FUNCTIONALITY OF OVERHEAD FREEWAY GUIDE SIGNS, TARGET VALUE, SIGN LIGHTING GUIDELINES AND EXECUTIVE SUMMARY

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Implementation

Texas is experiencing a severe depression which is creating a financial burden on all of the organizations in the state. Along with the loss of revenue, the State Department of Highways and Public Transportation is faced with a massive rehabilitation program with respect to overhead sign lighting. The state could save millions of dollars in its major metropolitan areas for maintenance and energy costs if it implements the sign lighting guidelines as presented in this report. All non-critical overhead guide signs around the state must be inventoried and lights not only turned-off but equipment taken off sign bridges for safety purposes.

Disclaimer

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard specification or regulation.

Acknowledgement

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"Functionality of Urban Freeway Guide Signing

-- Target Value and Executive Summary"

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CHAPTER 1

EXECUTIVE 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. A set of quidelines 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 was:

1. For Vertical (limited sight distance) situations one would expect to have signs with limited sight distance be improved by sign lighting. If reflectorized backgrounds are used one would not expect to see the large difference in detectability between lighted and unlighted signs as when opaque backgrounds are used.
2. The target value study substantiated the original hypothesis. In the 300-800 feet category the lighted sign was significantly more visible than the unlighted. The test signs in this catetory were detected well before the obstruction due to vertical geometry.

The results of this study did not conclusively prove sign lighting assisted in target detection in this as the 800-1200 foot category. 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.

3. The signs in the 0-5° area (Foveal Region) performed significantly better with sign lights. This is due to the influence of the environmental complexity on the sign. In the 5-10° area (Peripheral Region) the unlighted sign was significantly better. And in the greater than 10° area there was no significant difference due to sign lighting.

4. The T-mounted signs 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 other two categories indicating that motorists are not expecting to find signs in this particular location.

5. The target value of ground mounted signs are not as good as the overhead mounted signs.

6. The target value of overhead signs was well above both the ground mounted and T-mounted sign regardless of material. The target value for all signs were more than adequate for most exiting manuevers.

7. 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.

8. In all cases the target value of all signs regardless of sign lighting were between 2 and 3 times greater than the legibility distance.

QUESTIONNAIRE/TELEPHONE SURVEY

The questionnaire/telephone survey provided significant information regarding other states policies regarding sign lighting and traffic engineering opinions with respect to seeing the green background in the lights out condition. The results of these two surveys included:

1. Most states, Oklahoma the only exception, have either a formal or informal policy regarding sign lighting. This policy is to have a lights out policy in most noncritical situations.
2. The traffic engineers prefer high-intensity sheeting on signs with lights out. Most states generally use high-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 have been developed.

1. Signs which have the following chacteristics should be lighted.
   a. Critical sight distance of 1200 feet or less,

b. Horizontal Curvature with a radius less than 800 feet,

c. At critical diversion points where several lane changes are required,

d. Median mounted and overhead signs in close proximity to conventional freeway luminaires or median mounted luminaries.

Glare sources may be counteracted with sign lighting.

The following guidelines apply to unlighted freeway guide signs:

a. Any sign which does not fit in any category which requires sign lighting

b. The type of reflective sign material does not affect sign lighting

c. Reflective backgrounds should be used on overhead signs and T-mounts so that the green background is visible to the driver.

d. Any sign in a high ambient light level (above 10 foot-candles) which does not contain an action message.

e. Signs which do not have action messages nor require extensive vehicle manuevers may have opaque backgrounds provided an engineering study has been performed to determine whether an operational and/or lighting problem exists.

CHAPTER 2

BACKGROUND AND SIGNIFICANCE OF WORK

Target Value

In a study conducted in Pennsylvania (6) it was determined that (1) motorists could see reflective sheeting background signs further away, (2) found the reflective background sign easier to read and (3) preferred the signs with reflective background.

Another aspect of target value besides commanding attention is the recognition of the background color. Forbes (14) developed Table 1 which presents the required luminance for 75 percent correct color recognition for various surround luminances. These results indicate that the luminance levels for light colors are approximately 20-25 times the ambient and those for blue and green average 7 times.

Many factors affect the performance of reflective signs at night. Anderson (15) and Rumor (16) have shown that dirt reduce sign brightness about 50 percent. Allen (17) has measured losses from dirt on the windshield at 10 percent, he also found that brightness was reduced by 30 percent due to windshield tint. The tint filters out the infrared spectrum reducing red signs and signals by twice that of other colors.

Finch (18) found that over 50% of all headlamps are misaimed and that 64% of replacement headlamps fail to meet photometric requirements specified.

Five Background Luminances — Sign Luminance for 75 Percent Correct Color Recognition

Study Number	Average Background Luminance	Luminance (cd/m^2)					
	cd/m^2	White cd/m^2	Yellow cd/m^2	Orange cd/m^2	Red cd/m^2	Green cd/m^2	Blue cd/m^2
1	.1	3.0	6.1	3.2	2.1	1.7	1.3
2	.5	7.2	9.4	11.0	7.2	2.9	1.1
5	1.5	26.0	20.0	32.0	11.0	8.8	8.5
4	7.2	87.0	216.0	112.0	90.0	34.0	41.0
3	15.1	272.0	272.0	476.0	342.0	114.0	83.0

Ferguson and Cook (21) performed a questionnaire survey to determine motorists recognition of color, shape and a combination of both. They found that only 9% of the 1163 respondents knew that the color green was used for directional information. The shape of the sign was recognized by 11% of 1197 respondents and a combination of both color and shape was recognized by 15% of 671 respondents.

Recent tests conducted by the Virginia Highway and Transportation Research Council (7) have concluded that overhead signs employing high-intensity reflective sheeting, without internal illumination, have adequate legibility and target value where the sign is approached on a rural, constant grade, tangent roadway at least 1200 feet long.

Olson and Benstein (25) studied the effect of roadway geometry, sign position, and headlamp usage as it affects legibility distances. Table 2 presents this data. The standard by which all other conditions are evaluated is an overhead sign, 19.8 feet high centered over the lane, on a tangent constant grade section with vehicles headlamps on low. Sign position decreases legibility distance by 13 percent, a 2 degree right hand curve for an overhead sign has virtually no effect, however there is a 16% decrease for a roadside sign, and a left hand curve reduces legibility distance by 5% for overhead signs and 21% for roadside signs. Vertical crests increase legibility by 12 percent and vertical signs decrease by 5 percent for overhead signs with low beams.

Van Norris (26) found that if a truck observes a sign at a large distance there will be virtually no reduction on sign luminance from that found in a passenger car. However, at closer distances a 10 fold decrease of sign luminance can be expected. A reduction in luminance by a factor of 10 reduces legibility by a factor of 2.

Olson, et.al.. (27) studied the effect of different variables on the number of correct identification of signs in a similator. Figure 1, shows the effect on the percent correct responses for two legend sizes as a function of contrast. For legends 60 ft/in of letter height the percent correct response increases until a maximum of approximately 80% is attainded with a log contrast of 1.7. Legends of 30 ft/in increase to a maximum of 100% at log contrasts of 0.95. Figure 2, shows the effect these levels of glare had on the percent correct identification as a function of contrast levels. Glare levels had to reach above 5,000 ft-L before really significant effects of glare could be noted. Figure 3, shows the effects glare angle has on legibility. Anything much further away than the edge of the sign had little effect.

Table 2. Various conditons of roadway alignment, sign position, and headlamp beams, effect on legibility distance

Serial number	Road Alignment	Sign Position	Headlamp beam	Effect on legibility distance
1	Tangent, constant grade	Overhead, 6 m high, centered over lane	low	Standard
2	Tangent, constant grade	Overhead, 6 m high, centered over lane	high	15% higher than 1
3	Tangent, constant grade	Roadside, 2.4 m above pavement, 3.7 m to right of edge of pavement	low	13% lower than 1
4	Tangent, constant grade	Roadside, 2.4 m above pavement, 3.7 m to right of edge of pavement	high	5% higher than 1
5	2°Right hand curve constant grade	Overhead,6 m high centered over lane	low	almost same as 1
6	2°Left hand curve constant grade	Overhead, 6m high, centered over lane	low	5% lower than 1
7	2°Right hand curve constant grade	Roadside, 2.4 m above pavement, 3.7 m to right of edge of pavement	low	16% lower than 1
8	2°Left hand curve constant grade	Roadside, 2.4 m above pavement, 3.7 m to right of edge of pavement	low	21% higher than 1
9	Tangent, crest (8%)	Overhead, 6 m high, centered over lane	low	12% higher than 1
10	Tangent, sag (8%)	Overhead, 6 m high, centered over lane	low	5% lower than 1

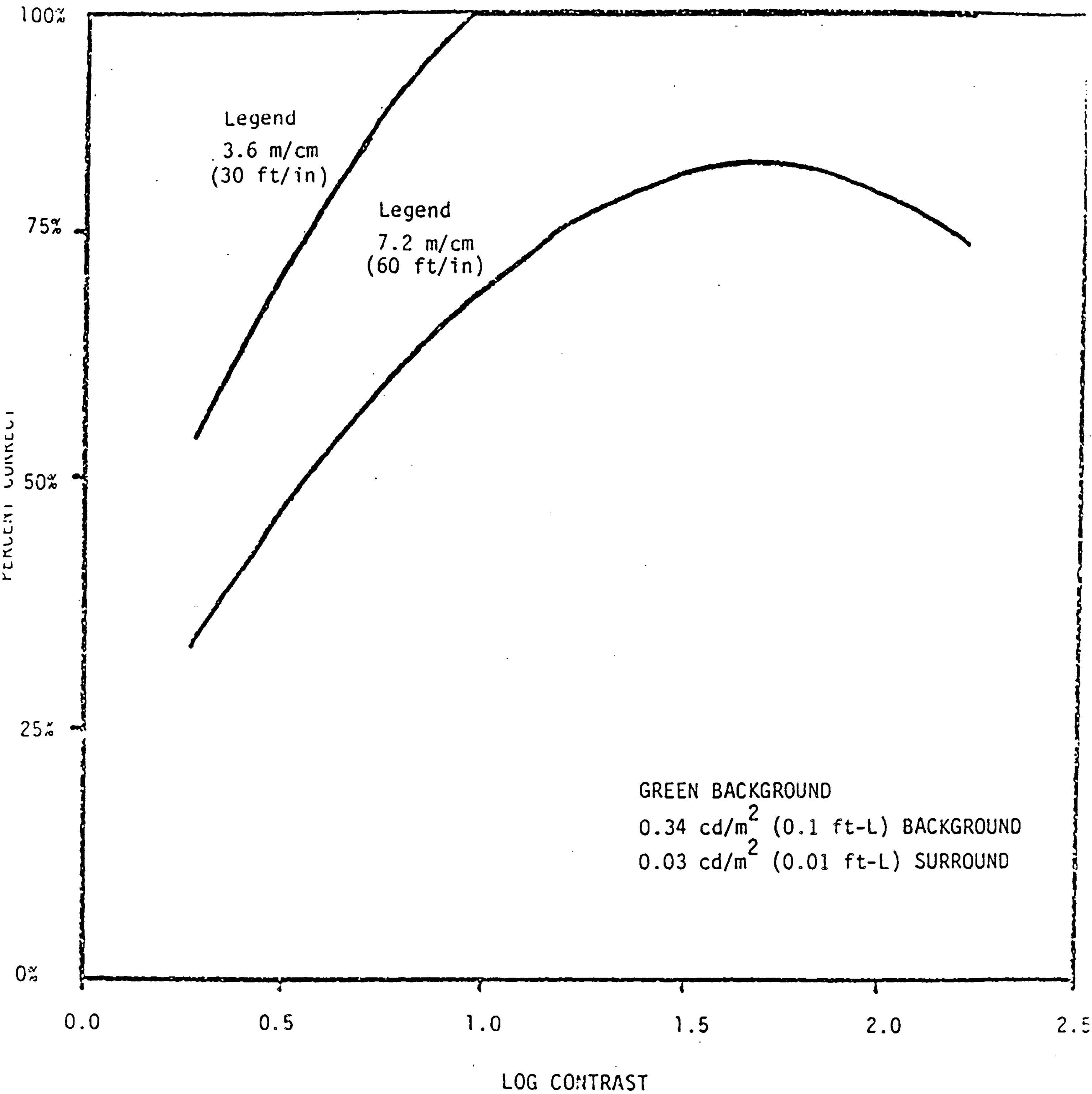

Figure 1. Percent correct identifications of two legend sizes as a function of the luminance contrast provided.

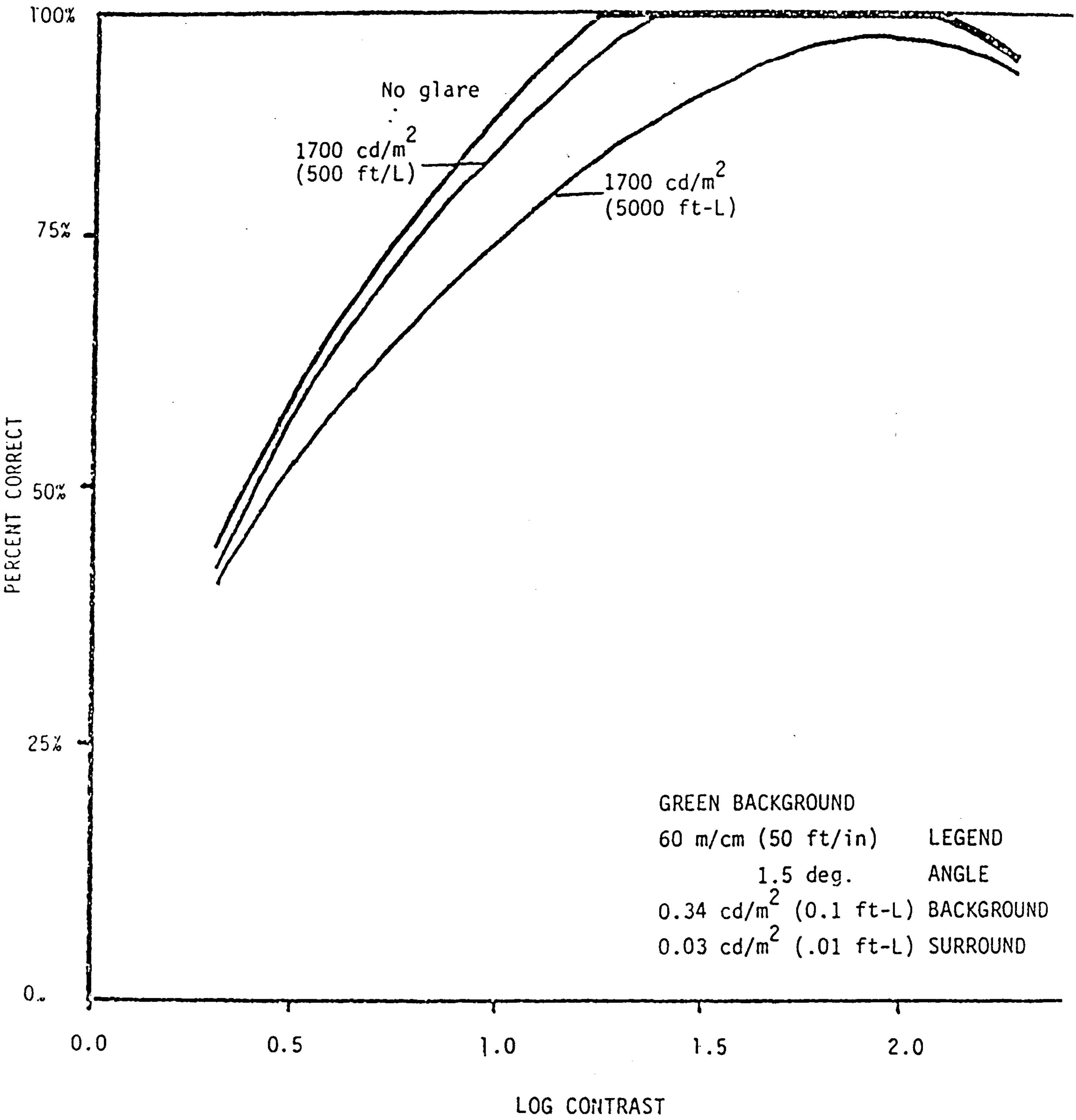

Figure #2. Effect of environmental glare on legibility.

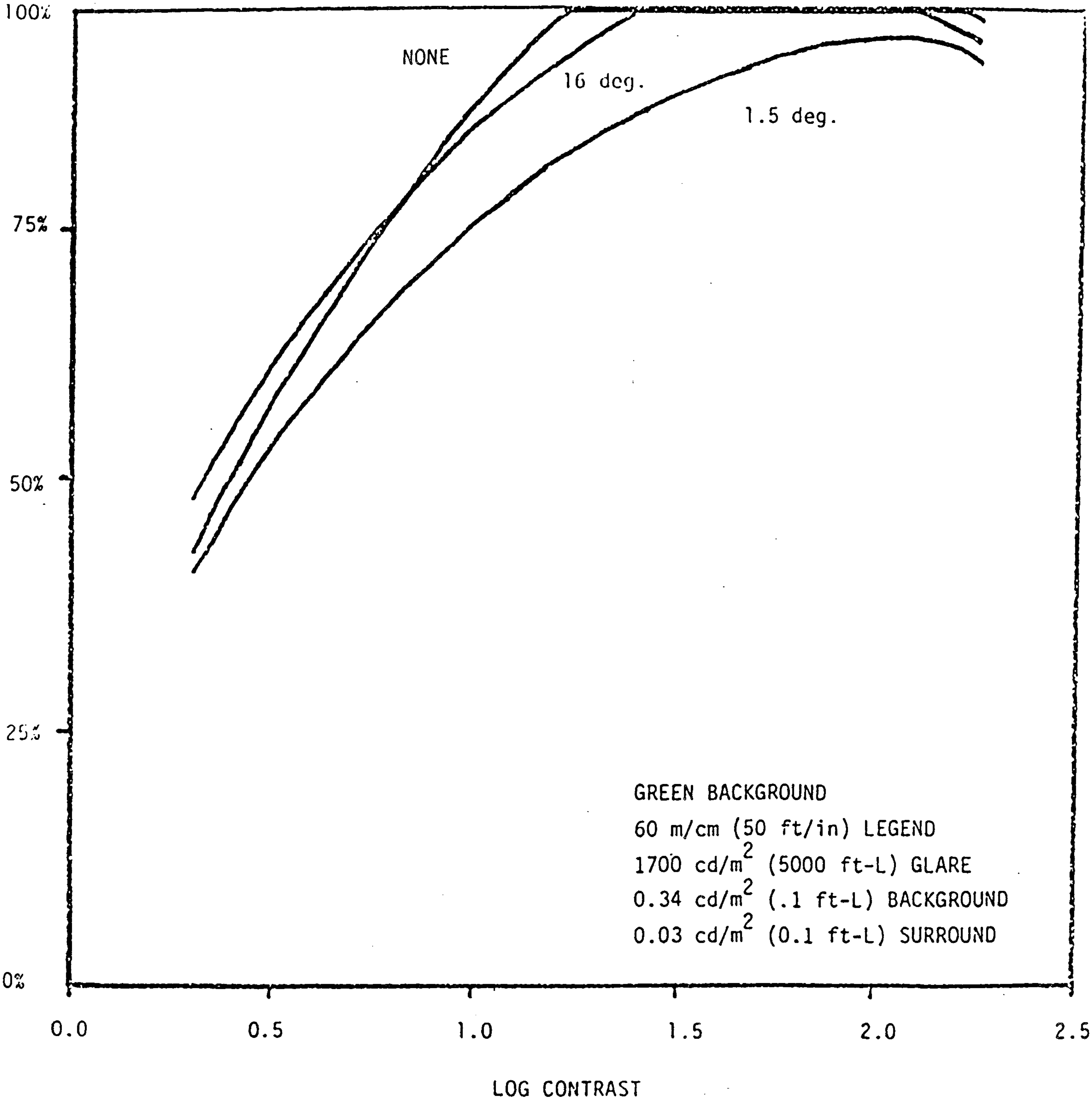

Figure 3. Effect of glare angle on legibility.

Caltrans (31) found that being able to see the green background at night contributed little to the value of the sign. High intensity sheeting interferes with the legibility of the sign message under low beam headlight, conditions due to the halation effect. Nonilluminated reflectorized signs are ineffective under conditions of heavy frost, dew, and fog conditions.

Complexity

Mace (10) Defined conspicuity as "Conspicuity like visiblity and legibility, is not an observable characteristic of a sign, but a construct which relates measures of perceptual performance with measure of background, motivation and driver uncertainty." Mace states that this definition make a sign more conspicuous if the destination or action is of interest or specific to the driver. This relates conspicuous to alertness by the driver. Mace also states that a sign a 2 foot-lambert increase in luminance is twice as conspicuous as a sign requiring a 4-foot-lambert increase in luminance to attain the same level of perceptual performance may have more construct validity than similar statements based upon probability of detection.

Jenkins and Cole (23) suggest that there are two aspects of complexity, (1) clutter and (2) distraction elements. Clutter is where the target has to compete with other similar objects. The effects of these similar, or confusing elements can be corrected by sign design if the confusion elements can be identified, of their size distribution is known and if their average reflectance is known. Distraction elements are those elements not necessarily similar to the target, but will attract the drivers attention. The act of noticing irrelevant information will take time and thus increase the demand load on the driver as less time is then available for the driving task.

Mace et al studied luminance requirements for yellow warning signs to be used with different complex situations. A field study showed that at low complexity sites Type II signs degraded to 36 percent of Federal Standards provided adequate luminance (.14 candelas/ft^2) for sign recognition beyond 500 ft. At high complexity sites, new type II signs in excess of the federal standards of provided luminance (.40 candelas/ft^2) was inadequate for sign recognition at 500 feet. At speeds below 35 mph, the required recognition distance is less, and signs degraded to 72 percent providing a luminance of .25 candelas/ft^2 were adequate.

Legibility and Target Value Models

Robertson (8) has developed two models to determine the cost per year of useful life for engineer grade sheeting and high-intensity sheeting. The engineer grade sheeting model is:

$$C = \frac{IC}{PF}$$

where

C = Cost per sq. foot of useful life

IC = Installed cost per sq. foot

PF = Performance year (manufacturer guarantee)

The model for the high-intensity sheeting:

$$C_{HI} = \frac{IC + AMC + AFC}{PF}$$

where

C_{HI} = Cost per square ft per useful life

IC = Installed cost per sq. ft. (Engineer Grade Sheeting)

AMC = Additional cost of high-intensity sheeting per square foot

AFC = Additional fabrication cost for high-intensity sheeting per square foot

Forbes (13) developed a predictive equation for expected recognition distance of a sign. This model is:

$$D = \frac{\frac{L - B}{L} + \frac{B - S}{B}}{2} \times ER$$

where:

D = Expected Recognition Distance

L = Sign Legend Luminance (if larger than background)

B = Sign Background Luminance

S = Surround Luminance

ER = Expected Recognition Distance [1200 feet x small dimension of the sign (feet)]

Cottrell (19) studied the cost per lumen per year of useful life and developed the following formula:

$$C = \frac{PC}{\frac{B_n + B_o}{2}} \times PF$$

where:

C = cost/lu/year of useful life

PC = Purchase price of sheeting per ft^2

B_n = Average luminance of new material

B_o = Minimum average luminance of material at end of its useful life

PF = Effective Performance Life (Warranty Period)

Assuming a straight line reduction in luminance over the materials useful service life, the cost savings can be calculated using the following formula:

$$S = \frac{C_1 - C_2}{C_1} \times 100\%$$

where:

S = Percent savings by using C_2

C_1 = Cost of using the alternative material

C_2 = Cost of using the preferred material

Gordon (20) evaluated several models with respect to target value in a laboratory study. The one which provided the best fit for predicting priority value was:

$$P = \frac{BR_{BiSi} + BR_{LiBi}}{(BR_{BS} + BR_{LB})} \times AR_{LB} \times SF \times 100$$

where:

P = Percent "first seen"

B_s = Surround Brightness

B_{Bi} and B_{Li} = Background and letter brightness for sign i

A_{Li} and A_{Si} = Area of Legend and sign i

A_{Si} and $A_{Si} - 1$ = Area of sign i and next smaller sign

BR = Brightness Ratio

$$BR_{BS} = \frac{B_B}{B_S} \quad \text{if } B_B > B_S$$

$$= \frac{B_S}{B_B} \quad \text{if } B_S > B_B$$

B_B = Background Brightness (ft - lamberts)

B_S = Surround Brightness (ft - lamberts)

B_C

$$BR_{LB} = B_B$$

$$B_L = \text{Legend Luminance}$$

$$AR_{LB} = \frac{A_{Li}}{A_{Bi}}$$ expressed as percent of longest ratio

$$AR_{LB} = \text{Legend to background area ratio}$$

$$SF^1 = \frac{A^{Si}}{A^{Si} + A^{Si} - 1}$$

$$SF^1 = \text{Size factor of sign 1}$$

$$SF^2 = (1 - SF^1) \frac{A^{Si}}{A^{Si} + A^{Si} - 1}$$

Sign Materials

"Three sources of information were employed in the comparative evaluation of various combinations of reflective sheeting on freeway overhead guide signs: observers judgement, luminance measurements, and cost analysis. These three sources converged in recommending the use of high-intensity foregrounds (legends and borders) on engineering grade backgrounds for freeway overhead guide signs.

Observers favored the HI/EG combination both in rating the features of these signs (more legible, more adequate, and less glare) and in consistently choosing the HI/EG combination over lack of the other combinations when stating their preference judgements. Brightness referred to the sign conspicuity and adequacy referred to how well the sign informed the observer and whether the sign could be used comfortably. The analysis of cost between HI/HI and HI/EG clearly favors the latter combination, and luminous measurements indicated that HI/EG provides contrast ratios for legibility that are at least as satisfactory as those for HI/HI." (2)

In a study conducted in California (3) it was proposed that the sign with nonreflectorized backgrounds which were nonilluminated would be restricted to advance exit, interchange sequences and similar overhead guide signs located at points where a drivers immediate response is not required. It was estimated that approximately 50 percent of these overhead signs would no longer require lighting. This would amount to a 20 year savings in electrical energy and maintenance of electrical components of $32 million.

In a Virginia study (7) where a comparative technique was employed to evaluate illuminated conventional signs, Engineering Grade Reflective Sheeting and High-Intensity Reflective Sheeting. The study concluded that with high beams and travelling along straight sections of roadway the unlighted high intensity signs were brighter than the illuminated conventional signs. On low beams the luminance of the high-intensity sheeting were not as bright. When there was stream traffic, the average luminance of the conventional signs were slightly higher then those of the unlighted high-intensity signs. On a curved approach the brightness of the unlighted high-intensity signs were not sufficient to provide the motorists with signs visibility and legibility equivalent to those obtained from the lighted conventional signs.

Risenbergs (9) studied the reflectivity of both Class A (Engineering Grade) Sheeting and Class B (High-Intensity Grade) Sheeting on a weatherometer. Figure 4, presents the loss of reflectivity as a function of the number of hours on the weatherometer for white Engineer Grade and High-Intensity Grade Sheeting. Engineer Grade sheeting failed at approximately 1975 hours on the weatherometer where as, high-intensity sheeting failed at 6900 hours. Figure 5, presents the same information as Figure 4 for the green sheeting. The Class A material failed at 2400 hours and the Class B material failed at 6950 hours. Mace (10) stated that type

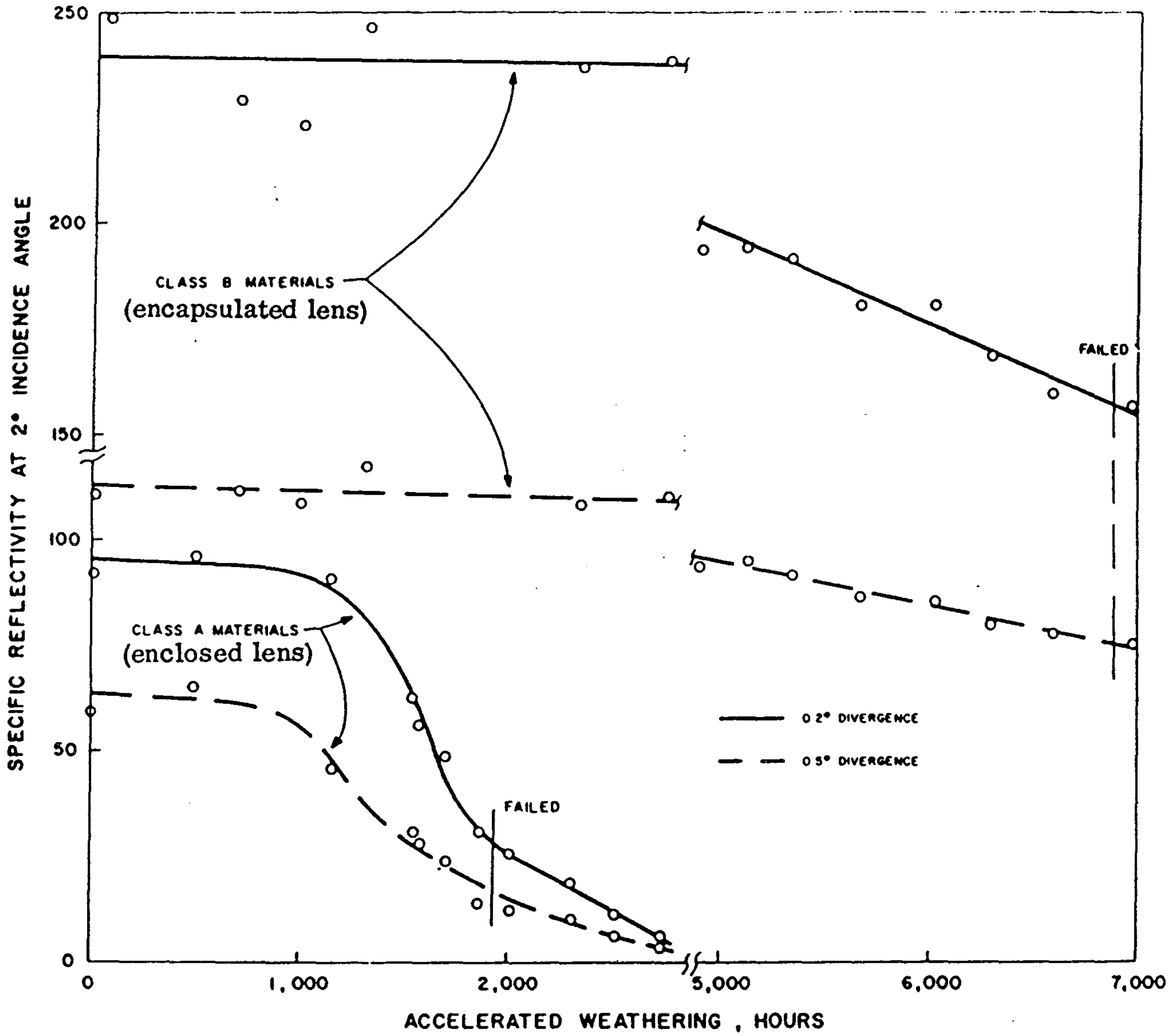

Figure 4. Accelerated weathering of silver — white Scotchlite sheeting — classes A and B.

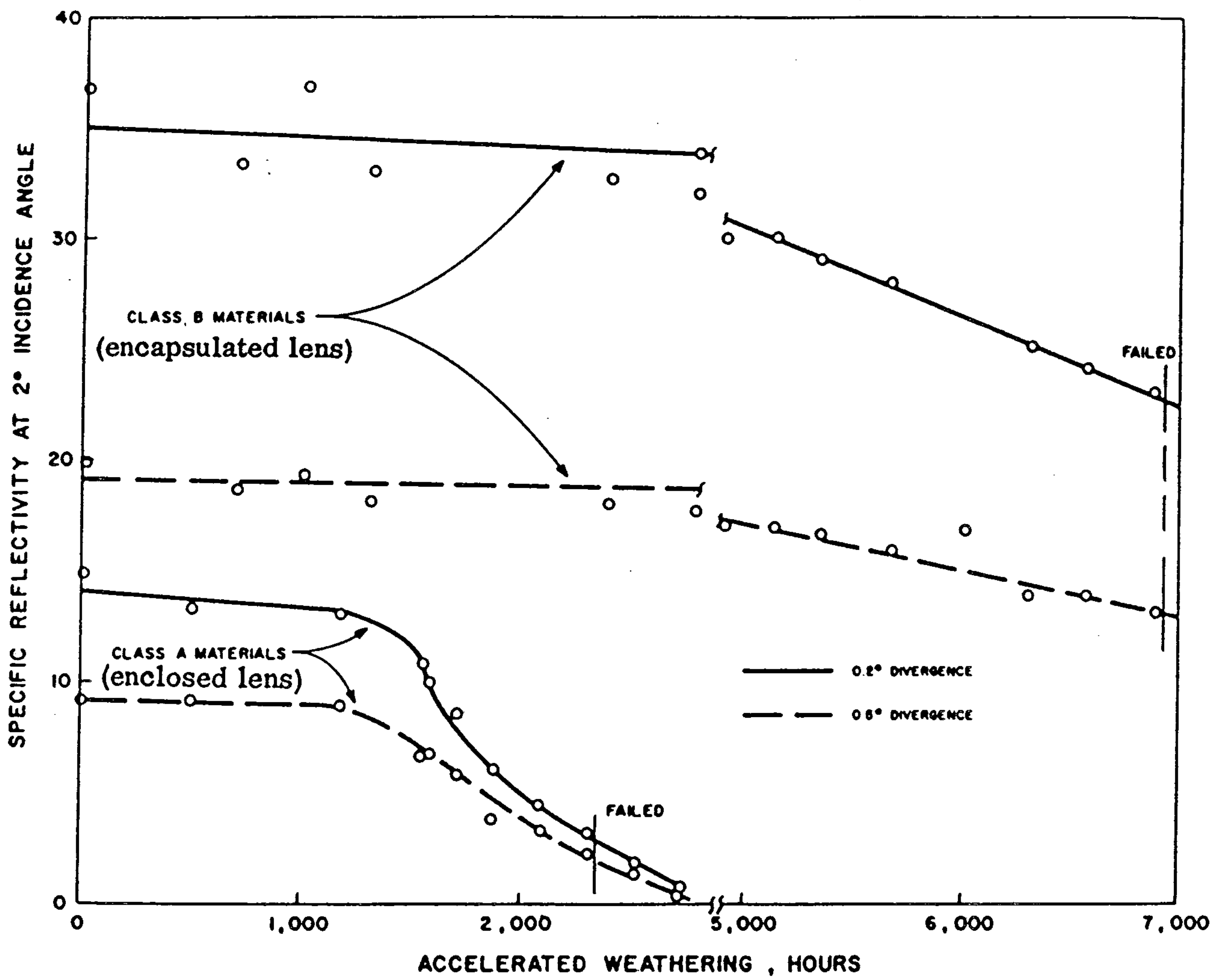

Figure 5. Accelerated weathering of green Scotchlite sheeting — classes A and B.

2 (Engineer Grade) materials below federal luminance standards may be adequate in low complexity areas. That type 3 (High-Intensity Grade) materials may not be sufficient in High complex areas.

Woods and Rowan (11) determined that with high beams the High-Intensity Reflective Sheeting without illumination showed a 5 percent increase and a 19 percent decrease when low beams were used. All of the legibility distances exceeded 590 feet. With this distance the use of high-intensity sheeting without illumination would not appreciably affect traffic operations.

Hermelink, et al, (12) performed a comparative evaluation of various combinations of reflective sheeting. One level was high-intensity and super-engineering reflective sheeting and level 2 was engineering grade reflective sheeting. Tables 3, and 4, present the mean ratings for the measure of perceived brightness, legibility, adequacy and glare for the sheeting materials occurring respectively, in the left and right overhead position. The higher the score the better the evaluation. Adequacy refers to how well the sign diverts the driver and how comfortable the driver is with the sign. With glare, a rating of 1 means no glare and 7 means excessive glare. Based on these results the recommended combination for non-illuminated overhead of each signs is engineer-grade reflective sheeting background with high-intensity stick-on lettering.

Table 3 overhead guide sign in left position

	HI/HI	HI/EG	SEG/SEG	EG/EG
Brightness	5.27	4.98	5.00	4.89
Legibility	5.08	5.20	5.37	5.32
Adequacy	4.93	5.20	5.24	5.26
Glare[a]	4.57	3.67	3.66	3.37

Note: Data for 19 observers
[a] $p < 0.001$.

Table 4 overhead guide sign in right position

	HI/HI	HI/EG	SEG/EG	EG/EG
Brightness[a]	5.23	5.18	3.71	4.53
Legibility[a]	5.21	5.86	4.50	5.00
Adequacy[a]	5.05	5.55	4.24	4.74
Glare[a]	4.09	2.87	3.08	3.82

Note: Data for 19 observers.

[a] $p < 0.001$.

Cottrell (19) performed a comparative analysis between Scotchlite brand high-intensity grade reflective sheeting and Seibeilite brand super engineering grade reflective sheeting under normal conditions. His findings concluded that high-intensity reflective sheeting is significantly brighter than the seibeilite super engineering grade reflective sheeting for the silver/white legend material. For the green background material, the two sheetings are not significantly different except for the ground mounted signs under high beam lights, where the high intensity sheeting is brighter. A cost analysis on the cost per lumen per year of useful life showed the high intensity sheeting to be more economical. From the analysis the Seibeilite super engineering grade reflective sheeting is not a viable substitute for sctochlite high intensity reflective sheeting.

Research reported by Californias translabl in June 1971 (30) determined that all reflective legends tested, including reflector button copy, high intensity copy, and engineering grade copy, have a nearly equal degree of reflectivity loss under dew conditions. They also found that the reflectivity of buttons is better than high intensity copy under frost conditions.

Service Type

The useful life of engineer grade sheeting varied from 3 to 10 years with a average of 7 years. The combination of buttons on porcelain enamel lasted 15 years or more. (1) In a Californian study (3) it was concluded that demountable button legend would perform effectively for 20 years or more. In another California study (4) the useful service life of High-Intensity Reflective Sheeting is 10 years compared to 20 years for porcelain on aluminum and 40 years for procelain on steel. Indiana indicated their porcelain enameled signs showed evidence of fading after it had been in place for slightly more than 15 years. (5) In the same report it was stated that Pennsylvania Cameo signs had an average service life of 15 years at which time they experience problems of delamination, fading and streaking. In a separate Pennsylvania study (6) it was stated the weatherometer tests indicated an expected service life of high-intensity and Super Engineer Grade Reflective sheeting to be about the same, 10 years.

A Federal Highway Administration Notice (22) states that field experience with high-intensity reflective sheeting indicates an expected life of 12 to 15 years or approximtely twice as long as engineer grade sheeting. Several signs have been observed that have been in use for 7 to 10 years and none had yet developed indication of significant deterioration.

Caltrans (31) used manufactures estimates of performances and their own weatherometer tests to develop the service life of various sign materials. These service lives are:

Porcelain enamel on steel	- 40 years
Porcelain enamel on aluminum	- 20 years
Reflector Buttons	- 20 years
Reflector Button adhesive systems	- 20 years
High-Intensity Reflective Sheeting	- 10 years

Engineering Grade Reflective Sheeting

(3 M and Adcolite) - 7 years

Engineering Grade Reflective Sheeting

(Sebeilite) - 10 years

In a study by Jones and Raska (32) it was determined that the durability and color retention of sign backgrounds utilizing vinyl tolulence acrylate, acrylic and alyid are relatively shot and therefore the use of the material is economically infeasible. With Porcelain enameled extrusion sign backgrounds color retention problems started occuring in two to three years along the coast of Texas. In other parts of the state the problem occurred in eight to ten years.

Fabrication and Installation Costs

In a Michigan study (5) the cost per year on a square foot basis was $2.56 for engineer-grade reflective sheeting (7 year-life) on Plywood with an aluminum sheeting overlay and $1.92 for high-intensity reflective sheeting with a projected 12 year service life. The Pennsylvania Report used a 8 year service life for engineer grade sheeting with an annual cost of $1.35 and a 15 year life for High Intensity with an annual cost of $1.12. Porcelainized enamel with a 15 year service life had an average annual cost of $1.47. This study also pointed out that the cost of maintaining signs fabricated solely from direct-applied reflective sheeting has been minimal, however demountable button legend sections on materials signs are subject to vandalism and flying debris.

Robertson (8) has included the average installation cost of five districts in Virginia. The costs on a per foot basis ranged from $5.00/sq ft with an overall average of $5.51/sq ft.

Sign Illumination

82% of the respondents do not illuminate roadside signs, whereas 92 percent illuminate overhead signs in at least some instances. Many agencies described selective policies based on the importance of the sign or the environment within which it is located. (1)

In a West Virginia study (28) it was reported that 68 percent of all overhead signs are externally illuminated. However, 8 agencies reported that they light 10 percent or less of their overhead signs, while 26 agencies reported lighting over 90% of their overhead signs. Most agencies are using mercury as a light source, and few are using high pressure sodium. Most are phasing out fluorescent. Appendix A, contains a summary of the results of the questionnaire survey of all 50 states.

Sign Inspection

15% of the agencies responding said they conducted monthly inspections, 5% quarterly, 20% semi-annual, 33% annually and 27% at other times. Nighttime inspections were conducted on all signs by 20%, half of the signs are inspected by 12%, a fourth, of the signs are inspected by 53%, and 9% indicasted they did not inspect any signs at night. (1)

Sign Maintenance

73% of the responding agencies have a regular sign cleaning program, 49% clean signs ever 3 months, 16% every 6 months, 32% ever year and 48% clean as required (1).

Federal Highway Administration Notice (22) states that in a study conducted by Risenbergs (9) that Engineer Grade Reflective sheeting would have a life expectancy of slightly more than 4 years (without maintenance) while the high-intensity material reached the equivalent of 14 years.

Sivak and Olson (29) determined the optimum and replacement retroreflectance for signs using U.S. low beams. Their values are contained in Table 5. The values apply to white, yellow and orange backgrounds of signs with black legends and to legends of signs with reflectorized backgrounds of up to .4 cd/m². The values apply to dark rural conditons. Interpretation indicates that for 75th percentiles

Table 5

OPTIMUM AND REPLACEMENT RETROREFLECTANCE (Cd/lx/m²)

U.S. Lower Beams

		Sign Location			
	Sign Luminance	Left Shoulder	Overhead	Right Shoulder	Shoulder Guide
Optimum	75 Cd/m²	2806 (Cd/lx/m²)	3547	736	856
85th Percentile	16.8 Cd/m²	630	798	168	189
75th Percentile	7.2 Cd/m²	270	342	72	81
50th Percentile	2.4 Cd/m²	90	114	24	27

performance retroreflectivities equal to or in excess of values obtainable from type IV (FP-73) sheetings will be required for yellow, orange, green and blue signs on the right shoulder and for all colors (including white) for signs in any other position.

CHAPTER 3

TARGET VALUE

Introduction

Sign lighting performs two vital functions for the freeway driver. the first, to make the sign more visible for the driver to read, and the second, so that the signs green background is visible to the driver. The second function sign lighting performs is the subject of this Chapter.

Federal Highway Administration (FHWA) maintains that for a sign to be conspicuous and command attention the green background must be visible to the driver. This is appropriately stated in FHWA's Manual on Uniform Traffic Control Devices section 2F-13 "Color, Reflection and Illumination of Freeway Guide signs shall conform to the provisions for expressway guide signs set forth in section 2E-5 and 2E-6. In addition, the background of all overhead signs that are not independently illuminated shall be reflectorized. When internal illumination is used, the sign colors shall appear essentially the same by day and by night."

Research Objectives

The objective of this research study was to determine whether sign lighting assisted the driver in locating freeway guide signs. With respect to different freeway geometrical designs it 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 do not have the 110-1200 foot critical sight distance provided. Therefore 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 falling on the sign face illuminating the sign. For signs with horizontal angles greater than 10° either left or right of the drivers line of sight may have to be illuminated to attract the driver attention to the sign.

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. All of the subjects were given the study objectives, general guidelines for the study and told the exact route they would be travelling along.

The study was conducted by driving through two routes and recording the target distances of the signs along the routes. Several signs included were not test signs. However, the target distance of these signs were recorded in order to protect against any sampling bias that could occur if the experimentor 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 told its location. The sign was either overhead left, overhead center, overhead right or ground right. Prior to the actual research study, the experiementors 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 the driver saw them and the actual spaciing of 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 B, contains the test administrators data recording form used in the study.

The test signs were broken into one of six categories. 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 shoudl be in the direct line of sight of the driver. The 5-10 degree signs shoudl be in the driver's peripherial 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 horizontal and vertical curvature, the tests being made are based on comparable signs. Table 6 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

Table 6: Houston Research Study
Vertical and Horizontal Sight Distances
Routes 1 and 2

Sign Group	Curve	Sign Type	Sign Material	Lighting Condition	Installation year
1	Vertical 300-800				
	Fannin	T-mount	E/B	Lighted	72
	Williams Trace	Ground	OP/B	Unlighted	83
2	Vertical 800-1200				
	Richmond	Overhead	HI/BL	Lighted	83
	Westcott	Median	E/BL	Unlighted	
3	Vertical >1200				
	Crestmont-King	Overhead	E/BL	Lighted	72
	Long-Wayside	Overhead	H/S	Unlighted	
4	Horizontal 0-5 Degrees				
	Westheimer	Overhead	E/B	Lighted	
	Airport-Kirkwood	Ground	OP/SO	Unlighted	84
5	Horizontal 5-10 Degrees				
	Sugarland Exit	Overhead	SE/SO	Lighted	
	Bissonett	Overhead	E/BL	Unlighted	
6	Horizontal 10-25 Degrees				
	Scott	T-mount	E/B	Lighted	72
	College Airport	T-mount	SE/B	Unlighted	83

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 a previous study (1-18-83-277) research report 277-1 that there was no significant difference in legibility between ground and overhead signs nor by sign material. For this reason the sign was selected based strictly on their geometric conditions without respect to their mounting position and/or materials.

Research Results

The results of this 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 7, presents the results, of this study for each of the signs.

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 sight distance category had a significantly longer distance (2995 feet) than the unlighted sign (1769). 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 feet 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

Table 7: Houston Research Study

Vetical and Horizontal Sight Distances

Routes 1 and 2

Sign Group	Curve	Sign type	Lighted avg	Unlighed avg	Sign Material
1	Vertical 300-800				
	Fannin	T-mount	2995		E/B
	Williams Trace	Ground		1769	O/B
2	Vertical 800-1200				
	Richmond	Overhead	1698		H/B
	Westcott	Median		1964	E/B
3	Vertical >1200				
	Crestmont-King	Overhead	1230		E/B
	Long-Wayside	Overhead		2845	H/S
4	Horizontal 0-5 Degrees				
	Westheimer	Overhead	2506		E/B
	Airport-Kirkwood	Ground		1767	O/S
5	Horizontal 5-10 Degrees				
	Sugarland Exit	Overhead	2214		S/S
	Bissonett	Overhead		3046	E/B
	Horizontal 10-25 Degrees				
	Scott	T-mount	1640		E/B
	College Airport	T-mount		1570	S/B

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 sign are located on a moderately complex loop freeway with fixed freeway lighting. Both are overhead mounted.

Discussion of Vertical Alignment Results

Because of the complexity of the results several of them should be discussed. The first is the criteria used to select the three critical sight distance categories. The 300-800 feet 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 raod 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 approximiately 750 feet to locate and read the sign. The 300-800 feet category was selcted as the most cricial 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 3.70 seconds to locate and read the sign.

Another important point to stress is that even though both the sign materials and sign location were not significant factors with respect to legibility they may be with respect to target value. The lighted sign was constructed with engineer grade background and button removable copy. The unlighted sign was conducted 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. As was pointed out by Mace, (24) 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.

The 800-1200 foot 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.

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 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 it appears that both sign lighting and ambient lighting increase target value for signs in moderate to severe sight distance situation. Sign lighting does not appear to aid in the target value for those situations in which sight distance problems do not exit.

Target Value for Sign with Horizontal Displacement Prblems

Many types of reflective sheeting have very narrow ranges in which this reflecivity is held to a maximum. After that angle is exceeded the reflectivity drops off rapidly. Three categories were chosen for Horizontal displacement. The 0-5° 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 category 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 retroreflectivly 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.

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 demand complexity. As complexity increases the sign must get brighter to overcome the effects of complexity. Woltman (33) and Mace (24) both have documented that as complexity increases signs must get brighter. Mace has also discussed the problem of quantifying complexity, therefore it is still subjective in nature. At what level of complexity should we go to brighter signs and at what level if, complexity does reverse constrast ratio aid in target value has not .pa been determined. Another reason could be the effect on target value that sign location has a 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 distance are well beyond the legibility distances of 788 feet as determined in the legibility study. The unlighted sign in the 5-10° category had a significantly greater target value (3046 feet) than the lighted sign (2214). Both of these signs were overhead mounted and constructed with the same background and legend material (Engineer Grade Reflective sheeting with high intensity copy). The sign with the longest target value besides being unlighted was in a rather high ambient light environment (.90 foot-candles) compared to the lighted sign which was in a transition zone from urbran to rural and had a lower ambient light level (.11 foot-candles). It is the authors contention that the ambient light level was the major difference in the target value distance. In the over 10° 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 a target value of 1640 feet and the unlighted sign 1570 feet. The reason for this is that the raised T-mounts are not located in the normal sign location. This violates driver expectancy and therefore it takes the driver longer to locate the sign. After drivers become aware of these signs and more raised T's are used their target value will increase. The target values are more than double the legibility distance for all types of sign materials.

Sign Ordering

The Statistical analysis for this portion of the study is contained in Appendix D. In this study several important issues with respect to target value were considered. It also provided an analysis to establish the validity of the target value study as conducted. This 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 and (3) did sign lighting have an effect on subjects detecting signs.

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 greater apart will usually be seen in the proper order than closely spaced signs. This conclusion is even further compounded if the first sign is unlighted and the second sign lighted, in the case of low to moderate complexity.

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 there are different probabilities associated with detecting a ground-mounted sign and an overhead sign. The probability of detecting an overhead sign is more than 2 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.

CHAPTER 4

STATES AND TRAFFIC ENGINEER OPINIONS ON SIGN LIGHTING

Introduction

No study of sign lighting can be complete without determining action other states have already taken and the feelings of 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 includes (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 and (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 Traffic Engineering Conference. This study was a questionnaire study administered to sixty-five traffic engineers attending the conference. The majority of the traffic engineers were from the State Department of Highways and Public Transportation for the State of Texas. However, some were also from municipalities and counties. Appendix D, contains the complete questionnaire administered to this group.

Results:

The results of 9 of the 10 questions are presented in Figures 6, through 13. The results indicate that 77 percent of the respondents felt

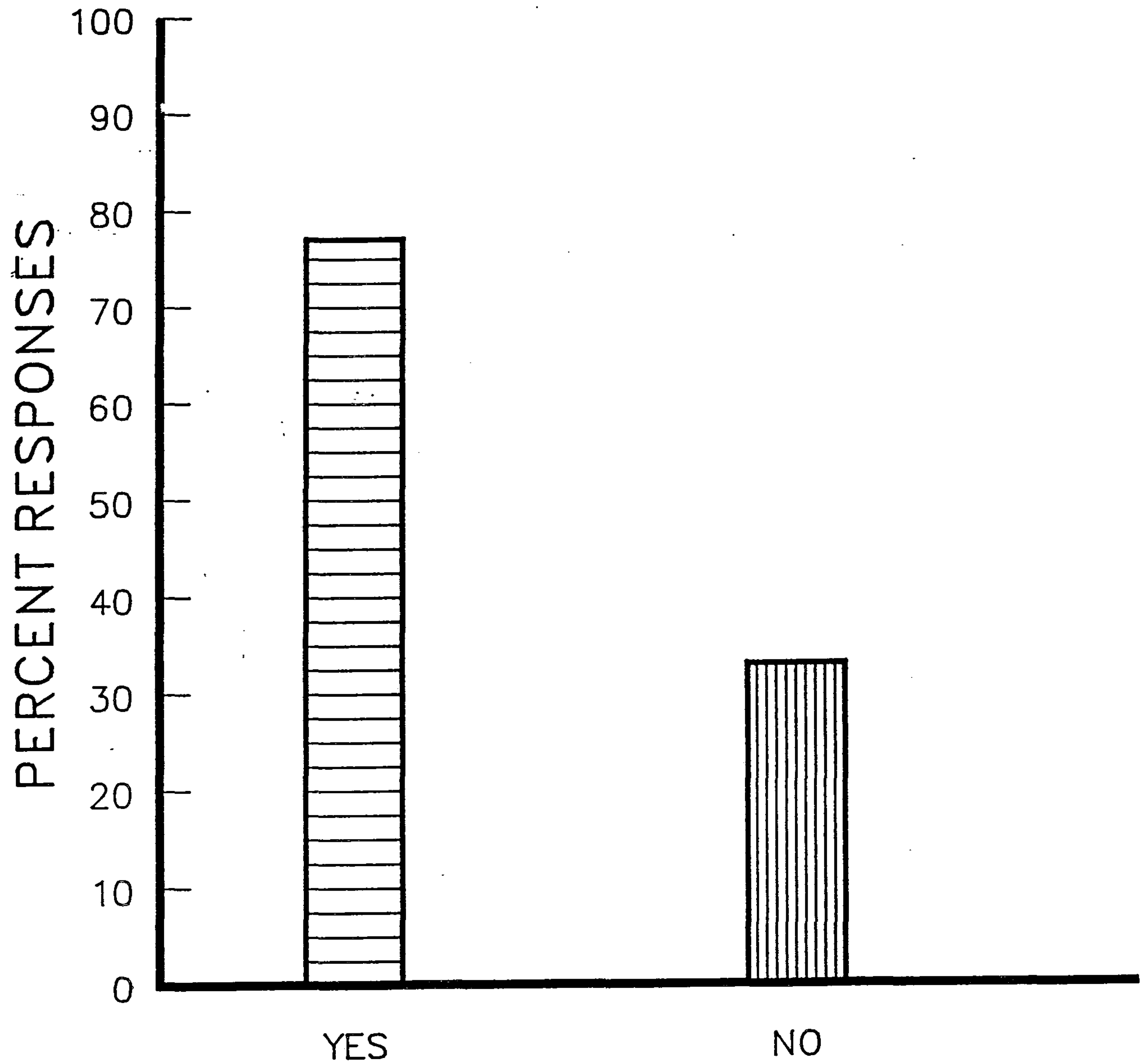

Figure 6: **Do you feel that all overhead guide signs should be lighted?**

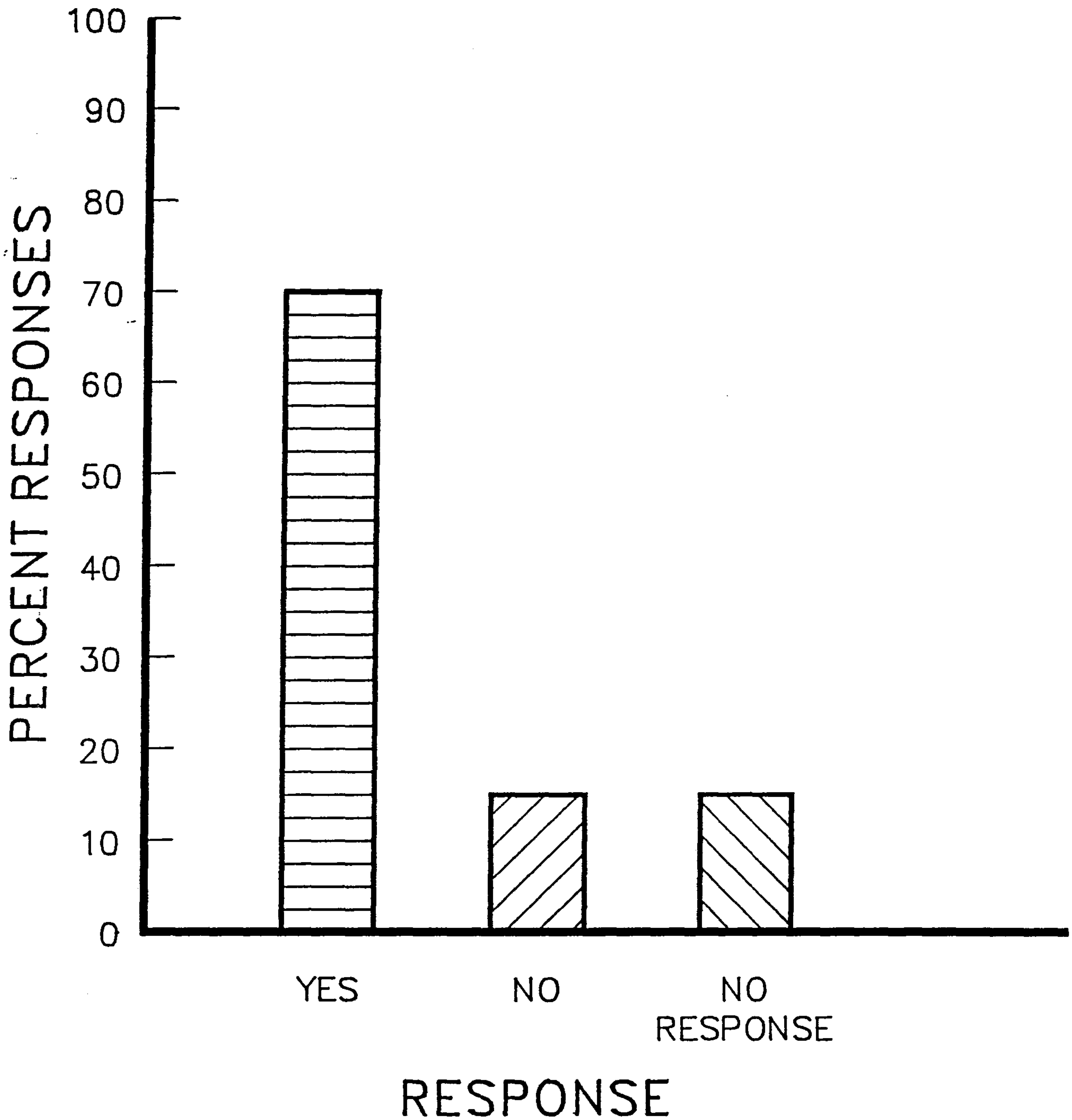

Figure 7: **Do you feel that it is mandatory for the unlighted sign to appear green at night?**

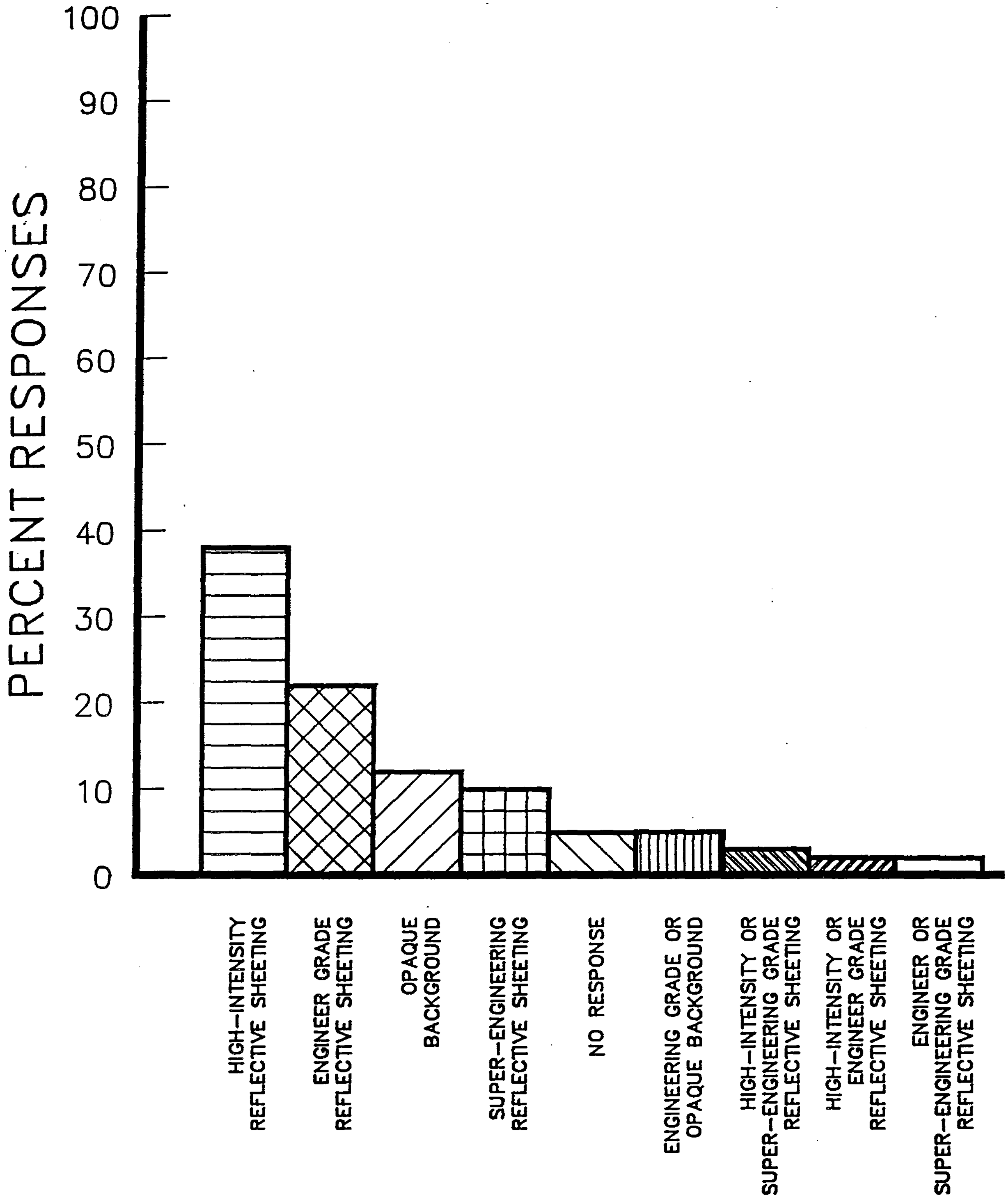

Figure 8: **In a rural unlighted freeway and an unlighted sign condition, would you use engineer-grade reflective sheeting, super-engineering grade reflective sheeting, high-intensity sheeting or an opaque background?**

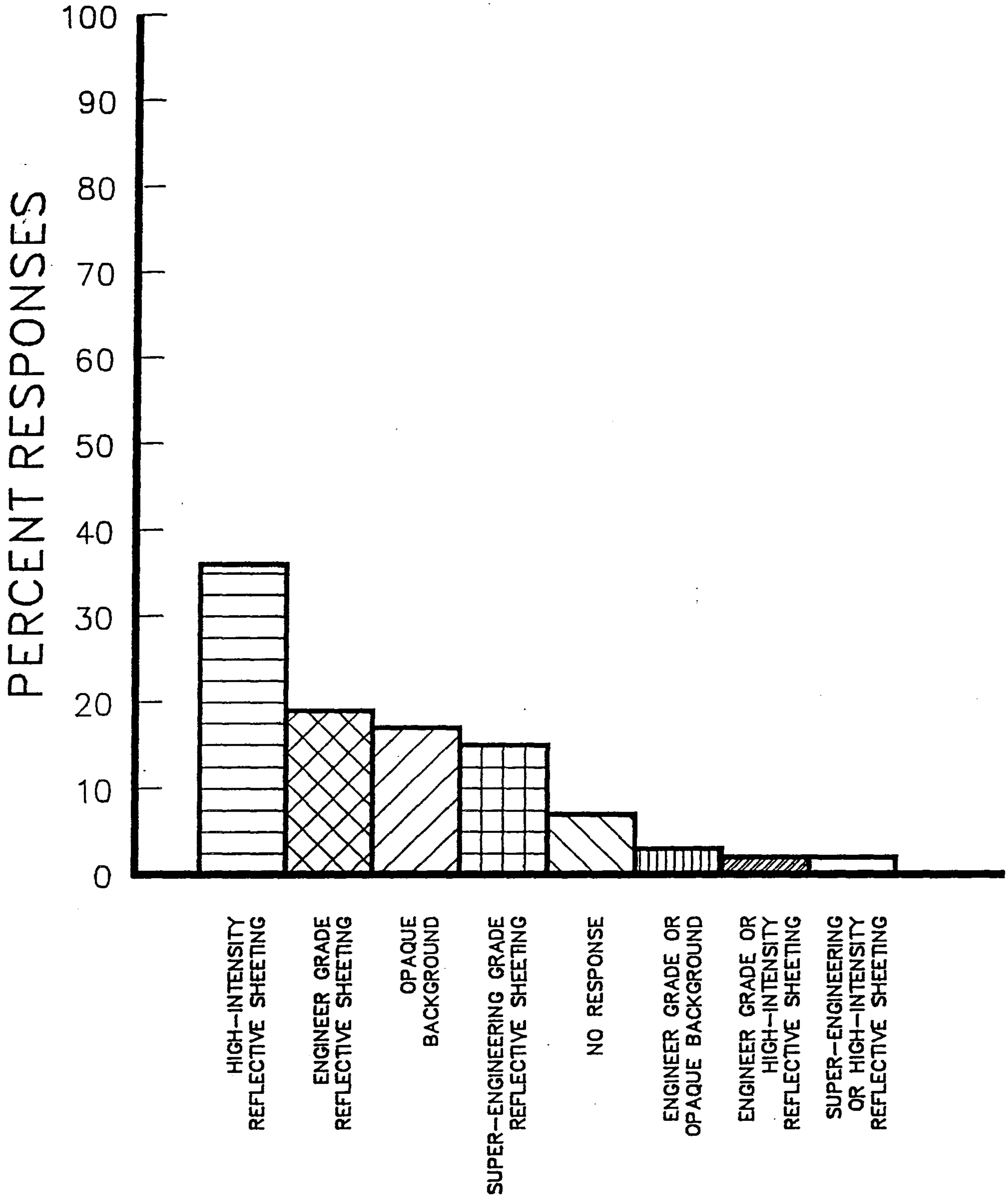

Figure 9: **Which of the four backgrounds would you use in an urban lighted freeway and an unlighted sign condition?**

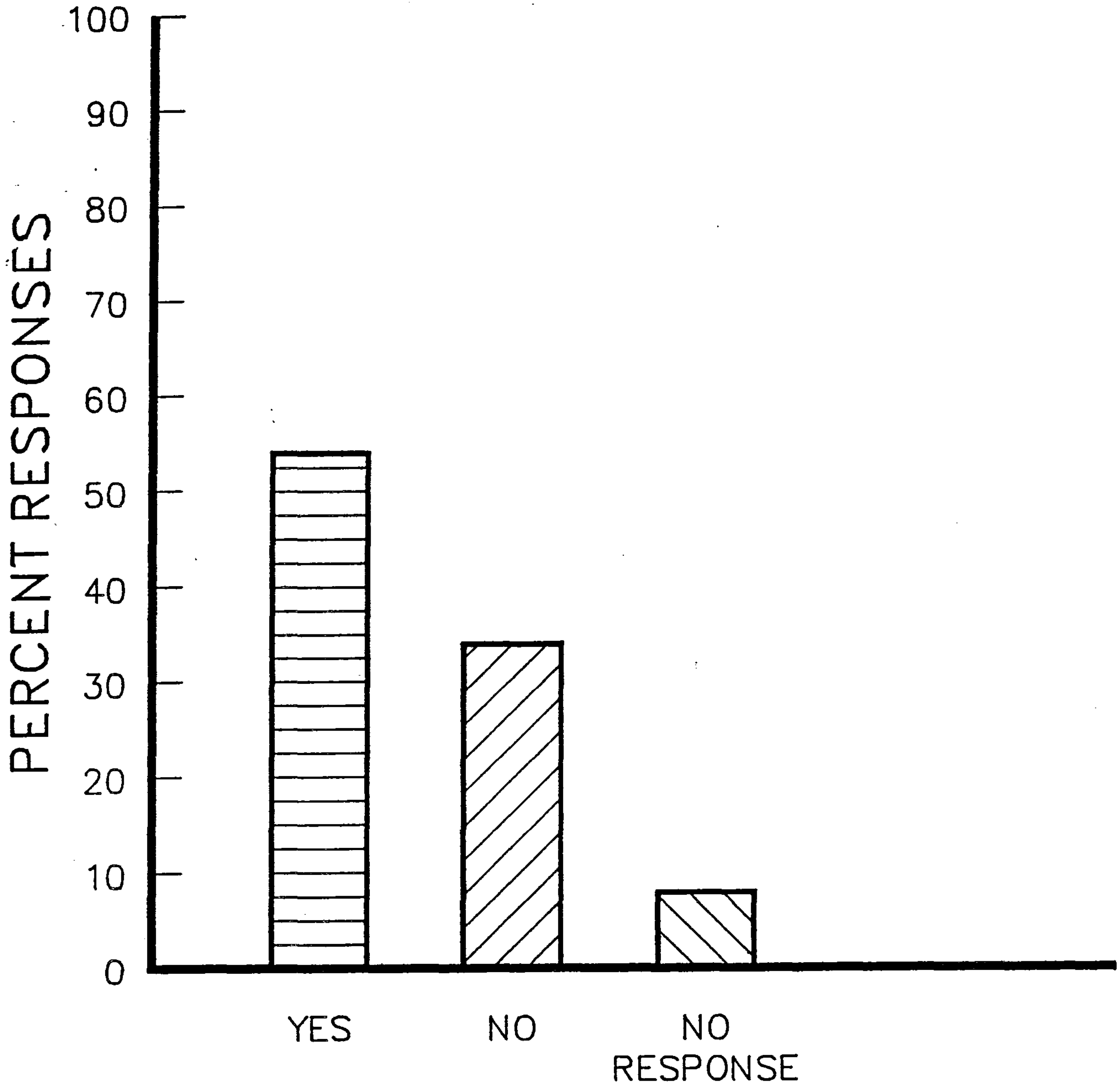

Figure 10: **Considering costs, hazards of maintenance operations and hazards to the traveling public caused by maintenance operations, do you feel that the background material should have the longest life possible regardless of whether it is reflective or not?**

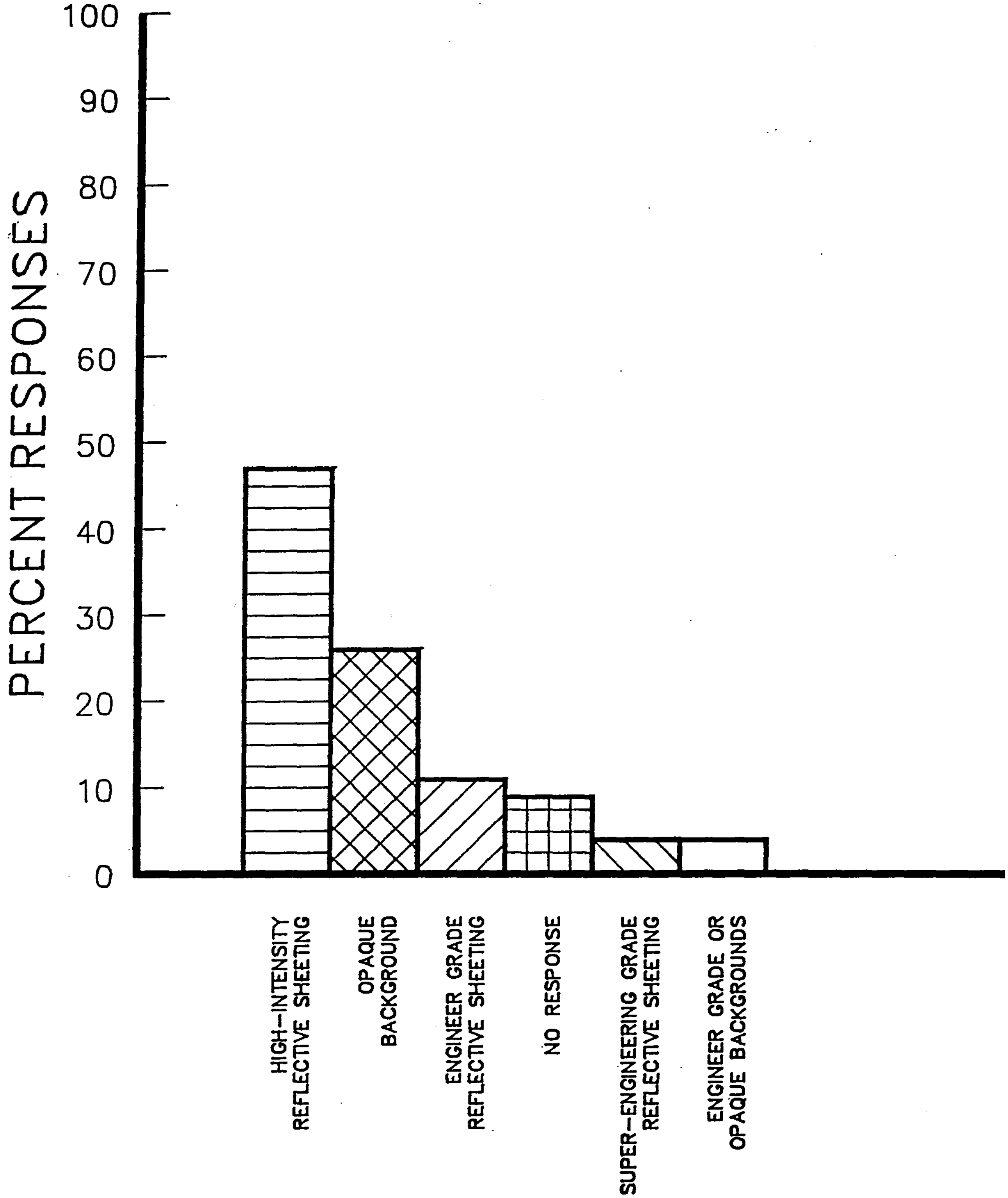

Figure 11: **Considering engineer-grade reflective sheeting has a 10-year life, super-engineering-grade has 10 years, high-intensity sheeting has 20 years and polyester opaque background has 50 years, which background would you use in an unlighted condition?**

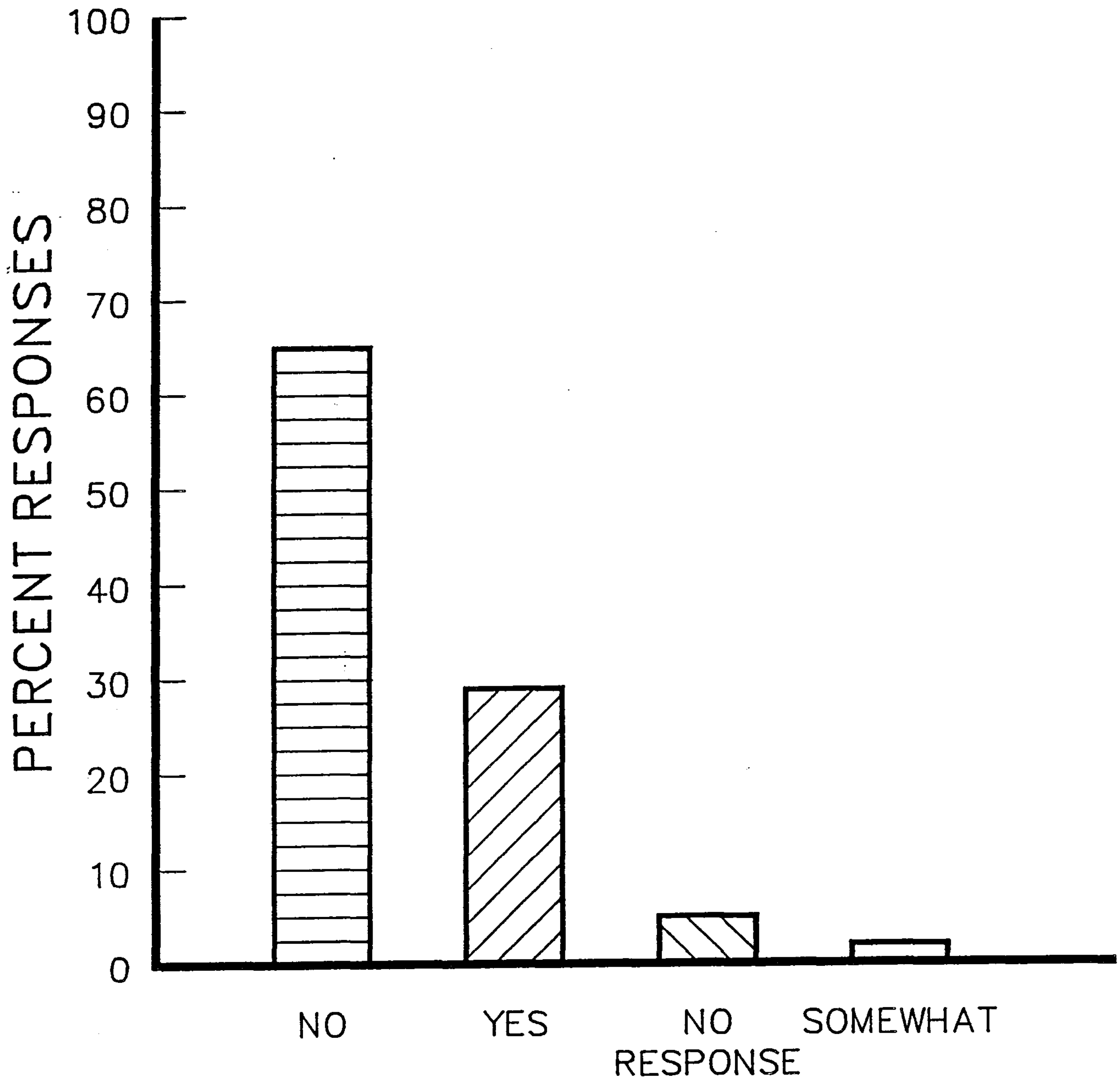

Figure 12: Does the fact that opaque backgrounds such as polyester appear black at night bother you?

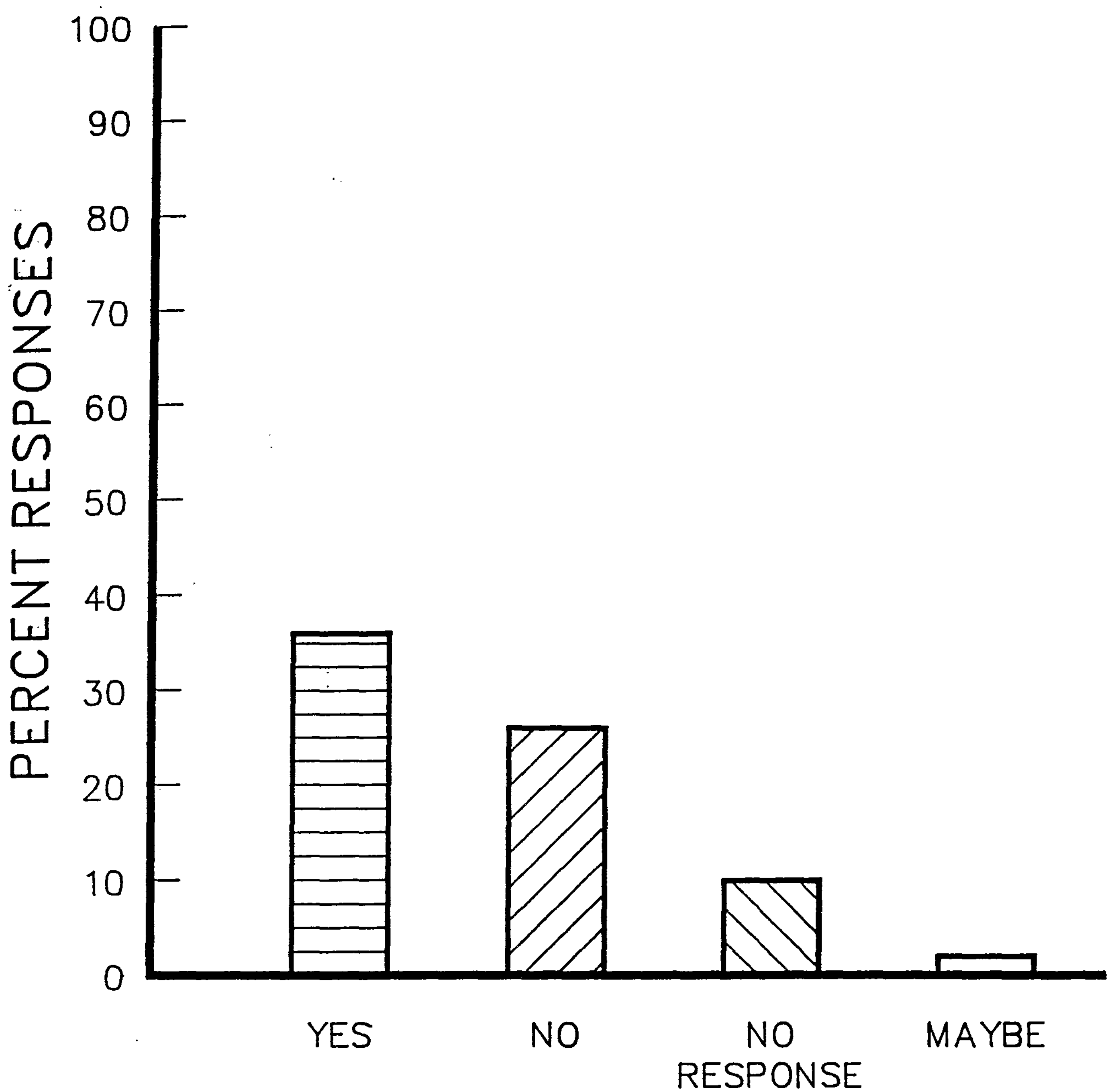

Figure 13: **Do you feel that with 1100'-1200' clear sight distance the opaque non-reflective copy gives adequate legibility distance in an unlighted condition?**

that overhead guide signs did not need to be lighted. The remaining 33 percent indicated that overhead guide signs should be lighted.

The respondents to questions 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. There was a fifteen (15) percent of the traffic engineers that either did not know or dit not understand the question.

Question 3 responses indicated that for normal unlighted overhead guide signs high-intensity reflective sheeting should be used. Thirty-eight (38) percent said they would use high-intnesity reflective sheeting, twenty-two (22) percent said they would use Engineer Grade, Twelve (12) percent opaque and ten (10) percent 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 that on lighted urban freeways with unlighted guide signs the engineer still found high-intensity reflective sheeting. Thirty-six (36) percent responded they would use the high-intensity reflective sheeting on urban freeways. The order of sign material used was indentical 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-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 understand the question.

Even though the opaque background sign had a service life of 50 years and high intensity sheeting has a 20 year service life and all other types have a 10 year service life, the engineers still selected high-intensity as the preferred material. Forty-seven (47) percent selected high-intensity as the preferred sign material, twenty-six (26) percent selected opaque, eleven (11) percent engineering grade and four (4) percent would use sign engineering grade. Nine (9 percent did not understand 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 Brdige Deck

Damaged Guard Rail

Damanged 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 nonreflective 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 qustionnaire study a telephone survey was conducted as part of this research project. Eight (8) states were selected as participants in the survey. The adjourning states to 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 E, contains all five questions used in the telephone survyey.

Results

Appendix E, also contains the answers for each question by state. In this section a summary of the results of each question will be made.

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 states 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 unless an engineering study determines that reflectorization is not sufficient and on horizontal curves using 800 foot radius as the critical criteria. Michigan uses critical sight distance and not type of background material as their criteria. Pennsylvania uses both a 1200 foot tangent sight distance and reflective background as criteria for no sign lights. New Jersey uses a portion of Michigans and Pennsylvania criteria, namely a 1200 foot tangent and background and copy material are not important. With respect to seeing the green background at night all states but one use devices which assures that the green background is visible. Only one state, California, does not feel that the green background is critical for drivers to see at night. No state has had a history of accidents or operational problems associated with turning sign lights off. California did receive one complaint when the lights were turned off. With the exception of Oklahoma, all states are in favor of eliminating sign lights as long as they are legible and do not violate any of the factors mentioned in Question 2. Oklahoma feels that sign lighting can be turned off in rural areas but not urban areas.

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APPENDIX A

WEST VIRGINIA QUESTIONNAIRE SURVEY

OVER HEAD SIGN SURVEY

1. Number of overhead signs on your highway system

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

2. What % of your over head 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 over head signs?

   Yes No

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

   ____

   ____

   ____

7. In your professional judgement, do you think over head signs should always be lighted?____

   ____

   ____

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

   ____

   ____

   ____

   ____

SUMMARY

State	Number of Signs	Percentage Lighted	Light Source	Costs/Year	Policy	Remarks
Alabama	100 - 500	98%	M	$500/yr/light	No	Sheeting on non-lighted Porcelain on Lighted No change in MUTCD wording
Arizona	500 - 1000	95%	F M	$259.29/sign	Yes	Hi-intensity on non-lighted Change MUTCD to not all lighted
California	> 1000	99%	F	$235/yr/light	Yes	Button Copy Reflectorized Change 2F-13 & 2E-6 in MUTCD to Certain Action Signs
Colorado	100 - 500	98%	F M	$200/yr/sign	No	Sheeting with Button Copy Change MUTCD to not all lighted
Connecticut	500 - 1000	75%	F M	-	No	Hi-intensity Change MUTCD to not always lighted
Delaware	100 - 500	75%	M	$300/yr	No	Hi-intensity Change MUTCD to light only interstate
Florida	1000	100%	F M	-	Yes	No Change in MUTCD
Georgia	500 - 1000	98%	M	$75/light	Yes	Change MUTCD to not all lighted
Idaho	100 - 500	46%	F M	$140/yr	No	Change MUTCD to not all need lighted Change shall to should in 2F-13
Illinois	> 1000	95%	F M (HPS)	$65/light	Yes	Use hi-intensity with good background and alignment No change in MUTCD
Indiana	500 - 1000	50%	M	$50/light	Yes	No change in MUTCD
Iowa	500 - 1000	75%	F M	N/A	No	Hi-intensity background with Button Copy of Hi Copy Change MUTCD to light all urban signs

State	Number of Signs	Percentage Lighted	Light Source	Costs/Year	Policy	Remarks
Louisiana	100 - 500	90%	F M	N/A	No	Change MUTCD from not all lighted to allow using judgement
Kansas	100 - 500	80%	20F 60M 17% MH	$60/year	No	Reflective Sheeting Change MUTCD to allow engineering judgement
Kentucky	500 - 1000	10%	F	N/A	No	Hi-intensity Sheeting Change MUTCD to not all lighted
Maine	100	0%	N/A	N/A	No	Sheeting B6 Button or Hi-intensity Copy No change in MUTCD
Maryland	>1000	90%	F	$150/yr	No	Hi-intensity No change in MUTCD
Massachusetts	>1000	2%	M	$500/yr	No	Hi-intensity legend and background Change MUTCD 2F-13- replace with May
Michigan	> 1000	1%		$300/yr		Change MUTCD 2A-16 to May be
Minnesota	>1000	90%	M	$175/yr	No	Hi-intensity on non-lighted Paint on lighted No change in MUTCD
Mississippi	100 - 500	0%			No	Hi-intensity B & C No need to light - No change in MUTCD
Missouri	> 1000	97%	M	N/A	Yes	No change in MUTCD
Montana	100 - 500	25%	M	$72/light	Yes	Overhead signing should be lighted
Nebraska	500 - 1000	90%	M HPS	$28/yr	Yes	Sheeting No need to light low speed, in-town No change in MUTCD

State	Number of Signs	Percentage Lighted	Light Source	Costs/Year	Policy	Remarks
Nevada	100 - 500	95%	F	N/A	No	Hi-intensity Change MUTCD to not all lighted
New Hampshire	100 - 500	35%	M	$130/yr	No	Hi-intensity B & C No need to light if in headlight scope No change in MUTCD
New Jersey Turnpike	100 - 500	98%	M	$70/light	No	Hi-intensity Change MUTCD to not all lighted
New Mexico	< 100	100%	75F 25M	$650/yr	Yes	Change MUTCD - 2E should expand to require judgement
New Jersey	> 1000	75%	F M	$80/yr	No	Opague with reflective copy Change MUTCD to not all lighted Require reflective background
New York	> 1000	1%	F	N/A	No	Light only in special circumstances No change in MUTCD
North Carolina	500 - 1000	95%	F M	$175/yr	Yes	Sheeting with lighted Hi-intensity with non-lighted Most should be lighted No change in MUTCD
North Dakota	< 100	100%	F M	$50/yr	Yes	Lighting is questionable in some areas No change in MUTCD
Ohio	> 1000	15%	F M	$120/yr	No	Sheeting Should not be lighted if reflectorized No change in MUTCD
Oklahoma	500 - 1000	95%	F M	N/A	Yes	Light in majority of cases No change in MUTCD
Oregon	> 1000	100%	F M	$80/yr	Yes	Light all directional signs No change in MUTCD

State	Number of Signs	Percentage Lighted	Light Source	Costs/Year	Policy	Remarks
Pennsylvania	1300	70%	M	$60/yr	No	Hi-intensity if sight distance is greater than 1200 feet No all need light if in headlight sweep Change MUTCD 2E-6 to allow reflectorization
South Carolina	100 - 500	80%	M	$110/yr/light	No	Hi-intensity for non-lighted Not all signs should be lighted Change MUTCD 2F-13 to allow reflectorization
South Dakota	< 100	0%			No	Hi-intensity background plus copy Change MUTCD to not all lighted
Virginia	> 1000	95%	F M	$30/yr/light	No	Hi-intensity Signs with 1200 feet sight distance should not be lighted
Tennessee	100 - 500	65%	F M HPS	N/A	No	Hi-intensity Change MUTCD to not all lighted
Texas	> 1000	95%	F M	$50/yr/light	Yes	Change MUTCD to not all lighted Where sight distance is greater than 1000 feet
Utah	100 - 500	95%	HPS	$120/yr	No	Hi-intensity Not all signs are lighted, particularly in Urban Areas No change in MUTCD
Vermont	100 - 500	25%	M	$125 - $150/yr	No	Sheeting plus button copy or sheeting Change MUTCD - 2A-16 only where 2E-16 critical Only light where reflectorization is inefficient
Washington	500 - 1000	100%	F M	$68/yr	Yes	Change MUTCD to allow non-reflective background with reflective copy

State	Number of Signs	Percentage Lighted	Light Source		Costs/Year	Policy	Remarks
West Virginia	100 - 500	95%	F	M	$150/yr	Yes	Change MUTCD 2A-16 to provide for judgement
Wisconsin	500 - 1000	50%	F	M	$125 - $150/yr	No	Non-reflective with lighted Hi-intensity on non-lighted Light only in urban areas Change MUTCD 2A-16 - engineering study is not appropriate
Wyoming	< 100	100%	F	M	$60/yr	Yes	Change MUTCD to not all lighted
Hawaii	< 100	95%	F	M	$15/yr	No	Sheeting Change MUTCD to not all lighted

APPENDIX B

TARGET VALUE STUDY TEST

ADMINISTRATIONS FORM

NAME ____________________ DATE ____________________

ATTENDANT ____________________ TIME START ________ FINISH ________

* = Test Sign

ROUTE 1
I 610 - US 59

Verification | Comments

KEY: START TAPE @ Over I-10 Bridge //

(I-10 West)

Start Sequence as soon as you enter freeway on I-10 at Washington

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

Test sign: Woodway Dr.(Overhead) Test Sign Distance ____

KEY: START TAPE @ Post Oak Blvd. (Overhead) ///////////////////////////

Start sequence at Richmond 1 1/10 mile sign (overhead)

Overhead ____
*2 Overhead ____

Test sign Richmond Ave. 3/10 (lighted) Test Sign Distance ____

KEY: START TAPE @ Hillcroft 1/2(Median) ////////////////////////////////////

Start sequence at Fondren Rd.
Exit 3/4 Mile

Overhead ____	Overhead ____	Ground ____	Overhead ____	Ground ____	Ground ____
Ground ____	Ground ____	Ground ____	Ground ____	Overhead ____	*3 Ground ____
Ground ____	Overhead ____	Ground ____	Ground ____	Ground ____	

Test sign Airport/Kirkwood 1/2 mile (unlighted) Test Sign Distance ____

ROUTE 1 CONTINUED

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 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 freeway 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 noticible section for the driver's peripheral vision. The 10-25 degree signs are outside this range. Table contains further information on these signs.

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 explane 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 t 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 2 has the results of the paired t tests for testing the average target distance difference 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 group. Finally the group for more than 1200 foot vertical curve had signifiacntly higher target distances when the sign was unlighted. The unlighted signs were targeted sooner than the unlighted 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 negligable 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 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 3 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 form 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 1: Houston Research Study
Vertical and Horizontal Sight Distances
Routes 1 and 2

Sign Group	Curve	Sign type	Lit avg	Unlit avg
1	Vertical 300-800			
	Fannin	T-mount	2995	
	San Felipe	Ground		938
2	Vertical 800-1200			
	Richmond	Overhead	1698	
	Westcott	Median		1964
3	Vertical >1200			
	Crestmont-King	Overhead	1230	
	Calais-M.L.K.	Overhead		991
4	Horizontal 0-5 Degrees			
	Westheimer	Overhead	2506	
	Airport-Kirkwood	Ground		1767
5	Horizontal 5-10 Degrees			
	Scott	T-Mount	1640	
	Bissonett	Overhead		3046
6	Horizontal 10-25 Degrees			
	Evergreen	Overhead	1660	
	College Airport	T-mount		1570

TABLE 2: 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 3: 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 3: 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 experimentor passed through the test course. Table 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 test 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 analagous 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 covariates. 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 covariate. If the response was 0, the distance to the nearest sign was used as a covariate. The reason for assigning these covariates 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.

The results of the Friedmans tests indicate that all of the sign groups in the analysis were not seen in a random order. That is to say, all hypothesis were rejected (alpha=.05) that the ranks were assigned in random order. The results are contained in Table 2. The number of treatments in Table 2 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 pval is less than .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 the 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 pval column represents the probability of obtaining a more extreme residual. This 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 only case in this study having a reversal. The Scott street sign 7 was a ground mount ulighted 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

$$\ln(p/(1-p)) = -2.957 + 0.001512 * D \qquad (1.$$

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. Table contains the print out of the logistic regression for fitting distances. The distances from the first sign in a test section are contained in Appendix.

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

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

where b1 throug 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

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

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 ulighted sign comparision are

$$\ln(p/(1-p)) = -3.278 + 1.793\text{ E-3} * D \quad \text{for lit signs} \quad (5a.$$
$$= -1.904 + 8.624\text{ E-3} * D \quad \text{for unlit signs} \quad (5b.$$

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 denoted by the symbol '*'. Appendix C contains the data used for graphing.

Table 2: 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 2 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 2 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

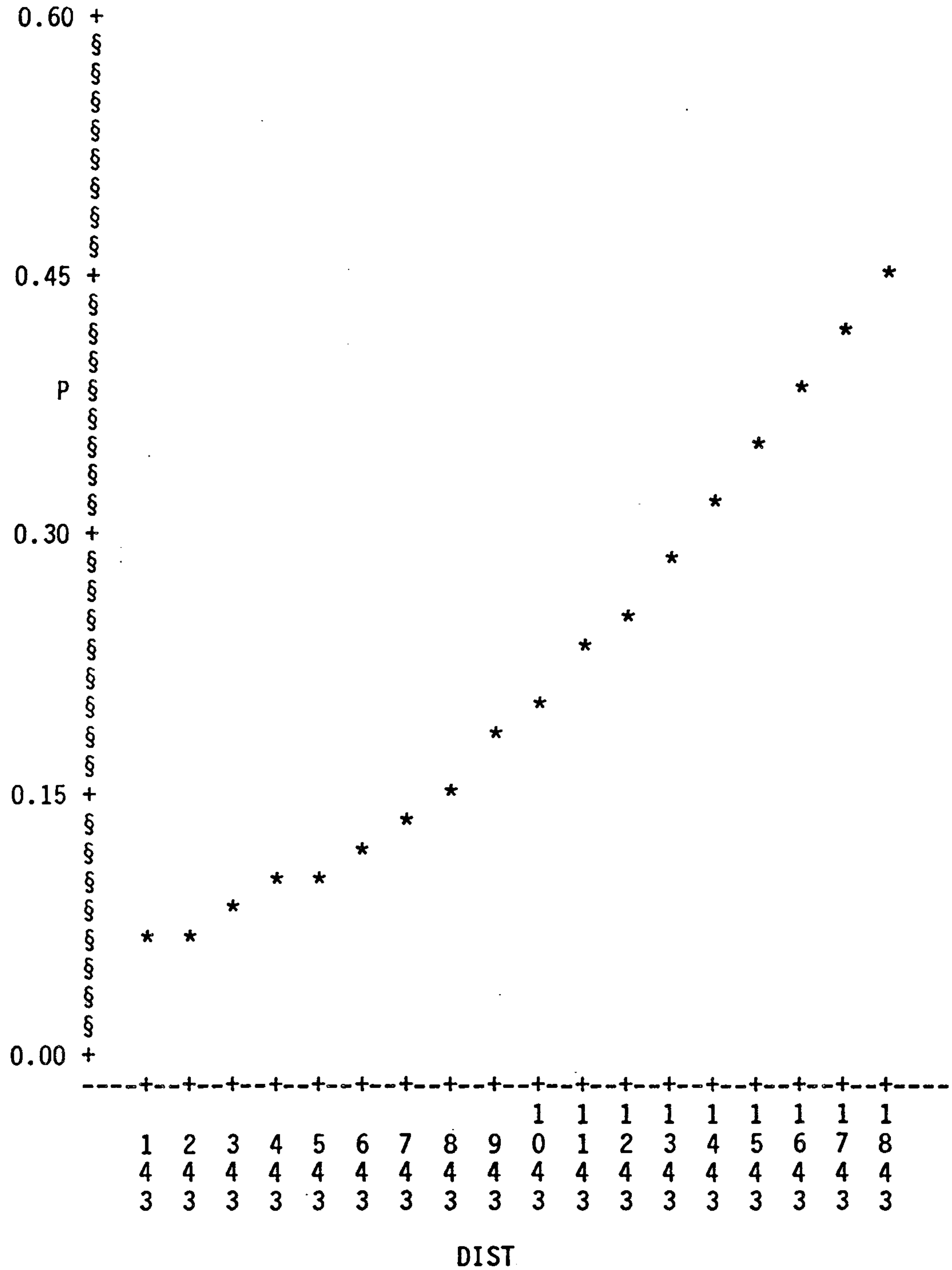
Friedmans test for file chimney1.dat

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

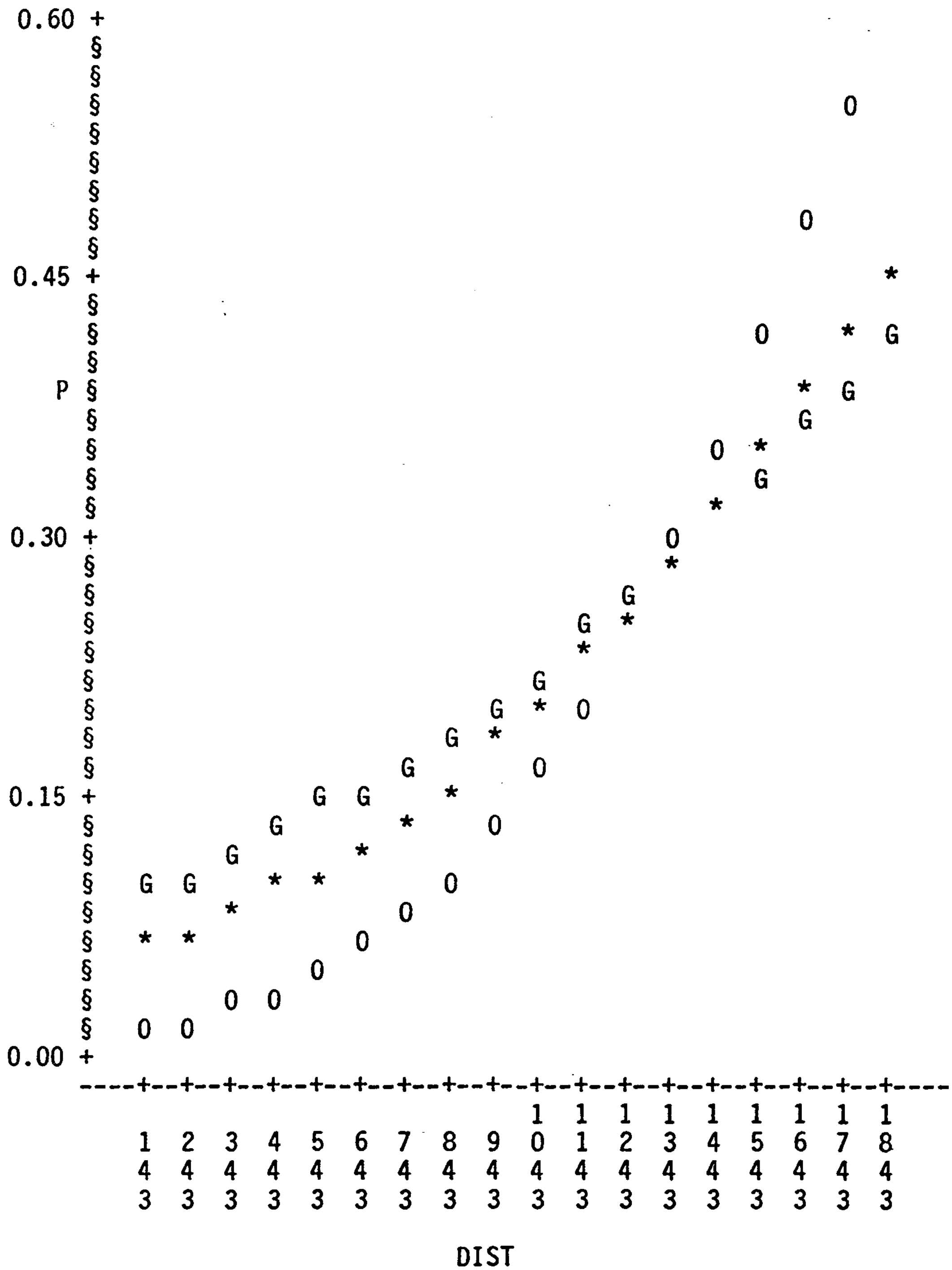
Plot 1: LOGISTIC REGRESSION FOR DISTANCE ONLY

Plot of P*DIST   Symbol is value of EFFECT



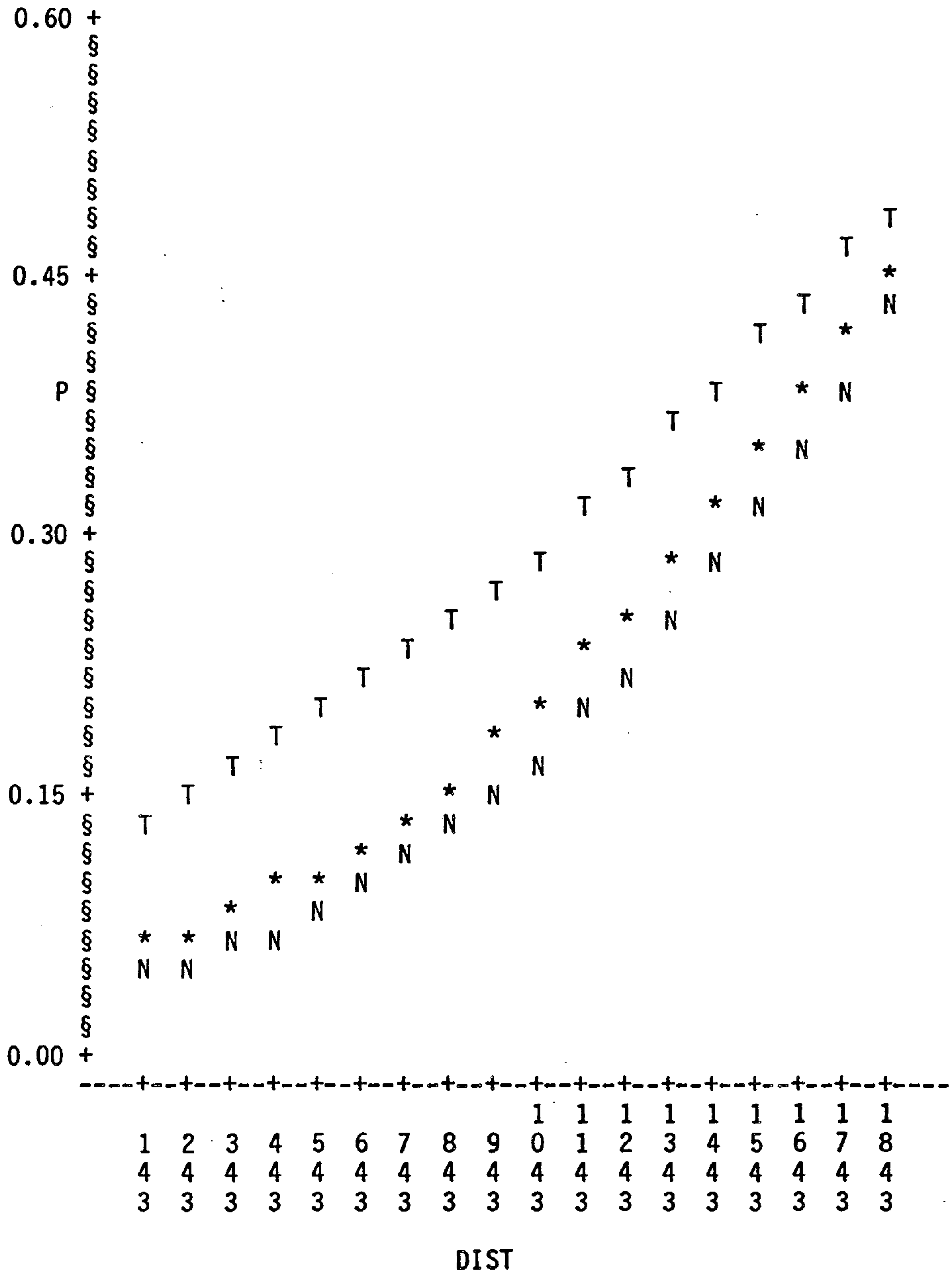
Plot 2: LOGISTIC REGRESSION FOR DISTANCE AND MOUNT

Plot of P*DIST   Symbol is value of EFFECT



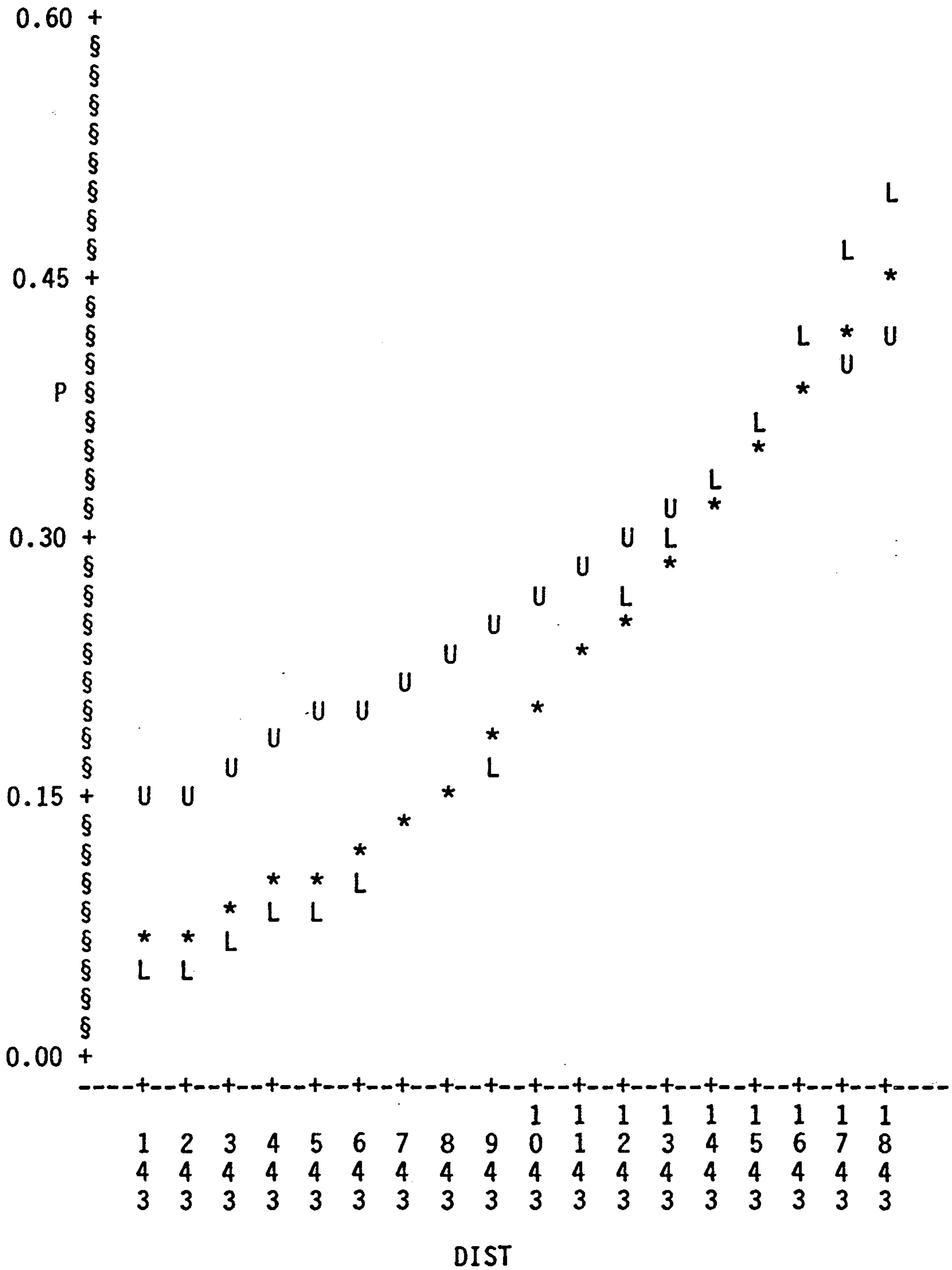
Plot 3: LOGISTIC REGRESSION FOR DISTANCE AND TEST SIGN

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 A:

LOGISTIC REGRESSION RESULTS WITHOUT SCOTT STREET

Table A1: Logistic Regression on Distances

FUNCAT PROCEDURE

RESPONSE: SEEN	RESPONSE LEVELS (R)= 2
WEIGHT VARIABLE:	POPULATIONS (S)= 13
DATA SET: NOSCOTT	TOTAL COUNT (N)= 535
	OBSERVATIONS (OBS)= 535

SAMPLE	DESIGN SWITCH	RESPONSE FREQUENCIES 1	2	TOTAL
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

SAMPLE	DESIGN SWITCH	RESPONSE PROBABILITIES 1	2	TOTAL
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		RESPONSE LEVELS (R)=	2
WEIGHT VARIABLE:		POPULATIONS (S)=	2
DATA SET: NOSCOTT		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
WEIGHT VARIABLE:
DATA SET: NOSCOTT

RESPONSE LEVELS (R)= 2
POPULATIONS (S)= 20
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: POPULATIONS (S)= 2
DATA SET: NOSCOTT 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 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	
GROUND	94	
OVERHEAD	3226	
GROUND	3372	
OVERHEAD	4005	
GROUND	4187	
OVERHEAD	7457	*1
OVERHEAD	8489	
OVERHEAD	10092	
OVERHEAD	12059	
OVERHEAD	12676	
OVERHEAD	13736	
OVERHEAD	15570	
OVERHEAD	19300	
OVERHEAD	21219	
GROUND	23024	
OVERHEAD	23593	*3

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

*4 COLLEGE/AIRPORT BLVD. 1 MI

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

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

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

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

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

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:

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 E

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 F

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.

I. 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 accidently; 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 should be taken into consideration?

A. Louisiana -

In favor of eliiminating 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 guide signs except for extreme case such as those signs having a 1200 ft. tangent distance.