FUNCTIONALITY OF GUIDE SIGNS

Research Report Number 277-2F
Research Project 1-18-84-277

Covering

TARGET VALUE STUDY, SIGN LIGHTING GUIDELINES AND EXECUTIVE SUMMARY

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SUMMARY

This is the second and final report of Research Project 1-18-83-277 entitled "Functionality of Urban Freeway Guide Signing." This research project was designed to determine the legibility and target value of urban freeway guide signs both lighted and unlighted for signs made from the most commonly used reflective and non-reflective backgrounds. This report presents the results of a target value study and a questionnaire and telephone survey to determine various state policies with respect to sign lighting, sign materials used, and factors taken into consideration when deciding to light or not light a sign. The report includes a set of guidelines to be used by Texas State Department of Highways and Public Transportation for lighting of urban freeway guide signs.

Target Value:

The target value study was conducted in an instrumented vehicle driving urban freeways in Houston, Texas. The significant findings of the target value study were:

1. In the 300-800 feet sight distance category the opaque background lighted sign was significantly more visible than the unlighted. The test signs in this category were detected well before the obstruction due to vertical geometry. There was virtually no difference due to lighting in the 800-1200 foot category. And finally in the greater than 1200 foot category the unlighted sign was significantly more detectable. When there is unlimited sight distance legibility is more important than target value.

2. The T-side mounted signs which are greater than 10 degrees horizontal displacement did not show any significant difference due to sign lighting. The target value distance for both signs was significantly smaller than the signs in the 0 to 5 degree and 5 to 10 degree range indicating that motorists are not expecting to find signs in this particular location.

3. The target value of ground mounted signs are not as good as the overhead mounted signs, but better than T-side mounted signs.

4. The target value of overhead signs was well above both the ground mounted and T-side mounted sign regardless of material. The target value distances for all signs were greater than required distances for most existing maneuvers.

5. In all cases, for both lighted and unlighted signs the target value was 2 and 3 times greater than the legibility distance.

6. Median mounted freeway illumination creates complexity and glare which is detrimental to both target value and legibility. High mast lighting does not have the same effect.

Questionnaire/Telephone Survey:

The questionnaire/telephone survey provided significant information regarding other states policies regarding sign lighting and traffic engineer opinions with respect to seeing the green background in the lights out condition. The eight states shown in Appendix H, page 90 were contacted regarding their policy on sign lighting. These states were selected based on their proximity to the State of Texas and geographical location across the United States. The State of California was selected because of their previous request to eliminate sign lighting. The results of these two surveys included:

1. Most of the contacted states, Oklahoma the only exception, have either a formal or informal policy regarding sign lighting. Their policy is to use non-lighted signs in most noncritical situations.

2. The traffic engineers prefer high specific-intensity sheeting on signs with lights out. Most states generally use high specific-intensity sheeting, however they claim their lights out policies do not consider sign material.

3. Most states allow lights to be turned off provided one of the following conditions do not exist.

    a. Critical sight distance is greater than 1200 feet.

    b. Horizontal Curvature is not less than an 800 foot radius.

    c. Sign does not contain any action message.

4. Traffic Engineers felt it was necessary to see the green background. Different states used different techniques to assure the visibility of the green background.

Sign Lighting Guidelines:

Based on the legibility study, the target value study, previous research work and the questionnaire and telephone survey the following guidelines for sign lighting were developed:

1. Signs which have the following characteristics should be lighted:

    a. Critical sight distance of less than 1100 feet.

    b. Horizontal curvature with a radius less than 800 feet.

    c. At critical diversion points.

    d. Median mounted overhead signs in close proximity to median mounted freeway illumination.

    e. Signs in locations with problems including glare and visual clutter.

All other urban overhead freeway signs do not require lighting provided reflective button copy is used and maintained.

RECOMMENDATIONS

The following recommendations are based upon the results of this study:

1. Overhead signs that have an unrestricted sight distance of 1,100 or more feet (except those included in Item 2 below or are in areas of high visual clutter) do not require lighting and the lighting should be omitted. These signs should be equipped with reflectorized background materials. Existing signs that meet these criteria should have the existing lighting removed or turned off.

2. Overhead signs at critical diversion points should be lighted regardless of sight distance.

3. Nonilluminated overhead signs and ground mounted guide signs in rural areas or areas that have minimal visual clutter should have engineer grade or super engineer grade background and have removable reflective button copy.

4. Removable reflective button copy should be used on all guide signs.

5. Signs that have restricted sight distance should be illuminated and have more durable opaque background coatings.

The above recommendations are made with the understanding that reflectivity will be maintained.

IMPLEMENTATION

The State would realize substantial savings in maintenance and energy costs in its major metropolitan areas if the sign lighting guidelines as presented in this report are implemented.

I SUBJECT

Increasing operational costs and maintenance costs for overhead guide sign lights make it desirable to eliminate as many sign lights as possible without diminishing overhead guide sign functionality. Limited personnel and funds make it increasingly difficult to operate and maintain sign lights. Maintenance on overhead sign lights requires lane closures which increase accidents and interrupt normal roadway operations. Elimination of as many sign lights as feasible will substantially reduce the number of lane closures necessary for maintenance operations.

Project 1-18-75-222 has proven that opaque background coatings are more durable and maintenance free than reflective background coatings. This research also indicated that the use of opaque background possibly does not decrease the functionality of the ground mounted guide signs.

Preliminary studies in Houston and El Paso under State project 1-18-75-222 indicated that legibility of overhead guide signs without fixed sign lighting is not impaired when sight distances are 1100 feet or over. There was some indication that when removable reflective button copy of the quality specified by the Texas Department of Highways and Public Transportation is utilized, legibility increases slightly when fixed sign lighting is not present.

Preliminary studies under State Project 1-9-80-270 indicate that as the luminance of legend to background ratio increases, legibility for ground mounted signs increases until the ratio of the legend luminance to the background luminance reaches 10 to 12, then it starts to decrease.

Therefore, it was desirable to take the initial studies and convert them into a full matrix to determine the requirements necessary for fully functional guide signs.

II. OBJECTIVES

1. When signs are not currently in place on freeways in Houston, construct and erect signs as needed, utilizing button removable and high specific-intensity reflective copy as text and backgrounds of opaque material, engineer grade reflective sheeting, super engineer grade reflective sheeting and high specific-intensity reflective sheeting.

2. Determine day and night functionality of overhead signs on freeways under existing traffic and the following conditions:

   a. Sight distances of 1000 or more feet and no horizontal or vertical curve over 2 degrees.

   b. Sight distances of 1000 or more feet with horizontal and/or vertical curves greater than 2 degrees.

   c. Under night conditions with fixed freeway lighting on and sign lighting on and off.

   d. Under night conditions with no fixed freeway lighting and sign lighting on and off.

3. Determine day and night functionality of ground mounted guide signs under above conditions as applicable.

4. Statistically analyze operational and maintenance costs and functionality of guide signs. The statistical analysis of variance regression and other parametric tests will be conducted. This shall also include but not be limited to conspicuity, human factors, economics and safety aspects.

III. BACKGROUND AND SIGNIFICANCE OF WORK

For the past several years many states have experienced problems with lighting equipment on large overhead freeway guide signs. The lighting equipment in most cases is over fifteen years old and needs replacing. The replacement costs of this equipment will be excessive and do not include future cost of electricity to power the lights.

This problem has forced some states to issue informal guidelines with respect to maintenance of lighting for freeway guide signs. These informal guidelines generally state "that non-critical guide sign lighting will not be replaced after the lighting has burned-out". In these non-critical situations power to the sign lights will be disconnected. California has petitioned the United States Department of Transportation for relief from the lighting requirements for overhead guide signs in the National Manual of Uniform Traffic Control Devices (MUTCD). California has cited the massive cost of replacing literally thousands of overhead guide signs with new lighting equipment, conduit and electrical lines.

The U. S. Department of Transportation, specifically the Federal Highway Administration (FHWA) has taken the position that all overhead guide signs shall be lighted unless the background is reflectorized and the sign does not have a critical sight distance of less than 1100-1200 feet. Section 2A-16 of the National MUTCD specifically states:

> Regulatory and warning signs, unless accepted in the standards covering a particular sign or group of signs, shall be reflectorized or illuminated to show the same shape and color both day and night. ALL OVERHEAD SIGN INSTALLATIONS SHOULD BE ILLUMINATED WHERE AN ENGINEERING STUDY SHOWS THAT REFLECTORIZATION WILL NOT PERFORM EFFECTIVELY. Reflectorization, non-reflectorization, or illumination of guide signs shall be as provided in subsequent sections.

The National MUTCD addresses the reflectorization of freeway guide signs in section 2F-13. Letters, numerals, symbols, and border shall be reflectorized. The background of freeway guide signs may be reflectorized or illuminated.

In general, where there is no serious interference from extraneous light sources, reflectorized signs will usually be adequate. However, on expressways where most driving at night is done with low beam headlights, the amount of headlight illumination incident to an overhead sign display is relatively small. Therefore, all overhead sign installations should normally be illuminated. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message. When a sign is internally illuminated the requirement for reflectorized legend and borders does not apply.

Various methods used for illumination are specified in Section 2A-17 of the National MUTCD.

Illumination may be by means of:

1. A light behind the sign face, illuminating the main message or symbol, or the sign background, or both, through a translucent material; or

2. An attached or independently mounted light source designed to direct essential uniform illumination over the entire face of the sign; or

3. Some other effective device, such as luminous tubing or fiber optics shaped to the lettering or symbol, patterns of incandescent light bulbs, or luminescent panels that will make the sign clearly visible at night.

The requirements for sign illumination are not considered to be satisfied by street or highway lighting, or by strobe lighting. And finally, when reflectorization is required, Section 2A-18 of the MUTCD specifies the means by which reflectorization may be achieved.

Reflectorization may be by means of:

1. Reflector "buttons" or similar units set into the symbol, message and border; or

2. Reflective sheeting, either on the sign background or where a white legend is used on a black or colored background in the symbol or message and border.

This portion of the research study was to determine whether sign lighting assisted the driver in locating freeway guide signs. With respect to different freeway geometrical designs the belief is generally held that freeway sign lighting assists the driver in providing the driver with additional time to obtain the critical information from the sign. Signs which are behind vertical crests or other obstructions may not have the 1100-1200 foot critical sight distance provided. Therefore it was thought sign lighting would provide more target value resulting in the driver having a longer time to extract the needed information. Horizontal curvature provides problems with respect to the amount of light from headlights falling on the sign face illuminating the sign. It was also thought that signs with horizontal angles greater than 10 degrees either left or right of the drivers line of sight may have to be illuminated to attract the drivers attention to the sign.

IV. RESEARCH METHODOLOGY

The target value study was conducted using test subjects from the Houston, Texas area driving two freeways. Each subject was tested for (1) visual acuity, (2) depth perception and (3) color attribute. Visual Acuity was 20-21 with four people 20-25. The average depth perception was 20-30 with three people above 20-50. The color attribute test showed no one to be color deficient. All of the subjects were given the study objectives, general guidelines for the study and told the exact route they would be travelling.

The study was conducted by driving through two routes and recording the target distances of the signs along the routes. Standard size vehicles were used. The speed and selection of high or low beams were at the drivers discretion. Several signs included in each route were not test signs. However, the target distances of these signs were recorded in order to protect against any sampling bias that could occur if the experimenter had been instructed to record the target distance of only the test signs. The distances were recorded using an automatic Distance Measuring Instrument (DMI). As the subject saw a sign they stated its' location. The sign was either overhead on left, overhead center, overhead on the right or ground mounted on the right. Prior to the actual research study, the experimenters listed in order the location of all freeway guide signs leading up to the test sign. From this ordering of signs the test administrator could indicate the order of the signs as the driver saw them and the actual spacing of the guide signs. When the subject indicated that the test sign was visible the DMI was activated and the distance to the test sign could be determined. Appendix A, contains the test administrators data recording form used in the study.

The test signs were classified into one of six groups as indicated in Table 1. Three pairs of the test signs had different lengths of vertical curvature before the signs and three pairs had different degrees of horizontal curvature before the test sign. The vertical curve length represents the distance to the nearest elevated section of freeway, such as an overpass before the sign. These lengths represent the distances at which the roadway could obscure the signs.

However these signs may become visible before the vertical obstruction because the vehicle may be on another elevated section prior to the sign.

The horizontal curve degree represents the angle at which the sign is visible to the driver. For instance a zero to five degree horizontal curve sign should be in the direct line of sight of the driver. The 5-10 degree signs should be in the driver's peripheral vision. The 10-25 degree signs are outside this range.

The vertical curvature signs all fell into the 0-5 degree Horizontal Curvature Class and the horizontal curvature signs all fell into the greater than 1200 feet vertical obstruction class. This combination of treatment effects was considered reasonable since it represents most of the combinations on Houston freeways. The combination also insures against comparing signs having the same horizontal curvature but different vertical curvatures. Similarly, signs having the same vertical curvature are not compared to signs having different horizontal curvatures. So, even though this design does not admit a formal test of the interaction between comparable signs, Table 1 presents the classification categories, test signs, location of test sign, material used in sign construction, and the sign lighting condition (lighted versus unlighted). Since actual freeway guide signs were used in this study, because of economic and time constraints, it was not practical to install each of the test material combinations at each location. Two signs (one lighted and one not lighted) were found that fit a particular category. In all cases it was not possible to find all overhead or ground mounted signs with the same sign materials in the same geometric category. It was determined from the legibility study of this project and reported in Research Report 1-18-84-277-1 that there was no statistically significant difference in legibility distance between ground mounted and overhead signs, or by sign material. For this reason the signs were selected based strictly on their geometric conditions without respect to their mounting position and/or materials.

TABLE 1: Houston Research Study
Test Sign Conditions
Routes 1 and 2

Sign Group	Curve	Sign Type	Sign Materials	Lighting Condition	Installation Year
1	Vertical 300-800				
	Fannin	T-Mount	EG/BC	Lighted	72
	Williams Trace	Ground	OP/BC	Unlighted	83
2	Vertical 800-1200 ft.				
	Richmond	Overhead	HI/BC	Lighted	83
	Westcott	Median	EG/BC	Unlighted	84
3	Vertical 1200 ft.				
	Crestmont-King	Overhead	EG/BC	Lighted	72
	Long-Wayside	Overhead	HI/SO	Unlighted	84
4	Horizontal 0-5 Degrees				
	Westheimer	Overhead	EG/BC	Lighted	84
	Airport-Kirkwood	Ground	OP/SO	Unlighted	84
5	Horizontal 5-10 Degrees				
	Sugarland Exit	Overhead	SE/SO	Lighted	84
	Bissonett	Overhead	EG/BC	Unlighted	84
6	Horizontal 10-25 Degrees				
	Scott	T-mount	EG/BC	Lighted	72
	College Airport	T-mount	SE/BC	Unlighted	83

* Sign groups 1, 2 and 3 had horizontal displacements of 0 to 5°. Sign groups 4, 5 and 6 had vertical sight distance of greater than 1200 feet.

V. RESEARCH RESULTS

The results of this portion of the research project will be presented in two sections. The first section will present the results of the target value distance study and the second will present the results, the sign order study. Table 2, presents the results for each of the signs.

A. Target Value

The results of the target value distance study verify the original hypothesis that as critical sight distance is decreased, sign lighting becomes a significant factor in attention attraction. The lighted sign in the 300-800 feet unrestricted sight distance category had a significantly longer target distance (2995 feet) than the unlighted sign (1769 feet). The signs in the restricted sight categories had a restriction prior to or within the normal viewing distance of the sign. However, as indicated by the target value distance many signs were detected well in advance of the sight restriction. The lighted sign was located on a moderately complex loop freeway, whereas the unlighted sign was on a rural unlighted freeway section with low complexity. The lighting conditions in the 800-1200 foot category were not significantly different for the test signs. The lighted sign was located on a highly complex loop freeway with fixed freeway lighting and had a target value distance of 1698 feet. The unlighted sign was located on a moderately complex interstate radial freeway with fixed freeway lighting and had a target value of 1964 feet. Both signs were classified as overhead (one on an overhead sign bridge, the other median mounted on a cantilever). The sign with no obstruction greater than 1200 feet upstream of the test sign resulted in the unlighted sign having a significantly greater target value (2845 feet) than the lighted sign (1230 feet). Both signs are located on a moderately complex loop freeway with fixed freeway lighting and both are overhead mounted.

B. Vertical Alignment Results

Because of the complexity of the results several aspects of the results should be discussed. The first is the criteria used to select the three critical sight distance categories. The 300-800 foot category is computed from the location of the last physical observation (sign bridge, road bridge, vertical crests, etc.) to the test sign. In the Houston area there are only a minimal number of signs which have this critical sight distance problem. The two signs selected had obstructions between 700-800 feet from the sign. In both cases the obstruction was a vertical crest in the road surface. Both signs, however, were seen well in advance of the vertical crest because of the elevation of the roadway. If a motorist was not looking far upstream for the sign, he would have had approximately 750 feet to locate and read the sign. The 300-800 feet category was selected as the most critical sight distance problem. If the sign does not have at least 300 feet of sight distance it should not be visible to the driver. Drivers do not have sufficient time to read a sign in 300 feet at 55 mph since this distance allows the driver only 3.70 seconds to locate and read the sign.

Another important point to stress is that even though both the sign materials and sign locations were not significant factors with respect to legibility, they may be with respect to target value. The overhead lighted sign was constructed with engineer grade background and button removable copy. The ground mounted unlighted sign was constructed with an opaque background with button removable copy. The combination of the environmental factors, material and lighting factors explain the differences in the target value of the two signs. This relationship is difficult if not impossible to quantify and define. An operational study, such as the one conducted in this study could not realistically evaluate the impact each of these factors have on target value, either alone or in combination.

TABLE 2: Houston Research Study
Vertical and Horizontal Sight Distances
Tests Results
Routes 1 and 2

Sign Group	Curve	Sign Type	Sight Distances Lighted Average	Sight Distances Unlighted Average	Sign Material
1	Vertical 300-800				
	Fannin	T-mount	2995		EG/BC
	Williams Trace	Ground Mtd.		1769	OP/BC
2	Vertical 800-1200 ft.				
	Richmond	Overhead	1698		HI/BC
	Westcott	Median		1964	EG/BC
3	Vertical 1200 ft. or more				
	Crestmont-King	Overhead	1230		EG/BC
	Long-Wayside	Overhead		2845	HI/SO
4	Horizontal 0-5 Degrees				
	Westheimer	Overhead	2506		EG/BC
	Airport-Kirkwood	Ground Mtd.		1767	OP/SO
5	Horizontal 5-10 Degrees				
	Sugarland Exit	Overhead	2214		SE/SO
	Bissonett	Overhead		3046	EG/BC
6	Horizontal 10-25 Degrees				
	Scott	T-mount	1640		EG/BC
	College Airport	T-mount		1570	SE/BC

* Sign groups 1, 2 and 3 had horizontal displacements of 0-5°. Sign groups 4, 5 & 6 had vertical sight distance of greater than 1200 feet.

The 800-1200 feet category was selected as the transition zone between those locations with severe sight distance problems and those with no sight distance problems. Both of the test signs were selected because of their similarities with respect to location, sign material and type of facility. The resulting target values obtained from each of these signs support these similarities. The lighted sign was in a slightly more complex location than the unlighted sign, and this is reflected in the target value distances.

The two signs in the over 1200 feet sight distance category had almost identical environmental and complexity factors. The major difference between the two signs besides the sign lighting is the background and legend materials. The unlighted sign which had high specific-intensity reflective background had a target value of 2845 feet. The lighted sign which had engineering grade reflective sheeting had a target value of 1230 feet. The results of this study indicate that for those signs tested, both sign lighting and ambient lighting increase target value for signs in moderate to severe sight distance situations. Sign lighting does not appear to aid in the target value for those situations in which sight distance problems do not exist.

C. Target Value for Signs with Horizontal Displacement Problems

Many types of reflective sheeting have somewhat narrow ranges in which this reflectivity is held to a near maximum. After that angle is exceeded, the reflectivity drops off. Three categories were chosen for horizontal displacement. The 0-5 degrees category is entirely within the drivers foveal area. In this area the eye obtains maximum light acceptance and maximum discrimination. The two signs chosen to represent this resulted in rather extraordinary results. The lighted sign had a greater target value than the unlighted sign. This is contrary to what one would expect due to the amount of light in the immediate area. The reason for this will be discussed in the following section. The next category represented signs that fall in the drivers peripheral area and are reduced in retroreflectivity because of the displacement of the headlamps and the sign. The results indicated that the unlighted sign was seen significantly farther (3046 feet) than the lighted sign (2214). And in the final category greater than 10 degrees the lighted sign had a target value of 640 feet and the unlighted sign had a target value of 570 feet.

D. Discussion of Horizontal Displacement Target Value

The major reason that the lighted sign had a greater target value than the unlighted sign was due to complexity. As complexity increases the sign must get brighter to overcome the effects of complexity. It has not been determined at what level of complexity that brighter signs should be used and at what level contrast ratio of sign to background aids in target value. Another reason could be the effect on target value that sign location has as stated in the critical sight distance section, remembering that sign location did not significantly affect legibility distance. This assumption may not hold for shoulder mounted signs. There were three ground mounted signs included in the target value study and they ranged from 938 to 1776 feet. These target value distances are well beyond the legibility distances of 788 feet as determined in the legibility study. The unlighted sign in the 5-10 degrees category had a significantly greater target value (3046 feet) than the lighted sign (2214 feet). Both of these signs were over head mounted and constructed with the same background and legend material (Engineer Grade Reflective sheeting with high specific-intensity reflective copy). The sign with the longest target value was unlighted in a high ambient light environment (.90 foot candles) as compared to the lighted sign which was in a transition zone from urban to rural and had a lower ambient light level (.11 foot candles). It is the authors' belief that the ambient light level was the major difference in the target value distance. In the over 10 degrees horizontal plane two raised T-mounted signs were selected to evaluate the T-mounts target values. The results of this study indicates that raised T-mounts did not have as great a target value as other sign types regardless of the lighting condition. The lighted sign had target value of 1640 feet and the unlighted sign 1570 feet. The target values are more than double the legibility distance for all types of sign materials.

E. Sign Ordering

The Statistical analysis for this portion of the study is contained in Appendices D, E, and F. In this study several important issues with respect to target value were considered. The analysis also established the validity of the target value study as conducted. The issues considered in this study included: (1) Was there any particular order in which subjects saw the signs or was it random? (2) Is there a different probability associated with detecting an overhead sign than a ground mounted sign? (3) Did sign lighting have an effect on subjects detecting signs?

F. Results of the Sign Ordering Analysis

The results of the analysis indicates that the sequence in which the subjects detected the signs were not random. Each driver (subject) generally detected the sign in a similar order. The order was not exactly the same and/or correct with respect to true roadside placement. Two signs were consistently reversed by most drivers. One was a ground mounted sign and the other was a lighted overhead sign. The lighted overhead sign was detected consistently before the ground mount sign. The spatial difference between the two signs was 283 feet.

A statistical model was developed to determine the probability of detecting a sign in the correct order. This model determined that the distance between signs is an important variable in predicting the orderly sign detection. This means that signs farther apart will usually be seen in the proper order than closely spaced signs. This conclusion is even further complicated if the one sign is lighted and the other sign unlighted.

The second important issue was to determine whether the probability of detecting ground-mounted signs are the same as that of overhead signs. The results, indicated that the probability of detecting an overhead sign is more than two times that of detecting a ground mounted sign.

The final issue was to determine the effect sign lighting had on the correct detection of signs. This statistical model using distance indicated that the slopes and intercepts were significant at the 10% level, which means that lighting has a weak effect on correct sequencing of sign detection.

VI. STATES AND TRAFFIC ENGINEERS OPINIONS ON SIGN LIGHTING

Introduction

No study of sign lighting can be complete without determining the action other states have already taken and the feelings of the traffic engineer with respect to sign illumination. This portion of the study was developed to obtain information regarding freeway guide sign illumination that cannot be determined through field or laboratory studies. The issues addressed in this study include (1) Policies other states have with respect to urban freeway guide sign lighting. (2) The types of sign materials used when signs are not illuminated. (3) Is it necessary for drivers to see the green background on nonilluminated signs? (4) What restriction each state places on nonilluminated urban freeway guide signs. Two studies conducted in this project will be discussed.

Questionnaire Study

The first study was conducted by Dexter Jones at the 1982 SDHPT Traffic Engineering Conference. This study was a questionnaire study administered to sixty-five State traffic engineers attending the conference. Appendix G, contains the complete questionnaire.

Results:

The results of 9 of 10 questions are presented in Figures 1, through 8. The results indicate that 77 percent of the respondents felt that overhead guide signs did not need to be lighted. The remaining 33 percent indicated that overhead guide signs should be lighted.

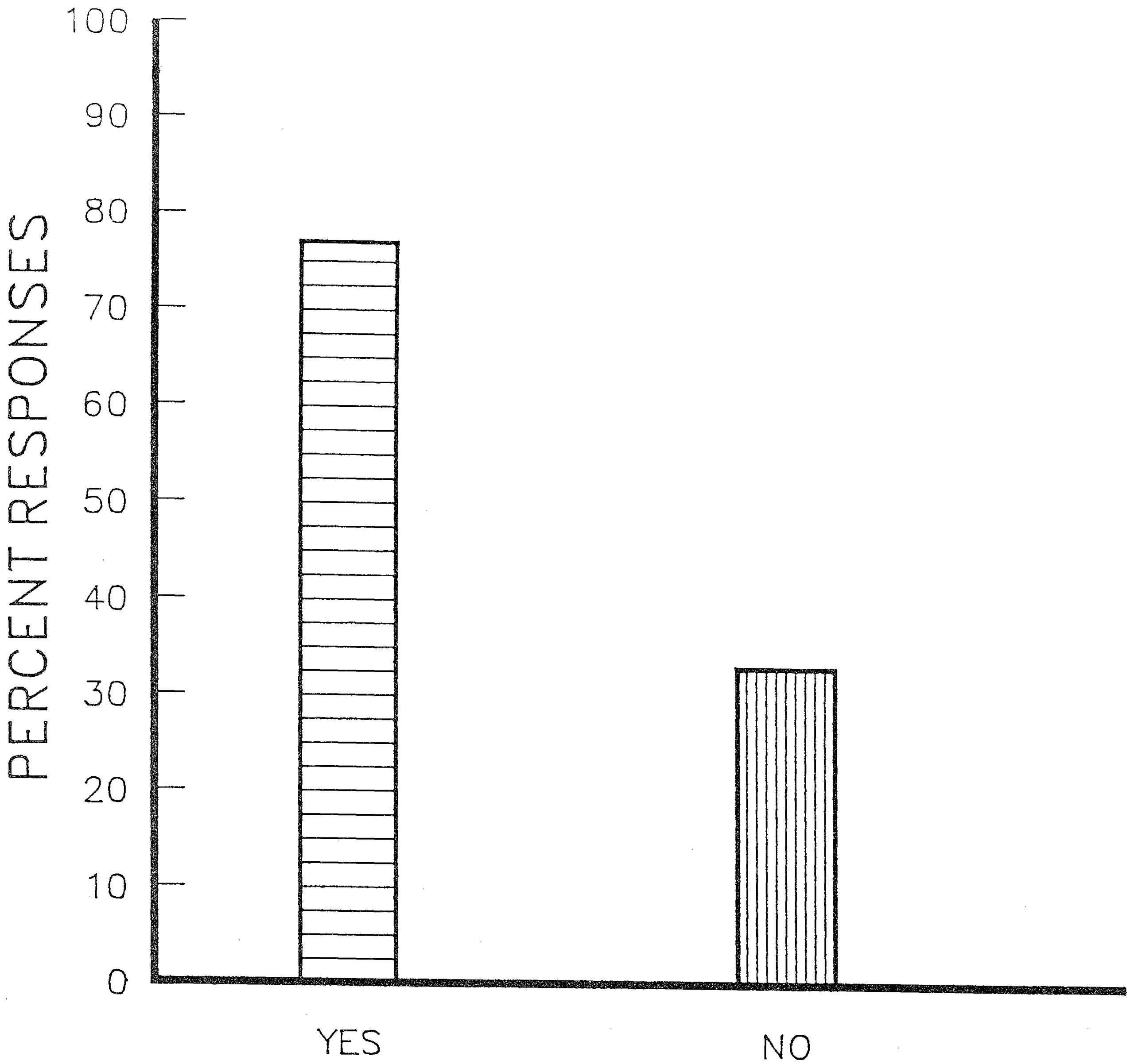


Figure 1: Do you feel that all overhead guide signs should be lighted?

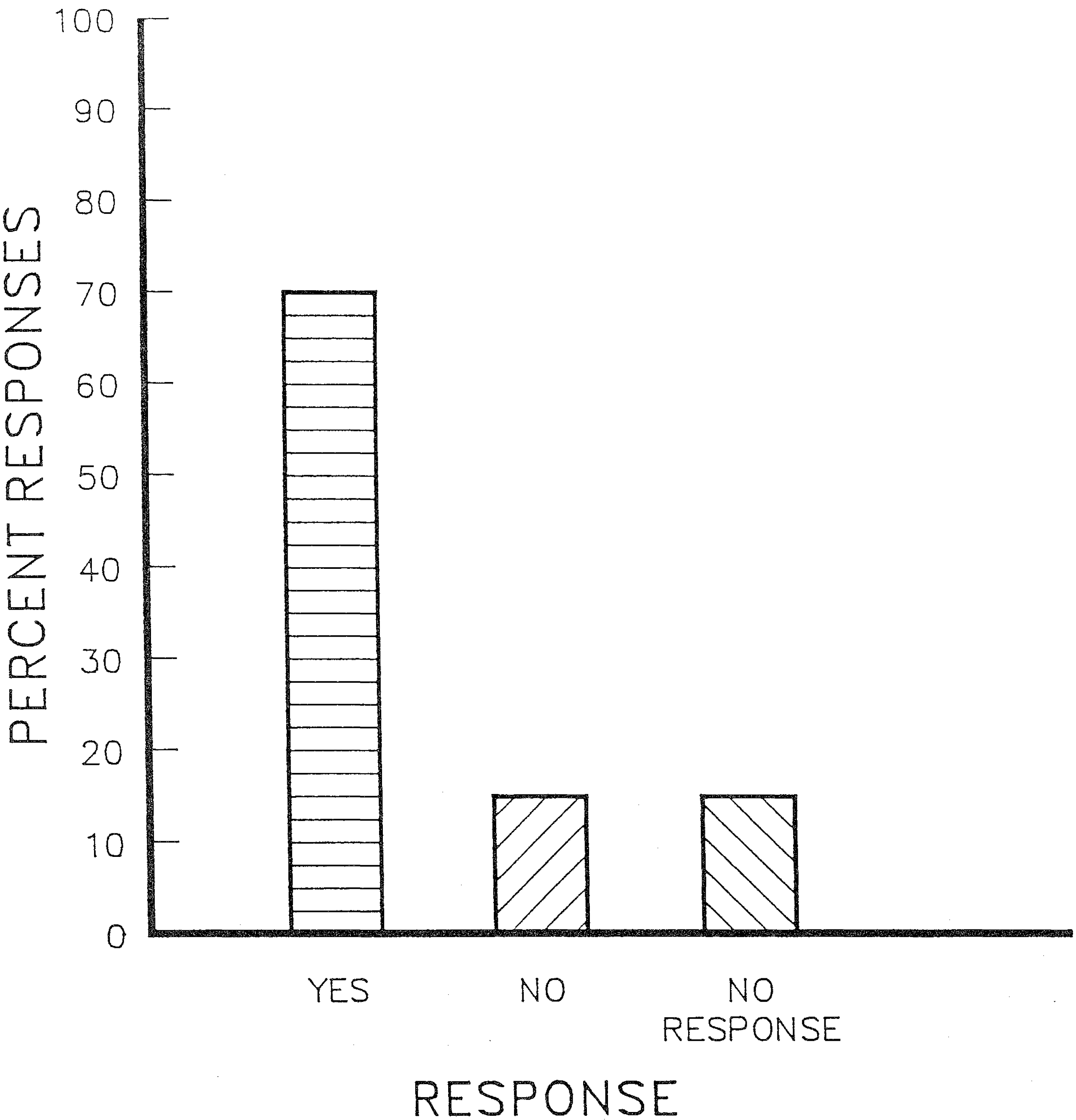


Figure 2: Do you feel that it is mandatory for the unlighted sign to appear green at night?

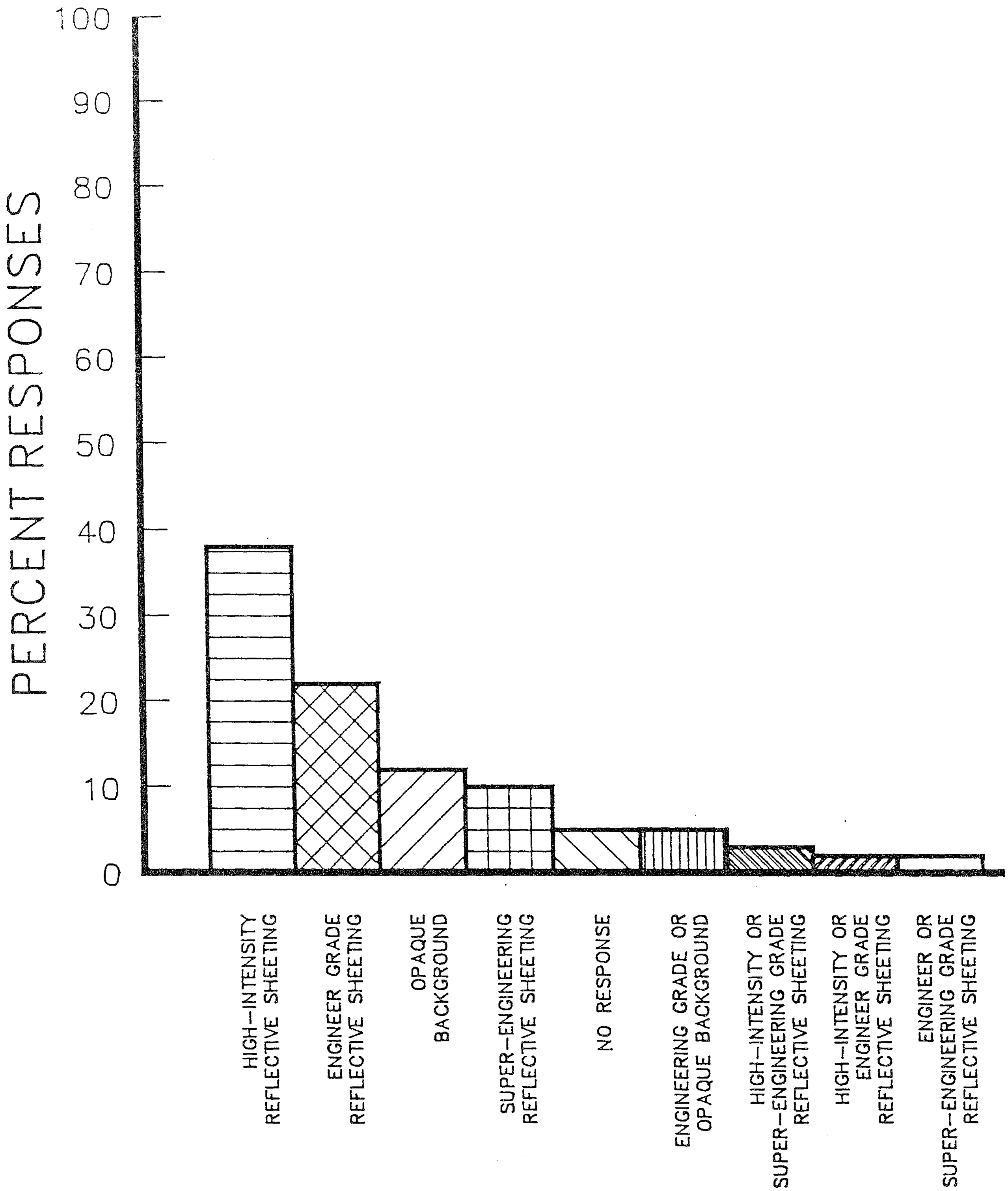


Figure 3 : In a rural unlighted freeway and an unlighted sign condition, would you use engineer-grade reflective sheeting, super-engineering grade reflective sheeting, high-intensity sheeting or an opaque background?

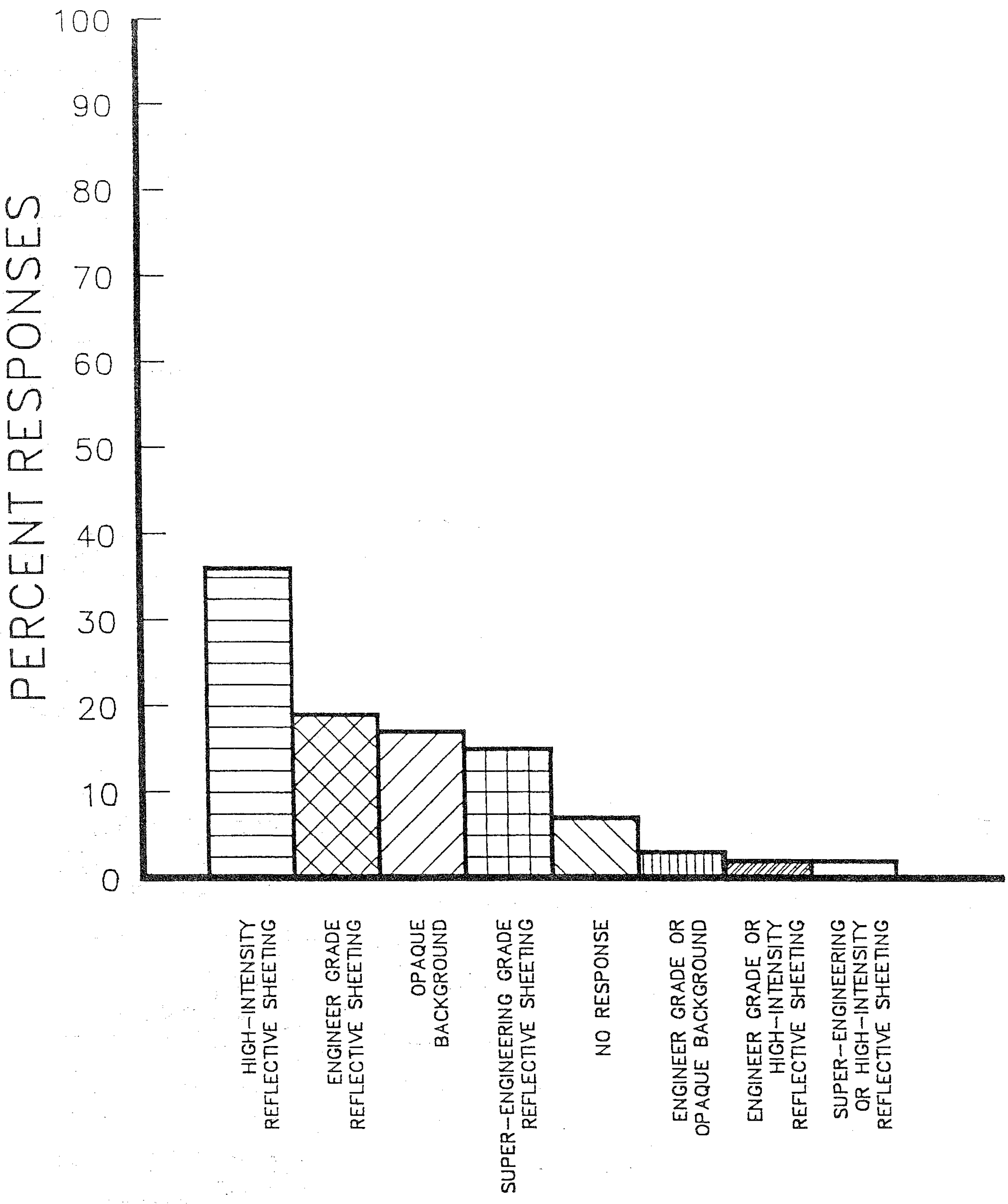


Figure 4: Which of the four backgrounds would you use in an urban lighted freeway and an unlighted sign condition?

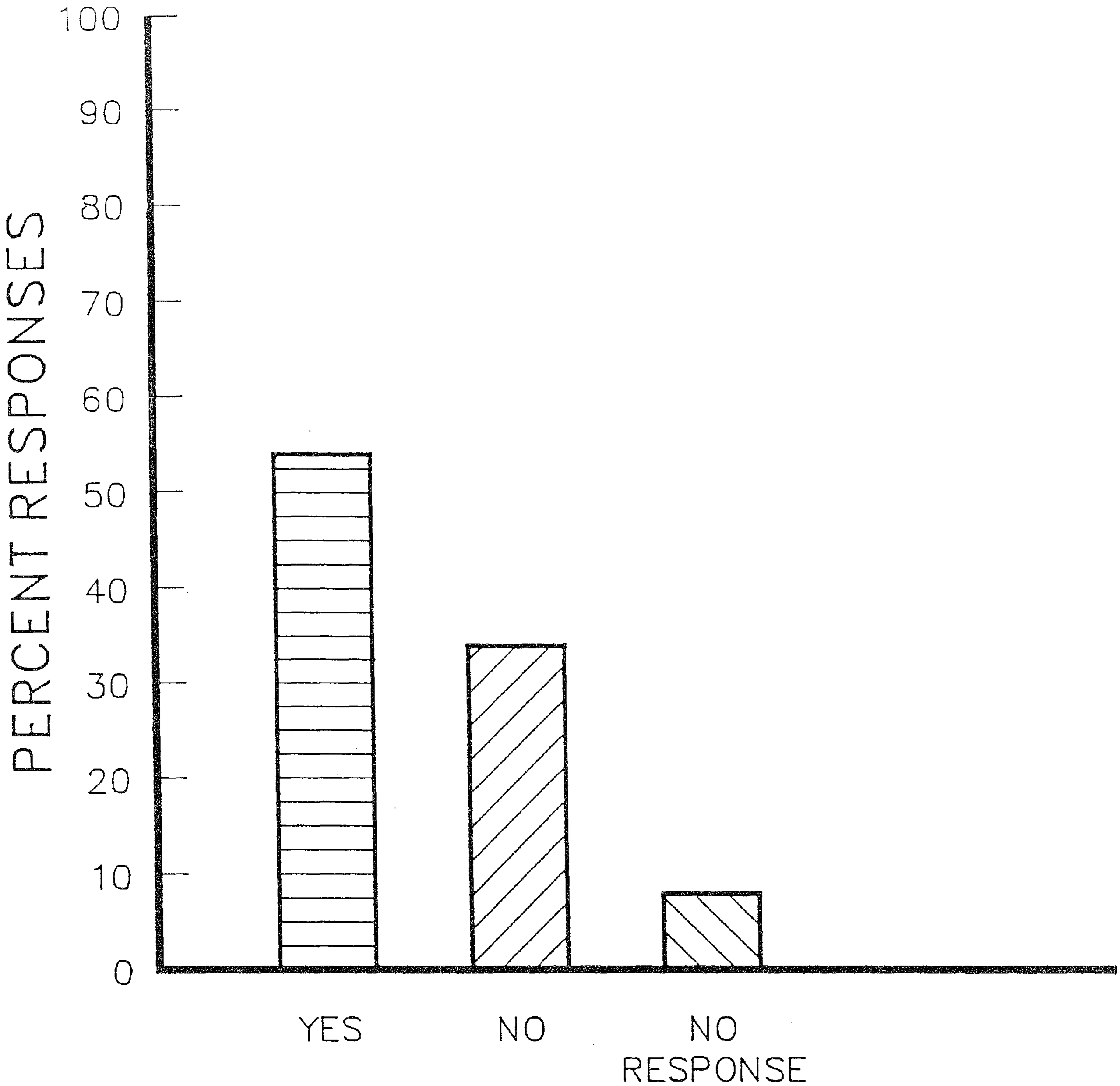


Figure 5 : Considering costs, hazards of maintenance operations and hazards to the traveling public caused by maintenance operations, do you feel that the background material should have the longest life possible regardless of whether it is reflective or not?

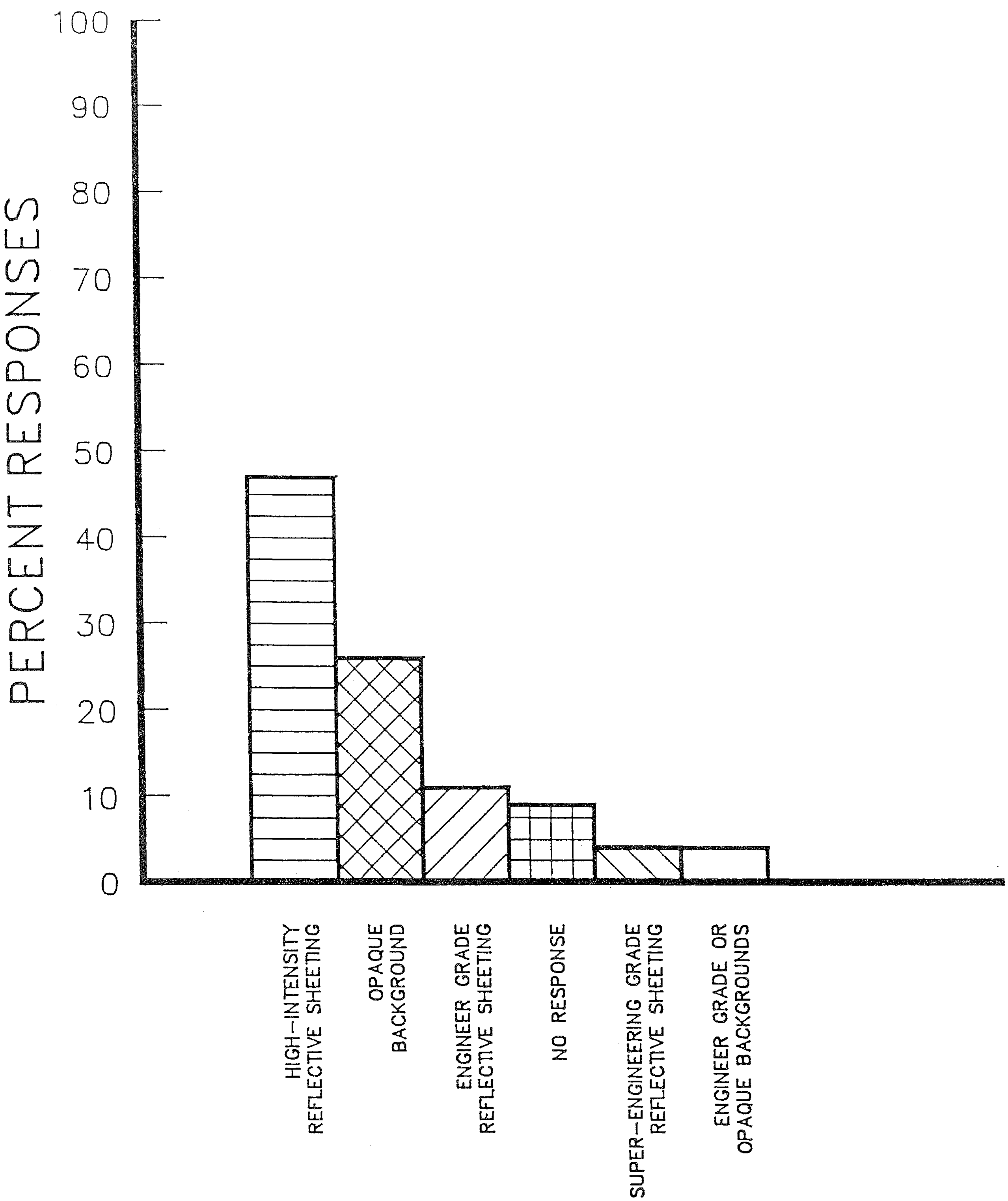


Figure 6 : Considering engineer-grade reflective sheeting has a 10-year life, super-engineering-grade has 10 years, high-intensity sheeting has 20 years and polyester opaque background has 50 years, which background would you use in an unlighted condition?

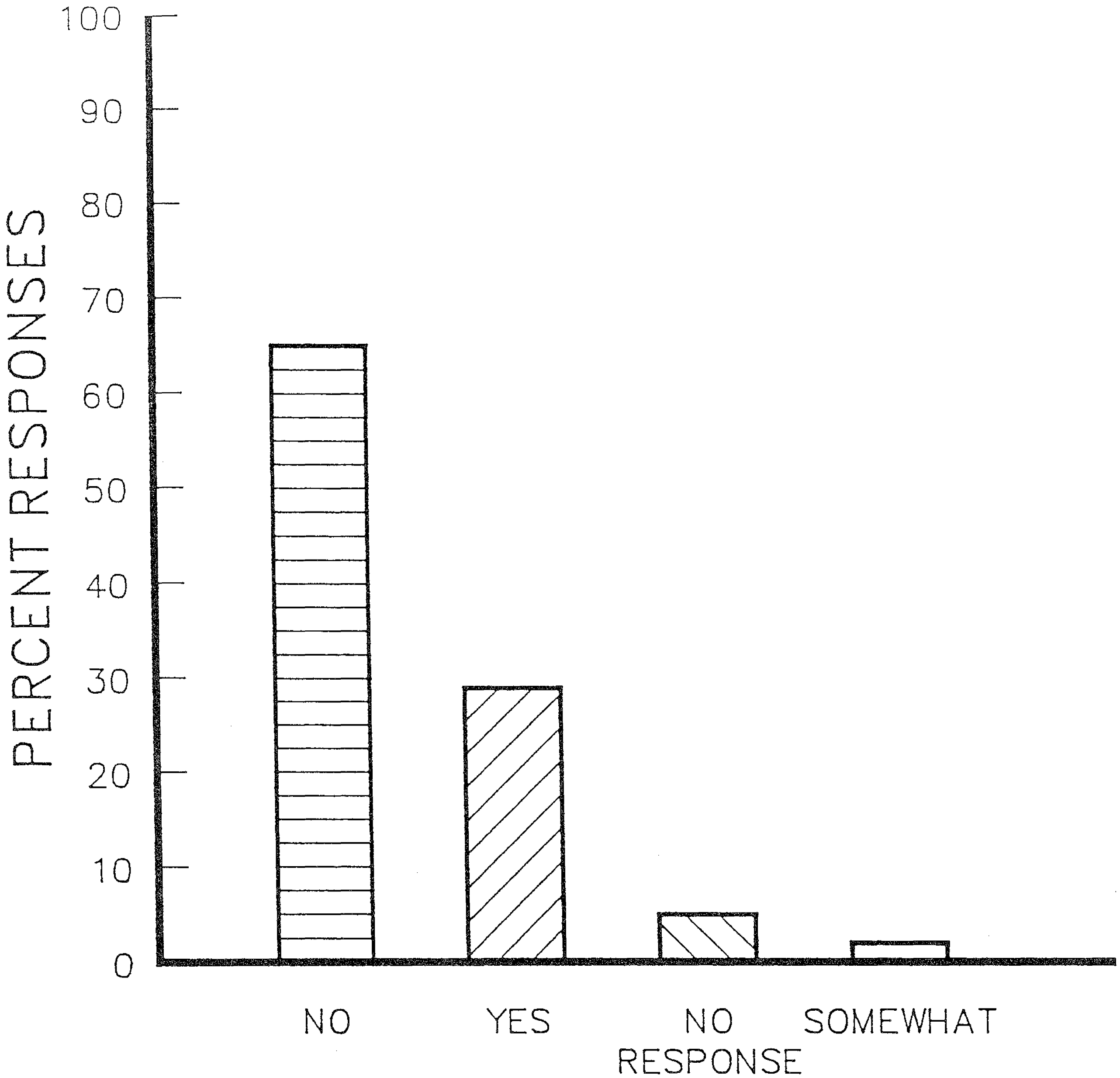


Figure 7 : Does the fact that opaque backgrounds such as polyester appear black at night bother you?

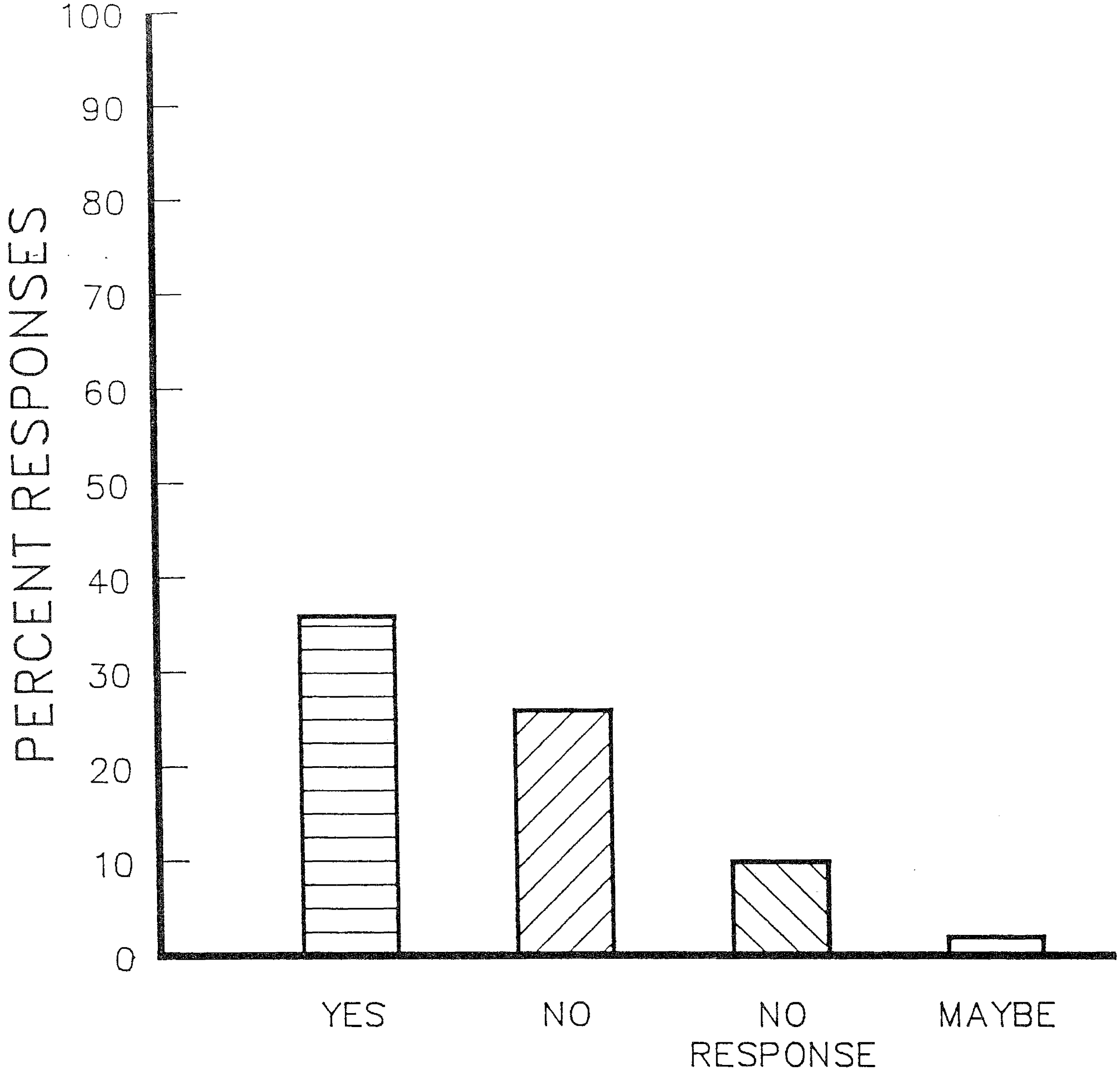


Figure 8 : Do you feel that with 1100'-1200' clear sight distance the opaque non-reflective copy gives adequate legibility distance in an unlighted condition?

The majority of the respondents to question 2 stated that they felt it was unnecessary for drivers to see green backgrounds at night. Seventy (70) percent of the respondents said they did not think it was mandatory to see green at night and fifteen (15) percent felt it was mandatory that drivers see green at night. Fifteen (15) percent of the traffic engineers either did not know, or did not understand the question.

Question 3 responses indicated that for normal unlighted overhead guide signs high specific-intensity reflective sheeting should be used. Thirty-eight (38) percent said they would use high specific-intensity reflective sheeting, twenty-two (22) percent said they would use Engineer Grade, Twelve (12) percent opaque and ten (10) percent super engineering grade reflective sheeting. Five (5) percent either did not understand the question or did not answer. The remaining respondents indicated a combination of the four types of Sign Materials.

Question 4 responses indicate that on lighted urban freeways with unlighted guide signs, the engineers still preferred high specific-intensity reflective sheeting. Thirty-six (36) percent responded they would use the high specific-intensity reflective sheeting on urban freeways. The order of sign material used was identical as for those used in the rural situation. Nineteen (19) percent responded they would use engineer grade sheeting, seventeen (17) percent would use opaque, and fifteen (15) percent super engineering grade reflective sheeting. Except for the high specific-intensity sheeting there is virtually no significant difference between the other three types of sign material.

The majority of the traffic engineers felt that the sign materials with the longest service life should be used in sign construction because of maintenance costs. Fifty-four (54) percent indicated they would use the material with the longest service life, whereas thirty-four (34) percent said they would not. Twelve (12) percent did not answer the question.

Forty-seven (47) percent selected high specific-intensity as the preferred sign material, twenty-six (26) percent selected opaque, eleven (11) percent engineering grade and four (4) percent would use super engineering grade. Nine (9) percent did not answer the question.

Over fifty (50) percent of the traffic engineers responding to the questionnaire indicated that an overhead guide sign which appeared black to them would not disturb or affect their driving abilities. Sixty-five (65) percent said that they would not be bothered by a black background, whereas, twenty-nine (29) percent said it would bother them. Five (5) percent did not respond.

In question 8 the traffic engineers were asked to prioritize seven different problem areas for maintenance. The priority provided by the engineers is given below: (The rank is in decending order).

Potholes in Roadway Pavement
Damaged Bridge Road
Spalled Bridge Deck
Damaged Guard Rail
Damaged Light Pole
Deteriorated Overhead Sign Panel
Non-Functioning Sign Light

These responses are obviously based on legal implications. It is extremely difficult to prove that an accident was caused by a badly deteriorated sign or one that is not lighted.

Over fifty (50) percent of the engineers felt that 1100-1200 feet clear sight distance is adequate, for an opaque background with reflective copy gives adequate legibility distance. Sixty-two (62) percent responded yes and twenty-six (26) percent responded no. Two (2) percent indicated that nonreflective copy may not provide sufficient legibility distance even with the 1100-1200 feet clear sight distance.

Telephone Survey

As a supplement to the questionnaire study a telephone survey was conducted as part of this research project. Eight (8) states were selected as participants in the survey. The states bordering Texas, Louisiana, Oklahoma, and New Mexico along with California, New Jersey, Pennsylvania, Michigan and Washington were selected as participants. Each state responded to all five (5) questions. Appendix H, contains all five questions used in the telephone survey.

Results

In the first question there was an even split between those states that had formal published sign lighting policies and those that have informal unpublished guidelines. In response to the question regarding the factors used in establishing the state policy we obtained a mixture of responses. Louisiana said that sign lights were used only in critical areas. California uses sign lights on "Action Messages" and locations where there is a critical sight distance. Washington does not illuminate reflectorized signs. Appendix H, also contains the answers for each question by state.

APPENDIX A

OVERHEAD SIGN SURVEY
(TARGET VALUE STUDY TEST)

OVERHEAD SIGN SURVEY

1. Number of overhead signs on your highway system

<100 100-500 500-1000 >1,000

2. What % of your overhead signs are lighted?__________Approx.

3. What type of light source is used?

Fluorescent Mercury Other________________________

4. Approximate cost per year per sign to maintain and supply energy to each sign light ________________________

5. Is your current policy to light all overhead signs?

Yes No

6. If you answer number 5 with a No, what material do you use on the overhead signs?____

____

____

7. In your professional judgement, do you think overhead signs should always be lighted?____________________________________

____

____

8. Do you then think the wording in the present Manual on Uniform Traffic Control Devices on overhead signs should be changed? If so, to what?____

____

____

ROUTE 1

KEY: START TAPE @ Airport Kirkwood (Overhead) ////////////////////////////

Start sequence at Sugarland 1 Mile

Overhead	____	Ground	____
Ground	____	*4 Overhead	____
Ground	____	Ground	____
Overhead	____	*5 Ground	____

Test sign Alt Spur 90 41 overhead Sugarland Exit Only — Test Sign Distance ____

Test sign Williams Trace Blvd. ground — Test Sign Distance ____

Exit Williams Trace Blvd.

KEY: START TAPE @ Kirkwood/Airport ////////////////////////////////////

Start sequence at Harris Co. (Ground) (Northbound)

Ground ____
Ground ____
Ground ____
Ground ____
Ground ____
*6 Overhead ____

Test sign Bissonnett Road (Unlighted) — Test Sign Distance ____

KEY: START TAPE @ Hillcroft Ave (Overhead) /////////////////////////////////

Start sequence at Chimney Rock (Overhead)

Overhead	____	Overhead	____
Ground	____	Overhead	____
Overhead	____	Overhead	____
Overhead	____	Overhead	____
Overhead	____	Ground	____
Overhead	____	Overhead	____
Ground	____	Overhead	____
*7 Ground	____	*8 Overhead	____
Overhead	____		
Overhead	____		
Ground	____		

Test Sign: San Felipe Road next right (unlighted) — Test Sign Distance ____

Test Sign: Westcott St. 1/4
Washington 1/2 (Overhead) — Test Sign Distance ____
T.C. Jester 1 1/4 (Lighted)

End of Route 1 Continue Driving Until You Reach 288

ROUTE 2
I 610 - I45

KEY: START TAPE @ Fannin St. Exit///

Start sequence at Almeda Rd. (Overhead 610 S - Eastbound)

Overhead ____
Ground ____
Overhead ____
Ground ____
Overhead ____
Ground ____
*1 Overhead ____
Overhead ____
Overhead ____
Overhead ____
Overhead ____

*2 Overhead ____
Overhead ____
Overhead ____
Overhead ____
Ground ____

*3 Overhead ____

1. Test sign Scott St. Exit 1 mile (Lighted) Test Sign Distance ____
2. Test Sign Calais/M.L. King (Unlighted) Test Sign Distance ____
3. Test sign Long/Wayside (Unlighted) Test Sign Distance ____

KEY: START TAPE @ Alvin Next Right Texas 35 ////////////////////////////////

Start sequence at I-45 Galveston (Turn of Bridge)

Overhead ____
Ground ____
Overhead ____
Overhead ____
Overhead ____
Ground ____
Overhead ____
Ground ____
Overhead ____

Ground ____
Overhead ____
Ground ____
*4 Overhead ____

4. Test sign College Ave/Airport Blvd. (UnLighted) Test Sign Distance ____
1 Mile
Exit South Belt Scarsdale Blvd.

CONTINUED ROUTE 2

KEY: START-TAPE @ After Exiting ////////////////////////////////////

Start Sequence at Fuqua St. Right Lane (Ground)

Ground ____
Overhead ____
Ground ____
Ground ____
Ground ____
*5 Overhead ____

Test Sign Clearwood Dr. Overhead — Test Sign Distance ____
Edgebrook Dr.
Exit 3/4

KEY: START TAPE @ Gulfgate ////////////////////////////////////

Start sequence at Woodridge Dr.
Telephone Dr.

Overhead ____
Ground ____
Overhead ____
Overhead ____
Ground ____
Overhead ____

*6 Overhead ____
Ground ____
Overhead ____
Ground ____

6. Test Sign Crestmont Rd/M.L. King Rd. (Lighted) — Test Sign Distance ____

KEY: START TAPE @ Calais /Holmes//

Start sequence at Scott Rd 2/10

Overhead ____
Overhead ____
Ground ____
Overhead ____

Ground ____
Overhead ____
Ground ____
*7 Overhead ____

Ground ____
Overhead ____
Overhead ____

7. Test sign Fannin St. 1/2 mile T-Mount (Lighted) — Test Sign Distance ____

CONTINUED ROUTE 2

KEY: START TAPE @ Stella Link Rd.///

Start sequence at Evergreen/Bellaire (Lighted)

*8 Overhead ____
Ground ____
Ground ____
Ground ____
Overhead ____
Ground ____
Overhead ____
Ground ____
Overhead ____
Ground ____

Ground ____
*9 Overhead ____
Ground

8. Test sign Evergreen /Bellaire 2/10 Mi.(Lighted) Test Sign Distance ____
9. Test sign Westheimer (Lighted) Test Sign Distance ____

APPENDIX B

DISTANCES BETWEEN SIGNS IN ROUTES

ROUTE 1
I 610 - US 59

START SEQUENCE AS SOON AS YOU ENTER FREEWAY ON I-10 @ WASHINGTON

OVERHEAD	0
OVERHEAD	1972
GROUND	2222
OVERHEAD	2658
OVERHEAD	5271 *1

*1 WOODWAY DR

START SEQUENCE @ RICHMOND 1 1/10 MILE SIGN (OVH)

OVERHEAD	0
OVERHEAD	4580 *2

*2 RICHMOND AVE. 3/10 (LIT)

START SEQUENCE AT FONDREN RD. EXIT 3/4 MILE

OVERHEAD	0
GROUND	411
GROUND	1350
OVERHEAD	3683
GROUND	6759
OVERHEAD	7955
GROUND	8366
GROUND	13168
GROUND	13895
OVERHEAD	15555
GROUND	15730
GROUND	22568
GROUND	23695
OVERHEAD	24748
GROUND	25160
GROUND	27045
GROUND	28959 *3

*3 AIRPORT/KIRKWOOD 1/2 MILE (NOT LIT)

ROUTE 1
I 610 - US 59

START SEQUENCE @ SUGARLAND 1 MILE

OVERHEAD	0	
GROUND	364	
GROUND	2816	
OVERHEAD	3474	
GROUND	4895	
OVERHEAD	6063	*4
GROUND	9793	
GROUND	11604	*5

*4 ALT SPUR 90 41 SUGARLAND EXIT ONLY

*5 WILLIAMS TRACE BLVD

START SEQUENCE AT HARRIS CO.

GROUND	0	
GROUND	568	
GROUND	3329	
GROUND	8128	
GROUND	10219	
OVERHEAD	12026	*6

*6 BISSONNETT ROAD (NOT LIT)

START SEQUENCE AT CHIMNEY ROCK

OVERHEAD	0	
GROUND	112	
OVERHEAD	3906	
OVERHEAD	4708	
OVERHEAD	5456	
OVERHEAD	9838	
GROUND	10207	
GROUND	10681	*7
OVERHEAD	11293	
OVERHEAD	12312	
GROUND	12421	
OVERHEAD	15630	
OVERHEAD	19456	
OVERHEAD	23172	
OVERHEAD	24031	
GROUND?	24148	
OVERHEAD	24838	
OVERHEAD	26920	
OVERHEAD	28987	*8

*7 SAN FELIPE ROAD NEXT RIGHT (NOT LIT)
*8 WESTCOTT/WASHINGTON (LIT)

ROUTE 2
I 610 - I 45

START SEQUENCE AT ALMEDA RD.

OVERHEAD	0		OVERHEAD	12059	
GROUND	94		OVERHEAD	12676	
OVERHEAD	3226		OVERHEAD	13736	
GROUND	3372		OVERHEAD	15570	
OVERHEAD	4005		OVERHEAD	19300	
GROUND	4187		OVERHEAD	21219	
OVERHEAD	7457	*1	GROUND	23024	
OVERHEAD	8489		OVERHEAD	23593	*3
OVERHEAD	10092				

*1 SCOTT ST. EXIT 1 MI. (LIGHTED)

*2 CALAIS/M.L.K. (UNLIGHTED)

*3 LONG/WAYSIDE (UNLIGHTED)

START SEQUENCE AT I-45 GALVESTON

OVERHEAD	0	GROUND	7023	
GROUND	104	OVERHEAD	9085	
OVERHEAD	2546	GROUND	10196	
OVERHEAD	4026	OVERHEAD	11448	
OVERHEAD	4642	GROUND	11748	
GROUND	5066	OVERHEAD	13161	*4
OVERHEAD	6490			

*4 COLLEGE/AIRPORT BLVD. 1 MI

ROUTE 2
I 610 - 45

START SEQUENCE AT FUQUA ST. RIGHT LANE

GROUND	0	
OVERHEAD	1354	
GROUND	5746	
GROUND	7235	
GROUND	7921	
OVERHEAD	9546	* 5

*5 CLEARWOOD/EDGEBROOK EXIT 3/4 MI

START SEQUENCE AT WOODRIDGE DR. - TELEPHONE DR.

OVERHEAD	0	OVERHEAD	7932	
GROUND	170	OVERHEAD	11412	*6
OVERHEAD	5071	GROUND	11577	
OVERHEAD	6541	OVERHEAD	12450	
GROUND	6683	GROUND	14672	

*6 CRESTMONT RD/M.L.K. (LIGHTED)

START SEQUENCE AT SCOTT RD 1/2 MILE T-MOUNT

OVERHEAD	0	GROUND	9276	
OVERHEAD	1310	OVERHEAD	9562	*7
GROUND	1399	GROUND	10079	
OVERHEAD	1763	OVERHEAD	12810	
GROUND	4779	OVERHEAD	14151	
OVERHEAD	5478			

*7 FANNIN ST. 1/2 MILE T-MOUNT (LIGHTED)

ROUTE 2
I 610 - I 45

START SEQUENCE AT EVERGREEN/BELLAIRE

OVERHEAD	0	*8	OVERHEAD	13075	
GROUND	422		GROUND	14131	
GROUND	990		OVERHEAD	14311	
GROUND	1094		GROUND	14337	
OVERHEAD	1497		GROUND	14338	
GROUND	1703		OVERHEAD	18751	*9
OVERHEAD	9878				

*8 EVERGREEN/BELLAIRE 2/10 MI (LIGHTED)

*9 WESTHIEMER (LIGHTED)L

APPENDIX C

TARGET VALUE STATISTICAL ANALYSIS

This appendix contains the results of a study of sign target distances. The objective of this study was to examine differences in the effects of lighting on target distances under different vertical and horizontal road curvature approach configurations.

Three pairs of the test signs had different lengths of vertical curvature before the signs and three pairs had different degrees of horizontal curvature before the test sign. The vertical curve length represents the distance to the nearest elevated section for freeways such as an overpass before the sign. These lengths represent the distances that the roadway or other obstacles can obscure the sign. However these signs may become visible before the vertical problem because the vehicle may be on another elevation before the obstruction nearest the sign. The horizontal curve degree represents the angle that the sign should be visible. For instance a zero to five degree horizontal curve sign should be in the direct line of sight of the driver. The 5-10 degree signs should be in the unfocused but noticeable section for the driver's peripheral vision. The 10-25 degree signs are outside this range.

The vertical curvature signs all fell into the 0-5 degree horizontal curvature class and the horizontal curvature signs all fell into the greater than 1200 feet vertical sight distance. This combination of treatment effects was considered reasonable since it represents most of the combinations on Houston freeways. The combination also insures against comparing signs having the same horizontal curvature but different vertical curvatures. Similarly, signs having the same vertical curvature are not compared to signs having different horizontal curvatures. So, even though this design does not admit a formal test of the interaction between horizontal and vertical curvature, the tests being made are based on comparable signs.

The basic question of this study is to find and explain the differences in target distances due to lighting within and between the groups of vertical and horizontal curve configurations.

There are 3 vertical curvature groups and 3 horizontal curvature groups. The difference in the lighted versus unlighted target distances for each individual were calculated and used as the response variable. The mean difference was tested for equality to zero using the paired test for each of the six groups. The mean differences were also compared for the three vertical curvature groups and for the three horizontal curvature groups.

Table 4 has the results of the paired tests for testing the average target distance. When there is no difference between lighted and unlighted signs the distance is zero. Lighting improved the target distance by 1226 feet in the vertical curve group of 300-800. There was no improvement due to lighting in the 800-1200 feet group. Finally the group for more than 1200 feet vertical curve had significantly higher target distances when the sign was unlighted. The unlighted signs were targeted sooner than the lighted signs on an average of 1615 feet. A one way ANOVA for these three groups shows that the three vertical sight distance groups have different average target distance differences for lighted and unlighted signs. These results at first seem confusing, but really are not. The short vertical sight distance group needs a lighted sign to cue the driver at longer distance since the short vertical sight distance may in fact obscure the sign. Furthermore, the improvement in the signs with further than 1200 foot vertical sight distance was negligible at driving speeds of 60 mph even though the difference was significantly different from zero. The unlighted sign was targeted about 20 seconds before the lighted sign of the pair.

Lighting significantly improves the target value for the 0-5 degree horizontal curve by 739 feet on the average. However the unlighted sign of the 5-10 degree group was targeted earlier than the lighted sign by 832 feet which is significant. There was no significant difference between the lighted and unlighted sign target distance for the 10-25 degree horizontal curvature group. A one-way ANOVA with Duncan's multiple range test indicates that all three groups had significantly different average distances. Table 5 contains the Duncan's multiple range test for both the horizontal and vertical curvature results.

In both cases, an examination of residuals and influential points was performed. Points with a Cook's D greater than 0.1 were trimmed from the first analysis of variance and the ANOVA was rerun. None of the conclusions changed because the target distance differences were symmetrically distributed about the mean. Hence the averages were not changed dramatically by trimming points equidistant from the average.

TABLE 2: Houston Research Study
Vertical and Horizontal Sight Distances
Tests Results
Routes 1 and 2

Sign Group	Curve	Sign Type	Sight Distances Lighted Average	Sight Distances Unlighted Average	Sign Material
1	Vertical 300-800				
	Fannin	T-mount	2995		EG/BC
	Williams Trace	Ground Mtd.		1769	OP/BC
2	Vertical 800-1200 ft.				
	Richmond	Overhead	1698		HI/BC
	Westcott	Median		1964	EG/BC
3	Vertical 1200 ft. or more				
	Crestmont-King	Overhead	1230		EG/BC
	Long-Wayside	Overhead		2845	HI/SO
4	Horizontal 0-5 Degrees				
	Westheimer	Overhead	2506		EG/BC
	Airport-Kirkwood	Ground Mtd.		1767	OP/SO
5	Horizontal 5-10 Degrees				
	Sugarland Exit	Overhead	2214		SE/SO
	Bissonett	Overhead		3046	EG/BC
	Horizontal 10-25 Degrees				
	Scott	T-mount	1640		EG/BC
	College Airport	T-mount		1570	SE/BC

* Sign groups 1, 2 and 3 had horizontal displacements of 0-5°. Sign groups 4, 5 & 6 had vertical sight distance of greater than 1200 feet.

TABLE 3: AVERAGE TARGET DISTANCE DIFFERENCES BETWEEN LIT AND UNLIT SIGNS

VARIABLE	N	MEAN	STANDARD DEVIATION	T	PR>§T§
GROUP=300-800 VERT					
TARG_DIF	27	2057.1481481	801.83984127	13.33	0.0001
GROUP=800-1200 VERT					
TARG_DIF	27	-266.48148148	985.77261266	-1.40	0.1720
GROUP=1200+ VERT					
TARG_DIF	27	239.62962963	194.01509619	6.42	0.0001
GROUP=0-5 DEGREES					
TARG_DIF	27	738.33333333	931.35967604	4.12	0.0003
GROUP=5-10 DEGREES					
TARG_DIF	27	-1406.5925926	1028.3640578	-7.11	0.0001
GROUP=10-25 DEGREES					
TARG_DIF	27	90.70370370	386.03575112	1.22	0.2331

TABLE 4: RESULTS OF ANOVA ON CURVE TYPES FOR HORIZONTAL CURVES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TARG_DIF

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	2	65358248.0740741	32679124.0370370
ERROR	78	53923664.1481482	691329.0275404
CORRECTED TOTAL	80	119281912.2222222	

MODEL F = 47.27 PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TARG_DIF MEAN
0.547931	431.8868	831.4619820	-192.51851852

SOURCE	DF	TYPE I SS	F VALUE	PR > F
GROUP	2	65358248.0740741	47.27	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
GROUP	2	65358248.0740741	47.27	0.0001

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: TARG_DIF
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE, NOT THE EXPERIMENTWISE ERROR RATE.
ALPHA=0.05 DF=78 MSE=691329
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	GROUP
A	738.3	27	0-5 DEGREES
B	90.7	27	10-25 DEGREES
C	-1406.6	27	5-10 DEGREES

TABLE 5: RESULTS OF ANOVA ON CURVE TYPES
FOR VERTICAL CURVES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TARG_DIF

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	2	80628990.0987654	40314495.0493827
ERROR	78	42960752.4444445	550778.8774929
CORRECTED TOTAL	80	123589742.5432099	

MODEL F = 73.20 PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TARG_DIF MEAN
0.652392	109.6606	742.1447820	676.76543210

SOURCE	DF	TYPE I SS	F VALUE	PR > F
GROUP	2	80628990.0987654	73.20	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
GROUP	2	80628990.0987654	73.20	0.0001

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: TARG_DIF
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE.
ALPHA=0.05 DF=78 MSE=550779
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	GROUP
A	2057.1	27	300-800 VERT
B	239.6	27	1200+ VERT
C	-266.5	27	800-1200 VERT

APPENDIX D

SIGN ORDERING STATISTICAL ANALYSIS

Sign Order Statistical Analysis

The main objective of this analysis is to study the order in which signs were observed through a test route, and then to determine if differences in observation order could be attributed to distances between signs, sign mount type, test sign type, or sign lighting.

The data was collected during the target distance study by recording the order of the signs as the experimenter passed through the test course. Table 6 contains the data. The order of the signs is recorded in each column for each of the subjects in the experiment. The last column contains the percent of correct observations of the signs.

Friedmans test was used to determine if the test signs were seen in a random order. This test uses the individuals as "judges" who assign an order to the signs. The test statistic is analogous to a randomized block design in the usual analysis of variance where the average ranks are compared. Logistic regression was used to determine the causes of sign order switching and distances between signs were used as covariance. The binary response was a 1 if a sign was not seen in its proper order, and it was a 0 if a sign was seen in its proper order. If the response was 1, the distance to the sign that should have been seen was used as a covariant. If the response was 0, the distance to the nearest sign was used as a covariant. The reason for assigning these covariance was the notion that close signs are confused more often than not. On the other hand, if the signs were not confused as often, one would think the signs were further apart.

<u>The results of the Friedmans tests indicate that all of the sign groups in the analysis were not seen in a random order.</u> That is to say, all hypothesis were rejected (alpha=.05) that the ranks were assigned in random order. The results are contained in Table 6.

The number of treatments in Table 6 represents the number of signs in the particular data set. The number of columns in the data set also represents the number of signs in a particular data set. The value of the test statistic is the results of the Friedman test statistic and has the indicated number of degrees of freedom from a chi-square distribution. If the p-val is less that .05, the null hypothesis of random ordering is rejected. The columns represent the sensitivity of the test statistic to a sign. The rank sum column is the sum of ranks for sign i, and the expected sum is the sum of ranks expected under the hypothesis of random ordering of the signs. The variance is the divisor of the i'th term in the test statistic. The standard residual is the i'th term of test statistic and represents the degree of departure from the null hypothesis contributed by the i'th sign. Each standardized residual has a chi-square distribution with one degree of freedom, so the p-val column represents the probability of obtaining a more extreme residual. The p-val is a diagnostic commonly used in ordinary analysis of variance.

Although the hypothesis of random ordering of the signs was rejected in all cases by Friedmans test, this does not indicate that all signs were seen in the correct order. In fact, the Scott Street test sign 8 was seen consistently before the Scott Street sign 7. However the Scott Street sign reversal was the case in this study having a reversal. The Scott Street sign 7 was a ground mount unlighted sign, whereas the Scott Street sign 8 was an overhead lighted sign. Also the signs were only 283 feet apart. The grouping of these three conditions were unusual for the data in this study and explained why the test sign was seen in the correct order in only 11 percent of the cases. The reversal had a very strong effect on the decisions for the logistic regression, and hence was removed from the analysis.

Logistic regression was used to model the probability that a sign was seen in the correct order. The model for predicting the probability of seeing a sign in the correct order given the distance to the next signs is given by

$$\text{In } (p/(-p))=-2.957 + 0.001512 * D \qquad (1.$$

where p = probability of sign being seen in the correct order

D = a. Distance to nearest sign if seen correctly
b. Distance to the sign that it was confused with if the sign was not seen in the correct order with D in the range of 146 to 1914 feet for both a. and b. above.

Both parameters in equation 1 were significantly different from zero which indicates that the distance between signs is an important measurement for predicting orderly sign targeting. The distances from the first sign in a test section are contained in Appendix B.

Distance also was a significant covariate when testing for the effect of mount, test sign types, and lighting. The coefficients for the models are calculated from the output by using the following formula for an effect, say A, having 2 levels.

$$\ln(p/(1-p))=(b1+b2) + (b3+b4) * D \text{ for level 1 of A} \qquad (2a.$$
$$=(b1-b2) + (b3-b4) * D \text{ for level 2 of A} \qquad (2b.$$

where b1 through b4 are taken from the coefficients in tables. The two logistic regression equations for comparing ground to overhead mount types given the distance separating signs are:

$$\ln(p/(1-p))= -2.390 + 1.202 \text{ E-3} * D \text{ for ground mounts} \qquad (3a.$$
$$= -4.352 + 2.609 \text{ E-3} * D \text{ for overheads} \qquad (3b.$$

Both intercepts and slopes of these equations are significantly different, which indicates that orderly targeting of ground mount and overhead signs have different probability distributions. The logistic regression equations for the lighted and not unlighted sign comparison are:

ln(p-))= -3.278 + 1.793 E-3 * D for lit signs (5a.

= -1.904 + 8.624 E-3 * D for unlit signs (5b.

The slopes and intercepts were not significantly different at the 5 percent level of significance, but were different at the 10 percent level. This indicates that lighting has a weak effect on correct targeting after adjusting for distance. Plots 1-4 are graphs of the equations above. Each graph has the plot of equation 1 superimposed on it and denote by the symbol "*". Appendix E contains the data used for graphing.

Table 6: Results of Friedmans Test

Friedmans test for file almeda3.dat

number of treatments	:	6
number of columns	:	6
value of test stat	:	125.6703000
degrees of freedom	:	5
pval	:	1.000000E-004

i	rank sum	expected sum	variance	standard residual	pval
1	150.000	91.000	75.833	38.253	.000
2	136.000	91.000	75.833	22.253	.000
3	103.000	91.000	75.833	1.582	.208
4	78.000	91.000	75.833	1.857	.173
5	52.000	91.000	75.833	16.714	.000
6	27.000	91.000	75.833	45.011	.000

Friedmans test for file fuqual.dat

number of treatments	:	2
number of columns	:	3
value of test stat	:	28.1739100
degrees of freedom	:	1
pval	:	1.000000E-004

i	rank sum	expected sum	variance	standard residual	pval
1	64.000	46.000	15.333	14.087	.000
2	74.000	92.000	15.333	14.087	.000

Friedmans test for file gulfgat1.dat

number of treatments	:	5
number of columns	:	5
value of test stat	:	95.5840000
degrees of freedom	:	4
pval	:	1.000000E-004

i	rank sum	expected sum	variance	standard residual	pval
1	123.000	75.000	50.000	36.864	.000
2	101.000	75.000	50.000	10.816	.001
3	76.000	75.000	50.000	.016	.899
4	47.000	75.000	50.000	12.544	.000
5	28.000	75.000	50.000	35.344	.000

Table 6 continued

Friedmans test for file scottl.dat

number of treatments	:	2
number of columns	:	2
value of test stat	:	14.4400000
degrees of freedom	:	1
pval	:	1.447449E-004

i	rank sum	expected sum	variance	standard residual	pval
1	28.000	37.500	6.250	7.220	.007
2	47.000	37.500	6.250	7.220	.007

Friedmans test for file fondernl.dat

number of treatments	:	2
number of columns	:	2
value of test stat	:	9.8461540
degrees of freedom	:	1
pval	:	1.702005E-003

i	rank sum	expected sum	variance	standard residual	pval
1	47.000	39.000	6.500	4.923	.027
2	31.000	39.000	6.500	4.923	.027

Friedmans test for file sugarl.dat

number of treatments	:	2
number of columns	:	2
value of test stat	:	5.5384620
degrees of freedom	:	1
pval	:	1.860289E-002

i	rank sum	expected sum	variance	standard residual	pval
1	33.000	39.000	6.500	2.769	.096
2	45.000	39.000	6.500	2.769	.096

Table 6 continued

Friedmans test for file harris1.dat

number of treatments	:	2
number of columns	:	2
value of test stat	:	3.8461540
degrees of freedom	:	1
pval	:	4.986007E-002

i	rank sum	expected sum	variance	standard residual	pval
1	44.000	39.000	6.500	1.923	.166
2	34.000	39.000	6.500	1.923	.166

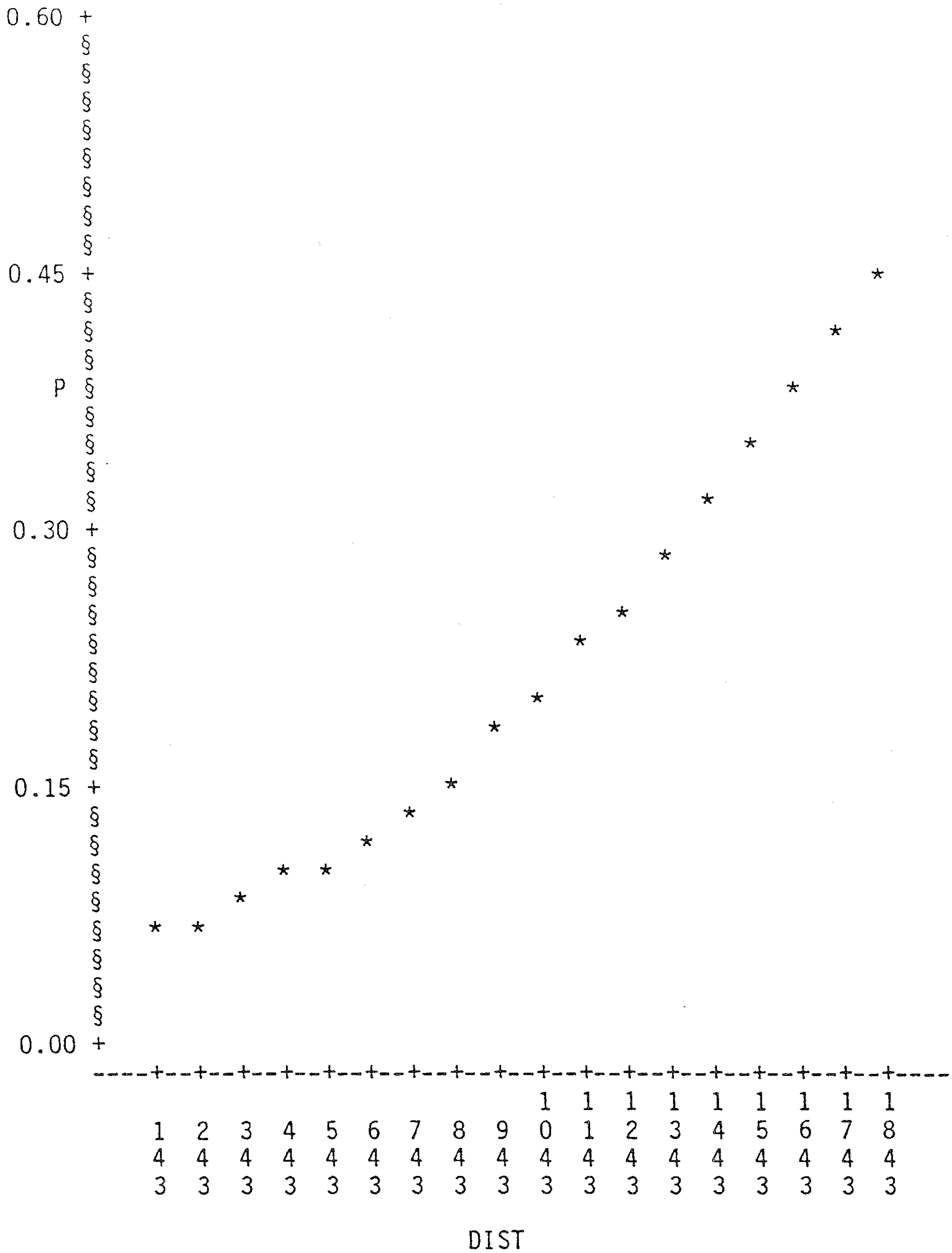
Friedmans test for file chimney1.dat

number of treatments	:	2
number of columns	:	4
value of test stat	:	37.6961600
degrees of freedom	:	1
pval	:	1.000000E-004

i	rank sum	expected sum	variance	standard residual	pval
1	97.000	130.000	43.333	18.848	.000
2	163.000	130.000	43.333	18.848	.000

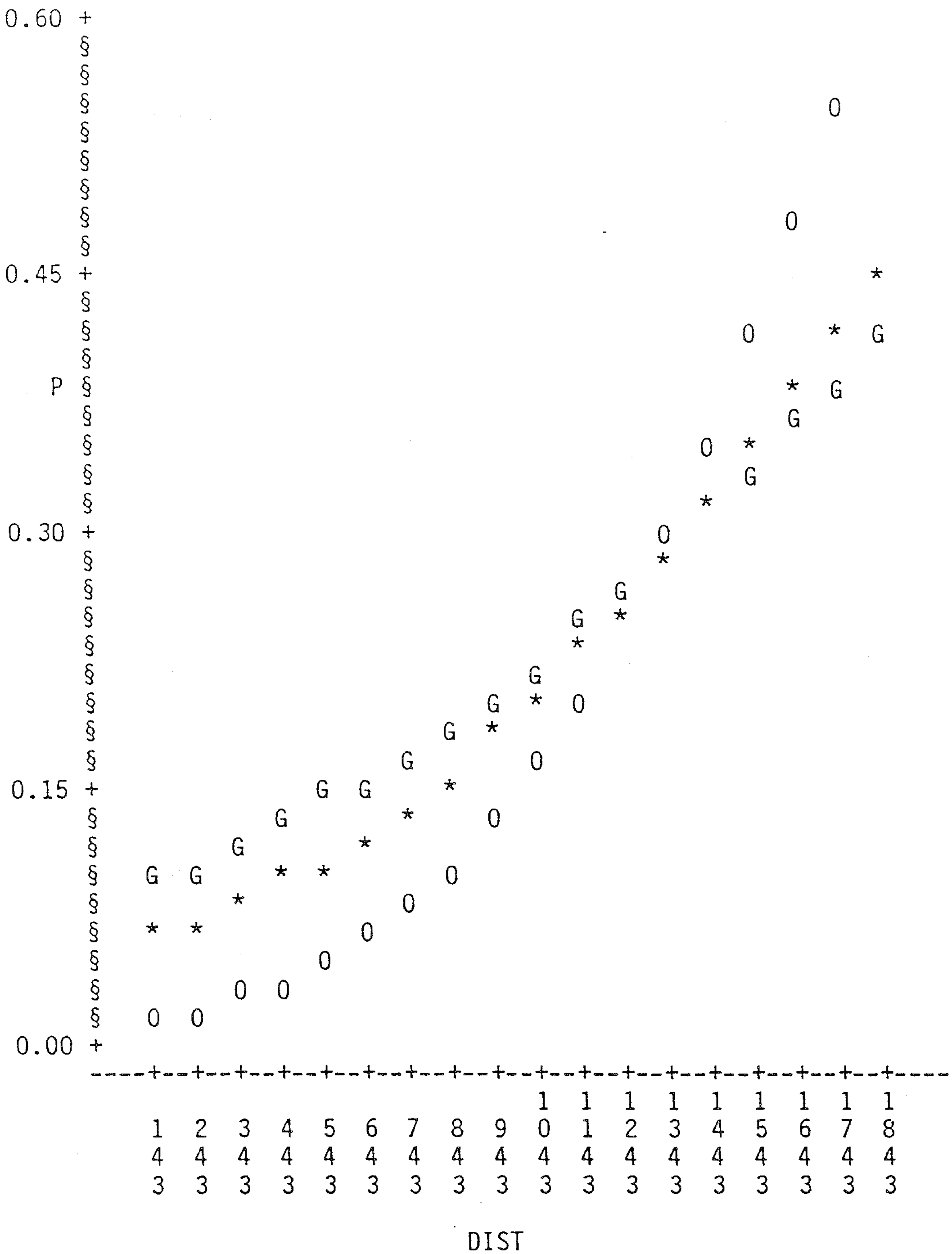
Plot 1: LOGISTIC REGRESSION FOR DISTANCE ONLY

Plot of P*DIST   Symbol is value of EFFECT



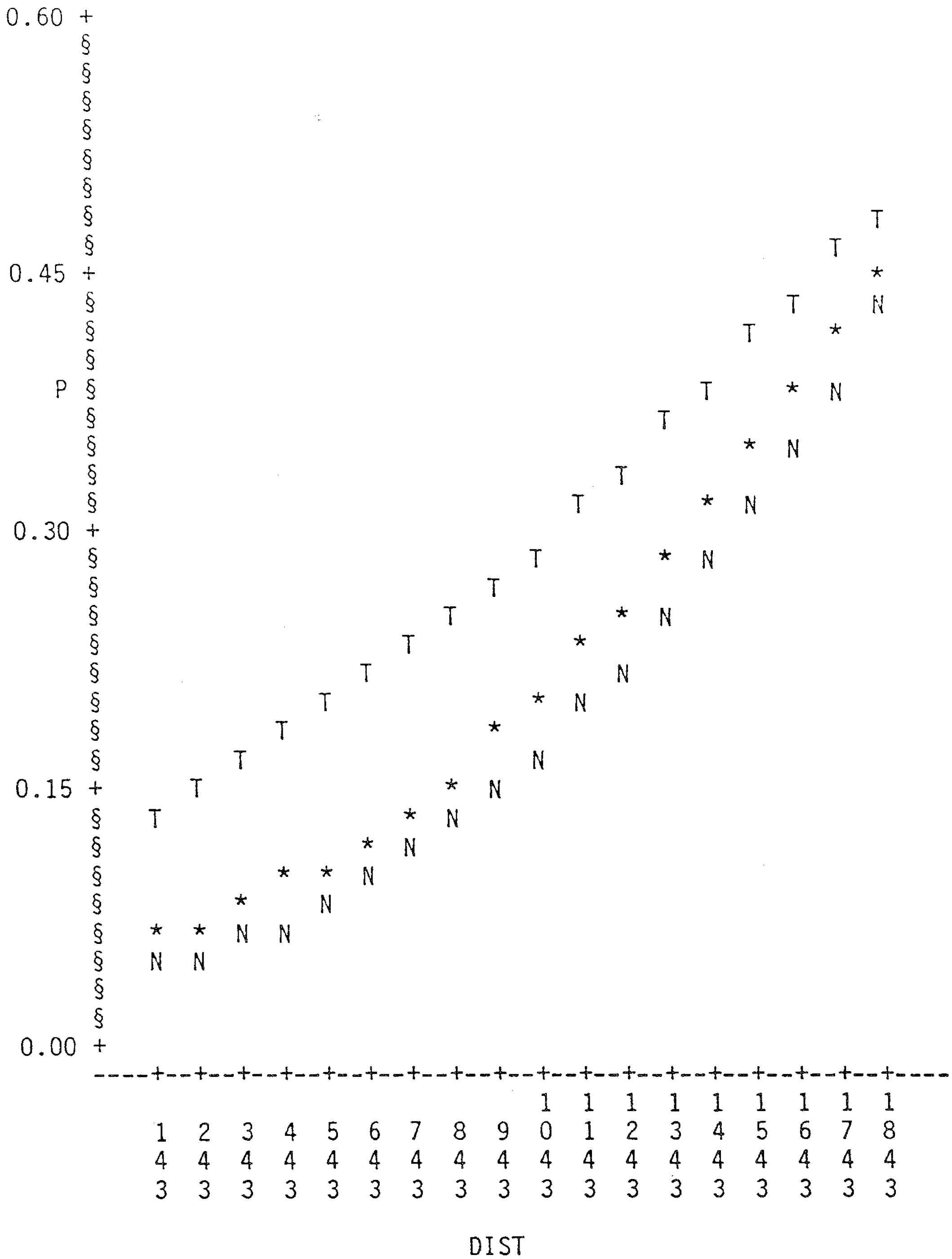
Plot 2: LOGISTIC REGRESSION FOR DISTANCE AND MOUNT

Plot of P*DIST   Symbol is value of EFFECT



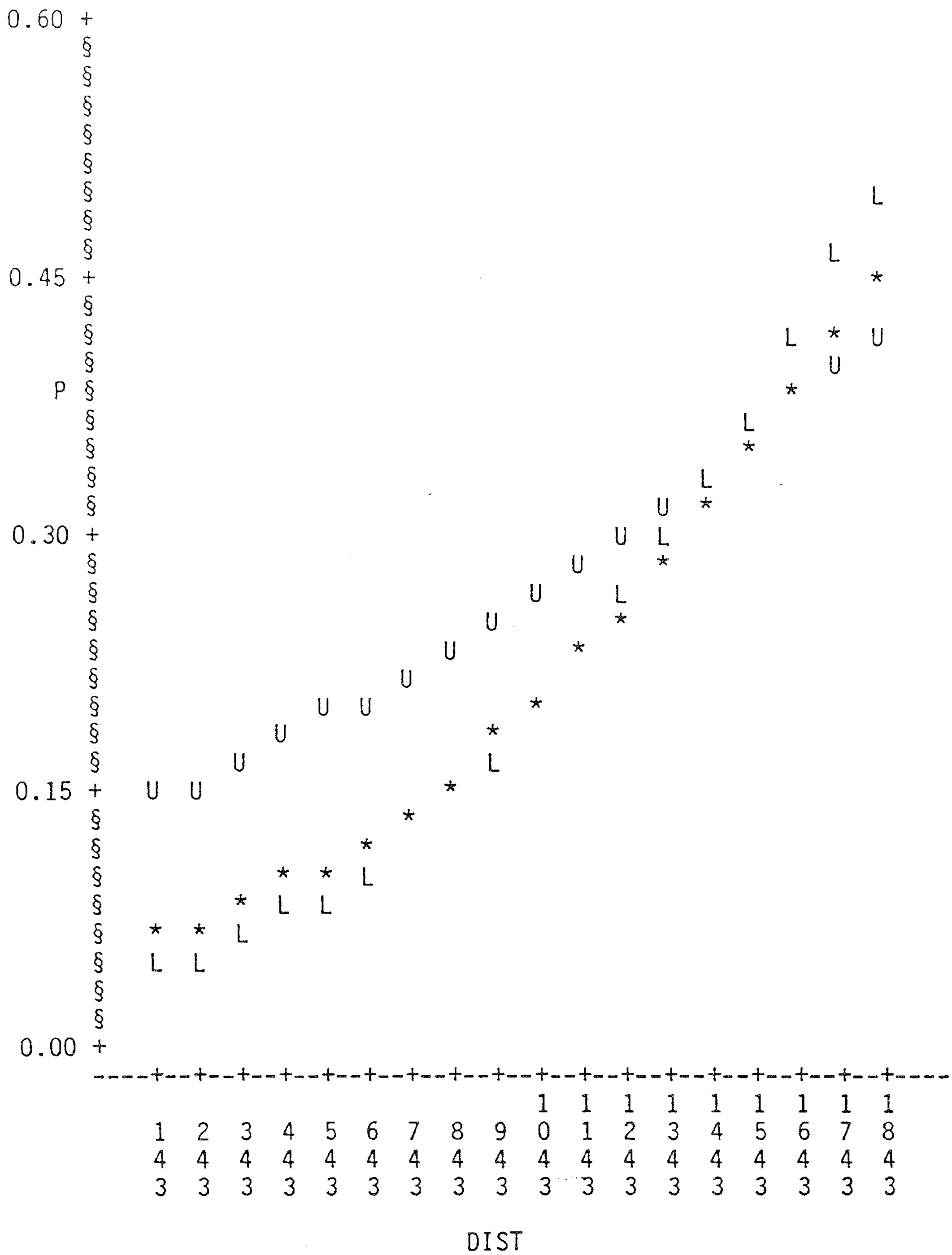
Plot 3: LOGISTIC REGRESSION FOR DISTANCE AND TEST SIGN

Plot of P*DIST   Symbol is value of EFFECT



Plot 4: LOGISTIC REGRESSION FOR DISTANCE AND LIGHTING

Plot of P*DIST   Symbol is value of EFFECT



NOTE: 7 obs hidden

APPENDIX E

LOGISTIC REGRESSION RESULTS WITHOUT SCOTT STREET

Table A1: Logistic Regression on Distances

FUNCAT PROCEDURE

RESPONSE: SEEN
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS (R)= 2
POPULATIONS (S)= 13
TOTAL COUNT (N)= 535
OBSERVATIONS (OBS)= 535

	DESIGN	RESPONSE FREQUENCIES		TOTAL
SAMPLE	SWITCH	1	2	
1	146	2	49	51.0
2	165	1	48	49.0
3	180	2	49	51.0
4	633	2	0	2.0
5	873	1	24	25.0
6	1019	12	40	52.0
7	1032	12	40	52.0
8	1038	1	0	1.0
9	1391	6	44	50.0
10	1421	38	14	52.0
11	1625	8	38	46.0
12	1807	36	16	52.0
13	1914	10	42	52.0

	DESIGN	RESPONSE PROBABILITIES		TOTAL
SAMPLE	SWITCH	1	2	
1	146	0.0392	0.9608	51.0
2	165	0.0204	0.9796	49.0
3	180	0.0392	0.9608	51.0
4	633	1.0000	0.0000	2.0
5	873	0.0400	0.9600	25.0
6	1019	0.2308	0.7692	52.0
7	1032	0.2308	0.7692	52.0
8	1038	1.0000	0.0000	1.0
9	1391	0.1200	0.8800	50.0
10	1421	0.7308	0.2692	52.0
11	1625	0.1739	0.8261	46.0
12	1807	0.6923	0.3077	52.0
13	1914	0.1923	0.8077	52.0

Table A1 continued

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	95.93	0.0001
SWITCH	1	52.06	0.0001
LIKELIHOOD RATIO	11	108.85	0.0001

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-2.95746	95.93	0.0001	0.301955
SWITCH	2	1	0.00151234	52.06	0.0001	.000209598

Table A2: Logistic Regression with Distance and Mount

FUNCAT PROCEDURE

RESPONSE: SEEN
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS (R)= 2
POPULATIONS (S)= 21
TOTAL COUNT (N)= 535
OBSERVATIONS (OBS)= 535

DESIGN			RESPONSE FREQUENCIES		TOTAL
SAMPLE	MOUNT	SWITCH	1	2	
1	GRND	146	2	49	51.0
2	GRND	165	1	24	25.0
3	GRND	180	1	25	26.0
4	GRND	633	1	0	1.0
5	GRND	1019	10	1	11.0
6	GRND	1391	3	22	25.0
7	GRND	1421	19	7	26.0
8	GRND	1625	4	19	23.0
9	GRND	1807	18	8	26.0
10	GRND	1914	10	42	52.0
11	OVER	165	0	24	24.0
12	OVER	180	1	24	25.0
13	OVER	633	1	0	1.0
14	OVER	873	1	24	25.0
15	OVER	1019	2	39	41.0
16	OVER	1032	12	40	52.0
17	OVER	1038	1	0	1.0
18	OVER	1391	3	22	25.0
19	OVER	1421	19	7	26.0
20	OVER	1625	4	19	23.0
21	OVER	1807	18	8	26.0

Table A2 continued

DESIGN			RESPONSE PROBABILITIES		TOTAL
SAMPLE	MOUNT	SWITCH	1	2	
1	GRND	146	0.0392	0.9608	51.0
2	GRND	165	0.0400	0.9600	25.0
3	GRND	180	0.0385	0.9615	26.0
4	GRND	633	1.0000	0.0000	1.0
5	GRND	1019	0.9091	0.0909	11.0
6	GRND	1391	0.1200	0.8800	25.0
7	GRND	1421	0.7308	0.2692	26.0
8	GRND	1625	0.1739	0.8261	23.0
9	GRND	1807	0.6923	0.3077	26.0
10	GRND	1914	0.1923	0.8077	52.0
11	OVER	165	0.0000	1.0000	24.0
12	OVER	180	0.0400	0.9600	25.0
13	OVER	633	1.0000	0.0000	1.0
14	OVER	873	0.0400	0.9600	25.0
15	OVER	1019	0.0488	0.9512	41.0
16	OVER	1032	0.2308	0.7692	52.0
17	OVER	1038	1.0000	0.0000	1.0
18	OVER	1391	0.1200	0.8800	25.0
19	OVER	1421	0.7308	0.2692	26.0
20	OVER	1625	0.1739	0.8261	23.0
21	OVER	1807	0.6923	0.3077	26.0

SOURCE	DF	CHI-SQUARE	PROB
MOUNT	1	7.78	0.0053
SWITCH	1	54.21	0.0001
SWITCH*MOUNT	1	8.93	0.0028
LIKELIHOOD RATIO	17	133.87	0.0001

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-3.37128	91.91	0.0001	0.351653
MOUNT	2	1	0.981011	7.78	0.0053	0.351653
SWITCH	3	1	0.0018563	54.21	0.0001	.000252118
SWITCH*MOUNT	4	1	-.00075352	8.93	0.0028	.000252118

Table A3: Logistic Regression for Mount Type Only

FUNCAT PROCEDURE

RESPONSE: SEEN
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS	(R)=	2
POPULATIONS	(S)=	2
TOTAL COUNT	(N)=	535
OBSERVATIONS	(OBS)=	535

DESIGN		RESPONSE FREQUENCIES		TOTAL
SAMPLE	MOUNT	1	2	
1	GRND	69	197	266.0
2	OVER	62	207	269.0

DESIGN		RESPONSE PROBABILITIES		TOTAL
SAMPLE	MOUNT	1	2	
1	GRND	0.2594	0.7406	266.0
2	OVER	0.2305	0.7695	269.0

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	125.43	0.0001
MOUNT	1	0.60	0.4370
LIKELIHOOD RATIO	0	-0.00	1.0000

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-1.12734	125.43	0.0001	0.100659
MOUNT	2	1	0.0782436	0.60	0.4370	0.100659

Table A4: Logistic Regression for Distance and Test Sign Type

FUNCAT PROCEDURE

RESPONSE: SEEN		RESPONSE LEVELS (R)=	2
WEIGHT VARIABLE:		POPULATIONS (S)=	20
DATA SET: NOSCOTT		TOTAL COUNT (N)=	535
		OBSERVATIONS (OBS)=	535

DESIGN			RESPONSE FREQUENCIES		TOTAL
SAMPLE	TEST	SWITCH	1	2	
1	NOT	146	2	49	51.0
2	NOT	165	1	24	25.0
3	NOT	180	2	49	51.0
4	NOT	633	2	0	2.0
5	NOT	873	1	24	25.0
6	NOT	1019	7	40	47.0
7	NOT	1032	6	20	26.0
8	NOT	1391	6	44	50.0
9	NOT	1421	19	7	26.0
10	NOT	1625	4	19	23.0
11	NOT	1807	18	8	26.0
12	NOT	1914	5	21	26.0
13	TEST	165	0	24	24.0
14	TEST	1019	5	0	5.0
15	TEST	1032	6	20	26.0
16	TEST	1038	1	0	1.0
17	TEST	1421	19	7	26.0
18	TEST	1625	4	19	23.0
19	TEST	1807	18	8	26.0
20	TEST	1914	5	21	26.0

Table A4 continued

DESIGN			RESPONSE PROBABILITIES		TOTAL
SAMPLE	TEST	SWITCH	1	2	
1	NOT	146	0.0392	0.9608	51.0
2	NOT	165	0.0400	0.9600	25.0
3	NOT	180	0.0392	0.9608	51.0
4	NOT	633	1.0000	0.0000	2.0
5	NOT	873	0.0400	0.9600	25.0
6	NOT	1019	0.1489	0.8511	47.0
7	NOT	1032	0.2308	0.7692	26.0
8	NOT	1391	0.1200	0.8800	50.0
9	NOT	1421	0.7308	0.2692	26.0
10	NOT	1625	0.1739	0.8261	23.0
11	NOT	1807	0.6923	0.3077	26.0
12	NOT	1914	0.1923	0.8077	26.0
13	TEST	165	0.0000	1.0000	24.0
14	TEST	1019	1.0000	0.0000	5.0
15	TEST	1032	0.2308	0.7692	26.0
16	TEST	1038	1.0000	0.0000	1.0
17	TEST	1421	0.7308	0.2692	26.0
18	TEST	1625	0.1739	0.8261	23.0
19	TEST	1807	0.6923	0.3077	26.0
20	TEST	1914	0.1923	0.8077	26.0

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	65.12	0.0001
TEST	1	3.68	0.0551
SWITCH	1	36.33	0.0001
SWITCH*TEST	1	1.50	0.2202
LIKELIHOOD RATIO	16	120.77	0.0001

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-2.60985	65.12	0.0001	0.323409
TEST	2	1	-0.620419	3.68	0.0551	0.323409
SWITCH	3	1	0.00132309	36.33	0.0001	.000219504
SWITCH*TEST	4	1	.000269114	1.50	0.2202	.000219504

Table A5: Logistic Regression for Sign Test Type Only

FUNCAT PROCEDURE

RESPONSE: SEEN
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS (R)= 2
POPULATIONS (S)= 2
TOTAL COUNT (N)= 535
OBSERVATIONS (OBS)= 535

DESIGN		RESPONSE FREQUENCIES		TOTAL
SAMPLE	TEST	1	2	
1	NOT	73	305	378.0
2	TEST	58	99	157.0

DESIGN		RESPONSE PROBABILITIES		TOTAL
SAMPLE	TEST	1	2	
1	NOT	0.1931	0.8069	378.0
2	TEST	0.3694	0.6306	157.0

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	87.08	0.0001
TEST	1	18.08	0.0001
LIKELIHOOD RATIO	0	-0.00	1.0000

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-0.982265	87.08	0.0001	0.105261
TEST	2	1	-0.447588	18.08	0.0001	0.105261

Table A6: Logistic Regression for Distance and Lighting

FUNCAT PROCEDURE

RESPONSE: SEEN
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS (R)= 2
POPULATIONS (S)= 13
TOTAL COUNT (N)= 535
OBSERVATIONS (OBS)= 535

DESIGN			RESPONSE FREQUENCIES		TOTAL
SAMPLE	LITE	SWITCH	1	2	
1	LIT	146	2	49	51.0
2	LIT	165	1	48	49.0
3	LIT	180	2	49	51.0
4	LIT	633	2	0	2.0
5	LIT	873	1	24	25.0
6	LIT	1032	12	40	52.0
7	LIT	1038	1	0	1.0
8	LIT	1391	6	44	50.0
9	LIT	1421	38	14	52.0
10	LIT	1625	8	38	46.0
11	NOT	1019	12	40	52.0
12	NOT	1807	36	16	52.0
13	NOT	1914	10	42	52.0

DESIGN			RESPONSE PROBABILITIES		TOTAL
SAMPLE	LITE	SWITCH	1	2	
1	LIT	146	0.0392	0.9608	51.0
2	LIT	165	0.0204	0.9796	49.0
3	LIT	180	0.0392	0.9608	51.0
4	LIT	633	1.0000	0.0000	2.0
5	LIT	873	0.0400	0.9600	25.0
6	LIT	1032	0.2308	0.7692	52.0
7	LIT	1038	1.0000	0.0000	1.0
8	LIT	1391	0.1200	0.8800	50.0
9	LIT	1421	0.7308	0.2692	52.0
10	LIT	1625	0.1739	0.8261	46.0
11	NOT	1019	0.2308	0.7692	52.0
12	NOT	1807	0.6923	0.3077	52.0
13	NOT	1914	0.1923	0.8077	52.0

Table A6 continued

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	39.37	0.0001
LITE	1	2.77	0.0963
SWITCH	1	24.91	0.0001
SWITCH*LITE	1	3.06	0.0803
LIKELIHOOD RATIO	9	105.83	0.0001

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-2.59095	39.37	0.0001	0.412943
LITE	2	1	-0.686814	2.77	0.0963	0.412943
SWITCH	3	1	0.00132768	24.91	0.0001	.000266034
SWITCH*LITE	4	1	.000465248	3.06	0.0803	.000266034

Table A7: Logistic Regression on Lighting Only

FUNCAT PROCEDURE

VARIABLE:
DATA SET: NOSCOTT

POPULATIONS (S)= 2
TOTAL COUNT (N)= 535
OBSERVATIONS (OBS)= 535

DESIGN		RESPONSE FREQUENCIES		TOTAL
SAMPLE	LITE	1	2	
1	LIT	73	306	379.0
2	NOT	58	98	156.0

DESIGN		RESPONSE PROBABILITIES		TOTAL
SAMPLE	LITE	1	2	
1	LIT	0.1926	0.8074	379.0
2	NOT	0.3718	0.6282	156.0

SOURCE	DF	CHI-SQUARE	PROB
INTERCEPT	1	86.29	0.0001
LITE	1	18.59	0.0001
LIKELIHOOD RATIO	0	-0.00	1.0000

EFFECT	PARAMETER	DF	ESTIMATE	CHI-SQ	PROB	STD
INTERCEPT	1	1	-0.978825	86.29	0.0001	0.10537
LITE	2	1	-0.454301	18.59	0.0001	0.10537

APPENDIX F

DATA FOR LOGISTIC REGRESSION PLOTS

LOGISTIC REGRESSION CURVE FOR DISTANCE AND MOUNT

OBS	P	DIST	EFFECT
1	0.060609	143	*
2	0.069812	243	*
3	0.080292	343	*
4	0.092190	443	*
5	0.105648	543	*
6	0.120810	643	*
7	0.137812	743	*
8	0.156780	843	*
9	0.177821	943	*
10	0.201012	1043	*
11	0.226394	1143	*
12	0.253963	1243	*
13	0.283659	1343	*
14	0.315359	1443	*
15	0.348876	1543	*
16	0.383958	1643	*
17	0.420290	1743	*
18	0.457507	1843	*
19	0.096877	143	G
20	0.106956	243	G
21	0.117947	343	G
22	0.129903	443	G
23	0.142875	543	G
24	0.156908	643	G
25	0.172043	743	G
26	0.188312	843	G
27	0.205737	943	G
28	0.224329	1043	G
29	0.244085	1143	G
30	0.264986	1243	G
31	0.286997	1343	G
32	0.310065	1443	G
33	0.334119	1543	G
34	0.359067	1643	G
35	0.384802	1743	G
36	0.411198	1843	G
37	0.018365	143	0
38	0.023712	243	0
39	0.030568	343	0
40	0.039325	443	0
41	0.050461	543	0
42	0.064539	643	0
43	0.082204	743	0
44	0.104166	843	0
45	0.131157	943	0

LOGISTIC REGRESSION CURVE FOR DISTANCE AND MOUNT

OBS	P	DIST	EFFECT
46	0.163862	1043	0
47	0.202819	1143	0
48	0.248287	1243	0
49	0.300111	1343	0
50	0.357606	1443	0
51	0.419514	1543	0
52	0.484063	1643	0
53	0.549148	1743	0
54	0.612594	1843	0

LOGISTIC REGRESSION CURVE FOR DISTANCE AND TEST SIGN

OBS	P	DIST	EFFECT
1	0.060609	143	*
2	0.069812	243	*
3	0.080292	343	*
4	0.092190	443	*
5	0.105648	543	*
6	0.120810	643	*
7	0.137812	743	*
8	0.156780	843	*
9	0.177821	943	*
10	0.201012	1043	*
11	0.226394	1143	*
12	0.253963	1243	*
13	0.283659	1343	*
14	0.315359	1443	*
15	0.348876	1543	*
16	0.383958	1643	*
17	0.420290	1743	*
18	0.457507	1843	*
19	0.047320	143	N
20	0.055037	243	N
21	0.063927	343	N
22	0.074142	443	N
23	0.085838	543	N
24	0.099182	643	N
25	0.114341	743	N
26	0.131479	843	N
27	0.150748	943	N
28	0.172281	1043	N
29	0.196180	1143	N
30	0.222502	1243	N
31	0.251252	1343	N
32	0.282368	1443	N
33	0.315713	1543	N
34	0.351069	1643	N
35	0.388138	1743	N
36	0.426549	1843	N
37	0.137255	143	T
38	0.150220	243	T
39	0.164176	343	T
40	0.179156	443	T
41	0.195183	543	T
42	0.212273	643	T
43	0.230431	743	T
44	0.249650	843	T
45	0.269910	943	T

LOGISTIC REGRESSION CURVE FOR DISTANCE AND TEST SIGN

OBS	P	DIST	EFFECT
46	0.291176	1043	T
47	0.313399	1143	T
48	0.336512	1243	T
49	0.360435	1343	T
50	0.385071	1443	T
51	0.410311	1543	T
52	0.436033	1643	T
53	0.462103	1743	T
54	0.488383	1843	T

LOGISTIC REGRESSION CURVE FOR DISTANCE AND LIGHTING

OBS	P	DIST	EFFECT
1	0.060609	143	*
2	0.069812	243	*
3	0.080292	343	*
4	0.092190	443	*
5	0.105648	543	*
6	0.120810	643	*
7	0.137812	743	*
8	0.156780	843	*
9	0.177821	943	*
10	0.201012	1043	*
11	0.226394	1143	*
12	0.253963	1243	*
13	0.283659	1343	*
14	0.315359	1443	*
15	0.348876	1543	*
16	0.383958	1643	*
17	0.420290	1743	*
18	0.457507	1843	*
19	0.046459	143	L
20	0.055081	243	L
21	0.065192	343	L
22	0.077009	443	L
23	0.090759	543	L
24	0.106681	643	L
25	0.125012	743	L
26	0.145978	843	L
27	0.169778	943	L
28	0.196565	1043	L
29	0.226426	1143	L
30	0.259359	1243	L
31	0.295254	1343	L
32	0.333877	1443	L
33	0.374865	1543	L
34	0.417730	1643	L
35	0.461874	1743	L
36	0.506624	1843	L
37	0.144220	143	U
38	0.155193	243	U
39	0.166839	343	U
40	0.179174	443	U
41	0.192210	543	U
42	0.205956	643	U
43	0.220417	743	U
44	0.235593	843	U
45	0.251476	943	U

LOGISTIC REGRESSION CURVE FOR DISTANCE AND LIGHTING

OBS	P	DIST	EFFECT
46	0.268054	1043	U
47	0.285309	1143	U
48	0.303215	1243	U
49	0.321738	1343	U
50	0.340839	1443	U
51	0.360472	1543	U
52	0.380582	1643	U
53	0.401111	1743	U
54	0.421993	1843	U

APPENDIX G

TRAFFIC ENGINEER QUESTIONNAIRE

APPENDIX

1982 TRAFFIC ENGINEERING CONFERENCE

OVERHEAD SIGN QUESTIONNAIRE

1. Do you feel that all overhead guide signs should be lighted?

2. If the answer to question 1 is no, do you feel that it is mandatory for the unlighted sign to appear green at night?

3. In a rural unlighted freeway condition and an unlighted sign condition, would you use engineer-grade reflective sheeting, super engineer-grade sheeting, high intensity sheeting or an opaque background?

4. Which of the above four backgrounds would you use in an urban lighted freeway and an unlighted sign condition?

5. Considering costs, hazards of maintenance operations and hazards to the traveling public caused by maintenance operations, do you feel that the background material should have the longest life possible regardless of whether it is reflective or not?

6. Considering engineer-grade reflective sheeting has a 10-year life, super engineer-grade has 10 years, high intensity sheeting has 20 years and polyester opaque background has 50 years, which background would you use in an unlighted situation?

7. Does the fact that opaque backgrounds such as polyester appear black at night bother you?

8. Rank from one (1) to seven (7) your order of priority for the following maintenance items.

   ( ) Spalled Bridge Deck
   ( ) Damaged Guard Rail
   ( ) Deteriorated Overhead Sign Panel
   ( ) Damaged Bridge Rail
   ( ) Non-functioning Sign Light
   ( ) Potholes in Roadway Pavement
   ( ) Damaged Light Pole

9. Do you feel that with 1100' to 1200' clear sight distance the opaque non-reflective copy gives adequate legibility distance in an unlighted condition?

10. Facing budgetary limitations which would you fix first, a bad pothole or a badly deteriorated sign?

APPENDIX H

TELEPHONE SURVEY OF STATES

Q1. Are any of your policies concerning overhead guide sign lights on freeway published or merely guidelines?

A. Louisiana (Baton Rouge)-
Their state policy is published and concludes that they will no longer maintain sign lighting.

B. Oklahoma (Oklahoma City)-
The state policy is set on informal guidelines (from standard ASGO manual).

C. New Mexico (Santa Fe)-
There are basically no lights on the signs; most of their policies are informal.

D. California (Sacramento)-
Their state policy on overhead guide sign lights is published.

E. Washington (Olympia)-
Their policy is either published or soon to be published.

F. Michigan (Lansing)-
Their policy is in the process of being published and they will send us a copy when it is completed.

G. Pennsylvania (Harrisburg)-
Most of their guidelines are informal, based on a Virginia study recommendation.

H. New Jersey (Trenton)-
All of their policies concerning overhead guide sign lighting are informal guidelines.

Q2. Is the sign lighting predicated on factors such as critical sight distance, and type of background and copy material? As an example: Do you have a separate set of guidelines at night if there is a critical sight distance problem?

A. Louisiana -

Lighting is not necessary except in extremely critical areas.

B. Oklahoma -

Their primary problem is whether cities can afford to get power at a particular location. The reason why some areas are not lighted is because local governments are not willing to pay for service.

C. New Mexico -

All road signs are very well illuminated so there is no separate set of guidelines.

D. California -

Concludes that action type sign or critical distance signs should remain on, however non-action signs do not need to be.

E. Washington -

Their policy states that overhead guide signs illumination shall be provided where an engineering study indicates reflectorization alone does not perform adequately, and on horizontal curves using 800 ft. as criteria.

F. Michigan -

Critical sight distance is a factor, however, the type of background material does not matter.

Q2. Is the sign lighting predicated on factors such as critical sight distance, and type of background and copy material? As an example: Do you have a separate set of guidelines at night if there is a critical sight distance problem?

G. Pennsylvania -

Most of their lighting is predicated on factors such as;

a) 1200 foot tangent sight distance

b) reflective background and legend

which they deem is necessary.

H. New Jersey -

They feel that background or copy material is not as important as sight distance. They use a 1200 ft. tangent as criteria.

Q3. Does the state policy deem it critical to use a green background for overhead sign lights?

A. Louisiana -
The state policy deems it critical because motorists recognize green as the standard type of background.

B. Oklahoma -
Their state prefers using a mercury vapor for a green tint as a background.

C. New Mexico -
Their traffic design engineer recommends a green background.

D. California -
They believe that a green background is not as important as whether the sign can be read at night.

E. Washington -
A green background for sign reflectivity definitely is needed.

F. Michigan -
Most of their signs have high intensity sheeting.

G. Pennsylvania -
They have started changing from non-reflective (black) background sheeting to a reflective background sheeting.

H. New Jersey -
In their opinion, overhead sign background should remain green so that it may be uniform with national standards.

Q4. What appears to be the operational; behavioral and accidental history where the lights have been left off?

A. Louisiana -

No accidental history to their knowledge where the lights are now being left off.

B. Oklahoma -

Does not know, but would like to have lighting in as many areas as possible.

C. New Mexico -

No accidental history to their knowledge.

D. California -

Accident rate did not increase, even when some lights were left off accidentally; had only one complaint.

E. Washington -

Wayne Gruen had no knowledge of accidental history or operational behavior where lights were left off.

F. Michigan -

Since they started changing over to high-intensity sheeting during the energy crisis, no related accidents have been reported.

G. Pennsylvania -

Art Breneman had no information about operation behavior when the lights were turned off.

H. New Jersey -

There has been no study to determine this, however, they have received no complaints from motorists.

Q5. Would you be in favor of reducing or even eliminating lights on overhead guide signs, and if so, what factors would be taken into consideration?

A. Louisiana -

In favor of eliminating sign lights all together, except for extreme cases.

B. Oklahoma -

Since they cannot get power to some locations, favors lights left off in some rural areas but not in urban areas.

C. New Mexico -

There are no lights on signs now since they feel that all of their roads are well illuminated.

D. California -

Their conclusions are that action type signs should remain illuminated, however, non-action type signs need not be.

E. Washington -

In favor of reducing overhead sign lighting, however, illumination of signs is needed when reflectorization is inadequate on curves and when there are structures on roadways.

F. Michigan -

They are in favor of removing all overhead sign lighting because of the high reflectivity sheeting intensity.

G. Pennsylvania -

Would be in favor of reducing or eliminating guide sign lights except for conditions such as a) 1200 ft. tangent sight distance and b) signs having reflective background and legend.

Q5. Would you be in favor of reducing or even eliminating lights on overhead guide signs, and if so, what factors should be taken into consideration?

H. New Jersey -

They are in the process of replacing all their signs with reflectorized background in order to be able to reduce the need for overhead guide sign lights. They would be in favor of eliminating all overhead guidesigns except for extreme case such as those signs having a 1200 ft. tangent distance.

APPENDIX I

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