Visibility distances should be calculated by the computer for a large sample of low beam situations randomly drawn from the population. The data will constitute a distribution of visibility distances with a large variation. By analysis of variance the total variance in the data can be assigned to the independent variables in proportion to importance as main effects and as interactions between two or more independent variables.

In this way the relative importance of the beam pattern, the aiming and the geometry of the road can be shown. This would be a useful tool in the choice between possible measures of improvements.

The computer model must draw a random sample from the population of situations of illumination on the road. This population is created by the variation in beam pattern, low beam aiming and road geometry. The distribution of variation in each parameter must be collected in a statistically correct way, by drawing random samples from the traffic environment to which the results are to be generalized.

Besides beam pattern, low beam aiming and road geometry, there are some other parameters which influence the conditions of illumination, e.g., low beam mounting height, mounting distance between the two headlights on the car and reflection properties of the road surface. These parameters should also be considered.

The variation in beam patterns is an important parameter in optimizing low beam visibility. There are primarily two types of variation concerning the beam pattern of new headlights. The first one is the extra-type variation which is the variation in beam pattern between makes and types of headlights. The second is the intra-type variation which is the variation in beam pattern between low beams of identical make and type. Then, there is another source of variation introduced in traffic as an effect of age and dirt. In the work on optimizing the low beam pattern the importance of these sources of variation must also be studied.

THE LIGHTING OF ROAD CURVES

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Introduction

The work reported here is a contribution to a major revision of the Australian Road Lighting Standard (SAA 1973). The revision will use the CIE light technical parameters (LTPs) as criteria of qualtiy (CIE 1977). Luminaire manufacturers will be required to provide tabulations of the maximum spacings possible for their products on straight roads to meet specific values of these criteria, derived from standard CIE computation (CIE 1982).

The question to be answered is whether a simple rule can be formulated that allows the spacings on curves to be derived from the spacings provided for the straight sections. At present, in the Australian Code, it is recommended that the spacing be closed up and the luminaires be mounted in the outside of the curve; the exact spacing is derived by multiple application of a simple template which crudely approximates the light patch formed on the road from a luminaire.

Calculations

Two series of calculations, using CIE LUCIE (CIE 1982), were made to determine the LTPs for a range of practical installations, viz:

Series 1

Road width W_k(m)	Mounting height H(m)	Radius of Curvature R_c(m)
7.55 (2 lane)	9, 10.5	100, 200
15 (4 lane)	13.5, 15	150, 200, 600

Overhang: Zero for all H, plus H/4 for H = 13.5 and 15 m

Spacing: 3 values of S between 2.5 H and 5 H

Arrangement: Single-sided on inside and outside of curve

Luminaires: Two production types, of semi-cut-off distribution, one with 3^0 toe-in and the other with 13^0 toe-in, with flux commensurate with W_k and H.

Road surface: CIE R3

Calculation field: Two situations were examined, (i) approaching the curve in which the curve reversal point was included in the calculation field, the length of which depended on R_c and (ii) in the curve where a constant calculation field of one span was used. In both cases the observer was positioned in the center of the road, 60 m from a luminaire which started the calculation field.

Series 2

Same installations as in series 1, but on a straight road with one spacing only of 5 H (conventional value in present Code).

Analysis

The LTP average road luminance (L) was found to be systematically related to radius of curvature and spacing. Therefore the necessary spacings on the curves were deduced by interpolation between the three spacings used in series 1, which gave the same values of L as on the straight in series 2 for each installation. Only the in-curve situation has been used further in the analysis, since it appeared impossible to achieve required luminance uniformities with any reasonable spacing at the approach to the curve. However, values of L were always high.

Regression analysis gave the following relationships:

(a) Mounting on the inside of the curve
$S/H = 2.50 \log R_c - 3.03$ ($r^2 = 0.89$, $p < 0.001$)

(b) Mounting on the outside of the curve
$S/H = 2.86 \log R_c - 2.51$ ($r^2 = 0.76$, $p < 0.001$)

Note that the relationships are derived from data using both luminaires, resulting in acceptable r values.

Subsequent analysis showed that the required values of the other LTPs ($U_o = 0.33$, $U_L = 0.5$) were, on average, achieved or exceeded in test installations ($p = 0.05$) for both luminaires, where S had been predicted from the above equations.

A third luminaire (SCO, but with a shorter throw and toe-in of 5^o) was used as a check. Analysis of the calculated LTPs at predicted spacings showed that required values were achieved or exceeded, except for U_L on the outside of the curve. However, noncompliance could be minimized if $H/W_k \geqq 1$.

Both overhang and toe-in improve performance of luminaires. The present design method, using the template, seriously overestimates the number of luminaires required to light a curve, i.e., the spacings are closed up too much.

A Simple Rule

The relationships can be used in a modified way to construct a simple graph (Figure 1) where the spacing on the curve of given radius is a proportion of that on the straight road. This applies to single-sided installations, using lanterns of semi-cut-off distribution, where the mounting height is equal to or less than the road width. For wider roads where luminaires need to be mounted on both sides of the road individual design calculations should be made.

Implications for Road Safety

Collisions with roadside objects, including utility poles, are a significant road safety problem. The conventional road lighting wisdom is that curves should be lit from the outside of the curve, whereas conventional road safety wisdom is that poles on the outside of a curve constitute a particular hazard.

From this work it can be seen that it is possible to adequately light curves from the inside. However, the number of poles increase, e.g., at R_c = 200 m by 1.4. The risk of striking a pole on the inside of a curve relative to one on the outside, all other circumstances being the same, is 0.74 (Fox et. al., 1979). Thus these data, at least in a simple way, suggest that there is nothing to be gained, road safety wise, in mounting road lighting columns on the inside of a curve.

References

CIE (1977) Publication 12.2. Recommendations for the lighting of roads for motorized traffic. Commission Internationale de l'Eclairage.

CIE (1982) Publication 30.2. Calculation and measurement of luminance and illuminance in road lighting. Commision Internationale de l'Eclairage.

Fox, J. C., Good, M. C., and P. N. Joubert. (1979). Collisions with utility poles. Office of Road Safety, Department of Transport, Australia.

SAA (1973) AS 1158 Public Lighting Code, Standards Association of Australia.

A DISCUSSION OF VISIBILITY RESEARCH NEEDS

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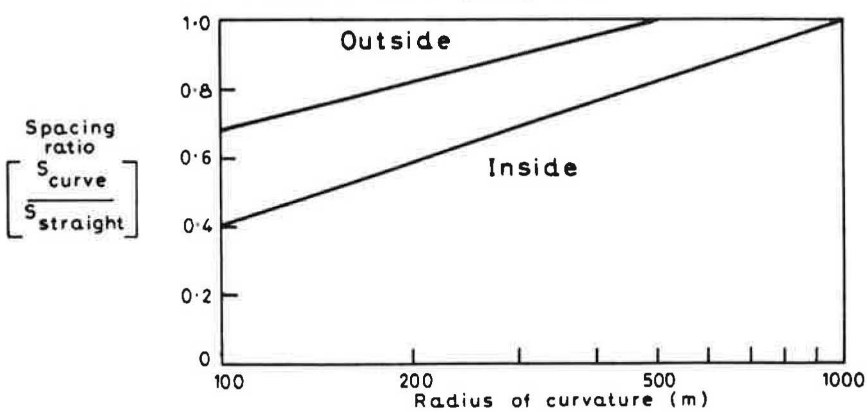
At the conclusion of the Symposium several contributors suggested areas of future research in visibility. These research areas were developed after hearing the presentation at the two-day Symposium. Many experts spoke their views with respect to many different yet related topics.

Specifically, the list of future research includes:

1. Determine the optimum rating of both vehicle and fixed lighting for different types of streets in urban areas.

2. Develop the night design driver.

Figure 1 - Curve Spacing Chart



Note: The spacing on the curve is the same as that on the straight when the radius of curvature is > 1000 m for inside mounting and 500 m for outside mounting. For $R_c < 100$ m the spacing ratio should not be < 0.5 for outside and not be < 0.33 for inside mounting.