detailed in CIE Publication No. 19/2 as the criterion measure of effectiveness for comparisons between vehicle headlamps and fixed lighting installations.

Initially, a revised, effective-contrast term (C_{eff}*) was defined to denote the dimensionless quantity derived by: 1) obtaining the difference between the luminance of a detection target and the luminance of its background, 2) dividing this figure by the level of background luminance alone, and, 3) adjusting the quotient to take an observer's relative contrast sensitivity (RCS) and the existing level of veiling luminance, or disability glare factor (DGF), into account. Values entered into calculations of C_{eff}* were determined according to current U.S. low-beam headlight performance specifications, a computer simulation of illuminance and luminance levels produced by a representative fixed lighting system, and the recommended (1983) IES Standard Practice for Roadway Lighting.

Key parameters describing the (simulated) hazard detection task included, first, the assumption of a 650-foot longitudinal separation distance between an observer and a to-be-detected hazard, both located in the center (northbound) lane of a six-lane divided highway. This detection distance was chosen as an intermediate, "compromise" figure with respect to the overall range of possible values defined by stopping sight distance (SSD) and decision sight distance (DSD) formulations for vehicles traveling at freeway speeds. Next, target characteristics were specified, describing a three-dimensional object consistent with current ASSHTO standards: A 7-inch sphere with a cylindrical base of the same diameter, colored a uniform 18% gray. For calculations of target luminance, this (simulated) hazard was modeled as a two-dimensional, flat vertical plane with a task detail size of 2.5 arc-minutes and a uniform reflectance of 12.7 percent. In all cases, the observer was presumed to be a 64-year old, alert driver performing under normal (dry) nighttime operating conditions.

The fixed lighting system included in the analysis consisted of a 68-foot staggered arrangement of 200-watt high-pressure sodium lamps (22,000 lumens/lamp), housed in medium cutoff, type-III distribution luminaires with a 30-foot mounting height, a 2-foot overhang, and a light loss (depreciation) factor of 0.81. Roadway width was 104 feet from edgeline to edgeline (including 12-foot median), and pavement type was designated as worn Portland cement with CIE R1 surface characteristics. Vehicle headlight systems considered in the analysis were #4,000, round 5 3/4-inch type 2 sealed-beam incandescent lamps and #H4656 type 2A1 halogen lamps.

The effectiveness of fixed versus vehicle-based lighting in providing the visual inputs needed to perform the defined detection task was determined for the driving situations involving: 1) an observer's vehicle alone, 2) an observer's vehicle plus an opposing (i.e., southbound) vehicle located downstream of the target position, and 3) an observer's vehicle plus an opposing vehicle located upstream of the target position. C_{eff}* values for the fixed lighting system in isolation -- ranging from maximum to minimum contrast levels depending upon a target's longitudinal position within a single luminaire cycle -- served as the common basis for comparison across all three driving situations.

For the 650-foot observer target separation distance, results of the analysis indicated that fixed roadway lighting reaches a level of effectiveness of roughly 150 to well over 300 times greater than that of vehicle headlights, both for situations involving an observer's vehicle alone and for situations involving an observer's vehicle plus an opposing vehicle located upstream of a (simulated) roadway hazard. In situations involving an observer's vehicle plus an opposing vehicle downstream of the detection target, fixed lighting systems are approximately ten times (i.e., 7x to 14x) more effective than vehicle headlights. The relative importance of each identified driving situation in the context of this research, as well as the issue of potential "conflicts" between fixed and vehicle-based lighting systems, were addressed in a summary and discussion of the findings.

USE OF THE PHILIPS OPEN-AIR LABORATORY FOR VISIBILITY RESEARCH

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The open-air road lighting laboratory in Eindhoven is used for three different activities:

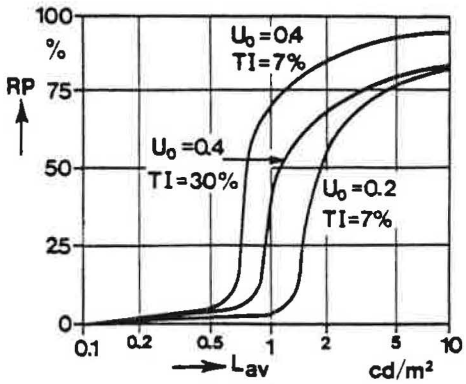
- road lighting research
- the testing of new road lighting systems
- demonstrating different realistic road lighting situations, especially for educational purposes

The facilities consist of an asphalted road surface, 250 m long and 17 m wide, flanked by masts mounted on rails. By moving the masts along the rails, the longitudinal spacing between the luminaires can be varied between 24 m and 48 m. Encircling each mast is a drum-like housing with eight separate compartments, in each of which a different type of luminaire complete with lamp and control gear can be installed. A selected luminaire, with the lamp already burning, can be moved to a gate in the drum and extended out over the road to give the desired amount of overhang. The height of the drums, and thus the height of the luminaires above the road, can be varied between 2 m and 16 m.

All sorts of arrangements (from single-sided to opposite and staggered) can be made by remote control from a control room at the end of the road, as can changes in spacing, mounting height, overhang, and luminaire and lamp type. Some installations employ lamps whose light output can be varied between 10 and 100 percent. From an observation room adjacent to the control room, observers can view the road with the perspective of a road user. In this room various instruments are available for instantaneously measuring the lighting quality parameters. A view of the road ahead as seen from the driver's position, together with measure lighting and geometric data of the installation, can be stored on videotape using a closed-circuit television system.

Many tests involving observers -- static tests especially -- have been conducted at the open-air laboratory. For example, the first tests on glare restriction measures for road lighting, which led to the CIE Glare Control Mark System for Road Lighting, were carried out here. Studies on the visibility of obstacles on the road under different lighting and weather conditions have been performed. For example, the results of revealing power calculations, as illustrated in Figure 1, have also been checked out in the open-air laboratory.

Figure 1 - Revealing Power (RP) at the darkest location on the road as a function of the average road-surface luminance (L_{av}) for different values of overall uniformity (U_o) and threshold increment TI (glare). Revealing power is defined as the percentage of objects (4') visible out of a set of objects, each of which has a reflectance value typical of the clothes worn by pedestrians. (ref: W. J. M. van Bommel; J. B. de Boer, "Road Lighting", 1980.)



Of course, the driving task involves rather more than just avoiding obstacles on the road. The general task of each road user is to get to the appointed destination as safely as possible, and to accomplish this the driver is constantly required to make decisions. Many of these decisions are based on the interpretation of the visual information available. This includes, amongst other things, details of the roadway, its alignment and immediate surroundings; the run of the road ahead; other vehicles such as cars and bicycles; pedestrians on or close to the roadway; and, of course, possible obstacles. The total range of visual information may therefore be of great complexity, especially when the scene is viewed dynamically.

Preparations are in hand for a series of investigations to be conducted at the open-air laboratory in which the relation between some of the above-mentioned aspects and the lighting will be examined. For this purpose, a measuring and recording setup is being prepared for installation in a normal motorcar to enable the detection speed of a motorist to be measured while he is performing a normal driving task.

REFLECTIVE CHARACTERISTICS OF ROADWAY PAVEMENTS DURING WET WEATHER

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Although the inclusion of pavement reflectance properties under wet weather conditions in the design of fixed lighting installations has been considered as necessary, it has been studied by fewer researchers and somewhat less systematically than dry pavement reflectance. The reasons are readily apparent when one considers what is required for such an investigation. One of the major problems is that measuring accuracy is much inferior to that for dry road surfaces, even in a laboratory, owing to the dynamically changing wetness of the pavement. Hence, among the tasks of this ongoing study are to explore techniques to characterize and predict, as well as accurately and rapidly measure, the reflectance properties of pavement surfaces in wet weather conditions.

Three fundamental tasks must be conducted to satisfy the goals of this study. These are 1) predict actual, full-scale roadway luminance patterns under dry and a variety of wet conditions using r-table data; 2) describe, measure, and track pavement wetness; and 3) classify reflectance characteristics by simple measurements of pavement physical properties. By and large, only preliminary data are available at this time but the hypotheses and techniques developed to address these tasks are briefly described here.

Frequently, when measured full-scale luminance patterns are compared with those predicted using laboratory generated r-tables, the results are less than satisfactory. For example, Keck and Odle found that field measurements were, on average, 50% to 75% greater than those predicted using r-tables derived from core samples. The reasons for these discrepancies are unclear and could possibly lead to erroneous conclusions about the validity of either the full-scale measurements, laboratory measurements, or both. Factors such as variations in the condition of the road surface (or wetness in the present case, e.g., puddles) and deviations from the design candlepower distributions of the luminaires can result in unaccounted-for variance in the full-scale data. Other factors, such as disagreements among various computer programs in calculating pavement luminance or the potential lack of validity due to the removal of cores from the roadway, and/or the reduced scale of the laboratory measurements, can cause further difficulty in pinpointing the source of error.

For this study, there will be four sources of reflectance data available from which to predict full-scale luminance patterns: 1) CIE classification R- or W-tables; 2) existing r-table atlases such as Erbay's or LTL's; 3) laboratory measurements obtained from extracted core samples; and 4) measurements obtained using the FHWA's prototype, Colorado Gonio-reflectometer.

In order to validate these sources of reflectance data, an apparatus has been constructed which will permit the rapid and accurate placement of a light source of known intensity distribution into desired geometric positions about a fixed spot on an actual roadway. The measuring photometer is then placed 70.5 feet from the spot (1/4 of the standard CIE viewing distance) to measure luminance with a 1^o viewing angle. By using such an apparatus, it is possible to eliminate all the sources of variation noted above and to validate each of the four sources of r-tables by using the 1/4-scale values as the standard against which to compare the other sources. If one or more sources of r-table data can be shown to be valid using this technique but still fail to accurately predict full-scale luminance patterns, it will be concluded that the source of error lies with some component of the field measurements rather than with the validated r-table sources. Alternatively, if the r-table data obtained from the above sources do not correlate with the 1/4-scale data, it will then be concluded that small-scale, laboratory generated