Another performance measure might be a driver's eye-scanning behavior. It would be expected that a driver's visual information acquisition should be highest when delineation cues are at a minimum. The aspects of a driver's eye scanning behavior that are sensitive to the various levels of road delineation are uncertain.

Speed and possibly speed variability might also be useful as a performance measure if poor delineation can be expected to lead to slower speed and more speed variability. The use of speed or speed variability as a performance measure to determine the effects of various levels of road delineation remains to be seen.

Snowplowable Raised Pavement Markers

For cube-corner type markers, the photometric performance (specific intensity) needs to be known as a function of the observation angle. At present, little is known about the photometric performance of cube-corner type markers as a function of the cube angles, especially the presentation and rotation angles. In addition, the photometric performance of the markers should be known as a function of wear and tear and exposure in the field, and an appropriate methodology should be developed to predict the useful marker life in the field. In order to develop such a methodology, a minimum acceptable level of photometric performance should be scientifically established for the markers in the field. Further, because of the different geometric conditions between tangent sections and curves it might be beneficial to develop and use markers with different photometric performance characteristics.

Delineation System Interactions

The use of snowplowable raised pavement markers should be investigated in the presence and the absence of other delineation elements such as reflective post delineators. The effects of overhead road illumination on the delineation aspects of snowplowable raised markers should be investigated. Questions about the placement of the markers along curves with different radii need to be resolved.

Many of the preceding points involve difficult trade-offs. Not only should driver performance and driver safety be considered, but also the costs and the expected economic benefits need to be considered within the overall delineation system framework.

Reference

1. R. W. Allen, et al., Driver's Visibility Requirements for Roadway Delineation. Volume I: Effects of Contrast and Configuration on Driver Performance and Behavior, November, 1977, Report No. FHWA-RD-88-165.

RESEARCH NEEDS RELATED TO SIGN LIMINANCE AND VISUAL COMPLEXITY OF HIGHWAY SIGNS

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The federal standards for luminance of retroreflective materials for traffic signs are absolute; they provide no differentiation based on driver need. Driver needs for sign luminance are of two types: (a) luminance levels that define sign legibility and (b) luminance levels that define sign conspicuity. A primary reason that the standards do not reflect these fundamental driver needs is the absence of conclusive data supporting practical and reliable guidelines and the fact that available luminance is dependent on several factors other than the specific luminance of sign material.

Research groups that have recently studied sign luminance and conspicuity include Cole and Jenkins, 1980, 1981, and Mace, et al., 1982. Both groups call attention to the importance of background complexity in the study of conspicuity. Cole and Jenkins state: "No object is conspicuous per se. It can only be conspicuous in a certain background; if the background changes, then the object may or may not remain conspicuous." Mace, et al. expanded this observation, giving equal importance to the role of driver motivation and uncertainty.

"Conspicuity, like visibility and legibility, is not an observable characteristic of a sign, but a construct which relates measures of perceptual performance with measures of background, motivation, and driver uncertainty." This definition recognizes that a stop sign is more conspicuous to the driver who is alerted that a sign is imminent, or a guide sign is more conspicuous to drivers traveling to the location indicated on the sign.

Cole and Jenkins, 1980, define a conspicuous object as one ". . . that will for a given background, be seen with certainty within a short observation time, regardless of the location of the object in relation to the line of fixation." Mace, et al. suggest a slightly different definition. "Conspicuity refers to the changes in target or surround or scene (e.g., luminance of target) which will offset the performance decrements associated with both uncertainty and background complexity." This definition agrees with the Cole and Jenkins definition of a conspicuous object, but replaces probability of detection with a stimulus dimension as the scale of measurement. A statement that a sign requiring a 2-ft.-lambert increase in luminance is twice as conspicuous as a sign requiring a 4-ft.-lambert increase in luminance to attain the same level of perceptual performance may have more construct validity than similar statements based on probability of detection.

Few studies have examined the effects of the visual complexity of nighttime highway environments on driver requirements for sign size and luminance. In general, the literature suggests that sign detection can be considered a function of the visual characteristics of the target and its surround. Both Mace and Jenkins have conducted related studies in the laboratory, and Mace has conducted some research in field situations.

On the basis of these studies, Mace, et al. published a hypothetical relationship between visual complexity, sign brightness, and visual performance. It is hypothesized that in low complexity areas, signs below federal luminance standards for Type 2 sheeting may be adequate and in high complexity areas, even new Type 3 sheeting may not be adequate for conspicuity.

Additional research is needed to scale visual complexity. A completely reliable scale may be impossible to produce, but from a practical perspective it may be perfectly adequate to reliably characterize the extreme ends of the complexity dimensions. The low end would define locations where sign maintenance is less important and the high end would define locations where special attention may be necessary. This may be the simplest way that a visual complexity scale would have useful application.

Another area that needs attention is sign position and its effect on the luminance available at the driver's eye level. In some situations, depending on road curvature and grade, sign position will have a greater impact on available luminance than sign size and specific luminance.

NIGHT WORK ZONE REFLECTORIZATION

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The country has witnessed a past era of building super highways capable of handling high volumes of traffic traveling at high speeds.

Rehabilitation of the superhighways constructed over the past few decades is becoming increasingly difficult because of increasing travel demand. Because many highways operate at or near capacity for long periods, the time during which maintenance operations can be effectively conducted is restricted. In many areas it is nearly impossible to close one or more lanes during the day, especially during morning and afternoon peak periods, without backing up traffic for miles. This necessitates the use of alternatives to typical freeway rehabilitation procedures, and sometimes the only alternative is to work at night, which is the only time that traffic volumes are low enough to allow lane closures without creating excessive congestion, and it is usually the last alternative chosen.

There are numerous reasons that night operations are unpopular; the concern for safety is one of the most important reasons. Night operations require that men and equipment be on a road illuminated either by existing street lighting or special illumination. It is emphasized that the work is done only at night and that the highway is reopened to traffic during the day.

In addition to closing one or more lanes, many states close the entire roadway and detour traffic to alternate routes. The night-only operation coupled with road closures can then present motorist situations that are unexpected, and enough has been said about "driver expectancy" to indicate the possible consequences of creating unexpected situations. The problem is compounded by low traffic volumes that lead to higher speeds.

All of these factors dictate that special measures be taken to keep the number and severity of night-work zone accidents at a minimum. Traffic control plays an important role in ensuring safety, and signing devices are important aids in assuring safety in night-work zones.

The Manual on Uniform Traffic Control Devices (MUTCD) states that traffic control should:

1. Fulfill a need;
2. Command attention;
3. Convey a clear, simple meaning;
4. Command the respect of road users; and
5. Give adequate time for proper response.

In the case of the latter, signs should be simple and legible, especially with the array of lights used during night operations (e.g., the variable message signs, work-site delineation and lighting, and equipment warning lights). Here, the provision and maintenance of reflectorization are quite important. A project initiated at the Virginia Highway and Transportation Research Council will evaluate the legibility of warning signs by using encapsulated lens sheeting. Legibility distance has been increased by about 15 percent through the use of modified lettering on various signs, and plans are underway to analyze legibility versus modified lettering for construction and warning signs.

In addition to signs, various devices are being used to channel traffic in night-work zones, including cones with internal lights or reflectorized sleeves on top, Type II barricades, chevrons of different sizes, and barrels. The spacing and proximity of these channelization devices to the work zones appears to vary. It is important that the detection and legibility distances be optimized, and here reflectorization is extremely important. Uniformity in the use of these devices is also important for night operations.

The variety of traffic control measures being used during night maintenance operations points up the need for research on sign complexity and reflectorization.

REFLECTORIZED INFORMATION NEEDS: WET PAVEMENT

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Whenever the pavement surface reflects light in a manner similar to the way a mirror does, pavement markings disappear from view. Drivers are deprived of guidance cues that they have learned to use and depend on, and a hazardous driving environment exists. The wider the roadway, the more dependent drivers are on lane markings and channelization markings such as for two or more parallel turn lanes, mandatory turn lanes, and "no turn" lanes. The safety value of yellow center lines, double solid yellow "no passing" zones, and two-way left-turn lanes are lost when the road surface is glazed with water or covered with mud or any other material such as spilled liquids or powders that conceal the painted markings on the pavement. Pedestrian crosswalks and stop bars can also lie concealed under a reflecting film that does not affect the pedestrian's view because they are looking down directly at the markings, whereas the driver's eyes are looking ahead at a shallow angle.

Nighttime driving scenes are likely to be more hazardous when the pavement is wet than on the same roadway in daylight. However, daytime scenes also can become a problem, especially when low sun angles are encountered or during bright overcast sky conditions. In urban areas the night scenes are likely to include advertising lights and signs. Even street lighting can create glare on wet streets that not only conceals pavement markings, but also constitutes glare sources at discomfort levels and occasionally at disabling glare levels. The safety implications of sign driving conditions are readily appreciated because they are so obvious.

More subtle safety problems occur when there exists other visual cues that are misleading, such as pavement joints, roadside shrubs and trees,