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Overhead Guide Sign Visibility Factors,

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Research, Development, and Technology
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FOREWORD

This research report was undertaken to examine the effect of lighting and/or reflectorization of the backgrounds on overhead guide signs. The Manual on Uniform Traffic Control Devices (MUTCD) currently requires in Section 2F-13 that "the background of all overhead signs that are not independently illuminated shall be reflectorized." Without lighting and/or reflectorization, such signs would appear black at night and, therefore, no longer satisfy the color code requirements contained in the MUTCD.

The study was initiated at the request of the Federal Highway Administration's Office of Traffic Operations and the National Committee on Uniform Traffic Control Devices. The report summarizes the findings of a series of literature and laboratory studies which compared the conspicuity between nonilluminated signs with opaque backgrounds and fully reflectorized or illuminated signs, investigated the speed and accuracy with which drivers respond to each class of signs, and reviewed the inherent value of color coding schemes. The results should be of interest to traffic operations engineers who are concerned with the design and installation of signs on multi-lane roads.

Sufficient copies of the report are being distributed to provide copies to each FHWA regional and division office and each State transportation agency. A second volume, FHWA-RD-88-197, containing appendices with detailed data from each study is available only from the National Technical Information Service, Springfield, VA 22161.

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INTRODUCTION

The project discussed in this report concerned the night use of overhead guide signs, including button and reflectorized copy and all practical combinations of reflectorized and opaque backgrounds. This project was a follow-up effort to the literature review by Gordon.(1) Gordon's review found areas requiring further investigation, including the comparison of nonilluminated-nonretroreflectorized signs with both illuminated-nonretroreflectorized and retroreflectorized signs.

The current project included the investigation of current signing practices throughout the country, development of a set of in-use luminance values for current overhead guide sign materials, development of life cycle costs for current signing materials and practices, and determination of driver response characteristics for these overhead guide sign systems.

These goals were met through review of the literature, field testing, and static and dynamic laboratory testing. While the results of the tests are presented, no attempt has been made to draw conclusions from these data.

LITERATURE REVIEW

Two separate reviews of the literature were undertaken. First, to establish the basis for having colored backgrounds on highway signs, a review of the literature on color coding was performed. Next a review of the literature concerned with drivers' sight distance and response time requirements was completed. The results of these reviews are briefly discussed in the following sections.

Determine the Value of Color Coding

The results of the literature review indicate that color (ie., green background vs. black background) enhances sign detectability, while the reduced contrast degrades legibility somewhat. Beginning in 1957, and continuing to as recently as 1984, color has been shown to assist drivers in understanding which visual objects in the driving environment are needed to safely negotiate the road system.(2, 3) Colored backgrounds, in this case green vs. black, enhance the detectability of signs by providing brighter backgrounds.

Unfortunately, a Virginia study found that drivers' are unaware of the meaning of the colors, and in many cases are not aware of the color/shape combinations used in current highway signing.(4) Recent work in Australia has shown that when searching strategies are employed by drivers, they are quite successful in detecting highway signs regardless of color.(5, 6) Finally, Forbes, studying the effects of sign brightness and size, found sign/background color combinations where black signs outperformed their colored counterparts.(7)

Does this mean that we should abandon, or retain, the current color coding scheme? In light of the conflicting results reported above, the answer is not an easy one.

When one looks at the causes of traffic collisions, human factors predominates; and recognition errors lead the list.(8) If consistent color coding of highway signs will help drivers recognize the various types of highway signs, color coding should be retained. While a significant portion of the subjects in the Virginia study were not familiar with the current color coding system, the research is over 20 years old, and hopefully the percentage of drivers familiar with the color coding system has increased. Even if the percentages are the same today as in 1966, there is no reason to penalize the drivers who <u>are</u> aware of the system.

The general consensus in the literature is that color coding appears to be in the best interest of traffic safety. When traffic signs must compete with advertising signs and other lights in the visual field, they need all the help they can get. The Woltman study presented such situations, and the results strongly support the use of color coding of highway signs.(3)

Determine Sight Distance and Time Requirements for Drivers

While this project is concerned with the <u>detection</u> of overhead guide signs, available literature concerning both detection and legibility was reviewed, and this information provided the basic guidelines to develop sight distance and time interval requirements for the driver. While a body of literature exists for the various characteristics relating to sign legibility, little was uncovered which related to detection of these signs. The review did find, however, that overhead guide signs are unique in many areas.

Overhead guide signs may serve two purposes. First, they convey information about upcoming events. Usually this "advance information" sign will indicate the name of one or more exits which follow, or will make the driver aware of the approach of an interchange with another major highway. The second type of overhead guide sign is the "action" sign. This indicates the correct lane for route transition or directs the driver to an exit.

Overhead guide signs are used predominantly by drivers unfamiliar with the area. Drivers familiar with a particular area typically become unaware of the signs and seldom use them for purposes other than confirmation of location. This makes detection of the overhead guide sign extremely important, for if it is missed it will probably be by the person who most needs the sign information for route guidance. However, the primary user is also the driver who is most likely to be searching for the sign, increasing the probability of sign detection.

The placement and number of overhead guide signs vary from jurisdiction to jurisdiction. Some highway engineers provide the minimum requirement of one advance information sign and one action sign, while others make use of a redundancy system which gives the driver several advance information signs. Overhead guide signs are found throughout the interstate highway system and therefore may be the only sign a driver sees, or may have to compete with billboards and other signs for the driver's attention.

Finally, because overhead guide sign messages are unique to a given location, and because drivers who typically use these signs are looking for a specific destination, these signs may be "read" by using a form of pattern recognition prior to the sign actually becoming legible, and the driver need only verify this information once the sign is truly legible (e.g., a driver looking for "Riverside Dr." would eliminate signs such as "Main St." because they are too short).

This part of the literature review focused on two major areas: The driver's work load, which may interfere with the timely sighting of the sign, and the actions which the driver must complete to react to the sign when sighted. Driver work load plays a major role in determining how quickly the driver detects the sign and, once detected, how much of the driver's attention may be devoted to reading and reacting to the sign.

For the purposes of this study, we have looked at driver detection, recognition and action requirements for times of peak traffic flow. These are times where the driver has the least time to perform the sign tasks, while at the same time is required to attend to the greatest possible traffic interference. At these traffic densities the driver is required to spend between 25 and 50 percent of the time attending to control and guidance functions. While the amount of time required by the driver for maintaining appropriate speed, following distance, lane position, and monitoring other traffic, is dependent on many factors, at least half of the time is still available for searching for overhead guide signs.

Factors other than basic path and speed control can add to the driver's work load, and these factors can lead to the driver becoming overloaded. Examples of these factors include other traffic, weather conditions, driver impairment, road conditions and geometry. Normally the driver can act as a multichannel processor, attending to several requirements at the same time, and allocating the necessary time to each according to its importance. For example, under normal conditions a driver can maintain lane position and appropriate speed, hold a conversation with a passenger, remain alert for potential hazards, and still search for an overhead guide sign. Once becoming overloaded the driver shifts from a parallel processor to a serial one, that is tasks are attended to one at a time in sequence. If path following is deemed most important, it will be attended to at the expense of other tasks, and "minor" tasks such as sign recognition will be ignored.

The driver's task when responding to highway signs are: (1) detection, (2) identification or recognition, (3) decision, (4) response and

(5) maneuver.(9) Overhead guide signs, as discussed above, are unique. Drivers needing the information contained in overhead guide signs have the advantage of knowing that these signs will be large, rectangular, green, and located generally on a structure over the specific roadway lane where the sign is located. Because, in most cases, the driver is actively searching for the overhead guide sign, detection and identification will take between 1.0 and 1.5 seconds. Messages on these signs can generally be read, and the driver can determine the appropriate response in 3 to 10 seconds. Finally, the driver's action is usually a lane change maneuver, and in the free flowing traffic assumption we have made it takes approximately 8 seconds per lane for the driver to perform the required task.

These times were used to determine the required sight distance for overhead guide signs. However it requires that two assumptions be made: (1) the sign placement allows the driver an unobstructed view of the sign and (2) physical limitations such as windshield cut off and dynamic visual acuity cause the sign to become illegible at some distance prior to the vehicle reaching the sign. As discussed above, there are two types of information conveyed by overhead guide signs, advance route guidance and an indication of the need for some action. The required detection distance for an overhead guide sign is dependent on which of these signs is being detected. If the sign conveys advance information the driver need only detect and read the sign before the message becomes illegible; however, if the sign requires some action on the part of the driver, the action may need to be started, or even completed, before the vehicle reaches the sign. Table 1 indicates minimum detection distances for several possible scenarios. It is assumed that it takes the driver 1.5 seconds to detect the sign, and the sign becomes illegible approximately 175 ft (53 m) prior to the vehicle reaching the sign.

As indicated in table 1, a minimum detection distance of 1300 ft (488 m) is not unreasonable. While this allows adequate sight distance for all of the advance information signs, it only provides sufficient time for one lane change when action signs are encountered. This reinforces the necessity for advance information signs with appropriate information to allow the driver to begin the necessary maneuver prior to the action sign.

Table 1. Required detection distances
for typical overhead guide sign conditions.

Sign Type	Vehicle Speed	Reading Time	Action Time	Visibility Requirement
Advance Information	55 mi/h	3 Sec	None	539 Ft
		5 Sec		700 Ft
		7 Sec		862 Ft
		10 Sec		1104 Ft
	65 mi/h	3 Sec	None	605 Ft
		5 Sec		796 Ft
		7 Sec		987 Ft
		10 Sec		1274 Ft
Action	55 mi/h	3 Sec	8 Sec	1011 Ft
		10 Sec	8 Sec	1577 Ft
		3 Sec	16 Sec	1657 Ft
		10 Sec	16 Sec	2223 Ft
	65 mi/h	3 Sec	8 Sec	1194 Ft
		10 Sec	8 Sec	1863 Ft
		3 Sec	16 Sec	1957 Ft
		10 Sec	16 Sec	2628 Ft

In a comprehensive review of the literature, Gordon found that the 1300 ft sight distance requirement can generally be met. (1 and see e.g., references 10 & 11) However, in tests where subjects were required to both see the sign, and also notice that the sign contained a message, all unobstructed signs were conspicuous from at least 1000 ft. When signs were merely required to be spotted, the minimum visibility distance increased to 1500 ft. Thus sign conspicuity, from an analytical review of the literature, appears to be sufficient in most cases. The real problem arises when there is obscuration of the sign, reducing the maximum possible visibility. Obscuration of signs by fixed objects at distances less than 1000 ft has been found almost 25 percent of the time in New York.(12) Gordon cites several other cases of line-of-sight obscuration of overhead guide signs.(1) Fixed object obscuration of signs represents only a portion of the problem. Moving obstacles, such as large trucks, have the potential of blocking the drivers view of the sign entirely. If a driver is next to a truck from the time the sign becomes visible until it is passed, there will be no indication that the sign was ever present.

While the data from the literature indicates that extant signing fulfills the drivers' minimum sight distance requirements, three studies were conducted to fulfill the goals of this research. First, to determine the range of expected luminance value of in-use materials, the brightness of both in-use and new overhead guide signs was determined. Next, a static laboratory test, designed to isolate the individual variables contributing to overhead guide sign conspicuity, was conducted. Finally, a simulator study was conducted to measure the conspicuity variables dynamically.

DETERMINE LUMINANCE, ARRAY, AND PHOTOMETRIC VALUES OF CURRENT SIGN MATERIALS

In this part of the study the photometric properties of signing materials currently used in the highway setting were determined, and the physical characteristics of current signing practices were photographically documented . Both data sets were used in development of the experiments which were conducted later in the project.

Data were obtained in four locations: Suburban Virginia in an area surrounding Washington, D.C.; Albuquerque and Santa Fe, New Mexico; Los Angeles, California; and in the Oakland bay area of Northern California. There were two assumptions made with respect to current signing practice:

1. There is a difference in the visual aspects of interstate highways at overhead guide sign locations which is dependent on the geographic location.

2. There is a basic visual difference between rural, urban and suburban locations.

The first assumption simply states that overhead guide sign locations appear visually different if located in eastern urban areas vs. western urban locations, and that these are still different from western rural settings. This assumption was based on the differences in road building practices across the United States. In the Washington, D.C. area, for example, there are several interstate highways which are depressed in elevation, while in Los Angeles most are elevated. The assumption proved to be false, and geographical differences were not found. Certainly, during the day a freeway in Los Angeles looks different than one in Washington, D.C., but at night these differences seem to disappear.

The second assumption was found to be true, but it was decided to re-define these differences in terms of background complexity. Four distinct background complexity levels were identified:

- Low Background Complexity.
- Cluttered Background Complexity.
- Distracting Background Complexity.
- High Background Complexity.

Low background complexity refers to a situation where there are almost no other competing light sources, and the sign is the basic target. While these areas are usually found in rural areas, locations of low background complexity were found in both the Los Angeles and Washington, D.C. areas. A cluttered background is one where there are other light sources in the background which do not compete for the drivers' attention. Distracting backgrounds, on the other hand, are those with light sources in direct competition for the drivers' attention. These light sources may be billboards or other road side signs (e.g., gas stations, restaurants, etc.) which are in line with, and the same height as, the target sign. High background complexity has both distraction and clutter.

Photometric data were obtained using a photometer with light values obtained in Foot-Lamberts. Luminance measurements were taken of both the background and legend at four locations on the sign. The photometer was placed on the shoulder of the highway at the road edge at a driver's eye height of 39 in. Data were obtained by aiming the photometer at the desired point on the test sign and observing the digital output. Measurements were taken at distances varying from 300 ft to 3600 ft from the sign. Two experimenters made the observations, and the highest "typical" reading was recorded, giving representative values for peak traffic flow. Occasional very high readings, which might be caused by mis-aimed headlights, were ignored. To determine the effect of distance on sign brightness, measurements were obtained at various distances from the sign.

The purpose of making these field measurements to establish the range of sign luminance levels representative of the real-world for use in later laboratory experiments. The data found in table 2 show little difference between sign materials or location, due in part to an inability to obtain sufficient data, and to other problems inherent with field collection of data which are discussed in the following paragraphs.[1] While the tests showed wide variation, the resulting measurements were not unrealistic of what the driver sees and, therefore, did provide useful input to the study.

A major problem with conducting field research is the inability to control all of the variables. In this study, differences in traffic flow, number of lanes, amount of truck traffic, and atmospheric conditions all added variability and decreased the differences between the materials. Additionally, regional differences added to the variability. Los Angeles

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[1] The values in table 2 are given in log ft lamberts because humans perceive differences in illumination as a function of the logarithm of the luminance. (19)

Table 2. Photometric values of current signing materials.

a. Legend luminance (log ft lamberts).

MATERIAL	LOCATION	DISTANCE FROM SIGN (FEET)					
		300	500	700	900	1100	1300
ENCAPSULATED LENS	VIRGINIA		-.050				
	NEW MEXICO			-0.30	-0.73	-0 75	-0.80
	LOS ANGELES			-1.10			
	OAKLAND	-1.60	-1.35	-1.30	-1.30	-1.25	-1.25
	NEW MATERIAL		0	0.10	0	0.10	
ENCLOSED LENS	VIRGINIA		-0.40	-0.60		-0.50	
	NEW MEXICO		-0.35				-0.60
	LOS ANGELES						
	OAKLAND						
	NEW MATERIAL		-0.20	-0.10	-0.20	-0.15	
BUTTON COPY	VIRGINIA		0				
	NEW MEXICO						
	LOS ANGELES		-0.60		-1.20	-1.40	
	OAKLAND	-1.25	-1.00	-1.00	-1.00	-1.00	-0.75
	NEW MATERIAL		0.60	0.70	0.70	0.70	

b. Background luminance (log ft lamberts).

MATERIAL	LOCATION	DISTANCE FROM SIGN (FEET)					
		300	500	700	900	1100	1300
ENCAPSULATED LENS	VIRGINIA			-1.20			
	NEW MEXICO				-1.80	-1.70	
	LOS ANGELES					-1.60	
	OAKLAND	-2.00	-1.70	-1.80	-1.70	-1.70	-1.70
	NEW MATERIAL		-0.70	-0.50	-0.60	-0.60	
ENCLOSED LENS	VIRGINIA		-1.50	-1.30		-1.20	
	NEW MEXICO		-1.50			-1.60	
	LOS ANGELES			-0.70			
	OAKLAND	-2.10	-1.90	-1.90	-1.90	-1.80	
	NEW MATERIAL		-1.00	-0.80	-0.80	-0.80	-1.80
NON-RETROREFLECTIVE LENS	VIRGINIA						
	NEW MEXICO						
	LOS ANGELES		-2.00				
	OAKLAND	-1.60	-1.80	-2.00	-2.00	-2.00	-1.90
	NEW MATERIAL		-2.00	-2.10	-1.80	-2.00	

was the only location where button copy on a nonretroreflective background was found. The bulk of the encapsulated sign material was found in New Mexico, while the majority of the enclosed lens material was in Virginia. Finally, variability was introduced through differences in sign mounting procedures. In New Mexico the tops of the signs were angled 5° forward, while the signs were mounted perpendicular to the road in Virginia.

The apparent similarity of the materials was, in part, due to a wide range of measurements obtained for each of the material types, thus the variability in measurements became large enough to obscure any actual differences. Further review of the literature found others had experienced similar problems and found similar reasons for the apparent similarity of the materials.(13,14,15)

Data from the Northern California site were obtained after the preliminary analysis of the first three sites had been conducted. This site was chosen as the State of California had fabricated three types of signs as part of a test. On the sign bridge were three signs: (1) button copy on porcelain background, (2) encapsulated lens copy on encapsulated lens background, and (3) encapsulated lens copy on enclosed lens background. This eliminated some of the variability caused by location differences. There was concern that, because data collected on the previous tests were based on the highest typical luminance value, differences which may have existed were not observed. For this set of tests a strip chart recorder was attached to the photometer, and the data were recorded continuously for a period of 5 minutes at each data point. The median values for these data, also found on table 2, did show differences between the sign materials. This finding reinforces the need for making comparisons of this type under very similar, if not identical, conditions.

A second series of tests were conducted to gather data on new materials. These tests were to determine the relationship between new materials and those degraded through exposure. The tests were conducted using procedures similar to those described earlier. Differences in methods occurred because the measurements were made on a test track, requiring nonilluminated signs to be lit by headlights of a test car rather than by free flowing traffic. Also, the photometer was placed next to the test vehicle to reduce any off-axis confounding which may have occurred in the earlier tests. Because the off-axis distances in the field varied greatly, and due both to the layout of the test track and inclement weather, no attempt was made to re-create the off-axis viewing conditions of the field tests.

There were few surprises in the data. Again, referring to table 2, more retroreflective materials were brighter than less retroreflective ones, and white materials (legends) were brighter than green ones (backgrounds). A comparison of the new materials with those tested in the field found greater differences between the new and used encapsulated materials than with the new and used enclosed lens materials.

LABORATORY CONSPICUITY STUDY

The previous tasks provided several questions which need to be answered if minimum overhead guide sign luminance requirements are to be established.

1. What role does sign brightness play in making the overhead guide sign conspicuous?
2. Does color play a role in the conspicuity of the sign?
3. How does background complexity affect the conspicuity of a sign?
4. What is the effect of sign obscuration on conspicuity?

To narrow the focus of these questions a screening experiment was conducted using a computer controlled slide presentation and data acquisition system. The purpose of the study was to determine those situations where the driver has problems detecting the overhead guide sign, and determining whether color information or additional brightness would aid the driver. The experimental design is found in figure 1.

The variables tested were color/luminance, background complexity, distance and obscuration. Combinations of materials including (1) encapsulated lens copy on encapsulated lens background, (2) encapsulated

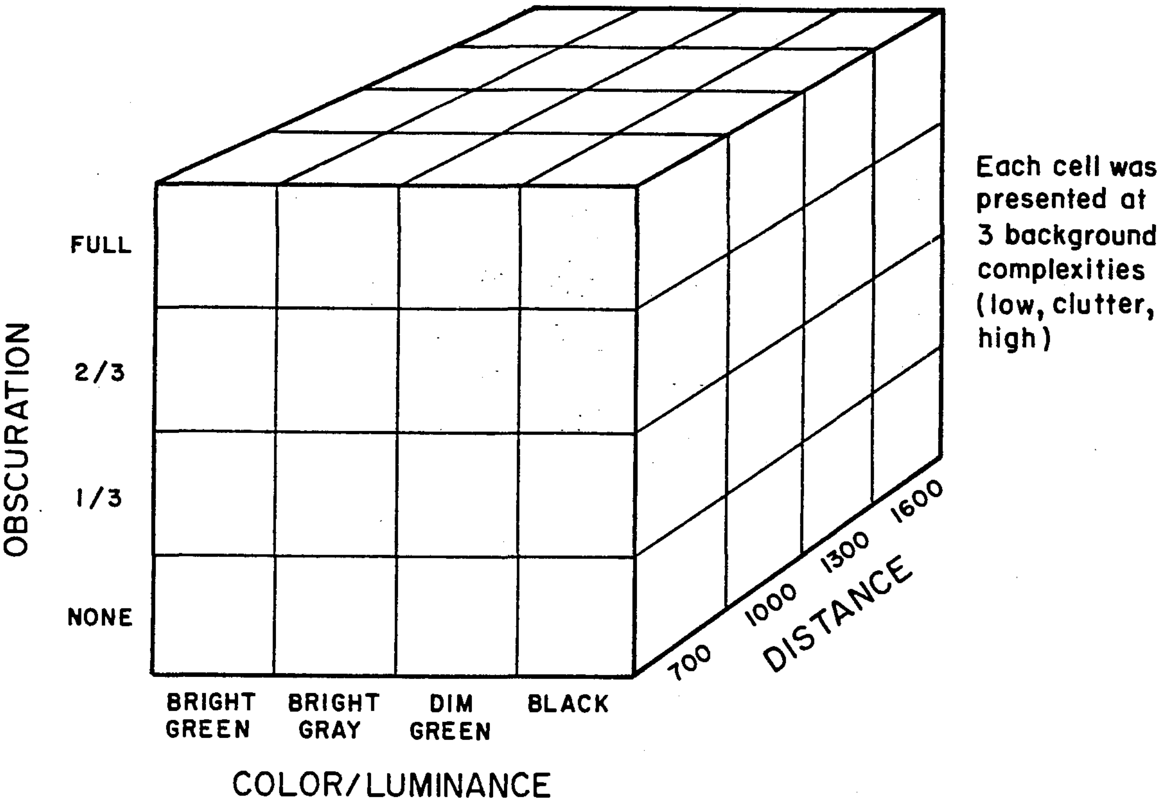


Figure 1. Laboratory conspicuity experimental design.

lens copy on enclosed lens background, and (3) button copy on a nonretroreflective background were represented in the color/luminance variable. Since illuminated and retroreflective signs appear green to the driver, and nonilluminated nonretroreflective signs appear black, both colors were presented in the tests. Gray, which is achromatic, was added to determine if possible differences in driver response were due to color, brightness, or their combination.

To determine the role color plays in the detection of the signs, the brightest luminance level was tested with both green and gray backgrounds. A photometer was used to ensure that the two stimulus slides had the same apparent luminance. Differences between various levels of brightness for the same color sign were tested by comparing a bright green sign with a sign having a green background measuring about 60 percent as bright. The bright green sign was similar in color to encapsulated lens material, and the dim green sign was similar in color to enclosed lens material. The final color/brightness condition simulated the nonilluminated nonretroreflective sign. This sign had a black background and measured 45 percent as bright as the bright signs. While close to the differences observed in the field testing, the 45 percent level was used as the photographic techniques used to develop the stimulus slides resulted in this value.

Three background complexity levels were used in the tests; low, clutter, and high complexity levels. Sign obscuration was accomplished by having a truck or bridge block portions of the sign. There were four levels of obscuration: none, one-third, two-thirds, and full. Each sign was presented to the driver as part of an overall driving task. Four distances were used, and signs were presented in descending distance order (ie., a given sign would be presented at 1600 ft, then 1300 ft, 1000 ft, and finally at 700 ft).

The driver was instructed to exit on a particular street, and that whenever a sign appeared a response was necessary. The driver used a "joystick" to indicate responses. If a sign was detected but not legible, the driver was instructed to press the button located on the stick. If the sign contained the street name being searched for, the driver indicated so by moving the stick forward if the name was on an advance information sign, or to the right or left as directed by an action sign. If no sign was present, the driver indicated this by moving the joystick to the rear.

The slide presentation - data acquisition system has the capability of presenting a stimulus slide and obtaining responses from up to 6 subjects at a time. For each subject, responses were judged correct or incorrect, and response time was obtained. A reward-penalty structure was used to motivate appropriate subject behavior (see ref. 16 for the rationale of using these structures). Drivers were rewarded for correctly and quickly responding to the slide and penalized for incorrect responses.

A total of 120 stimulus slides were tested. They were presented in a pseudo-random order to 100 subjects. The subject population was equally divided by sex, and further into three age groups (<25, 25-55, >55), however analysis of the data found no significant differences between these groups.

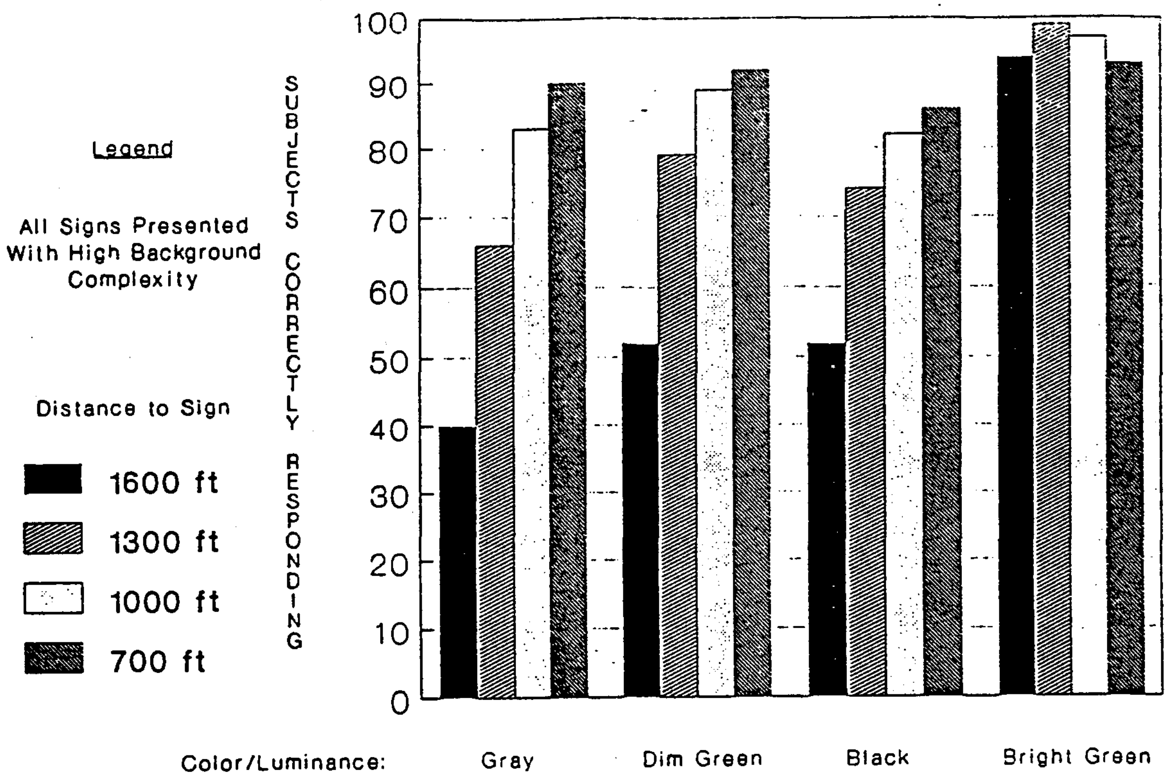
Figures 2 and 3 are example histograms of the number of subjects correctly responding to the signs as a function of the four major variables: color/luminance, obscuration, background complexity and distance. The results indicate that the most serious impediment to successful detection of overhead guide signs is obscuration, and the example plots clearly show this result, as well as the other trends in the data.

Figure 2 indicates subject responses for both the 1/3 and 2/3 obstructed sign with the high background complexity. For the 2/3 obstructed sign at 1600 ft the gray sign was the worst performer, with only 40 subjects having correct responses. The dim green and black signs proved slightly better with 52 correct responses, but the best response was provided by the bright green sign, with 94 correct responses. As the distance to the sign decreases the task of detecting the sign becomes easier. At 1300 ft, the recommended minimum sight distance, the only signs approaching an 80 percent detection rate were green. By 1000 ft all signs are detected by over 80 percent of the drivers, and as the distance is decreased to 700 ft all signs are essentially equal in performance.

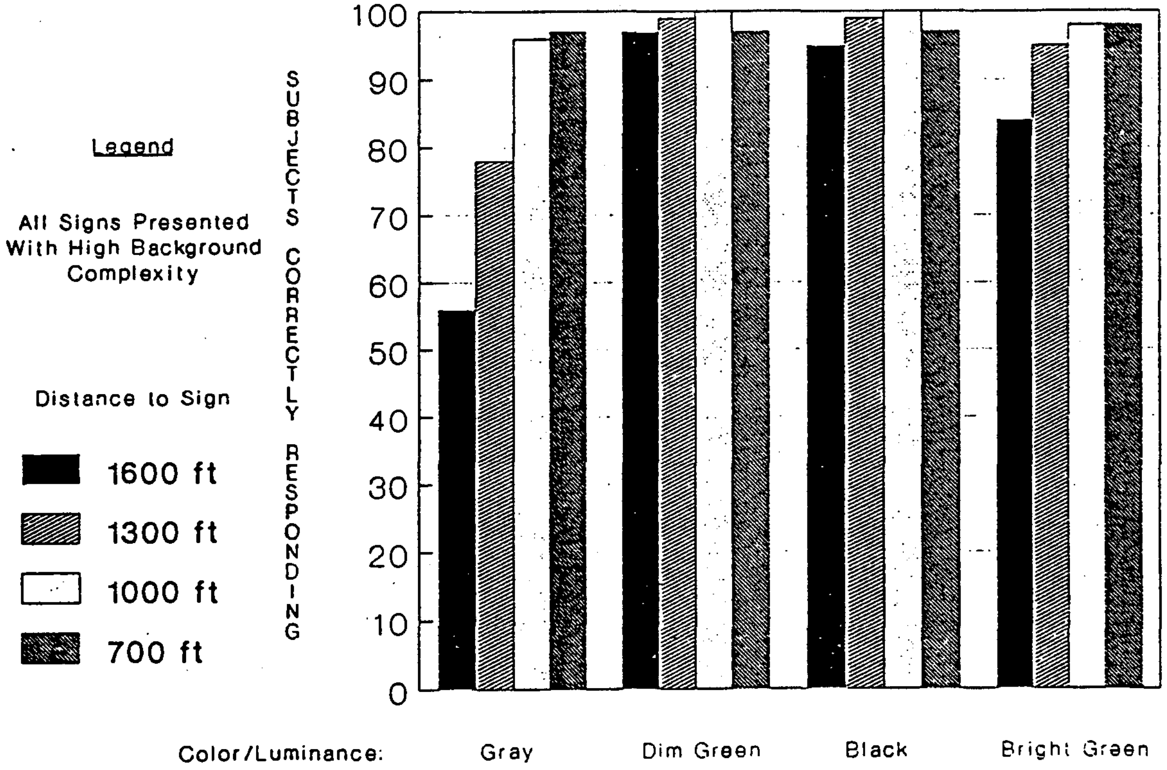
For the 1/3 obscured only the gray sign appears to perform poorly, and with more of the sign visible the poor performance is only apparent at the furthest distance. At 1300 ft the gray sign begins to approach an 80 percent detection rate, and by 1000 ft all signs were detected by over 90 percent of the subjects.

The data in figure 3 shows what happens when the background complexity is reduced, and the sign is fully visible. In these cases, all signs performed equally well and all were almost perfect.

The experiment was designed so that both color and brightness could be evaluated for their ability to assist driver detection. If only brightness were the key factor, the bright green and gray signs would by equal, with the dim green sign and black sign following. If the combination of color and brightness were required, then bright green would have performed best, followed in turn by gray, dim green and black. Finally, if color were the key cue, then the green signs would be the best performing, followed by the black and gray signs.



a. All signs 2/3 obscured.



b. All signs 1/3 obscured.

Figure 2. Number of correct responses as a function of sign material.

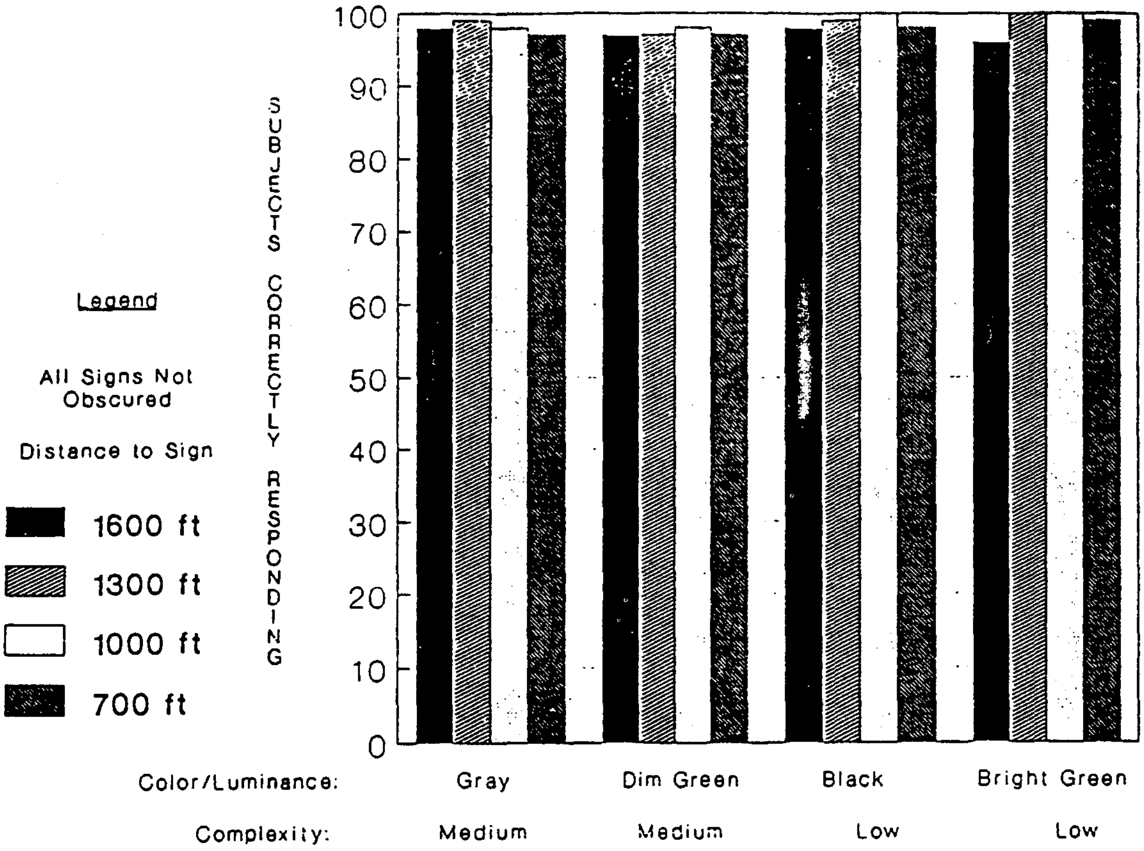


Figure 3. Number of correct responses as a function of sign material and background complexity.

The data indicate that color was the key factor accounting for high detection rates, but this was true <u>only</u> when the sign was <u>significantly</u> obscured. Even though its luminance was equal to the bright green sign, the data show the gray sign as the poorest performer.

FHWA HIGHWAY SIMULATOR (HYSIM) EXPERIMENT

Following the static experiments, an experiment was conducted in the FHWA HYSIM to validate the previous results. The HYSIM facility includes an interactive driving simulator and a computer controlled sign projection system.(17) The independent variables included background, sign color/luminance, sign obscuration, sign type and driver sex. Age was included as a covariate, and the key measures were response distance, response time and correctness.

Two background levels were used in the HYSIM study as opposed to three in the static tests. There was no effect observed due to background in the static tests, but there was concern that when the signs were viewed dynamically, background might effect the drivers' responses. For the dynamic tests, one of the background scenes represented a very dark rural environment with no fixed lighting near the roadway. The second environment was somewhat less rural, with a few fixed lights on the horizon.

The static tests indicated that a combination of color and luminance played an important role in helping the driver to detect obscured signs. While 3 background colors were used in the static tests, gray overhead guide signs are not found on the highway. In the HYSIM tests two colors, green and black, were used. Three luminance values were selected for testing, one representative of an illuminated sign, one representative of encapsulated lens material, and one of enclosed lens material. The green sign was shown at all three luminance levels, and the black at the two lower luminance levels.

Three levels of obscuration were used; none, one-third and two-thirds obscured. Three sign types were used and the driver's response required selection between two, three and five alternatives. As in the static tests, the driver was required to make an overt response when a sign became visible. Additionally, the message of the sign indicated to the driver which of the alternatives was correct.

Thirty-six subjects were obtained through advertisements placed in local newspapers. The population group was divided equally by sex, and distributed fairly evenly between the age range of 17 to 74. Each subject was tested for both visual acuity and contrast sensitivity, and all scores were within normal population norms.

Each subject was asked to drive the HYSIM twice. The background complexity was changed for each of these runs so that each subject saw all of the test conditions. For each background complexity the subjects drove a scenario lasting approximately 1 hour. During the scenario, which presented a typical interstate roadway and scene, subjects were to react to various road signs, negotiate curves, and obtain route guidance information from the overhead guide signs to arrive at the proper destination. Subjects were instructed to respond each time an overhead guide sign was present and to obey the sign if the proper destination was present.

The data collected included response distance, response time, and correctness. The response data were the direct result of the drivers' overt responses when the sign became visible. Correctness was determined by observing whether the drivers took the proper route at an interchange. Therefore it was possible that a given sign was visible at a sufficient distance to indicate good detectability, and that the drivers responded correctly to the sign message; but that some factor resulted in an unsafe lane change maneuver close to the interchange point. To be able to identify this situation, lane profile data were obtained for each interchange.

A statistical summary for the response and correctness data is presented in figure 4. In the figure, the arrows connecting the various p values indicate interactions between the independent variables. For response distance, interactions were observed between color/luminance and both sign type and obscuration. The mean reaction distance was 677 ft with a standard deviation of about 60 ft. In <u>all</u> cases the variations observed were within the one standard deviation range. The color/luminance - obscuration interaction confirmed the static test results. The same interactions were observed for reaction time. The mean reaction time was 1.9 seconds, and the standard deviation was 0.85 seconds. Again the range from best to worst was about one standard deviation. For correctness there was an interaction between color/luminance and obscuration, but not between color/luminance and sign type. As with the other measures, the results all fall within the one standard deviation range. While statistical significance was observed for sex, this difference was really due to age. Although age was used as a covariate in the analysis, as a group the men were older than the women. The analysis detected the age effect in the sex variable.

Figures 5 through 8 show some of the differences that were observed. Figure 5 is a cumulative distribution plot of response distance for each of the backgrounds. In the HYSIM the sign first becomes visible 750 ft down the road. While slight differences are noted between the backgrounds, 85 percent of the drivers have indicated that the sign was visible within 125 ft of its presentation. Figures 6 and 7 show the same data, but separate each color/luminance combination. The results of these analyses are similar to the static tests with green signs performing better than black ones and bright signs performing better than dim ones. However, even the sign with the poorest response data (black, dim, rural background) has an 85th percentile response distance of less than 150 ft after presentation.

Figure 8 shows typical response data as a function of sign color/luminance and obscuration. For nonobscured signs, one is hard pressed to find practical differences. The difference between the best and worst scoring signs accounted for less than 100 ft of detection distance. For signs which were 2/3 obscured, the differences were both statistically significant (p <.001) and showed practical differences. As sign obscuration increased, response time increased and response distance decreased. These differences were so great that in some cases the sign was missed completely.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE		
	RESPONSE DISTANCE	RESPONSE TIME	CORRECTNESS
COLOR/LUMINANCE	<.001 .002	<.001 .003	.026 <.001
OBSCURATION	<.001	<.001	<.001
SIGN TYPE	.002	.003	<.001
BACKGROUND	<.001	<.001	.011
SEX	<.001	<.001	<.001

Figure 4. Statistical analysis summary.

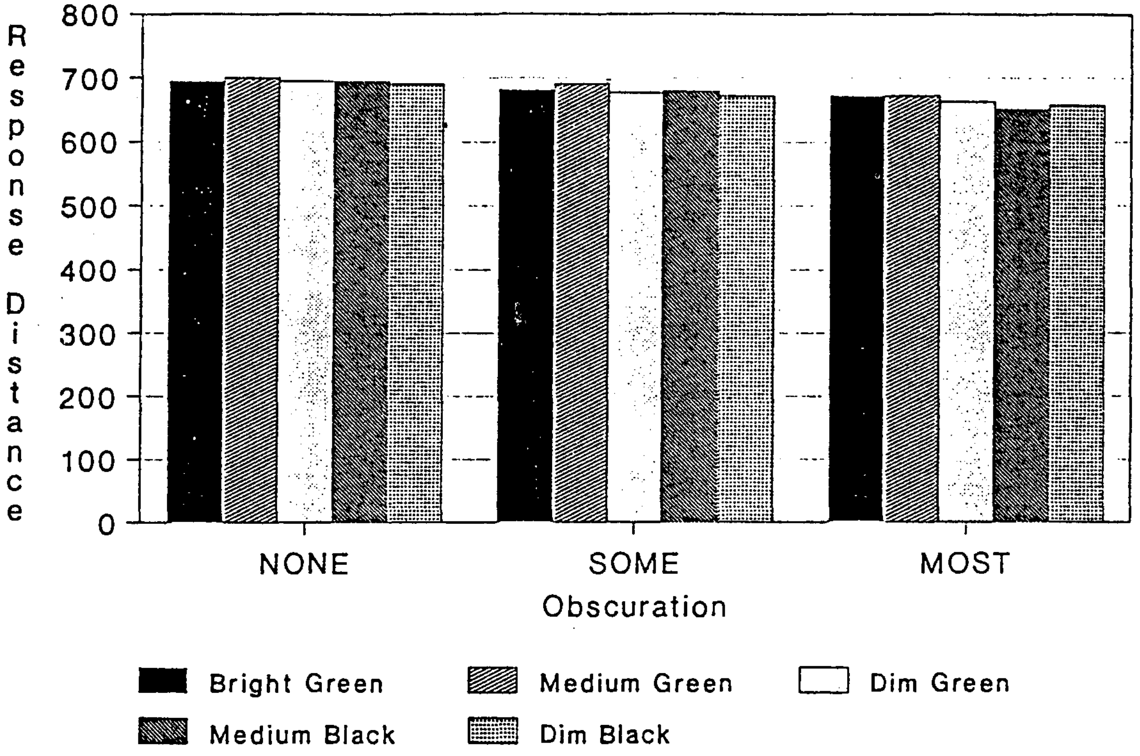


Figure 5. Typical HYSIM response data.

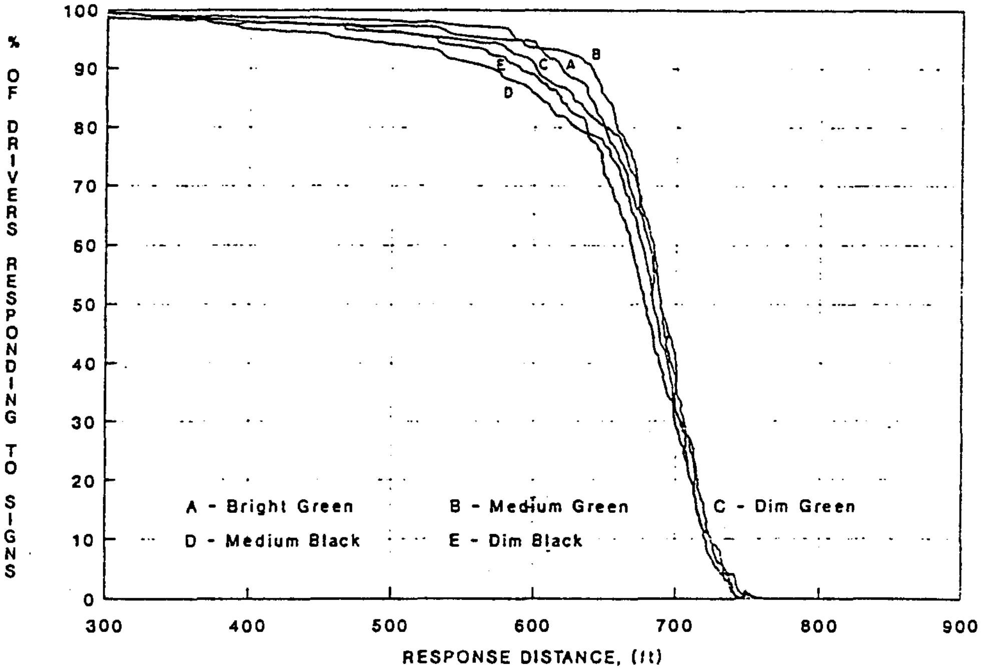


Figure 6. Distribution of response distance, rural background.

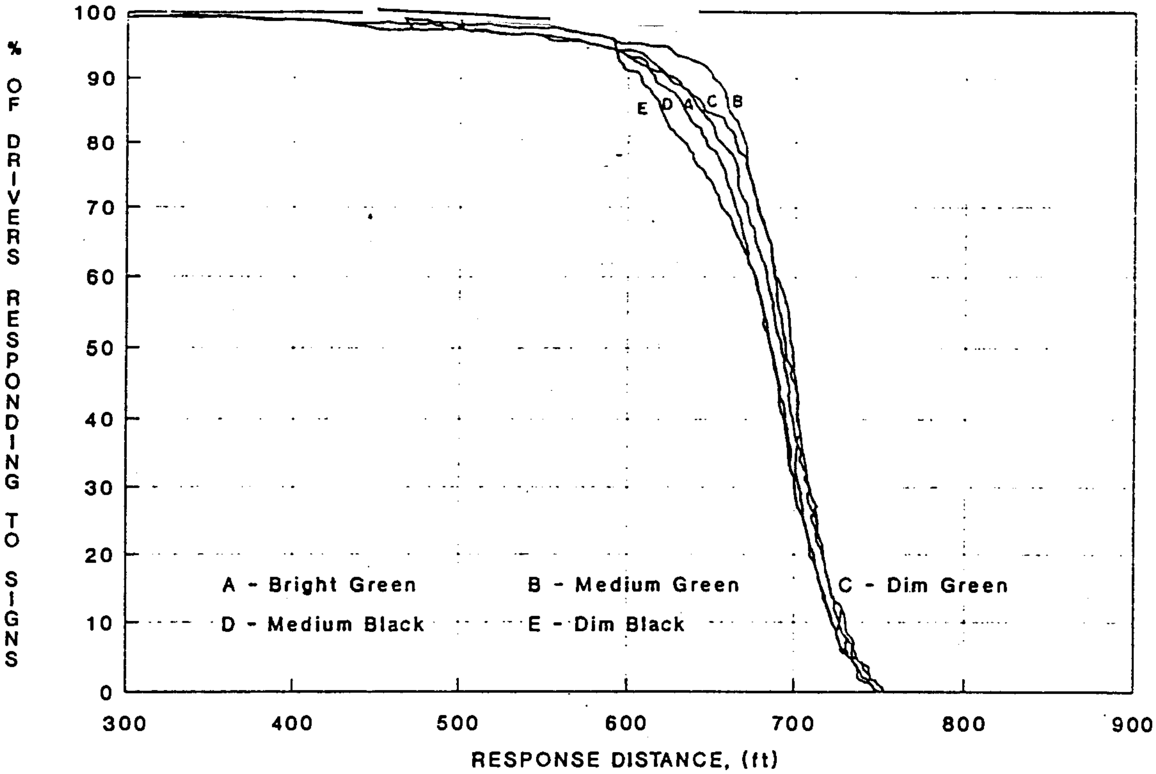


Figure 7. Distribution of response distance, urban background.

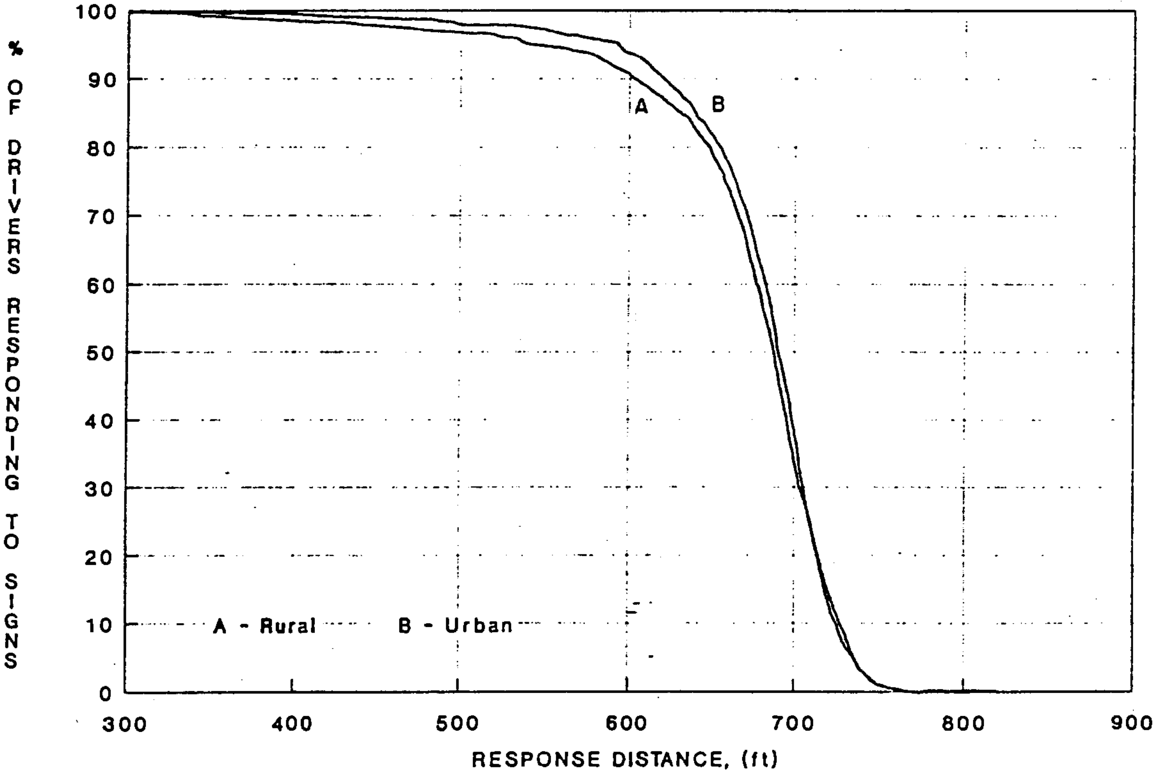


Figure 8. Distribution of response distance, rural and urban backgrounds, colors and luminance levels combined.

OVERHEAD GUIDE SIGN AND LIGHTING COSTS

The cost of installing new overhead guide signs made of various combinations of background and message materials, as well as the cost of providing illumination for these signs, was determined. For these analyses an example sign of 165 ft^2 was chosen. The present worth of the sign was assessed by determining the cost of the original sign along with the necessary maintenance or replacement to provide a 20-year service life. Lighting system costs were determined by developing 20-year cost estimates for each of the components (i.e., luminaires, electricity, power system, and structures) of the lighting system. Installation and maintenance costs were likewise computed for a 20-year period.

Cost information for these projections came from various States for installation and maintenance factors, and from manufacturers and distributors for the material and life cycle data. A total of 540 combinations of lighting systems, power systems, support systems and electric rates were developed. These are combined with a possible 7 recommended combinations of background and legend materials making the overall matrix of conditions massive.

For comparison purposes we have chosen two sign types, a nonretroreflective sign having a button copy legend on porcelain enamel background, and a retroreflective sign made of encapsulated lens legend and background. For the driver to have a color cue at night, either sign may be used, but the nonretroreflective sign must be illuminated. For the comparison we have assumed costs for installation of two 250 watt mercury vapor luminaires, including central cost values for annual maintenance, electricity costs, a power system and the structure required for the luminaires.

The present worth cost of the illuminated nonretroreflective sign will be approximately $11,000. The cost can be reduced more than 50 percent by using the retroreflective sign with no illumination. In this case the present worth cost of the sign will be about $5,300. If, however, the color cue is not presented at night, the savings will be even greater. The nonretroreflective sign without illumination has a present worth cost of only $4,000. These amounts can change as much as plus or minus 25 percent if either low- or high-cost estimates are used.

In this example there is a clear distinction between the various alternatives. In the real world the distinctions may not be so clear. With over 3,500 possible combinations to choose from, and with local costs varying from location to location, cost comparisons must be made on an individual basis.

DISCUSSION AND SUMMARY

Because little differences were observed between the sign types, it becomes necessary to determine the performance requirement for the sign. If, for example, we demand a 100 percent detection rate at 1300 ft, and only one sign is posted, the data indicate the sign should be bright green, have no distracting elements in the background and nothing should obscure it. Since 100 percent detection is unreasonable, we may choose to drop the requirement to 95 percent for the same conditions (ie., detection rate at 1300 ft with one sign). In this case both the static and dynamic tests[2] show that all signs will meet the criteria until the sign becomes 2/3 obscured. Once this level of obscuration is reached, only the bright green sign will be acceptable. Dropping the requirement to 75 percent will allow all signs to meet the criteria when 2/3 obscured. If, however, a truck completely blocks the sign from the drivers' view, the detection obviously drops to zero.

The literature review found too many signs erected with permanent visibility obstructions. These signs will not be able to meet even the most relaxed detection criteria without providing the driver with detection aids. One alternative to aiding driver detection is the installation of multiple advance information signs. The MUTCD recommends the installation of two advance information signs whenever practical. Several benefits are gained by this strategy. If one of the signs is obscured by a moving object, the other still has a chance to be detected.

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[2] Because HYSIM presents these signs at 750 ft, the detection distance has been calculated assuming an unobstructed sight distance of 1300 ft.

Also, even if both signs are 2/3 obscured, the probability of detecting one of the signs at 1300 ft, if each sign has a 75 percent probability of detection, will be 94 percent. If three advance information signs are presented, and all signs are 2/3 obscured, the probability of detecting any one of these signs is 98 percent. (A complete discussion of the statistical method used to calculate these probabilities is found in ref. 18. The formula is basically $\{1 - (1 - \text{detection rate})^x\}$ where x = the number of signs present). If one of the signs is less obscured, the probability of detecting one of the signs increases to almost 100 percent.

To determine minimum signing practice for overhead guide signs it appears that a set of objective performance requirements should be established, and decisions should be based on the ability of a sign, or signs, to meet this standard. It is also clear that the usefulness of overhead guide signs will be enhanced by ensuring that new installations provide at least 1300 ft of unobstructed sign visibility. While the relocation of existing signs with less than 1300 ft of unobstructed visibility will also improve effectiveness, these changes do not appear to be operationally feasible.

To look beyond the numbers and investigate the effects these variables have in the real world, it is important to distinguish between statistical and practical significance. Statistical significance refers to the degree of confidence one can place in differences observed in the data. In these studies, sign type, color/luminance, background and obscuration exhibited a high degree of statistical significance. This indicates that the observed differences in response distance, response time, and correctness can be attributed with a high degree of confidence, to the independent variables. Practical significance refers to the "real world" effects of these differences.

The following results were found to be statistically significant:

- Green signs provide greater detection distances than black or gray signs.
- As signs become brighter detection distances increase.

- Increasing the obscuration of a sign decreases its ability to be detected.
- More complex backgrounds compete with the signs for the drivers attention.
- As the drivers age increases, detection distance decreases.

From a real-world point of view, these statistically significant results have the following practical implications:

- The differences between sign colors, luminance levels, and obscuration was found to be within one standard deviation. In practical terms this means there were no differences between any of the conditions.
- The elderly driver is not helped by any particular sign configuration. When reaction distance was compared for the color/luminance variable, the difference between the best and worst configurations was about 60 ft. Even at 45 mi/h the best configuration allows the driver less than 1 second of additional detection time.

REFERENCES

1 D.A. Gordon. Night Visibility of Overhead Guide Signs: A Review of the Literature. Report No. FHWA/RD-84/087. Washington, DC: Federal Highway Administration, 1984.

2 F. Birren. Safety on the highway: A problem of vision, visibility, and color. Am. J. Ophthalmology, 1957, Vol. 43, No. 2, pp. 265-270.

3 H.L. Woltman, R.H. Stanton and R.A. Stearns. Information Sign Color Evaluation Employing a Video Presentation. St Paul, MN: 1984, 3M Co.

4 W.S. Ferguson and K.E. Cook. Virginia Highway Signing Phase 1: Driver Awareness of Sign Colors and Shapes. Charlottesville, VA: 1966, Virginia Highway Research Council.

5 P.K. Hughes and B.L. Cole. Search and attention conspicuity of road traffic control devices. Australian Road Research, 1984, Vol. 14, No. 1, pp. 1-9.

6 S.E. Jenkins and B.L. Cole. Daytime Conspicuity of Road Traffic Control Devices. Vermont South, Victoria, Australia: 1984, Australian Road Research Board.

7 T.W. Forbes. Research on Traffic Sign Requirements, Final Report. East Lansing, MI: 1967, Michigan State University.

8 H.R. Miller, R.W. Allen and A.C. Stein. Driver Factors, Simulators and Other Instrumented Measurement Approaches. Warrendale, PA: 1983, Society of Automotive Engineers (Paper 830563).

9 K. Perchonok and L. Pollack. Luminous Requirements for Traffic Signs. Report No. FHWA/RD-81/158. Washington, DC: Federal Highway Administration, 1981.

10 D. Solomon. Interstate Sign Tests. U.S. Bureau of Public Roads, unpublished.

11 Caltrans Reflective Sheeting Study Team. Use of Reflectorized vs. Illuminated Overhead Mounted Guide Signs. Sacramento, CA: California Department of Transportation, 1978.

12 K.C. Hahn, E.D. McNaught and J.E. Bryden. Nighttime Legibility of Guide Signs. Report NYSDOT-ERD-77-RR 50. Albany, NY: Engineering Research and Development Bureau, 1977.

13 D. van Norren. Overhead Signs Without External Illumination? Part I: Literature Review and Calculations. Report IZF 1978-C20. Soesterberg, the Netherlands: Institute for Perception TNO, 1978.

14 D. van Norren. Overhead Signs Without External Illumination? Part II: Experiment on Legibility Distance. Report IZF 1978-C28. Soesterberg, the Netherlands: Institute for Perception TNO, 1978.

15 W.P. Youngblood and H.L. Woltman. A Brightness Inventory of Contemporary Signing Materials for Guide Signs. Presented at the annual meeting of the Transportation Research Board, 1981.

16 M.L. Cook, R.W. Allen and A.C. Stein. Using Rewards and Penalties to Obtain Desired Subject Performance. Proceedings of the Seventeenth Annual Conference on Manual Control. Pasadena, CA: Jet Propulsion Laboratory, 1981.

17 K.M. Roberts. The FHWA Highway Driving Simulator. Public Roads. 1980, Vol. 44, No. 3, pp. 97-102.

18 R.W. Allen, H.R. Jex and A.C. Stein. A Cybernetic Test for the Detection and Deterrence of Impaired Human Operators. In: Preprints of the 9th World Congress of IFAC. Vol. VI, 1984, pp. 251-256.

19 W.E.K. Middleton. Vision Through the Atmosphere. Toronto, Ontario, Canada: University of Toronto Press, 1952.

20 Missouri Highway and Transportation Commission. Missouri Standard Specifications for Highway Construction. Jefferson City, MO: Author, 1981.

21 Hall Signs, Inc. Price Sheet G-85. Bloomington, ID: Author, 1985.

22 Robert Snow Means Co. Inc. Means Site Work Cost Data. Kingston, MA: Author, 1985.

23 F.D. Shepard. Review of Sign Overlay Procedures in Virginia. (Draft of paper offered for Presentation at the 1985 Annual TRB Meeting). Virginia Highway & Transportation Research Council: Charlottesville, VA: 1984.

24 Stimpsonite Products Division, Amerace Corp. Stimpsonite Products Suggested Price List. Niles, IL: Author, 1986.

25 Maryland State Highway Administration. Contract AW-725-50-085, Signing Project for MD 295 from MD 175 to the Baltimore County Line, Plan Sheets. 1983.

26 Missouri Highway and Transportation Department. Unit Bid Prices. Jefferson City, MO: 1984.

27 California Department of Transportation (Caltrans). Guide Sign Reflectorization Projects – Summary of Costs (Staff Notes). Sacramento, CA: Undated.

28 Caltrans. Staff Note. Sacramento, CA: Undated.

29 Maryland State Highway Administration. Contract AW-725-501-085, Bid Summary. 1983.

30 Robert Snow Means Co. Inc. Means Electrical Cost Data. Kingston, MA: Author, 1985.

31 General Electric Co. Lighting Systems Product Catalog (GEA-1200A). Hendersonville, NC: Author, 1985.

32 J.E. Upchurch, and J.T. Bordin. Evaluation of Alternatuve Lighting Systems for Guide Sign Illumination. Tempe, AZ: Arizona State University, 1986.

33 Guth Lighting Division, General Signal Co. Product Catalog 839/R. St. Louis, MO: Undated.

34 Lighting Systems Dept., General Electric Co. Product Catalog GEA-9776E. Hendersonville, NC: Author, 1983.

35 Holophane Division, Manville Products Corp. Product Catalog HL-489. Denver, CO: Author, 1983.

36 Holophane Division, Manville Products Corp. Product Catalog HL-844. Denver, CO: Author, 1985.

37 General Electric Co. General Electric Lamps. Hendersonville, NC: Author, 1985.

38 Energy Information Administration, U.S. Department of Energy. Analysis of the Projected Electricity Prices to 1995, DOE/EIA-0470. Washington, DC: Author, 1985.

39 Electrical World. 35th Annual Electric Utility Industry Forecast. New York, NY: Author, 1984.

40 Energy Information Administration, U.S. Department of Energy. Annual Outlook for U.S. Electric Power, DOE/EIA-0474(86). Author, 1986.

41 Caltrans. Maintenance Expenditure Report (Computer Printout). Sacramento, CA: Author, 1985.

42 Caltrans. Standard Plans. Sacramento, CA: Author, 1984.

43 R.N. Robertson, and J.D. Shelor, Using Encapsulated-Lens Reflective Sheeting on Overhead Highway Signs. Transportation Research Record #628. Washington, DC: Transportation Research Board, 1977.

44 IKG Industries, Division of Harsco Corp. Grating Products Catalog. Elizabeth, NY: Author, Undated.

45 Nebraska Department of Roads. Aluminum Box Truss Overhead Sign Supports (Plan 697-C). Lincoln, NB: Author, Undated.

46 Texas State Department of Highways and Public Transportation. Sign Walkway and Handrail (SSW(1)). Austin, TX, 1982.

47 Virginia Department of Highways and Transportation. Typical Details for Overhead Sign Structures (Plan PTS-5D). Richmond, VA: Author, 1986.

48 Maryland State Highway Administration. Luminaire Supports Plan. Glen Burnie, MD: Author, Undated.

49 Ohio Department of Transportation. Mercury Vapor Sign Lighting Details II (TC-31.21). Columbus, OH: Author, 1979.

50 Richardson Engineering Service, Inc. General Construction Estimating Standards. San Marcos, CA: Author, 1986.

51 AASHTO. Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals. Washington, DC: Author, 1975.

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16. Abstract

The project discussed in this report concerned the night use of overhead guide signs, including button and reflectorized copy and all practical combinations of reflectorized and opaque backgrounds. This project was a follow-up effort to the literature review by Gordon.(1) Gordon's review found areas requiring further investigation, including the comparison of nonilluminated-nonretroreflectorized signs with both illuminated-nonretroreflectorized and retroreflectorized signs.

The current project included the investigation of current signing practices throughout the country, development of a set of in-use luminance values for current overhead guide sign materials, development of life cycle costs for current signing materials and practices, and determination of driver response characteristics for these overhead guide sign systems.

These goals were met through review of the literature, field testing, and static and dynamic laboratory testing. While the results of the tests are presented, no attempt has been made to draw conclusions from these data.

Volume II, FHWA-RD-88-197, contains appendixes with detail data on each study.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply by	To Find	Symbol
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t

VOLUME

Symbol	When You Know	Multiply by	To Find	Symbol
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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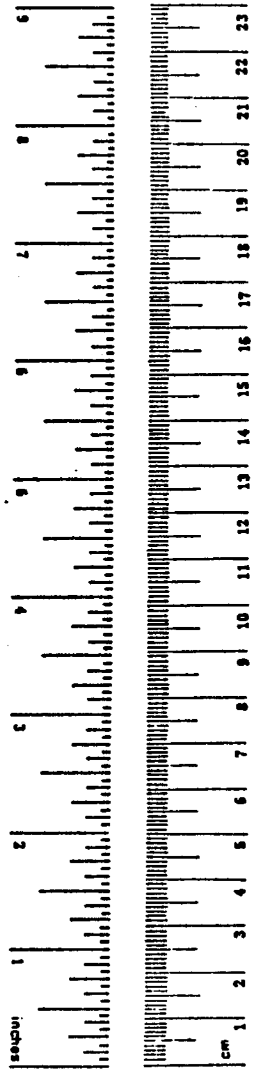
*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	

MASS (weight)

Symbol	When You Know	Multiply by	To Find	Symbol
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	

VOLUME

Symbol	When You Know	Multiply by	To Find	Symbol
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F