curbing or shoulder discontinuities, driveways, and many other man-made or natural roadside features. The misleading nature of such visual cues may not play any role until the painted pavement markings are removed on a wet pavement. However, these same features can be used to safely guide drivers if consideration is given to how these features look to motorists when the road is wet.

One extremely important technological development in pavement marking is the raised pavement marker (RPM). Both reflectorized and nonreflectorized RPMs have proven extremely beneficial to motorists because they protrude above the surrounding pavement upward through the sheet of water, thus breaking the mirror-like surface. Initial cost, replacement cost, and traffic disruption during placement are negative aspects of RPMs. Therefore, work needs to be done to reduce cost, increase durability, and lessen traffic disruption associated with RPM placement.

A market exists for a better RPM, and therefore manufacturers and inventors will work to create improved RPMs. In the meantime and at all locations, traffic authorities need to learn to analyze the wet roadway scene and to determine other visual cues that are present. When other cues are recognized, they can be manipulated to provide positive guidance or at least to avoid misleading drivers when pavement markings temporarily disappear from view.

In order to identify these other visual cues, it must be possible to "look through the eyes" of the driver who is unfamiliar with the territory. This requires a bit of mental gymnastics for a traffic engineer who is thoroughly immersed in knowledge of the roadway. Such traffic engineers could safely drive the roadway without pavement markings, they would know the number of lanes, the width of the lanes, the location of the intersections with crosswalks, and the location of the two-way left-turn lanes. How, then, can such a traffic engineer divest himself of this ingrained knowledge? One way is to view movies or TV tape recordings made when wet pavement conditions exist. Such scenes also can be viewed by ordinary motorists whose responses can be obtained. Slides can be used for this purpose, but they are not as likely to capture the dynamic unfolding of the roadway scene.

Once the problem is acknowledged, there will be other techniques that research can produce to assist in analyzing visual cues for a safer roadway scene when the pavement is wet. As such improved techniques are developed, promulgated, and used, it will become increasingly easy for traffic engineers to decide where RPMs are essential and where RPMs must be maintained in order to overcome other visual cues that cannot be changed.

Also, it must be recognized that the more frequent RPMs are used, the more motorists will depend on them. Especially hazardous then will be those roadways where RPMs are not replaced when broken, and those locations where RPMs suddenly are not used. A carefully planned transition must be made from RPM to "no RPM" roadways. Research could well be conducted on this aspect of traffic management when the pavement is wet.

REFLECTORIZED GUIDE SIGNS AND DRIVER RESPONSE

Fred R. Hanscom, Transportation Research Corporation

The use of reflectorized versus nonreflectorized backgrounds on guide signs is a controversial issue. Although highway agencies are required to operate under severe financial constraints, illumination or reflectorization of overhead guide signs may create a perceived unnecessary monetary burden. On the other hand, consideration of driver safety requires a sufficient level of service from guide signs to ensure adequate driver detection, recognition, and response time.

A nonreflectorized guide sign appears to have a black background to a motorist approaching it at night. That the nighttime surrounding is also black gives rise to a question of reduced conspicuity of the guide sign. Basically what the driver sees, in the case of a nonreflectorized guide sign background, is a black-on-black presentation with only the white border and legend to provide contrast in the environment. A guide sign with a reflectorized background appears just as it would during a daylight condition - a green sign with white legend and border. This green sign offers a high visual contrast against the black nighttime surround, the net effect of which is higher target value. The relative effects between these two guide sign presentations is unknown.

An unpublished study, conducted as part of the National Cooperative Highway and Transit Research Program (NCHRP) Project 3-21, validated a set of effectiveness measures to be applied in the evaluation of guide signs. The study procedure involved gathering both driving performance measures and in-depth questionnaire responses for approximately 11,000 motorists exiting from freeways. The applied questionnaire data analysis determined causative factors associated with performing specific erratic maneuvers. Through the use of various types of regression analyses, we were able to quantify the relative percentages of specified vehicle behavior due to various factors such as driver familiarity and guide sign information processing.

Although this project was conducted during daylight hours, its results cannot be directly related to the nighttime reflective guide sign issue. However, because certain erratic maneuvers were associated with driver failure to detect guide signs, direct inferences from this study can be applied to any guide sign condition characterized by reduced target value.

Results indicated that driver failure to detect guide signs was associated with erratic maneuver occurrence in exit gore areas as follows:

1. Late Lane Change (weave over solid gore extension line): 4 to 19 percent
2. Gore Weave (weave over painted cross-hatched gore marking): 25 to 84 percent
3. High Risk Gore Weave (weave over through-travel lane in addition to Gore Weave): 35 to 100 percent.

Differing occurrences noted above were attributable to site-specific differences.

Recommended Research

There is a need for further field study to determine the driver performance impact of non-reflectorized guide signs. Two candidate study procedures are:

1. Controlled Field Observation

   Erratic vehicle occurrence between matched test and control sites.

2. In-Vehicle Navigational Task Performance

   Driver commentary or other response measures of information acquisition and information processing over test courses involving route finding tasks using both reflectorized and nonreflectorized signs.

REFLECTORIZED GUIDE SIGNS: HUMAN FACTORS

Richard F. Pain, Essex Corporation

Five human factors aspects of guide signs are discussed to identify outstanding future research issues.

Legibility

Much is known about legibility. Letter height, font, stroke width, legibility distance, reading time, information extracted per glance, effects of contrast, and acuity deficiencies have been researched and design guidelines have been developed. However, there are questions that cannot be fully answered by available research.

Standards that require illuminated overhead signs demand a high initial and maintenance cost. Methods for maintaining legibility, conspicuity, and color code, but at a reduced cost, would benefit operating agencies and taxpayers.

Another interesting question is whether higher-intensity sign faces or letters can improve legibility. The very high intensity reflective sheeting under development or in the marketplace presents design options with unknown effects on driver perception.

A continuing research need is to improve sign legibility under poor visibility conditions. Another continuing dilemma is the effort to maintain legibility when drivers are in impaired states.

Attention Value/Complexity

For many years researchers and traffic engineers have been aware that the complexity of the sign and its background affect attention value and, in all likelihood the driver's ability to extract information from the sign. Only in recent years have resources been allocated to research this topic. The results of the research are discussed by D. Mace elsewhere in this Circular.

Attention value or conspicuity has been studied, and the impact of brightness ratio, size, and color on visibility or detection distance are generally known. Given these characteristics, the visibility distance of a particular sign can be predicted.

Again, although much is known, much is left to determine. Many studies of attention value were performed using stimuli without white borders. The outdoor field validations of results were performed on bordered signs but the effect of a white border, particularly at lower sign face luminances, is not understood.

The effect of low sign face luminance on attention value and driver performance is a current question being studied for the Federal Highway Administration (FHWA) by Systems Technology, Inc.

An offshoot of this question is the need to determine an optimum visibility distance. Is it possible that signs can be detected too far away? Obviously too short a distance is deleterious. Such a question should be debated to determine if it is worth answering.

Information Coding

Guidelines have been written to standardize the type of information found on guide signs. What is useful information for motorist navigation is a difficult judgment and one requiring additional research.

Expectancy and Priority

Often color is considered the redundant or secondary source of information. In some circumstances, for example, at night, color is the first piece of information perceived by the driver. This alerts the driver and gives him or her more time to attend to (read) the sign and it eliminates confusion with other types of signs.

What happens when there are minor code inconsistencies? Further, is there any effect on driver understanding, expectancy, or behavior when color coded and noncoded signs are included in a sign sequence. Finally, how much inconsistency is tolerated before the meaning of the coding scheme is undone or loses credibility?

System Performance

Only one accident study has addressed the effect of reflectorization on highway system performance, but because of confounded variables it is impossible to interpret. Intermediate criterion measures of guide sign performance were developed and validated by Hanscom and Berger (1). There is a need to develop normative data for the validated measures. Traffic engineers can then compare results of evaluations performed by using these measures against nationally standardized data.

Research Needs Overview

The predominant research themes identified here are as follows:

A. If sign face background brightness and sign color are substantially reduced at night:

   - Is driver behavior altered due to:
     - Loss of color code
     - Attention value
     - Greater variability in legibility performance
   - Are drivers with visual acuity deficiencies or other impairments (alcohol, fatigue) put at greater risk?
   - At what point does the color coding loose credibility?
   - Does a reflectorized white border counteract changes in attention value from lower sign luminance?
   - Are driver behavior changes different for heavier traffic volume or impaired visibility conditions?