netherlands Commission on Public Lighting adopted the recommendations that are compared with ASA practice in Table 3.

Use of the Netherlands recommendation has provided twice as much illumination on urban intermediate area streets and three to four times as much light on continuous urban or rural highways as compared with that specified by ASA practice. Likewise, according to latest reports, Germany provides 1.5 ft-c, France provides 2 to 3 ft-c, and Belgium 1.5 to 2.0 ft-c. This relatively good lighting is appreciated by, and is popular with, the European night-driving public.

Additional evidence of progress abroad is the fact that they are not only using visual data as a basis for their foot-candles, but several countries are actually omitting foot-candles and recommend installing lighting on the basis of its pavement brightness, which is a visual factor; for example, Belgium, 0.45 ft-L; and Netherlands, 0.6 ft-L.

These visual criteria simplify recommendations. Factors for pavement reflectiveness (such as Table 2) are no longer necessary, and the seeing effectiveness of their roadway lighting is assured because they are also specifying cutoff luminaire candlepower distributions such as were described in previous papers (8, 9, 12, 14).

To obtain the Netherlands foot-candle equivalency given in Table 3, there is the following statement on page 5 of the Netherlands recommendations (13):

> ...The above-mentioned luminance of 2 cd/m^2....(0.6 footlambert brightness)...corresponds, for lighting installations and road surfaces such as those customary in this country (see Appendix C), to an average illumination of 20 to 30 lux (2.0 to 2.8 foot-candles) on the road surface, approximately....The above-mentioned level must be maintained in normal operation, taking into account dirt collected on the fittings and the deterioration of the luminous flux from the light sources, on roads where the greatest density of motorized traffic can be expected...

The European countries are placing their best lighting on their highways where speeds are high. In contrast are certain tendencies in the U.S. Good lighting on the highways is in the best balanced interest of night motor vehicle transportation.

TABLE 3

1952 U.S. STANDARDS VS 1959 CONTINENTAL EUROPEAN RECOMMENDED PRACTICE FOR HIGH REFLECTIVENESS LIGHT CONCRETE OR LIGHT FINISHED ASPHALT PAVEMENT[a]

Roadway[b]	Recommended Practice		
	A.S.A. 1953[c] (avg. ft-c)	Netherlands 1959	
		Equiv. Illumin.[d] (avg. ft-c)	Pavement Brightness Actually Specified (ft-L)
Expressway and freeway:			
Continuous urban	0.6	(2.0) - (2.8)[e]	0.6
Continuous rural	0.6	(2.0) - (2.8)[e]	0.6
Interchange urban	1.2		
Interchange rural	1.2		
Other:			
Major	0.75	(2.0)	0.6
Collector	0.6	(1.5)	0.45
Local or minor	0.45	(1.0)	0.3

[a]Reflectance 20 percent or more.
[b]Urban intermediate area classification.
[c]In use January 1962.
[d]Not specified, but in accordance with suppositions in text of their recommendations as to possible equivalency on favorable light reflectiveness pavements in Netherlands.
[e]Medium reflectiveness (asphalt).

At the Washington, D.C., World Traffic Engineering Conference, Granville Berry, City Engineer of Coventry, England, said:

> In U.S.A., and to some extent Great Britain, the benefits of installing good roadway lighting are being largely overlooked. We can no longer afford to do this. Lighting should not be an afterthought.

Charles Prisk (7) of the U.S. Bureau of Public Roads said this is a challenging comment. Granville's formal report (22) states:

> While excellent work is being done in relighting some of their cities...the general standard of lighting on the American road system lags behind that in Britain...In Philadelphia...a ten year relighting program is due to be completed in 1964 which includes some very excellent installations designed to higher levels of lighting than laid down in the American Standard Practice for Roadway Lighting (now under revision).

The Principles of ASA state:

> American Standards are sometimes adopted by a governmental agency or other organizations for mandatory applications.

In preparing its recommended practice, I.E.S. should study, implement, and use the reports on visual needs for night driving by American researchers as well as those of European laboratories. Also to be considered is the highway safety study (7), reports by the Michigan State Highway Traffic Center (24), the Texas Transportation Institute (25) as well as the Ohio State Institute for Research in Vision (1, 2, 3).

Figure 3. Kingston, N.Y., Intersection entry to New York Thruway arterial spur; illumination at intersection, 3 to 4 ft-c; approaches, 3 ft-c.

I. E. S. should also consider the fact that in many instances American roadways are lighted with several times as much foot-candle illumination as that specified by the 1953 standard practice. This has evolved from the fact that there has been great progress in the development and production of luminaires and light sources that are highly efficient in providing good night seeing conditions. One example is the 3- to 4-ft-c illumination of the intersection entry of the New York Thruway Arterial spur at Kingston, N. Y., shown in Figure 3.

INCREASING PUBLIC VALUE TO INCREASE USE

When roadway lighting having higher public value in seeing factor effectiveness is provided, it merits the confidence, enthusiasm, and support of the public. Use of such lighting is continuing to increase in the U. S. Another reason for this progress is improved economics. The cost of putting light on the street has gone steadily downward for the past 20 years.

The evidence and trends make it clear that the public is getting greater value than ever before in street lighting service. Over the past two decades, advancements in vapor light source efficiency and life have made sizeable contributions to cost reduction. Furthermore, the life of mercury vapor lamps is many times that of filament. Mercury lamps have a rated life of three years compared to six months for incandescent. One relamping trip of six trips appreciably changes the relamping and maintenance expense figures.

FUTURE LAMPS

In preparing recommended practice, consideration should be given to the announcements of double-light-output-per-watt lamps for roadway lighting. These lamps may be available and in use before publication and distribution of a new practice. The

resulting increase in light output should be recommended for use to improve seeing for night motor vehicle transportation. Also, control of candlepower distribution and luminaire brightness (8, 9, 12, 13, 14, 15, 17, 18, 19, 20, 24, 25) should be considered.

More than ever before, there are a large number of people who realize that one should be prescribing visibility so substantial—and visual comfort which is more reasonable—for the public welfare, benefit, and enthusiasm.

CONCLUSION

American highway, traffic, and illuminating engineers are just as interested in night transportation as are the European engineers. The economics of night seeing from roadway lighting per dollar cost have been and will continue to be significantly improved. Visual data available should be studied, thoroughly considered, and used. It is hoped that this study and presentation of data and motivations on roadway lighting will aid others to take appropriate action.

REFERENCES

1. Blackwell, H.R., Pritchard, B.S., and Schwab, R.N., "Illumination Requirements for Roadway Visual Tasks." HRB Bull. 255, 117-127 (1960).
2. Blackwell, H.R., Proc., Research Symposium, Illuminating Engineering Research Institute, N.Y. (1960).
3. Blackwell, H.R., "Development and Use of a Quantitative Method for Specification of Interior Illumination Levels on the Basis of Performance Data." I.E. (June 1959).
4. Platt, F., "Operations Research on Driver Behavior." Traffic Engineering (Sept. 1961).
5. "American Standard Practice for Street and Highway Lighting." Illuminating Engineering Society, N.Y. (Feb. 27, 1953).
6. "I.E.S. Recommended Practice of Street Lighting." I.E. (Jan. 1941).
7. Prisk, H.S., "The Federal Role in Highway Safety." Highway Safety Study U.S. House of Representatives Document No. 93.
8. Rex, C.H., "Comparison of Effectiveness Ratings—Roadway Lighting." HRB Bull. 298, 35-50 (1961).
9. Rex, C.H., "Advancement in Roadway Lighting." HRB Bull. 255, 158-189 (1960).
10. Marsh, B.W., "Aging and Driving." T.M. Matson Award Paper, Traffic Engineering (Nov. 1960).
11. Hulbert, S.F., Burg, A., Knoll, H.A., and Mathewson, J.H., Institute of Traffic and Transportation and School of Medicine J.A.O.A. (Jan. 1958); also Proc. Nat. Conf. on Simulation, Automotive Safety Foundation, Washington, D.C. (1961).
12. de Boer, J.B., "Road Surface Luminance and Glare Limitation in Highway Lighting." HRB Bull. 298, 56-73 (1961).
13. "Recommendations on Public Lighting." Commission on Public Lighting and Foundation on Illumination (May 1959).
14. Rex, C.H., "Ratings for Visual Benefits of Roadway Lighting." HRB Bull. 226, 27-55 (1959).
15. Fowle, A.W., and Kaercher, R.L., "Light Distributions for Effective Control of Glare in Roadway Lighting." Illuminating Engineering (1962).
16. Waldram, J.M., "Visual Problems in the Streets and Motorways." Illuminating Engineering (1962).
17. Fowle, A.W., and Kaercher, R.L., "Roadway Brightness and Illumination as Related to Luminaire Distributions." Illuminating Engineering (April 1961).
18. Rex, C.H., "New Developments in the Field of Roadway Lighting." I.T.E. Trans. (1959); also T.E. (March 1960).
19. Rex, C.H., and Franklin, J.S., "Relative Visual Comfort Evaluations of Roadway Lighting." Illuminating Engineering (March 1960).

20. Rex, C. H., "Computation of Relative Comfort and Relative Visibility Factor Ratings for Roadway Lighting." Illuminating Engineering (May 1959).
21. "French Recommendations for Public Lighting." Association Francaise de L'Eclairage, Paris.
22. Berry, G., "World Traffic Engineering Conference." City Engineers Office, Coventry, England.
23. American Standards Association, Bull. PM 156-D10M357.
24. Forbes, T. W., "Some Factors Affecting Driver Efficiency at Night." HRB Bull 255, 61-71 (1960).
25. Cleveland, D. E., "Driver Tension and Rural Intersection Illumination." Proc., Inst. of Traffic Engineers (1961); also T. E. (Oct. 1961).
26. "I. E. S. Committee Roadway Lighting Resolution of Intent Relating to Table IV; D 12.1; 1953 A. S. A. Practice." Illuminating Engineering, p. 451 (July 1959).

Appendix A

REPRESENTATIVE PAVEMENT[1] BRIGHTNESS[2] AS VIEWED BY DRIVER APPROACHING LUMINAIRE ALONG THE 0.5 MH LRL VIEWING PAVEMENT AT DISTANCE OF 200 FT WITH LUMINAIRE ALONG 0 MH LRL[3]

Long. Dist. (MH)	Brightness Along LRL (ft-L)			
	0 MH	0.5 MH	1.0 MH	1.5 MH
1.5	0.0069	0.621	0.025	0.012
2.5	0.0053	0.049	0.017	0.0087
3.5	0.004	0.036	0.011	0.0058
4.5	0.0029	0.023	0.0065	0.004

[1] Surface is 8 percent diffuse reflectance traffic-worn asphalt.
[2] In foot-Lamberts per 1,000 cp.
[3] An abbreviation of data shown in Figs. 5 and 6 (14), Fig. 6(9), and Appendix B (8).

Appendix B

AUTHOR'S NOTES ON ROADWAY LIGHTING HIGHLIGHTS, WORLD TRAFFIC ENGINEERING CONFERENCE, WASHINGTON, D.C. AUGUST 24-26, 1961

R. J. Smeed, Deputy Director, Road Research Laboratory, Great Britain, stated that the U.S. may lead the world in traffic engineering features other than roadway lighting, but it is lagging behind British and Continental European practice in the use of high-quality roadway lighting. Further he said we are much better off when streets are lighted well; i.e., poor lighting may as well be omitted. The night accident rate should be far less than day rate. Why is the reverse existing? The high night rate would be less likely if roadways were properly lighted. The street lighting in U.S. is not as good as that in some portions of Europe.

C. H. Rex was recognized for the following discussion comment to direct attention of the 400 delegates to an activity in which U.S. may at least be abreast of European technology.

Digital computer ratings for the relative seeing factor effectiveness of roadway lighting (relative visual comfort and relative visibility) will be made available Fall,

1961. The method of evaluation and comparison of predicted vs measured visual ratings have been presented previously in the reports of papers presented at sessions of the HRB Annual Meeting. These reports include other valuable information on traffic engineering.

Granville Berry of Coventry, England, said that in U.S., and to some extent in his own country, the benefits of installing good roadway lighting are being largely overlooked. We can no longer afford to do this. Lighting should not be an afterthought. Charles Prisk of the U.S. Bureau of Public Roads said this is a challenging comment.

P. Lefevre, Chief, Roads and Bridge Engineer, Belgium Ministry of Public Works, said the standard of highway illumination has increased considerably during the past three years and on highways outside urban areas is now ranging from 10 to 15 lux (1.0 to 1.4 ft-c). (December 1961 "Light and Lighting" L. Gaymard 2 to 3 ft-c)

Belgium has a comprehensive program of lighting all intersections where accident rate is 12 per year. Also they are installing lighting systems on all roads carrying over 10,000 vehicles per 24-hr day. They expect to light 700 km of highway during the next five years. The lighting they have installed has paid for itself in accident prevention alone. Additional benefits are shifts in some traffic to night hours, and when lighted, the people enjoy the freedom of convenient night travel. These extra benefits may top everything else. (December 1961 "Light and Lighting" A. Boereboom 1.5 cd per sq m = 0.45 ft-L)

G. Botsch, France, said everyone agrees lighting does reduce accidents. In dealing with financial matters, there are some who believe that the grading of priority for various measures may involve philosophers and psychologists as well as traffic engineers.

A. Berti, Director General Autostrada Serrovalle, Milan, Italy, called for better lighting techniques and recommendations on lighting of tunnels as well as roadway intersections.

R. Riekenbert, Germany, said that it is their common practice to light highway intersections.

Henry Barnes, Baltimore, and General Reporter W.T.E.C. Electronics Session, said good roadway lighting is very important on highways and streets. In Baltimore getting rid of 8,000 gas lights has helped appreciably reduce fatal night accidents. Comment during first afternoon session: "If ignorance is bliss, we certainly have nothing to worry about."

In opening the World Traffic Engineering Conference on August 24th, Secretary of Commerce Luther H. Hodges said that 56 percent of motor vehicle traffic is generated by social and recreational activities of the motorists.

> ...But I would like to conclude by urging you to give particular attention here and in all of your planning to the opportunities for greater research. New Knowledge, developed within a framework of earnest international cooperation, is the sound basis for progress in any technical field. It is especially essential in a discipline whose answers to our traffic problems will have far reaching consequences for the economic and social patterns of the future...

Roger Coquand, Director of Highways, France, general report:

> ....But it goes without saying that all research on the geometric character of roads, on signs, the lighting and marking of roadways, the roughness of surface, highway lighting, and the improvement of winter servicing are of the greatest concern in safety....

Charles Noble, Consulting Engineering, Princeton, N.J., general report referring to contribution by J. R. Dorfwirth, Vienna, Austria.

> ...The view that speed change lanes should have a different color than the main freeway pavement is widely held. However, unless the visibility and rideability of the lanes are of equal or superior quality to the main freeway pavement the motorist will shun the lanes. He will seek out what looks and rides best...

Referring to contribution by George A. Hill, District Engineer, California Division of Highways:

> ...The Author sets forth such excellent guiding principles for interchange designers that they bear repeating. His eight golden rules are as follows:
>
> ...4. Adequate warning of impending on and off movements must be provided.
>
> ...8. Maximum day and night visibility to interchange areas of decision should be provided.
>
> Above all, let us get away from the minimums in providing motor traffic facilities. It is too much to ask the traveller to risk his life on minimums. Drivers usually drive by maximums. Often they cannot adjust to minimum designs. The driver needs and is entitled to a factor of safety equally as much as the piece of steel you will put into your next bridge.
>
> Let us think and act somewhat in the spirit of the great architect, Burnham, who said, "Make no little plans for they have no power to stir men's minds."

P. Lefevre, Chief Engineer-Director of Roads and Bridges, Ministry of Public Works and Reconstruction, Belgium:

> ...In order to remove the effect of the geometric or physical design Features of the various lit or unlit stretches of road, the ratio of nighttime accidents to daytime accidents was calculated. On roads with average-to-poor lighting, all other things being equal, the night rates were 1.40 to 1.49 times higher than the day rates. On unlit roads this figure was 1.45, almost the same, in fact, as in the previous category. On very well lit roads, the coefficient varied between 1.17 and 1.25. Thus the possible reduction in nighttime accidents would be in the order of 20 percent were the roads to be consistently well lit...

The Italian Ministry of Transport called attention to twelve scientific research subjects. Street lighting is No. 9 on their list.

H. J. H. Starks, F. Garwood, G. O. Jefficoate, and R. J. Smeed, Great Britain on ... street lighting and accidents:

> The influence of street lighting on accidents has been studied by comparing the accident frequencies occurring on 64 lengths of road before and after the introduction of better lighting.
>
> The Laboratory studies may be summed up as follows:
>
> 1. Good modern street lighting reduced the average frequency of injury accidents in darkness by 30 percent.
>
> 2. There was strong evidence that the reduction in pedestrian accidents was greater than the reduction in other types of injury accidents.
>
> 3. There were no significant differences between the accident reductions for fluorescent, mercury, and sodium lighting.
>
> 4. The total savings in accident costs on the 64 lengths were more than sufficient to pay for the increases in the capital and running costs of the improved lighting installations...

Quote from "Lighting Conferences." Light and Lighting, p. 245 (Aug. 1961), Andre Boereboom, Belgium, Chairman of the C. I. E. (International) Roadway Lighting Committee said:

> the papers and discussions on street lighting had been most valuable and he emphasized the great responsibility that rested on the shoulders of lighting engineers in all countries to produce the best possible street lighting.