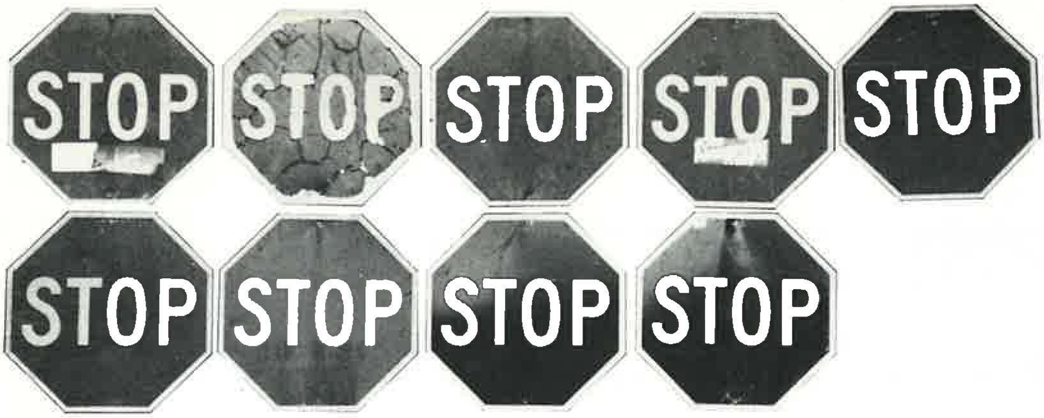
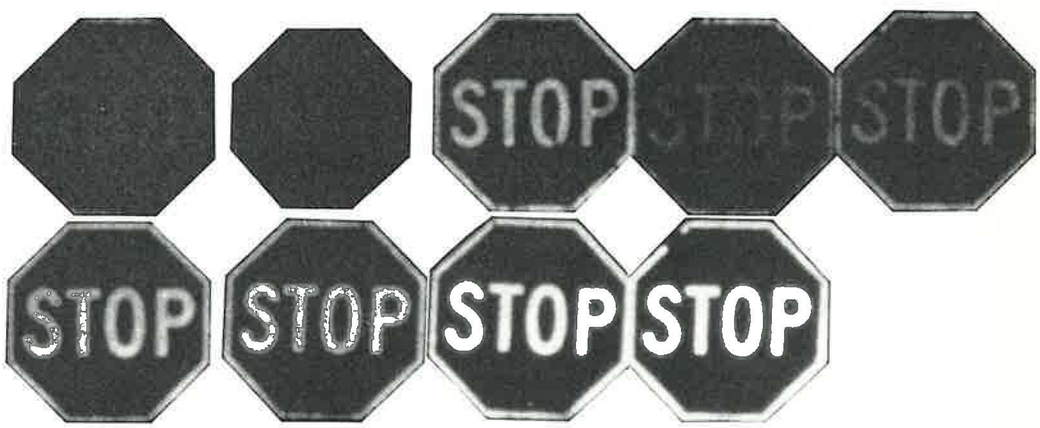


Retroreflectivity Research To Enhance Driver Safety

JEFFREY F. PANIATI

The Federal Highway Administration (FHWA) has been concerned for some time that highway signs, markings, and other traffic control devices are not being replaced in a timely manner. Studies of in-service traffic signs have shown that signs that are acceptable during daylight can have a markedly different appearance at night. One property of traffic control devices that requires further study is retroreflection.



Difference between daytime and nighttime retroreflectivity of STOP *sign* (2).

Retroreflection occurs when light rays from an automobile strike the surface of a traffic control device and are redirected back toward the driver (see Figure 1). Retroreflective traffic control devices are used to provide the driver with the necessary warnings, regulation, and guidance at night.

Accident statistics indicate that there is a nighttime driving problem. The fatality rate (fatalities/vehicle miles of travel) is more than three times higher at night than during the day. A variety of factors contribute to this disparity (fatigue, intoxication, etc.), but driver reliance on traffic control devices increases as visibility decreases. Many of the cues (curbs and sidewalks) used by the driver for visual guidance by day disappear at night. Inclement weather and glare from opposing vehicles only serve to compound the nighttime driving problem. Improving the visibility of traffic control devices can decrease the demands on the driver. Good traffic signs and roadway delineation reduce the need to search for information and allow increased attention to the driving task.

Over time, retroreflective materials deteriorate and their ability to return light to the driver diminishes. The current *Manual on Uniform Traffic Control Devices* (MUTCD) contains no minimum performance requirements to specify when retroreflective traffic control devices should be replaced. The practicing traffic engineer must rely solely on engineering judgment and a subjective assessment of the sign's condition.

Need for Standards

The FHWA recognizes that minimum retroreflective requirements for traffic control devices must be determined. These requirements will be based on the driver's need to detect and respond to traffic control devices safely and efficiently. To develop performance specifications for retroreflective traffic control devices, FHWA established the High Priority National Program Area

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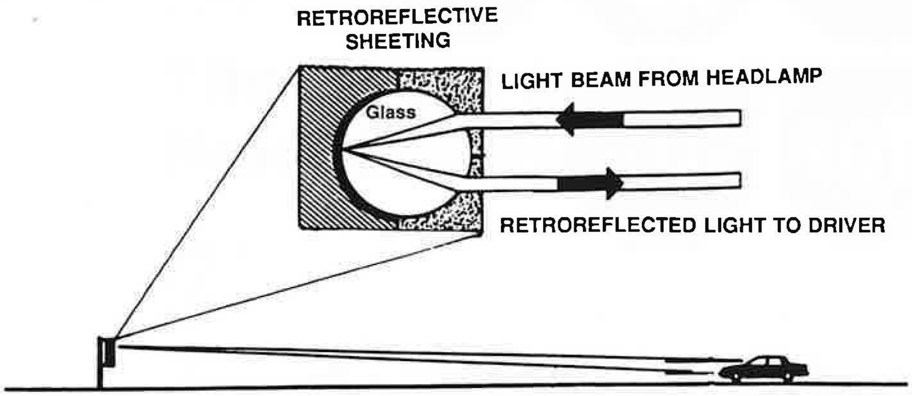

FIGURE 1 *Principle of retroreflection (1).*

(HPNPA), which is part of a larger program that falls under the 1986 Nationally Coordinated Program (NCP) of Highway Research, Development, and Technology.

The FHWA Office of Safety and Traffic Operations Research and Development is coordinating a research program on minimum in-service retroreflective requirements. The FHWA Office of Traffic Operations has provided technical guidance in the development of this program and will be responsible for directing implementation of the results.

Numerous funding sources are involved in the cooperative program, including FHWA research contracts, the National Cooperative Highway Research Program (NCHRP), FHWA staff studies, the Grants for Research Fellowship (GRF) program, Small Business Innovation Research (SBIR) efforts, and Highway Planning and Research (HP&R) studies. The share of support for this research program by each of these sources is shown in Figure 2.

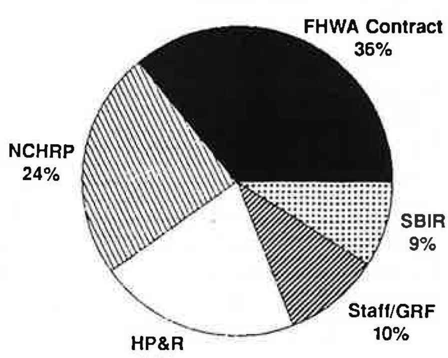

FIGURE 2 *Share of funding for retroreflectivity research program.*

Using the Right Tools

Several major topics are included in the retroreflectivity research program as explained in the following paragraphs (Figure 3). The goal of the HPNPA is not just to obtain the information necessary to determine minimum retroreflectivity requirements, but also to develop management programs and measurement devices necessary to effectively implement these requirements.

Minimum Visibility Requirements

The first question that had to be answered in the development of performance requirements for in-service traffic signs was "Does a relationship exist between driver visibility and sign retroreflectivity measurements?" In a 1986 FHWA in-house research study, "Retroreflective Requirements for Traffic Signs—A Stop Sign Case Study" (*1*), a relationship between the distance at which a STOP sign can be recognized by the driver and its measured retroreflectivity level was identified. Through this effort the feasibility of determining retroreflectivity requirements for control devices was established.

A sample of stop signs that were removed from service as part of a sign-replacement program is shown on page 13. The difference between the daytime and nighttime appearance of the signs is clearly shown, and the range of in-service signs that can be found on the nation's highways is indicated.

In 1987, a much larger FHWA study, "Minimum Visibility Requirements for Traffic Control Devices," was initiated to determine (a) the minimum distances at which traffic control devices should be visible to the driver and (b) the level of retroreflectivity required to satisfy these visibility requirements. As part of this study, a series of laboratory and controlled vehicle studies was conducted to fill gaps in the current state of knowledge. These studies included the time required by drivers to complete typical driving manuevers (stop, speed reduction, lane change) and the distances at which drivers can perceive and recognize signs.

Computer models have been developed to study the impacts on the required visibility distances of sign placement, glare from opposing vehicles, and changes in alignment. The retroreflectivity requirements output by this model will be validated as part of this study. This project is scheduled to be completed in June 1989.

Implementation Strategies

Before any widespread implementation of retroreflectivity requirements can be made, their potential economic impact must be assessed. The desire for increased driver safety must be balanced with the economic constraints of the highway agencies that must implement the requirements. A 1989 NCHRP research project scheduled to be completed in mid–1991, "Implementation Strategies for Sign Retroreflectivity Standards," will provide this type of assessment.

As part of this study, a representative sample of retroreflectivity data will be collected from in-service traffic signs. Data-collection sites will include a variety of geographic locations, roadway classes (Interstate, primary, urban), and jurisdictional levels (state, county, city). These data will be used to estimate the effect of establishing minimum retroreflectivity levels and to develop economic-based priorities for sign maintenance budgets.

The data collected will help answer questions on how to maximize the benefit obtained from limited sign maintenance dollars. For example, should a highway agency spend its limited sign maintenance funds to upgrade the most critical signs (e.g., STOP, YIELD) on all roadways or should it concentrate on upgrading all signs on heavily traveled roadways? Guidelines for staging the implementation of retroreflectivity requirements and an estimate of their effects on highway jurisdiction will be provided.

Service Life of Signs

One of the problems of managing retroreflectorized traffic signs is identifying signs that need to be replaced because of loss of retroreflectivity. Sign replacement practices vary. Some agencies replace traffic signs based only on driver complaints, whereas others conduct subjective visual inspections. Still others arbitrarily replace signs every 5 to 7 years. Thus, signs with several years of service life remaining may be removed, resulting in a waste of money, and signs with insufficient retroreflectivity may remain. If not replaced, these deficient signs could lead to an accident for the motorist and a tort liability case for the highway agency.

An FHWA GRF program study, "Prediction of the Service Life of Warning Signs," examined the feasibility of predicting when a sign is likely to need replacement. Retroreflectivity data for signs with known dates of installation were collected and a model of the deterioration of sign retroreflectivity was developed. Although this model is applicable only to symbol warning signs, it has laid the groundwork for developing additional models. Under a 1988 FHWA study, "Service Life of Retroreflective Traffic Signs," this research will be expanded to include other types of signs and a range of climatic conditions. This study is scheduled to be completed in 1990.

Sign Management System

As part of an FHWA in-house effort, the Sign Management System (SMS) is being developed to provide state and local highway agencies with a predictive tool for use in managing a sign inventory. This microcomputer-based system allows creation of a sign inventory and tracking of the age and condition of signs. The goal of the system surpasses the development of a simple inventory; computer models developed as part of the FHWA "Service Life" contract will be used to predict when a sign is likely to need replacement. This will assist highway agencies in locating deficient signs, using limited maintenance funds more efficiently, and projecting future budget needs.

An IBM-PC-compatible version of the data base management portion of the software is currently available and runs under MS-DOS. It is a menu-driven system that can be used to create an inventory and track the performance of signs. The predictive software is expected to be in operation in 1990.

Traffic Sign Retroreflectometer

If minimum retroreflectivity levels are to replace the subjective replacement methods currently used, then a practical system for measuring the condition of existing signs must be available. A portable measuring device is available; however, it is not suitable for rapid measurement of numerous signs; the user must place the instrument against the sign face. Its value is limited to spot checks and acceptance testing. An ongoing NCHRP (Project 5–10) research project, "A Mobile System for Measuring Retroreflectance of Traffic Signs," is being conducted to assess the feasibility of developing a practical, safe, cost-effective instrument for measuring sign retroreflectivity in daylight from a moving vehicle.

The system concept, which has been developed in Phase I of Project 5–10, consists of a video camera to collect sign images and a microcomputer to analyze the image and output retroreflectivity information. The construction and testing of a laboratory proof-of-concept model is under way. Completion of Phase I is scheduled for 1988. If the design proves feasible, a laboratory model will be used to develop several prototypes in Phase II. Scheduled to begin in 1989, Phase II will provide for the evaluation of these prototypes by one or more state highway agencies.

Pavement Marking Retroreflectometer

The limitations of existing devices for measuring the retroreflectivity of pavement markings are similar to those for traffic signs. Portable instrumentation is available for spot measurements, but it must be placed directly on the marking. This does not allow for rapid assessment of retroreflectivity. Through an SBIR study scheduled for completion in 1989, "Measuring Retroreflectivity of Pavement Markings," a laser technique for the measurement of pavement marking retroreflectivity from a moving vehicle is being developed. Phase I of this effort proved the feasibility of this technique. Phase II is under way and will convert the laboratory model to a working field instrument.

This instrument will be suitable for acceptance testing of new markings when

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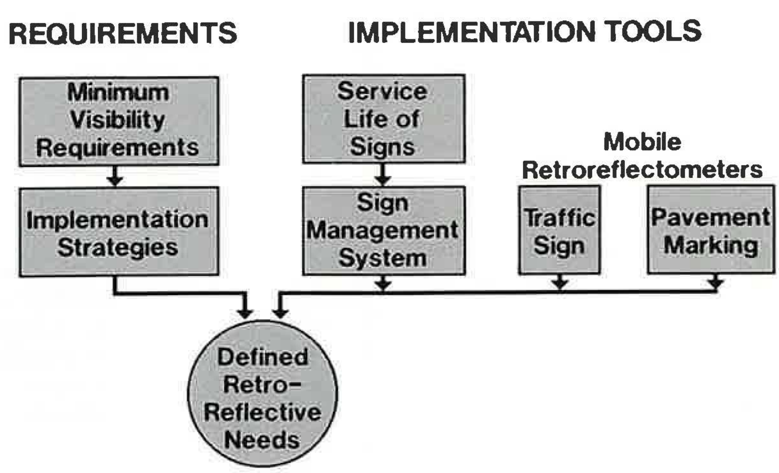

FIGURE 3 *Flowchart of retroreflectivity research program.*