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HEADLAMP BEAM USAGE ON U. S. HIGHWAYS

by

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ABSTRACT

Headlamp beam usage by drivers at seventeen locations in the continental United States was analyzed. Information observed for each vehicle included; type of vehicle, number of headlamps, direction of travel, speed, initial beam usage, beam change in response to opposing vehicle, distance from opposing vehicle when beam change was accomplished, presence of leading vehicle, and trailing distances. Observations were made at selected test sites in fifteen states and included: fourteen unlighted, rural, two-lane sections (one repeated); one unlighted, suburban, two-lane section; one unlighted, suburban, four-lane section with depressed median; and one suburban, two-lane section with overhead lighting.

ACKNOWLEDGEMENT

The authors wish to express their appreciation and acknowledge the cooperation and assistance afforded them by the Federal Highway Administration Regional Office personnel, the State Highway Department, and the State Police officials in all of the states where these surveys were conducted. Preliminary site selection was conducted in each site area by local State Highway personnel by the project engineer so that the task of ultimate site selection was greatly simplified. Other administrative assistance was afforded in recruiting observers and site guards and in setting up the test facilities, all of which materially reduced the task of conducting the surveys for which the authors are most grateful.

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I. INTRODUCTION

The nighttime traffic accident rate, on a vehicle-mile basis(1)*, is significantly higher than the daytime rate, and the existence of this situation infers that some change takes place in the highway/vehicle/driver system, in the absence of daylight, which is detrimental to safety.

Several factors are of importance to the analysis of this problem of increased nighttime accident rate, and they all concern the driver rather than the highway or the vehicle. The driver must gather information by visual, auditory, and tactile means, process this information, and make decisions based on it. He must perform physical control actions based on his decisions. Changes in illumination of the driver's physical environment which occur when darkness comes certainly reduce his ability to gather visual information, so it is obvious that his task becomes more difficult. It is also probable that fatigue and consumption of alcohol, both of which increase following the working day, are serious incidental factors. For the population of drivers, then, the driving task becomes more difficult and the competence level decreases during nighttime, making logical an increased rate of driver error and, therefore, an increased accident rate.

Phase I of this project, an investigation of headlamp glare(2), provides a thorough analysis of driver performance under various conditions of illumination encountered in nighttime driving. It is the objective of this investigation, Phase III, to record drivers' headlamp beam usage in practice and to determine the frequency of occurrence of situations simulated in Phase I. Hazardous situations of particular interest are driving too fast for available sight/stopping distance and the meeting of two vehicles, during which at least one driver's visibility is impaired by glare from the high beam lights of the opposing car.

Information recorded during this study and presented here concerns relation of drivers' headlamp beam usage to the total traffic situation. A literature search reveals that no data taken by a stationary observer on headlamp beam usage have been published, and only one study using a moving observer has been conducted(3). Of primary interest is beam usage on two-lane, unlighted, rural highways where the visibility problem is most severe(2), and beam usage on these highways is reported in greatest detail. Results obtained on a two-lane, unlighted, suburban highway, a limited access, four-lane, unlighted, suburban freeway, and a two-lane, suburban street with overhead lighting are reported for comparison.

An important point is that the information given here is the result of observation of normal, bidirectional, real traffic samples which were unaffected by observation procedure.

*Superscript numbers in parentheses refer to the List of References at the end of this report.

II. SELECTION OF TEST SITES

A. Physical Criteria for Test Site Selection

The following physical criteria for test site selection were used:

(1) Two-Lane, Rural, Unlighted Sites (14)

(a) The sites were level, or nearly level, tangent highway sections at least 1,800 ft in length. The 1,800-ft length was chosen because it was felt that most dimming actions would occur within this interval and to avoid instrumenting an excessive length of highway. Visibility from one end of the site to the other was unobstructed.

(b) Night traffic was moderate, neither greater than 300 vehicles per hour nor less than 20 vehicles per hour. Sites with surveyed ADT volumes of 3,000 to 5,000 vehicles per day provided adequate night traffic volumes. Test sites having high-volume peaks of short duration (such as near a manufacturing plant) were avoided.

(c) The sites contained no major connecting roads, commercial entrances, restricted speed sections, or restricted passing sections. They were free of large or lighted billboards and large information or warning signs.

(d) Highway construction was typical of the general area, in good condition, and, where possible, traffic lanes were 12 ft wide.

(e) Space existed near the center of the site for location of an observation vehicle. The space was either in the right-of-way or on adjacent land, and it was in a position such that the control vehicle was well back from the highway and inconspicuous to passing motorists. Visibility from this position to the ends of the sites was unobstructed.

(2) Suburban Test Sites (3): Four-Lane, Unlighted Freeway; Two-Lane Unlighted Highway; and Two-Lane Street with Overhead Lighting

With the exception of higher traffic volumes at these sites, the criteria used for the rural sites applied.

B. Other Criteria for Test Site Selection

To meet the study objective of determining headlamp beam usage characteristics on a nationwide scale, areas in which test sites were to be located were chosen throughout the country. The areas were picked to include variation in topography and climatic conditions as well as location. Listed below are the areas and conditions included as planned and accomplished.

(1) Areas of the U. S.

- (a) Northeast
- (b) Mid-Atlantic
- (c) Southeast
- (d) Midwest
- (e) Gulf Coast
- (f) Rocky Mountains
- (g) Northwest
- (h) Southwest

(2) Types of Topography

- (a) Mountainous
- (b) Rolling
- (c) Flat

(3) Climatic Conditions

- (a) Clear
- (b) Fog/haze
- (c) Rain
- (d) Snow

C. Test Site Selection Procedure

Making use of the criteria for site selection, general test site locations were proposed as follows for the two-lane, unlighted, rural sites:

Test Site No.	Test Site Location
1	Mountainous area of New York, Vermont, or New Hampshire.
2	Near-coastal area of Maine or Massachusetts.
3	Mountainous area of eastern Tennessee or western North Carolina.

Test Site No.	Test Site Location
4	Flatland farming area of Georgia, Alabama, or Mississippi.
5	Grassland area of central Florida.
6	Flatland farming area of Indiana or Illinois.
7	Forested flatland area of central Wisconsin or lower peninsula of Michigan.
8	Flatland farming area of Nebraska.
9	Near-coastal lowland area of southern Louisiana.
10	Rolling grassland area of south-central Texas.
11	Valley agricultural area of California, between Coastal and Sierra Nevada mountain ranges.
12	Plateau or desert area of south-central Arizona.
13	Western foothills of Cascade mountains in Washington or Oregon.
14	Mountainous area of west-central Colorado.

Test sites were selected and used in the areas proposed. Site 7 was used twice, first with snow conditions (7A), and again without snow (7B).

In addition to the unlighted, rural, two-lane sites, three other test sites were proposed. These included:

Test Site No.	Description
15	An unlighted, suburban, four-lane freeway with 50-ft median.
16	An unlighted, suburban, two-lane highway.
17	A two-lane, suburban street with overhead lighting.

For convenience, sites 15 and 17 were chosen in the San Antonio area and site 16 in the Washington, D. C., area.

Table 1 gives general information about each site. More comprehensive data and an outline map showing locations are given in Appendix A.

TABLE 1. LOCATIONS AND BRIEF DESCRIPTIONS OF TEST SITES

Site	Location	Description	Dates	Vehicles Observed
1	New York: U. S. 4, 1.6 miles south of intersection with New York 146	2-lane, unlighted, 11-ft lanes, rural	5/8/68-5/12/68	3130
2	Maine: U. S. 1, 3.5 miles north of north intersection with Maine 127	2-lane, unlighted, 12-ft lanes, rural	5/15/68-5/19/68	3505
3	Tennessee: U. S. 11W, 4.5 miles west of west intersection with U.S. 25E	2-lane, unlighted, 12-ft lanes, rural	1/31/68-2/1/68, 2/23/68-2/25/68	2950
4	Georgia: U. S. 82, 4.1 miles east of east city limit of Albany	2-lane, unlighted, 12-ft lanes, rural	1/11/68-1/15/68	2837
5	Florida: Florida 24, 5.8 miles west of intersection with Florida 232	2-lane, unlighted, 10-ft lanes, rural	1/18/68, 1/22/68	3404
6	Illinois: Illinois 121, 0.4 mile north of intersection with Dillon Road	2-lane, unlighted, 12-ft lanes, rural	2/9/68-2/13/68	3853
7A	Michigan: Michigan 57, 4.5 miles east of intersection with U. S. 131	2-lane, unlighted, 12-ft lanes, rural	2/16/68-2/20/68	2659
7B	Michigan: Michigan 57, 4.5 miles east of intersection with U. S. 131	2-lane, unlighted, 12-ft lanes, rural	5/23/68-5/27/68	2051
8	Nebraska: U. S. 77, 4.5 miles north of intersection with U. S. 30	2-lane, unlighted, 12-ft lanes, rural	4/10/68-4/14/68	4967
9	Louisiana: U. S. 165, 2.4 miles north of Fenton	2-lane, unlighted, 12-ft lanes, rural	4/18/68-4/22/68	2277
10	Texas: Texas 16, 4.0 miles north of Helotes	2-lane, unlighted, 12-ft lanes, rural	12/26/67-12/30/67	1028

TABLE 1. LOCATIONS AND BRIEF DESCRIPTIONS OF TEST SITES (Cont'd)

Site	Location	Description	Dates	Vehicles Observed
11	California: California 132, 0.5 mile west of Paradise Gates Road	2-lane, unlighted, 12-ft lanes, rural	3/20/68- 3/24/68-	7229
12	Arizona: U. S. 60, between mileposts 138.41 and 138.64	2-lane, unlighted, 18-ft lanes, rural	3/13/68- 3/17/68	5619
13	Oregon: Oregon 22, 10.7 miles east of intersection with Interstate 5	2-lane, unlighted, 12-ft lanes, rural	3/27/68- 3/31/68	3258
14	Colorado: U. S. 6, 3.0 miles west of intersection with Colorado 13	2-lane, unlighted, 12-ft lanes, rural	6/5/68- 6/9/68	1330
15	Texas: Interstate 410, between Ingram Road and Culebra Road exits	4-lane, unlighted, suburban, 50-ft median	7/10/68- 7/14/68	7024
16	Maryland: U. S. 5, 3.3 miles south of 4-lane section which intersects beltway	2-lane, unlighted, 12-ft lanes, suburban	7/19/68- 7/22/68	6783
17	Texas: San Antonio, McCullough Avenue south of Basse Road	2-lane, with overhead lighting, 18-ft lanes, suburban	7/3/68- 7/5/68	5099

III. TEST SITE LAYOUT AND INSTRUMENTATION

A. Test Site Layout

Figure 1 is a schematic plan view of the test site. The diagram shows location of major items of instrumentation and personnel and their orientation to the highway.

B. Instrumentation

The headlight data monitor system consists of five basic units, and the following are brief functional descriptions of these units:

(1) Light Source/Photoelectric Detector Pair

The source/detector pair acts as a single pole, single throw switch; open when the light beam across the highway is uninterrupted, and closed when the light beam is broken (as by the presence of a vehicle between source and detector). Normal test site operation requires thirteen source/detector pairs at 100-ft intervals along the test section. As a vehicle proceeds through the site, interrupting each light beam in turn, the detectors send signals to the data monitor control unit.

(2) Observer Control Panels

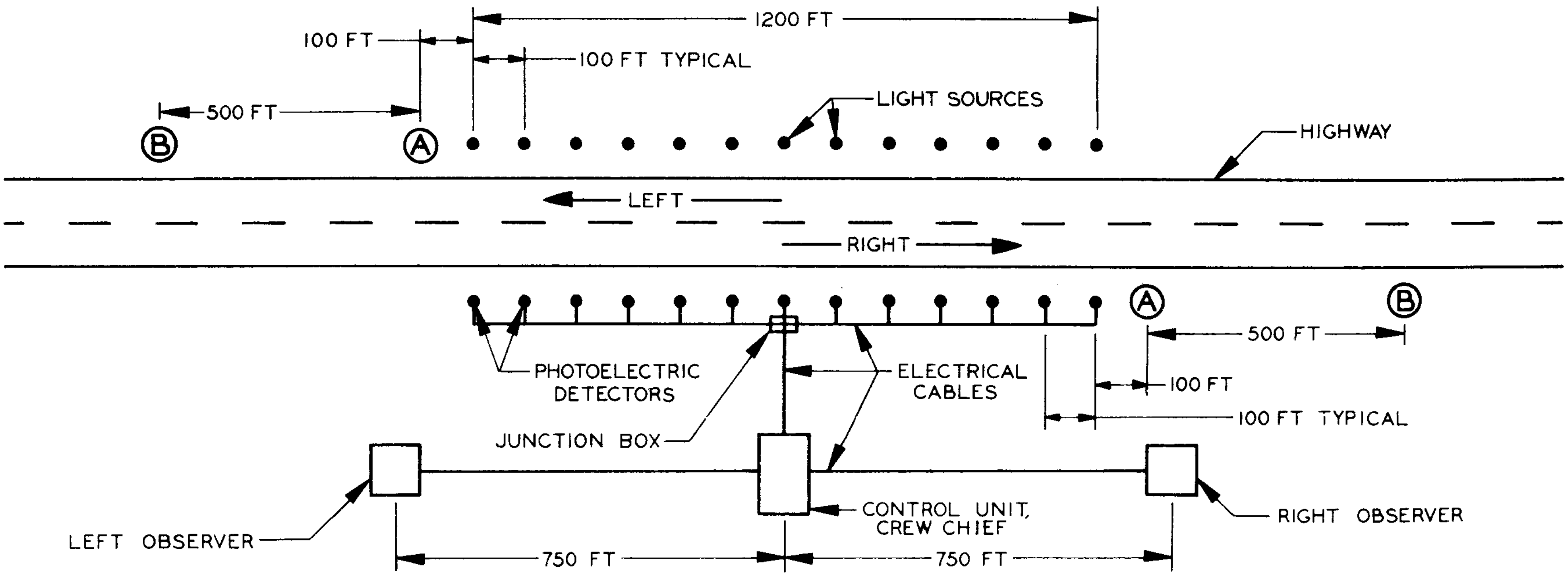
The observer control panels allow the observers to record pertinent information about each vehicle passing through the test site. The information recorded includes type of vehicle, number of headlamps, initial beam usage, and beam changes. These panels also have a built-in intercom system for communication between observers and crew chief.

(3) Junction Box

The junction box provides an interconnection point for the two detector cables, the two observer control panel cables, and the cables which connect to the data monitor control unit. The purpose of this interconnection is to allow flexibility in the positioning of the instrument truck, which is desirable because of terrain variations among the test sites.

(4) Data Monitor Control Unit

The data monitor control unit receives information signals from the observers and the detectors and converts these signals to



POINTS (A): SIGNS READING, "PLEASE DIM LIGHTS"

POINTS (B): SIGNS READING, "RESUME NORMAL LIGHTING"

FIGURE 1. SCHEMATIC DIAGRAM OF TEST SITE

control pulses for the recorder. That is, it causes the correct stylus in the recorder to write when a given event occurs. In addition, it contains an interval timer to write time marks on the chart, and it also provides automatic recorder actuation, when a vehicle enters the test site, if the recorder is initially in a standby state.

(5) Recorder

The recorder employed is a Brush model RE 3610-02, 100-channel electric writing event recorder. The chart speed used was 5 mm/sec with 60 Hz power. Of the available channels, 30 were used to permanently record coded information on the strip chart. Power for the instrumentation was provided by a portable 1250-w alternator. The recorder unit completes the data acquisition system.

(6) Signs

The signs placed at locations A and B (Figure 1) were for the purpose of causing drivers to switch to low beam when in open road situations, thus assisting the observers in identification of beam usage. This was particularly helpful when observing two-lamp, dual beam headlights.

IV. EXPERIMENTAL PROCEDURE AND DATA REDUCTION

A. Data Collection

With the equipment set up as described in Section III, the data collection process was initiated. **Observers were instructed to record for each vehicle:**

(1) Type of vehicle (car or truck)

(2) Number of headlamps the vehicle had (2 or 4)

(3) Beam usage upon entering the test site (high or low)

(4) Any beam change made by vehicle after initial sighting.

As classified in this study, a "truck" was any vehicle other than a normal passenger car. The crew chief coded each truck entry manually for later classification, e.g., the "PK" entry on Figure 2.

The observer stationed at the right end of the site recorded the above data for each vehicle proceeding left to right, and vice versa. An observer's orientation sheet is included as Appendix C.

The event recorder system, described in Section III, makes possible the simultaneous recording of vehicle position versus time, for any number of vehicles in the site, in addition to beam usage and descriptive information. A sample data strip is given in Figure 2. Of 50 available channels, counting upward from the bottom of the page, a mark in a specific channel indicates the occurrence of a specific event. The code is:

Channel(s)	Event(s)
2	Time mark, 15-min intervals
11-23	Interruption of light beams (leftmost is 11)
31,41	Vehicle is a car
32,42	Vehicle is a truck
33,43	Vehicle has 2 headlamps
34,44	Vehicle has 4 headlamps
35,45	Vehicle using high beam when initially sighted
36,46	Vehicle using low beam when initially sighted
37,47	Completion of a beam change
38,48	Compliance with "PLEASE DIM LIGHTS" sign

The only marks made by the recorder styli are the horizontal dashes. The heavy lines connecting vehicle traces to data items, the code "PK", and the time were added by the crew chief to aid data reduction.

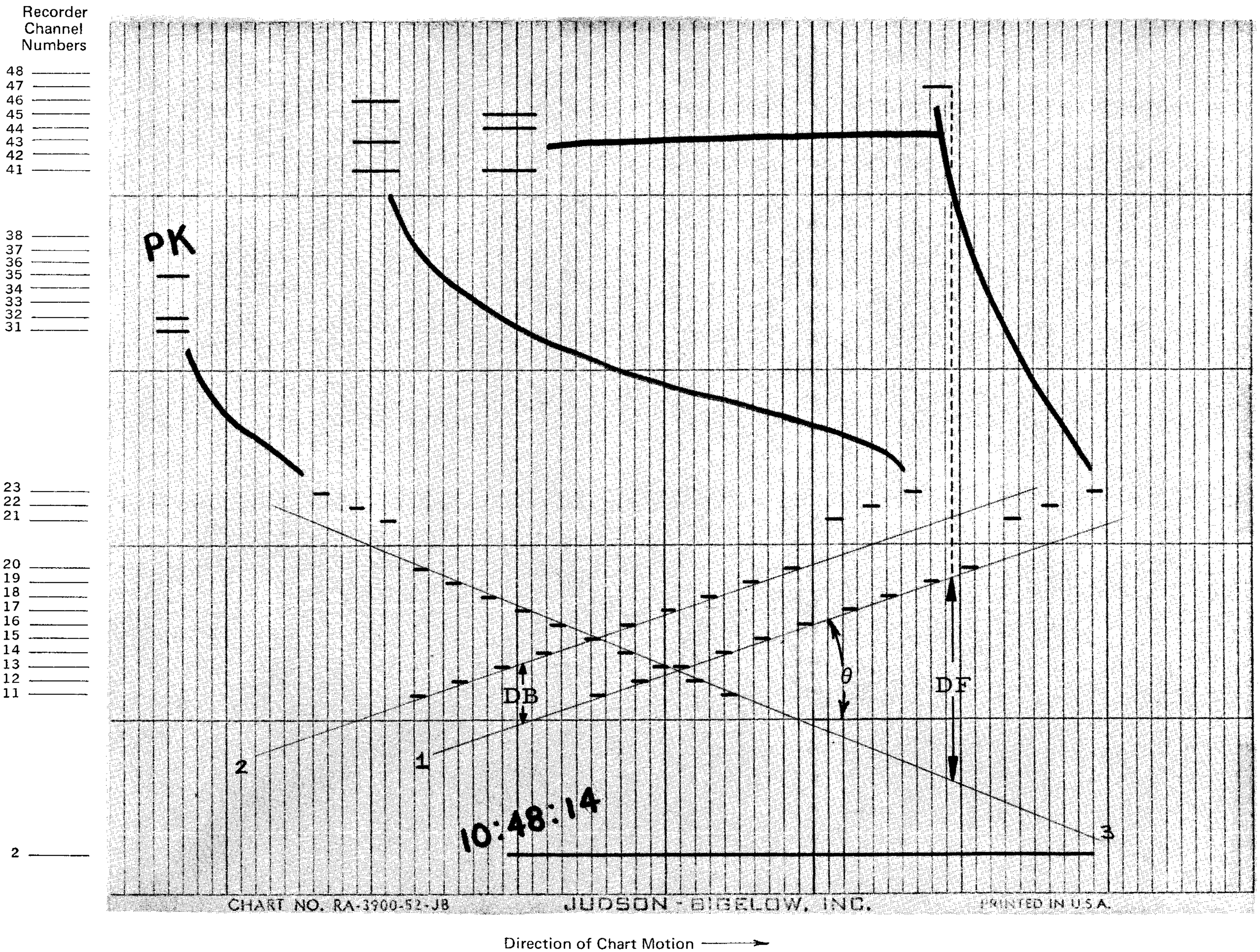


FIGURE 2. SAMPLE DATA STRIP

B. Data Reduction

Figure 2 will be used as an example to illustrate the data reduction process. The line numbered "1" follows the position-time trace of the first vehicle to enter the test site. The horizontal axis is time, one in. equalling 4.76 sec. and the vertical axis is position, one in. equalling 1,059 ft. These relations hold only for the analysis of channels 11-23 because the other channels convey information in a simple yes (a mark) or no (no mark) mode. The slope of line "1", or the acute angle (θ) it makes with the horizontal axis, can be read as speed according to the following formula:

$$\text{SPEED (mph)} = 151.7 \tan \theta$$

The calculations leading to this formula are given in Appendix B. A plastic protractor-ruler was constructed to read directly in miles per hour and in feet to simplify data reduction, and it is shown as Figure 3.

The speed of vehicle 1 is read as 52 mph.

Beginning at the right of the page, the first light beam interrupted by vehicle 1 corresponds to channel 23 which is the rightmost beam in the test site. Therefore, the direction of vehicle 1 is right to left or, simply, left.

Following the heavy line from line 1 to the three horizontal dashes, it is found that the dashes appear in channels 41, 44, and 45. Therefore, vehicle 1 is a car having four headlamps and entering the site using high beam. The single horizontal dash indicated to be a part of the data on vehicle 1 is in channel 47, denoting a beam change (high to low, since vehicle 1 was on high beam initially) at that point. Vehicle 3, using the above reasoning, is proceeding right, so vehicle 1 dimmed in deference to vehicle 3. By extrapolating the position-time trace of vehicle 3 back to the point when dimming occurred, the intercar distance at dimming is "DF", or 1450 ft, as read by the ruler portion of the template in Figure 3.

Vehicle 2 is proceeding left also, and at 52 mph. The distance "DB" by which vehicle 2 trails vehicle 1 is read as 430 ft. Following the heavy line to the three horizontal dashes, it is found that they appear in channels 41, 43, and 46, so vehicle 2 is a car having two headlamps and entering the site using low beam. No beam changes are shown, so vehicle 2 proceeded through the site on low beam.

Vehicle 3 is proceeding right, and at 62 mph. The three dashes are in channels 32, 33, and 36. Therefore, vehicle 3 is a truck (generally, something other than a passenger car) having two headlamps and using low beam. The code "PK" states that vehicle 3 is a pickup, placing it in the light truck (G.C.W. 1 ton or less) category.

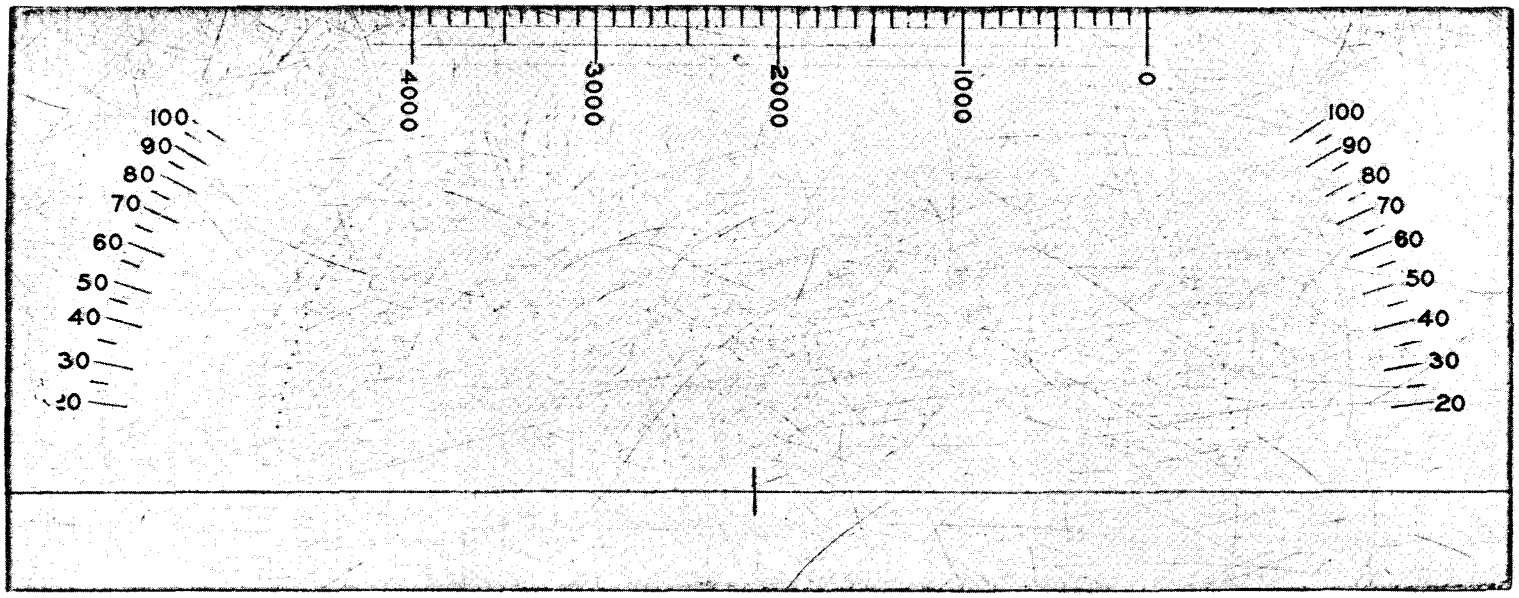


FIGURE 3. PLASTIC TEMPLATE FOR READING SPEEDS AND DISTANCES FROM CHART

To summarize the data taken from Figure 2:

Vehicle number	1	2	3
Vehicle type	Car	Car	Light truck
Number of headlamps	4	2	2
Beam usage entering site	High	Low	Low
Dimmed for opposing vehicle	Yes	No	No
DF	1450 ft	--	--
Followed vehicle through site	No	Yes	No
DB	--	430 ft	--
Met vehicle in site	Yes	Yes	Yes

To complete the data reduction process, the data were coded onto computer cards for later use in calculations.

V. SUMMARY OF FINDINGS

A. All Two-Lane, Rural Sites (Sites 1-14) Combined

1. Findings on Vehicle Characteristics

The data in Table 2 serve to describe the vehicle population observed and to confirm that this population is a valid sample of the nation-wide vehicle population. Registration figures show that 83.5 percent of vehicles currently in use are passenger cars[4, 5], and that the remaining 16.5 percent fall into truck or bus categories. It must be noted that Table 2 describes a nighttime vehicle population, which explains the slightly higher percentage of trucks observed when compared to nationwide registration.

TABLE 2. VEHICLE TYPES AND HEADLAMP CONFIGURATIONS

	Number Observed	Percent of All Vehicles Observed
All Vehicles	50,031	100.00
Cars	40,518	80.99
Light Trucks	3,937	7.87
Heavy Trucks	5,576	11.14
4-Lamp Vehicles	33,388	66.74
2-Lamp Vehicles	16,643	33.26

In addition, 15 percent of the trucks observed had four head-lamps, and 79 percent of the cars observed had four headlamps.

2. Findings on Vehicle Speeds

Speed limits for nighttime driving at the test sites used varied from 50 mph to 70 mph. Of all the vehicles observed, 53.66 percent were exceeding their respective speed limits. When the pavement was dry, the average speed was 60.46 mph, and when the pavement was wet, the average speed was 55.37 mph.

The findings of Phase I of this investigation[2] show that the following distances apply for the detection of a standardized pedestrian dummy under clear atmospheric conditions:

TABLE 3. DETECTION DISTANCES FOR A STANDARDIZED PEDESTRIAN DUMMY

Traffic Situation	Beam	Detection Distance, ft 15-Percentile Driver	Median Driver	85-Percentile Driver
Open Road	High	630	775	870
Open Road	Low	280	375	515
Meeting	High	200	250	315
Meeting	Low	200	250	315

Using the method of calculation adopted by the A. A. S. H. O. (6), the following stopping distances from speed are found to apply:

TABLE 4. STOPPING DISTANCES FROM SPEED

Speed, mph	Perception/Reaction/Stopping Distance, ft Dry Pavement	Wet Pavement
30	158	193
35	195	248
40	236	309
45	279	376
50	327	452
55	379	527
60	434	620
65	489	707
70	554	820
75	622	945
80	696	1083

It should be noted that these distances include 1.5 sec perception time and 1 sec reaction time before braking.

If "safe speed" is defined as the maximum speed from which the driver could stop his vehicle in order to avoid striking a standardized pedestrian dummy, the following "safe speeds" apply:

TABLE 5. "SAFE SPEEDS" FOR GIVEN TRAFFIC, BEAM USAGE, AND PAVEMENT CONDITIONS

Traffic Situation	Beam	Pavement	"Safe Speed," mph 15-Percentile Driver	Median Driver	85-Percentile Driver
Open Road	High	Dry	75	80	80
Open Road	High	Wet	60	65	70
Open Road	Low	Dry	45	50	65
Open Road	Low	Wet	35	40	50
Meeting	Either	Dry	35	40	45
Meeting	Either	Wet	30	35	40

The following table shows percentages of vehicles observed exceeding the "safe speed" for their traffic situation, beam usage, and pavement condition. This table is based on the median driver, since the procedures employed in the investigation could not classify particular drivers according to visual capability.

TABLE 6. PERCENT OF VEHICLES OBSERVED EXCEEDING "SAFE SPEED"

Traffic Situation	Beam	Percent of Vehicles Exceeding "Safe Speed" Dry Pavement	Wet Pavement
Open Road	High	1.88	16.2
Open Road	Low	74.79	95.1
Meeting	Either	93.54	98.6

3. Findings on Dimming Situations

Of the 2,789 vehicles observed as initially on high beam and which subsequently met another vehicle, 2,294 vehicles, or 82.25 percent dimmed in deference to the opposing vehicle. The mean intercar distance at which these dimming actions occurred was 1,714 ft, and the standard deviation of the mean was 1,264 ft. Figure 4 is the distribution of dimming actions observed. Figure 5 is the density function.

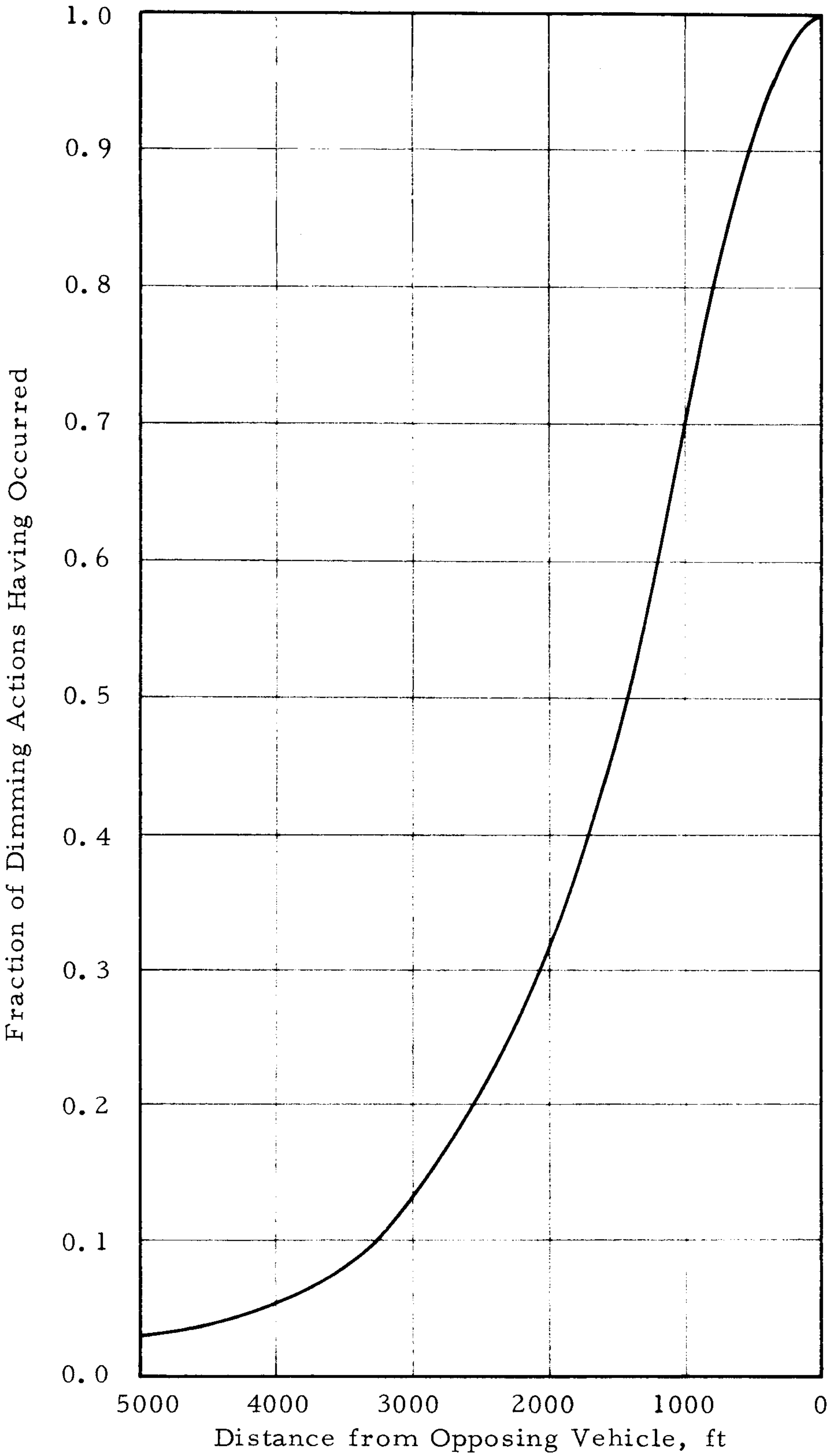


FIGURE 4. DISTRIBUTION OF DIMMING ACTIONS, SITES 1-14

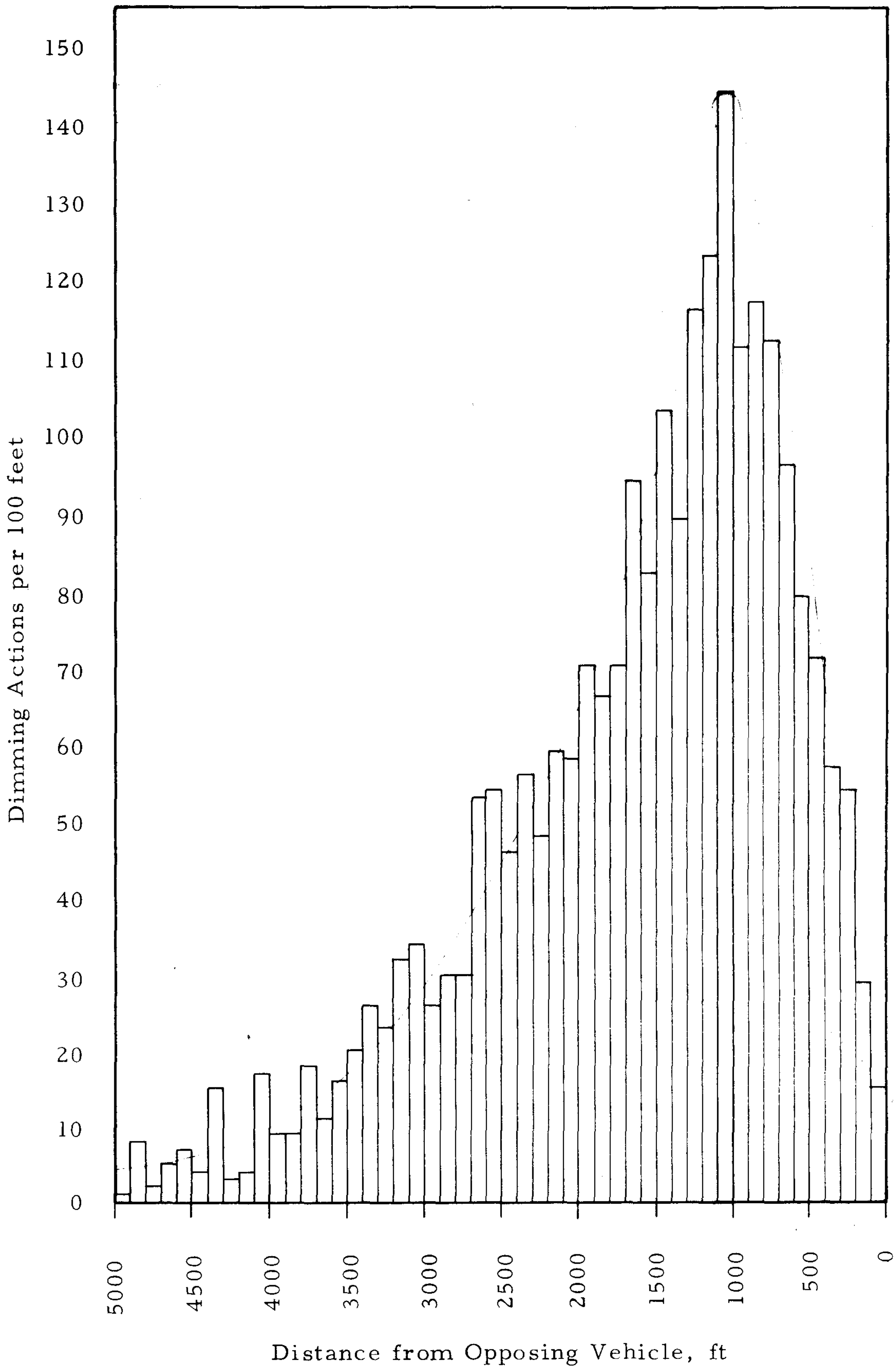


FIGURE 5. DENSITY OF DIMMING ACTIONS, SITES 1-14

State statutes on dimming of headlamps vary widely, but they generally require use of low beam for intercar distances less than 600 ft. Using 600 ft as standard, the average driver observed was far more courteous than dictated by law.

At an intercar distance of 1,714 ft, the disability veiling brightness from high beam lamps is less than 0.1 ft-lambert, or less than 2 percent of the maximum value (2). The dimming action, therefore, is made in most cases long before significant glare disability occurs; this possibly reflects the onset of driver discomfort or anticipation of discomfort.

When two vehicles meet, both on high beam, dimming by the driver of one vehicle usually acts as a reminder for the other driver to dim. The first driver to dim could be motivated by courtesy or by the wish to avoid glare from the opposing vehicle's headlamps or by some combination of these factors. Dimming by a driver when the opposing car is using low beam is probably motivated by courtesy toward the other driver.

The tabulation from which Figures 4 and 5 were constructed is given in Appendix B. Polynomial approximations of degree five were generated for the curves of Figures 4 and 5 by the method of least squares, and they are given below:

Approximation of Dimming Distribution (Figure 4)

$$y_4 \cong 1.00292 + 5.65925 \times 10^{-6}x - 5.30440 \times 10^{-7}x^2 + 2.67331 \times 10^{-10}x^3 - 5.21093 \times 10^{-14}x^4 + 3.65834 \times 10^{-18}x^5$$

$(0 \leq y_4 \leq 1.0, \; 0 \leq x \leq 5000)$

Approximation of Dimming Density (Figure 5)

$$y_5 \cong -12.8173 + 3.22128 \times 10^{-1}x - 2.80594 \times 10^{-4}x^2 + 9.69877 \times 10^{-8}x^3 - 1.53374 \times 10^{-11}x^4 + 9.22555 \times 10^{-16}x^5$$

$(0 \leq y_5, \; 0 \leq x \leq 5000)$

4. Findings on Beam Usage Related to Traffic Situation

Definitions:

(a) Open road situation: no opposing vehicle in test site and no leading vehicle within 600 ft.

(b) Meeting situation: 1000 ft or less from opposing vehicle

(c) Following situation: leading vehicle present within 300 ft

The categories are designed so that each vehicle observed fell into at least one category and in some cases more than one. Each category was applied separately to each vehicle without regard to the number of categories into which the vehicle fell.

TABLE 7a. HEADLAMP BEAM USAGE IN OPEN ROAD SITUATIONS

Beam Usage	Low	High	Total
Number of Vehicles Observed	17,476	5,700	23,176
Percent of Vehicles Observed	75.41	24.59	100.00

TABLE 7b. HEADLAMP BEAM USAGE IN MEETING SITUATIONS

Beam Usage	Low	High	Total
Number of Vehicles Observed	17,409	1,314	18,723
Percent of Vehicles Observed	92.98	7.02	100.00

TABLE 7c. HEADLAMP BEAM USAGE IN FOLLOWING SITUATIONS

Beam Usage	Low	High	Total
Number of Vehicles Observed	8,251	574	8,825
Percent of Vehicles Observed	93.50	6.50	100.00

As shown in Table 7a., over 75 percent of nighttime drivers observed used low beam in situations where high beam use would have been feasible and would have increased the visibility of the highway scene without impairing the vision of other drivers. Although observation cannot identify the factors causing this action, probable factors are driver inattention, refusal by the driver to be bothered with changing beam, and ignorance of the visibility improvement obtainable with use of high beam. Some drivers unquestionably believe they can see better with low beam because more light is directed onto the road immediately in front of the vehicle when low beam is used, and they do not realize that this light does not reach out far enough for adequate distance vision.

Data presented in Table 7b. show that high beam use in meeting situations observed was comparatively infrequent. Using contingency tables to test the hypothesis that beam usage was independent of traffic situation for the meeting case, a chi-square of 2294.77 was obtained, so the hypothesis was strongly rejected (see Appendix B for calculations).

Table 7c. presents data on beam usage in following situations. Testing the hypothesis that beam usage was independent of traffic situation for the following case yielded a chi-square of 1326.59, so this hypothesis was also rejected.

It is interesting to note that heavy trucks (commercial) used high beam in 67 percent of open road situations, indicating that professional drivers are more aware of the visibility improvement obtainable with high beam use.

In order to determine the effect of traffic volume on beam usage in open road situations, open road usage and traffic volume were recorded for each 15-min interval of operation. The intervals were classified by volume in increments of 10 vehicles per hour, and the mean percentage of high beam usage was calculated for each increment. The result is shown in Figure 6 and represents clear weather and dry road conditions only.

Although the average driver is not conscious of traffic volume in terms of vehicles per hour, he is conscious of the time interval between vehicles he meets. Below some threshold time interval, he will not be bothered with changing back and forth between high and low beam, but will stay on low beam. This threshold, which varies among drivers, is the actual relationship shown in Figure 6.

5. Findings on Overall Visibility Conditions

Visibility conditions on two-lane, paved, unlighted, rural highways in the United States are estimated using the following data and assumptions:

(a) "Visibility Distances" are based on detection distances for a standardized pedestrian dummy by the median driver tested(2), which are:

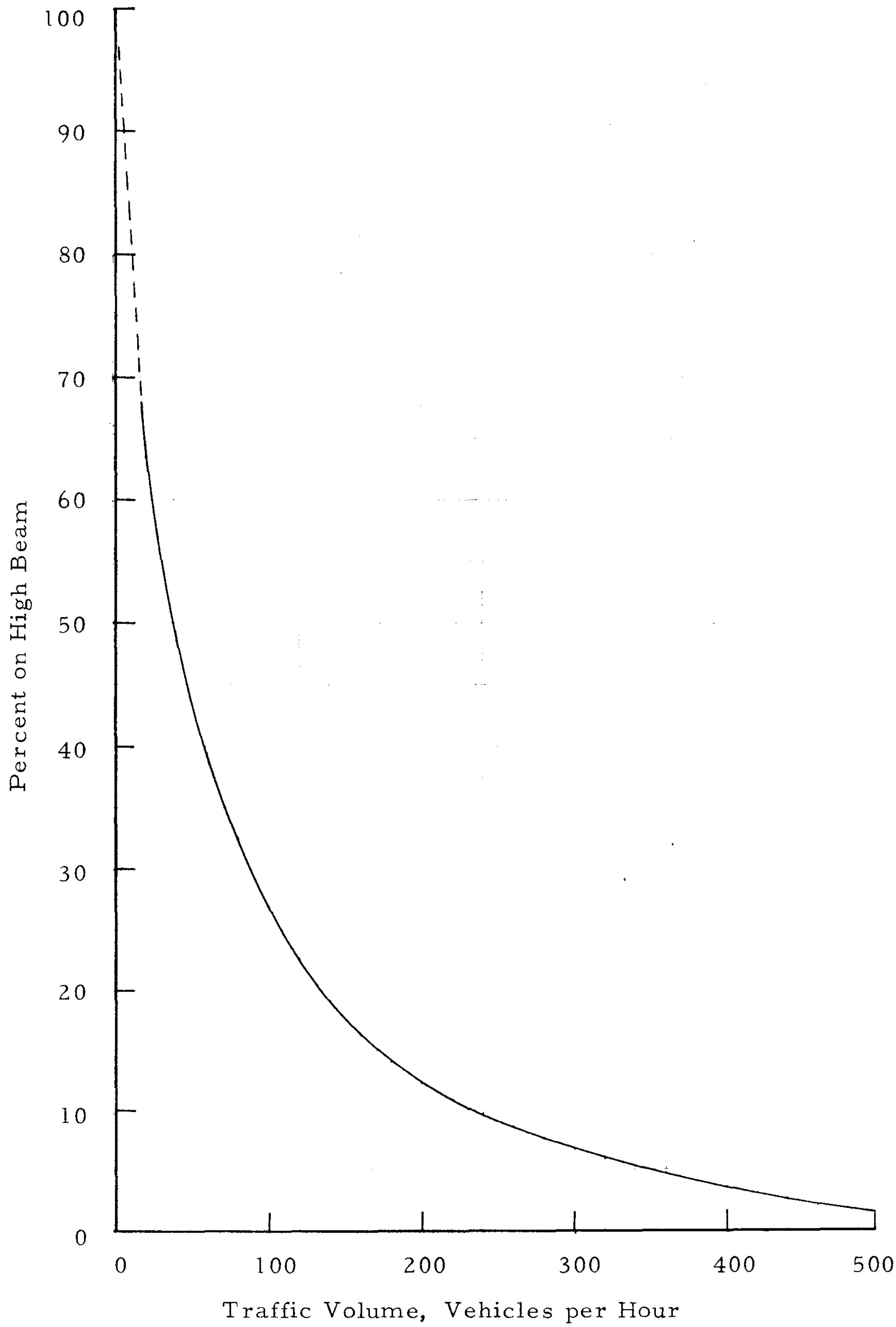


FIGURE 6. EFFECT OF TRAFFIC VOLUME ON BEAM USAGE IN OPEN ROAD SITUATIONS, SITES 1-14

Traffic Situation	Beam	Visibility Distance, ft
Open Road	High	775
Open Road	Low	375
Meeting	Either	300*

*A meeting, during which the driver's visibility averages 300 ft, includes intercar distances from 2,000 to 0 ft.

(b) All vehicles are assumed to be traveling at the observed overall average speed (60.46 mph), so each meeting involves each vehicle for a period of 11.3 sec.

(c) The average nighttime hourly traffic for a given section of highway is 2.67 percent of the ADT for that section (as observed during the course of this investigation).

(d) The average legal period of darkness is assumed to be 11 hr per day.

(e) Total two-lane, rural, surfaced mileage (includes only pavement classes better than gravel/crushed rock surface treatment) in the U.S. is 1,033,813 miles(7).

(f) Distribution of two-lane, rural, surfaced mileage in the U.S., according to ADT, is assumed to be the same as that for two-lane, rural, state primary highways(7).

Tables 8-10, which follow, give data calculated on the bases listed above, using 1966 data which have not been projected to the study time period.

TABLE 8. VEHICLE MILES OF NIGHTTIME TRAVEL CLASSIFIED BY AVERAGE NIGHTTIME VOLUME

Average Daily Traffic (ADT)	Average Nighttime Volume, Veh/Hr	2-Lane, Rural, Surfaced Mileage	Nighttime Vehicle Miles of Travel Per Night
0-400	0-11	275, 402	16, 799, 522
400-999	12-27	277, 697	58, 038, 673
1000-1999	28-53	236, 643	104, 122, 920
2000-2999	54-80	114, 594	83, 882, 808
3000-3999	81-107	58, 434	60, 128, 586
4000-4999	108-134	31, 512	41, 784, 912
5000-9999	135-267	34, 645	76, 426, 870
10, 000-14, 999	268-401	3, 763	13, 825, 262
15, 000-19, 999	402-534	982	5, 050, 426
20, 000-29, 999	535-801	114	837, 102
30, 000-39, 999	802-1068	21	215, 880
40, 000 and over	1069 and over	6	72, 600
	TOTALS	1, 033, 813	461, 185, 561

TABLE 9. DISTRIBUTION OF NIGHTTIME TRAVEL ACCORDING TO VOLUME

Average Nighttime Volume, Veh/Hr	Fraction of Travel in Volume Interval	Cumulative Fraction of Travel through Interval
0-11	0. 0364	0. 0364
12-27	0. 1258	0. 1622
28-53	0. 2258	0. 3880
54-80	0. 1819	0. 5699
81-107	0. 1304	0. 7003
108-134	0. 0906	0. 7909
135-267	0. 1657	0. 9566
268-401	0. 0300	0. 9866
402-534	0. 0110	0. 9976
535-801	0. 0018	0. 9994
802-1068	0. 0005	0. 9999
1069 and over	0. 0001	1. 0000

TABLE 10. TIME INTERVAL BETWEEN MEETINGS AND PERCENT HIGH BEAM USAGE IN OPEN ROAD SITUATIONS CLASSIFIED BY AVERAGE NIGHTTIME VOLUME

Average Nighttime Volume, Veh/Hr	Mean Volume in Interval, Veh/Hr	Time Interval Between Meetings, sec	Fraction of High Beam Use, Open Road
0-11	5.5	655	0.82
12-27	19.5	185	0.65
28-53	40.5	89	0.49
54-80	67	54	0.36
81-107	94	38	0.28
108-134	121	30	0.22
135-267	201	18	0.12
268-401	334.5	11	0.05
402-534	468	8	0.02
535-801	668	5	0
802-1068	935	4	0
1069 and over	-	-	0

Tables 8-10 present data necessary to calculate "visibility distance," as defined earlier in this section. For the sake of brevity, the following definitions are made:

α = time interval between meetings, sec

β = fraction of high beam use in open road situations

γ = mean duration of meeting situation $\div$ α $\qquad \gamma = \frac{11.3}{\alpha}$

In mathematical form:

$$\text{visibility distance} = 300(\gamma) + 775(1-\gamma)\beta + 375(1-\gamma)(1-\beta),$$

where the restrictions and assumptions noted earlier in this section hold. The distances calculated by this equation should be taken as practical maximums, especially at high traffic volumes, since visibility when meeting a queue of vehicles is quite probably less than the 300-ft minimum assumed for calculation[2]. It is possible that additional light provided by vehicles leading the one under analysis tends, to some extent, to offset the effect of the opposing queue.

Table 11 combines data from Tables 8 and 9 with visibility distances calculated by the above equation.

TABLE 11. AVERAGE NIGHTTIME TRAFFIC VOLUME, CUMULATIVE FRACTION OF NIGHTTIME TRAVEL, AND VISIBILITY DISTANCE RELATED TO ADT

Average Daily Traffic (ADT)	Average Nighttime Volume, Veh/Hr	Cumulative Fraction of Travel through Interval	Visibility Distance, ft
0-400	0-11	0.0364	696.0
400-999	12-27	0.1622	614.5
1000-1999	28-53	0.3880	536.6
2000-2999	54-80	0.5699	473.2
3000-3999	81-107	0.7003	431.3
4000-4999	108-134	0.7909	401.6
5000-9999	135-267	0.9566	345.7
10,000-14,999	268-401	0.9866	300
15,000-19,999	402-534	0.9976	300
20,000-29,999	535-801	0.9994	300
30,000-39,999	802-1068	0.9999	300
40,000 and over	1069 and over	1.0000	300

Figures 7 and 8 present data from Table 11 graphically. Figure 7 shows visibility distance as a function of traffic volume, and Figure 8 shows the cumulative fraction of nighttime travel and number of miles of nighttime travel as functions of visibility.

B. Two-Lane, Rural Test Site Groupings by Area

One of the objectives of this study has been to determine whether or not headlamp beam usage is a regional characteristic. For this purpose, the rural test sites are grouped as follows:

Area	Site
Northeast	1, 2
Southeast	3, 4, 5
Midwest	6, 7A, 7B, 8
Gulf Coast	9
Rocky Mountain	14
Northwest	11, 13
Southwest	10, 12

Of the seven areas listed, five include more than one site. These multiple-site areas have bases for internal comparison from which to determine the homogeneity of beam usage characteristics. Tables 12-16 give data on sites in these areas. The reader is referred to Appendix B for data on sites in the Gulf Coast and Rocky Mountain areas.

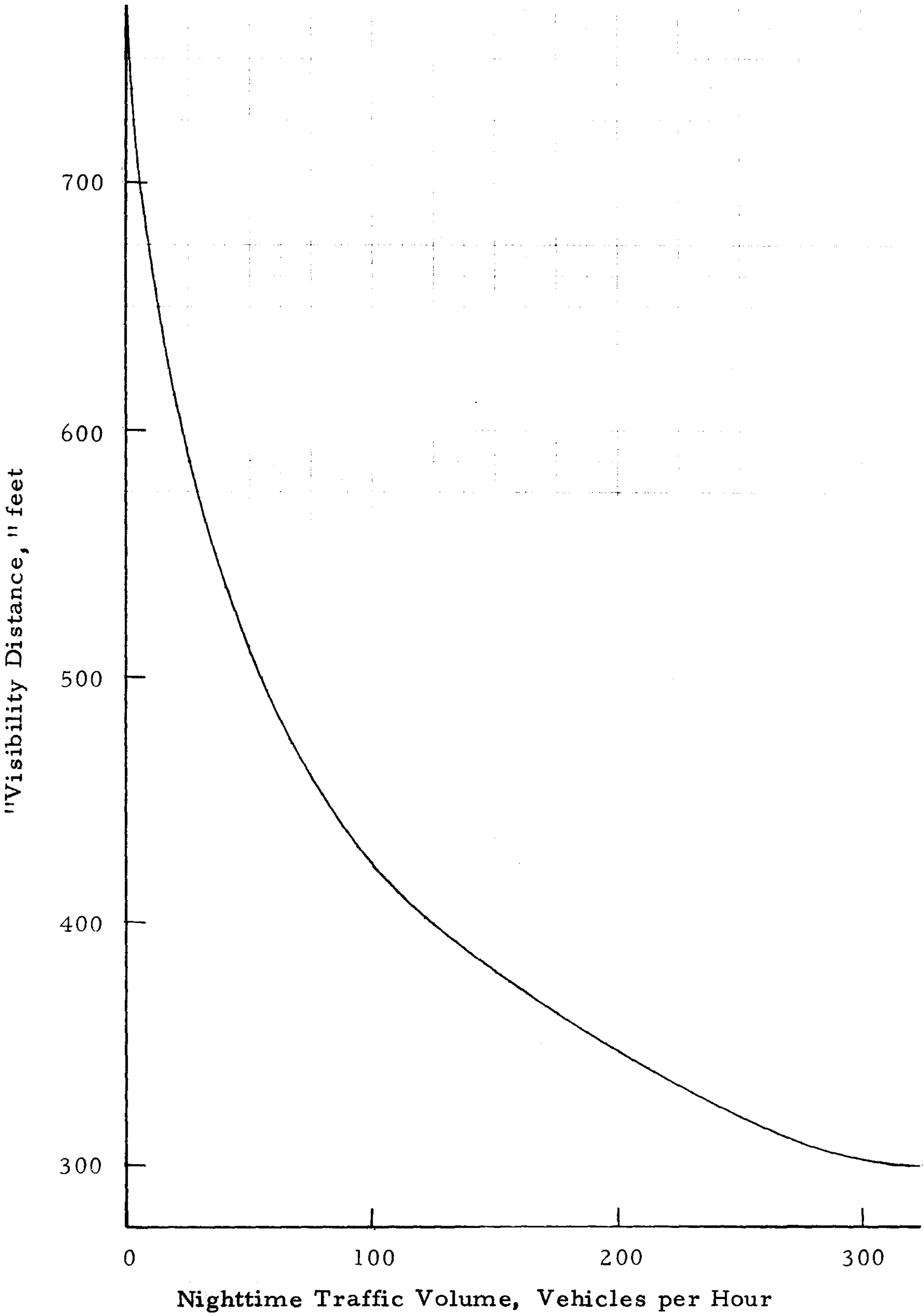


FIGURE 7. "VISIBILITY DISTANCE" RELATED TO TRAFFIC VOLUME

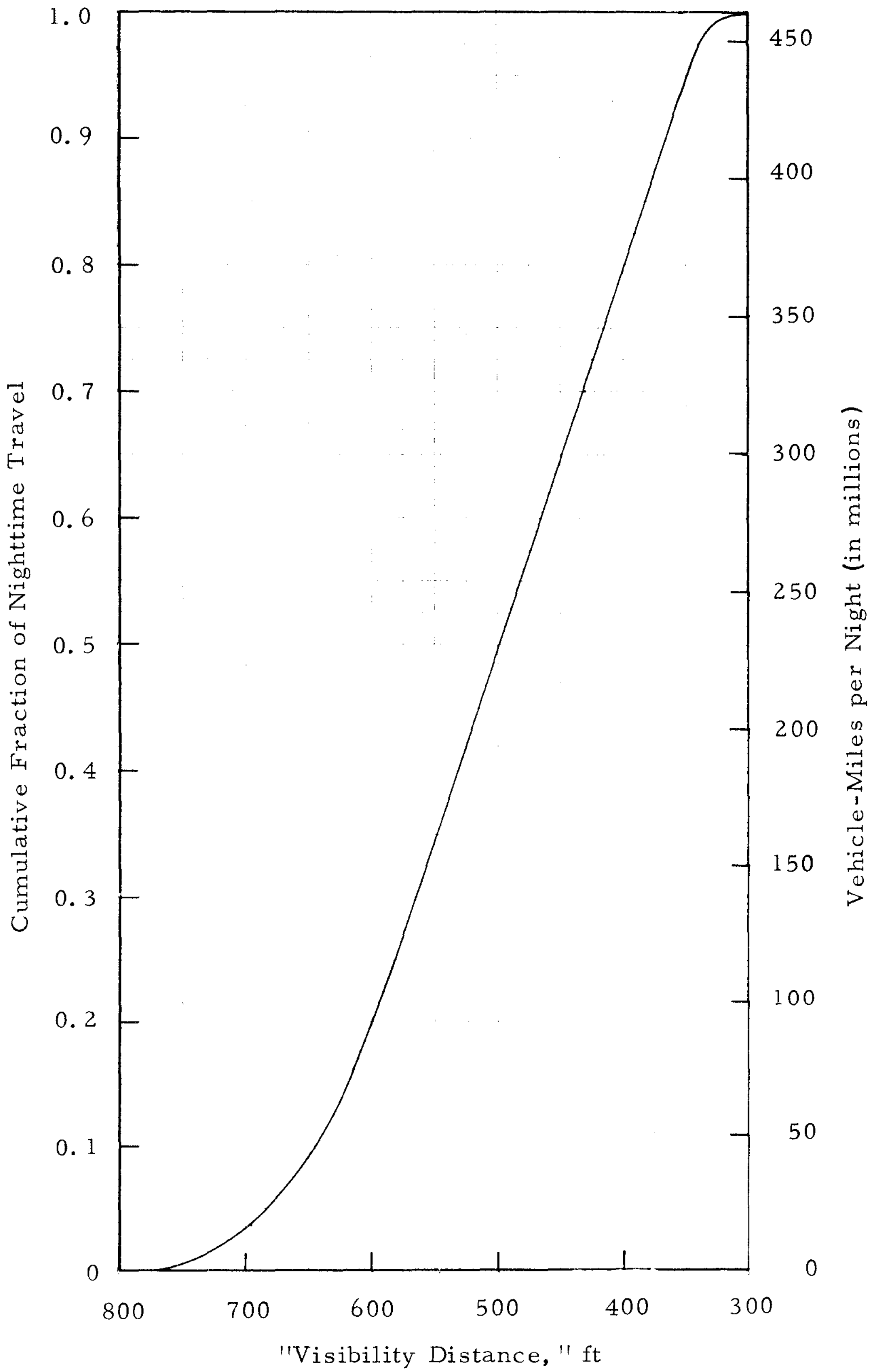


FIGURE 8. DISTRIBUTION OF NIGHTTIME TRAVEL WITH RESPECT TO VISIBILITY DISTANCE

1. Northeast Area

Data in Table 12 show that driver actions observed at sites 1 and 2 were very similar, indicating that the Northeast grouping is valid.

2. Southeast Area

Data in Table 13 show that driver actions observed at sites 3, 4, and 5 were similar, yet different than those observed in other areas, indicating that the Southeast grouping is valid. Open road beam usage appears more constant if it is considered that drivers of heavy trucks (professional drivers) used high beam in 67 percent of open road cases observed.

3. Midwest Area

Data in Table 14 show a similarity in driver actions observed at sites 6, 7A, 7B, and 8, with the exceptions of beam usage in following situations and the lower average dimming distance at site 6. The comparatively low dimming distance at site 6 was probably caused by the vertical "sag" toward the center of the site, which made headlamps of opposing vehicles seem less bright. Actions observed in the Midwest were similar, but different from those observed in other areas, indicating that the Midwest grouping is valid.

4. Northwest Area

Data in Table 15 indicate a similarity in driver actions observed at sites 11 and 13. The more frequent use of high beam at site 13 is logical in view of the lower average traffic volume there, as shown in Section V. A. 4.

The data indicate that the Northwest grouping is valid, since driver actions are similar, yet different from those observed in other areas.

5. Southwest Area

Data in Table 16 show that there is little similarity between driver actions observed at sites 10 and 12, indicating that the Southwest grouping is not homologous.

Tables 12-16 compare data on test sites within each area, and it remains to compare data for each area as a whole to that for the other areas. Table 17 lists the most significant beam usage information for each multiple-site area.

TABLE 12. DATA ON TEST SITES IN THE NORTHEAST

Test Site	1	2
% Passenger Cars	95.18	89.02
% Light Trucks	3.32	6.13
% Heavy Trucks	1.50	4.85
% Having Four Headlamps	80.06	66.90
% Having Two Headlamps	19.94	33.10
% of Open Road Cases on Low Beam	69.10	73.72
% of Open Road Cases on High Beam	30.90	26.28
% of Meeting Cases on Low Beam	91.28	89.63
% of Meeting Cases on High Beam	8.72	10.37
% of Following Cases on Low Beam	97.68	97.60
% of Following Cases on High Beam	2.32	2.40
Sight Distance through Site, ft	3,900	6,500
Average Distance at Dimming, ft	1,570	1,624
% of Vehicles Exceeding Speed Limit	36.10	38.94

TABLE 13. DATA ON TEST SITES IN THE SOUTHEAST

Test Site	3	4	5
% Passenger Cars	56.37	85.16	91.16
% Light Trucks	5.66	5.85	3.41
% Heavy Trucks	37.97	8.99	5.43
% Having Four Headlamps	49.73	68.63	62.96
% Having Two Headlamps	50.27	31.37	37.04
% of Open Road Cases on Low Beam	49.24	59.62	69.63
% of Open Road Cases on High Beam	50.76	40.38	30.37
% of Meeting Cases on Low Beam	76.57	81.86	86.16
% of Meeting Cases on High Beam	23.43	18.14	13.84
% of Following Cases on Low Beam	65.32	93.30	94.68
% of Following Cases on High Beam	34.68	6.70	5.32
Sight Distance through Site, ft	2,800	12,500	4,900
Average Distance at Dimming, ft	1,103	1,016	1,150
% of Vehicles Exceeding Speed Limit	56.00	72.12	57.40

TABLE 14. DATA ON TEST SITES IN THE MIDWEST

Test Site	6	7A	7B	~~7C~~ 8
% Passenger Cars	83.52	90.33	90.69	87.66
% Light Trucks	4.09	6.58	6.48	3.81
% Heavy Trucks	12.38	3.09	2.83	8.53
% Having Four Headlamps	74.81	81.01	79.47	80.29
% Having Two Headlamps	25.19	18.99	20.53	19.71
% of Open Road Cases on Low Beam	82.13	72.93	76.03	87.64
% of Open Road Cases on High Beam	17.87	27.07	23.97	12.36
% of Meeting Cases on Low Beam	91.48	94.73	93.03	98.68
% of Meeting Cases on High Beam	8.52	5.27	6.97	1.32
% of Following Cases on Low Beam	84.72	80.04	98.83	99.32
% of Following Cases on High Beam	15.28	19.96	1.17	0.68
Sight Distance through Site, ft	7,300	15,000	15,000	6,000
Average Distance at Dimming, ft	1,347	1,840	2,159	2,275
% of Vehicles Exceeding Speed Limit	35.38	82.44	83.03	34.87

TABLE 15. DATA ON TEST SITES IN THE NORTHWEST

Test Site	11	13
% Passenger Cars	75.67	84.78
% Light Trucks	9.18	12.68
% Heavy Trucks	15.15	2.54
% Having Four Headlamps	58.35	62.03
% Having Two Headlamps	41.65	37.97
% of Open Road Cases on Low Beam	96.72	78.32
% of Open Road Cases on High Beam	3.28	21.68
% of Meeting Cases on Low Beam	99.49	92.10
% of Meeting Cases on High Beam	0.51	7.90
% of Following Cases on Low Beam	97.36	96.66
% of Following Cases on High Beam	2.64	3.34
Sight Distance through Site, ft	7,000	6,500
Average Distance at Dimming, ft	2,751	2,532
% of Vehicles Exceeding Speed Limit	55.86	53.99

TABLE 16. DATA ON TEST SITES IN THE SOUTHWEST

Test Site	10	12
% Passenger Cars	79.57	66.35
% Light Trucks	20.04	13.72
% Heavy Trucks	0.39	19.93
% Having Four Headlamps	51.56	58.73
% Having Two Headlamps	48.44	41.27
% of Open Road Cases on Low Beam	14.65	96.36
% of Open Road Cases on High Beam	85.35	3.64
% of Meeting Cases on Low Beam	62.22	98.22
% of Meeting Cases on High Beam	37.78	1.78
% of Following Cases on Low Beam	90.09	96.32
% of Following Cases on High Beam	9.91	3.68
Sight Distance through Site, ft	2,500	6,500
Average Distance at Dimming, ft	974	1,669
% of Vehicles Exceeding Speed Limit	19.75	69.51

TABLE 17. BEAM USAGE DATA FOR FOUR AREAS OF THE U.S.

	Northwest	Midwest	Northeast	Southeast
% of Open Road Cases on Low Beam	89.89	80.31	71.30	59.60
% of Meeting Cases on Low Beam	97.82	95.78	90.32	81.98
Average Distance at Dimming, ft	2573	1807	1601	1082
Rank, Open Road Low Beam Usage	1	2	3	4
Rank, Meeting Low Beam Usage	1	2	3	4
Rank, Average Dimming Distance	1	2	3	4

It appears that consistent patterns do exist in the areas analyzed; that is, drivers in the Northwest use headlamps to least advantage, and drivers in the Midwest, Northeast, and Southeast use headlamps to progressively greater advantage.

It is beyond the scope of this investigation to determine why these regional differences exist. They are, however, results of conditioning processes which form the drivers' habits, so it is apparent that conditioning of drivers with respect to beam usage differs from area to area.

Figure 6, Section V.A., shows the overall relation between traffic volume and beam usage in open road situations. Similar curves have been prepared for each area and are presented in Figure 9. Examination of Figure 9 reveals that area ranks according to low beam use, during periods of specified traffic volume, remain consistent with ranks shown above.

C. Two-Lane, Rural Test Site Groupings by Topography

Attempts to develop correlation in beam usage with types of topography were relatively unsuccessful. Test sites were categorized as:

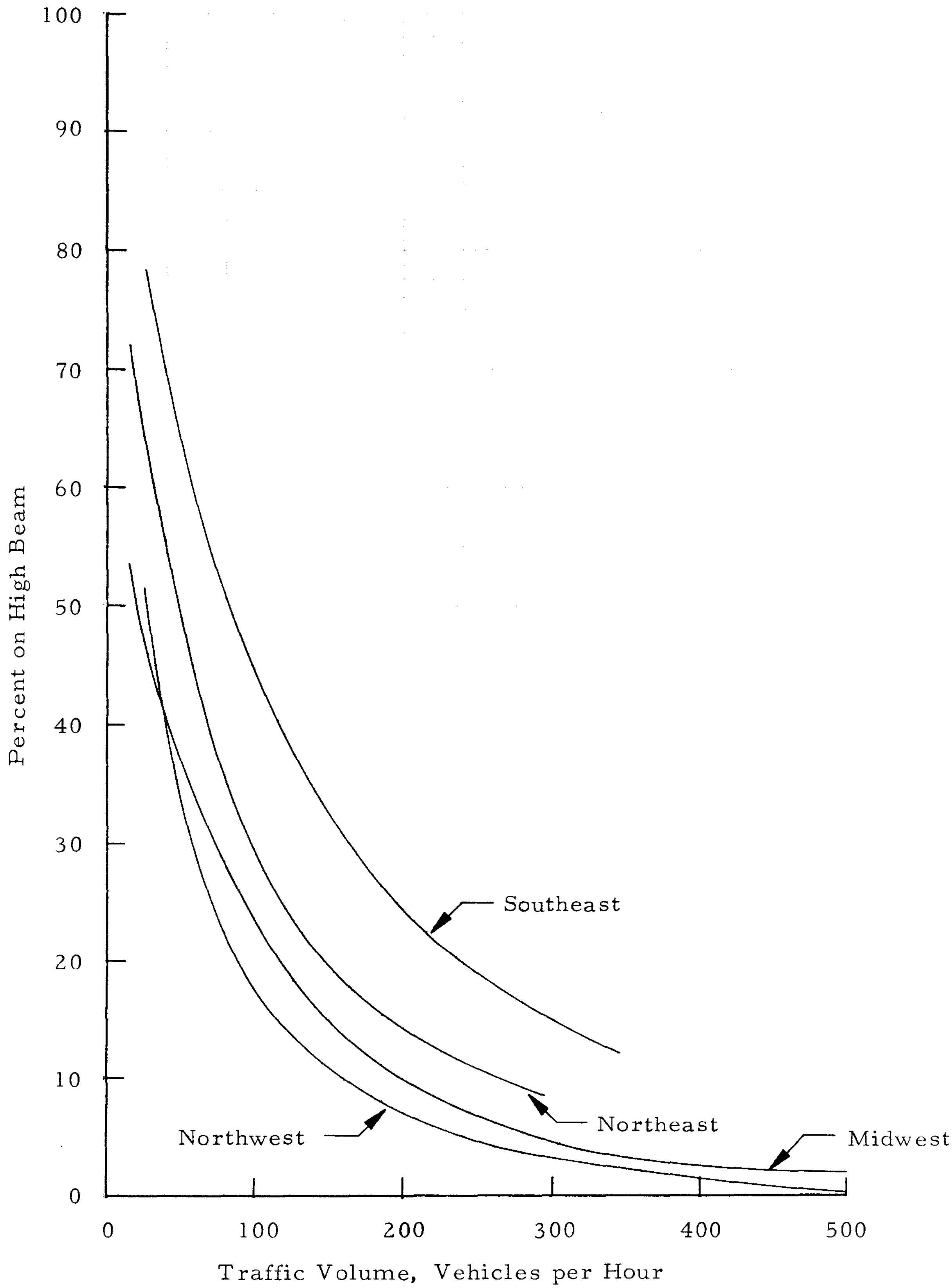


FIGURE 9. EFFECT OF TRAFFIC VOLUME ON BEAM USAGE IN OPEN ROAD SITUATIONS FOR FOUR AREAS OF THE U.S.

Area	Site
Mountainous	1, 3, 13, 14
Flat farmland	4, 6, 8, 11, 12
Rolling, wooded farmland	2, 7a, 7b, 10
Coastal flatland	5, 9

Of these, only the coastal flatland sites, 5 and 9, showed similar results, and it seems probable to be more attributable to regional characteristics of drivers and traffic than to topography.

Site 10 may be atypical. Insofar as selection criteria were concerned, it appeared to conform satisfactorily; however, it carried, essentially, only farm-to-market traffic and commuters to jobs in the city, and it had virtually no commercial or through traffic. One specific factor may have had a major influence on the unusually high proportion of high beam use. This factor was the presence of a large population of deer in that area. The local drivers, who comprised the bulk of the traffic on this road, were well aware of the hazard presented by these deer, because of frequent accidents caused by them.

D. Effect of Weather Conditions on Beam Usage

Data in Table 18 show beam usage changes from that observed under clear, dry conditions for various conditions of weather, and these data have been corrected for traffic volume. The sample sizes are included to show which data are more subject to scattering error. Each condition is discussed separately in the following sections.

TABLE 18. EFFECT OF WEATHER CONDITIONS ON BEAM USAGE

Weather Condition or Road Condition	Change in High Beam Use, Open Road Situations, %	Sample Size
Light Fog	+7	300
Wet Road	+5.5	4,473
Rain	+5.5	5,095
Blowing Snow	+3.5	423
Snow on Shoulder	0	216
Heavy Fog	-2	409

1. Light Fog

All data for the light fog case were recorded at a site having a dark bituminous pavement with reflective white center and edge lines. It is commonly believed that low beam should be used in fog, but the drivers observed used high beam to a greater extent than normal. No conclusive data on visibility in fog are available to judge whether the drivers were right or wrong in their action. It is probable that the good contrast between pavement and markings allowed the drivers to see farther through the light fog (with reference to pavement delineation) with high beam than with low beam.

2. Wet Road; Rain

The wet road and rain cases share the majority of their samples, so they will be considered as one case. As rain progressed from very light (a mist) to moderately heavy, no significant change in beam usage could be found. It appears, therefore, that the more important factor is the decrease in reflectance of the pavement and surroundings when they become wet, which causes increased high beam use. It should be noted, however, that no "downpour" cases were observed, making observation of the effect of (reflective) raindrops impossible.

3. Blowing Snow

As in the case of light fog, all blowing snow observations were made at a site having good contrast between pavement and markings. Undoubtedly, the snow in the air had some glaring effect, but high beam use could have been advantageous in view of the contrast mentioned previously.

4. Snow on Shoulder

This case involved fresh snow on the shoulder of the highway (obscuring the edge lines) and a wet pavement. It appears that glare from the snow, if any, had negligible effect on beam usage.

5. Heavy Fog

Pavement visibility in the heavy fog cases was 250 to 500 ft. The pavement was PCC, and it had a higher reflectance than bituminous pavements. The decrease in high beam use is logical according to current theory, but the decrease is perhaps smaller than expected. It is possible that the comparatively high reflectance of the pavement acted to even out visibility distances with high and low beam.

E. Prediction of Beam Usage and Visibility

To predict open road beam usage for a given section of two-lane, rural, unlighted highway on the basis of this investigation, the following factors should be taken into account:

(1) Area of the Country

(2) Traffic Volume

(3) Weather Conditions

Having determined the above factors, calculation using data from Figure 9 and Table 18 will yield the percentage of open road traffic using high beam. If the location of the section in question falls outside the areas shown in Figure 9, Figure 6 can be used as a substitute.

If the section is in one of the areas analyzed, beam usage in meeting situations can best be estimated using Table 17. If the section is not in an analyzed area, Table 7b should be used. Beam usage in following situations can be estimated by using Table 7c, since this item was not analyzed by area.

Estimates of average dimming distance for sections in some areas are given in Table 17, and, outside these areas, the overall average of 1,714 ft may be used.

As developed in this investigation, visibility is estimated on the basis of detection distances for a standardized pedestrian dummy by the median driver tested[2]. This dummy had a diffuse reflectance of 17 percent, and it was probably more easily seen than the average highway hazard, helping to ensure that visibility conditions calculated are practical maximums. Further, these visibility estimates are for clear conditions, and they are given as functions of traffic volume only. With these restrictions noted, visibility may be estimated using Figure 7.

F. Four-Lane, Unlighted, Suburban Test Site with Median

The median at the test site was 50 ft in width, and this greater lateral separation distance between opposing vehicles caused a marked reduction in glare from opposing headlamps[2].

Of the 78 vehicles observed as initially on high beam and which subsequently met another vehicle, only 34 dimmed, a much lower percentage than that observed for two-lane sites. The drivers who did not dim probably assumed that their high beam lights would interfere little with the visibility of a driver in the opposing lanes, and that their increase in visibility was more important, even though, legally, they were still required to switch to low beam.

The average dimming distance was about the same as the mean for all two-lane, rural sites, but in this divided, four-lane case, the dimming distance can hardly be explained on a disability glare basis. The most likely conclusion is that force of habit caused the dimming distances observed.

Of those vehicles observed in open road situations, about 21 percent used high beam with an average volume of about 150 vehicles per hour. This high beam usage figure is about 3.5 percent higher than would be expected on a two-lane road, indicating that beam usage for the divided, four-lane case is slightly less dependent on traffic in the opposing lanes, but that force of habit causes drivers to use their headlamps similarly in vastly different glare environments.

G. Two-Lane, Unlighted, Suburban Test Site

This site was run to determine whether the beam usage habits of drivers accustomed to a suburban environment differed from those of drivers accustomed to rural driving. The ADT at this site was very high (estimated to be in excess of 15,000 vehicles per day), and at times the traffic flow exceeded the capacity of equipment and personnel. Data taken during periods of relatively low volume, considered to be most reliable, show that driver performance did not differ significantly from that observed at the rural, two-lane test sites.

H. Two-Lane, Suburban Site with Overhead Lighting

A preliminary study was run at this test site to determine the feasibility of operating it on a full-scale basis, and it was decided that the preliminary study in itself would be sufficient. This preliminary study revealed that no more than 2 percent of vehicles in any hour used high beam at all, and that those who did use high beam probably did not realize which beam they were using.

About 1.5 percent of drivers observed during the first hour after sunset used high beam, presumably the result of negligence, since no driver, initially using high beam, who subsequently dimmed was observed to switch back to high beam. No driver failed to dim when an opposing driver flashed his lights.

During late hours, when the traffic volume was quite low, the use of high beam stabilized at about 1 percent.

The overhead lighting at this test site was sufficiently bright to reveal objects at distances far beyond the reach of the vehicle headlamps, and the data indicate that drivers were aware that high beam use would not improve their visibility. As reported by the San Antonio City Public Service Board, the average pavement illumination at the site was 1.0 ft-candle, with a maximum of 2.0 ft-candle and a minimum of 0.8 ft-candle.

VI. CONCLUSIONS

Based on the findings of this investigation, the following conclusions are drawn:

(1) Headlamp beam usage is highly dependent on the traffic situation. Few drivers use high beam in meeting and following situations as compared to open road situations (Section V. A. 4.).

(2) Most drivers dimming their headlamps for an approaching vehicle did so at long intercar distances, assuming that the opposing driver would do likewise. Since most dimming actions took place before significant glare disability could occur, it is likely that the anticipation of an approaching unpleasant glare situation motivates drivers more strongly than does actual glare discomfort or glare disability (Section V. A. 3.).

(3) Over 60 percent of vehicles observed were traveling at speeds in excess of those considered "safe" by the criteria of this report (Section V. A. 2.). The existing speed/visibility situation is, therefore, considered dangerous.

(4) There are marked variations in beam usage habits of drivers from area to area in the United States. These variations are assumed to be the result of different conditioning processes, as yet unidentified (Section V. B.).

(5) Usage of headlamp beams was observed to be independent of topography.

(6) Weather conditions do affect headlamp beam usage, although to a rather small extent in the specific cases observed (Section V. E.). Analysis of driver actions under various weather conditions is limited by the lack of precise visibility information. It should be noted that this conclusion is based on calculations involving a relatively small sample of weather/highway variations as well as vehicle observations.

(7) Most drivers are aware that overhead lighting generally provides visibility better than that available from automobile headlamps. Consequently, most drivers used low beam where overhead lighting was present (Section V. I.).

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APPENDIX A

TEST SITE LOCATIONS AND DESCRIPTIONS

Site 1

Dates of Operation: Wednesday, 5/8/68 - Sunday, 5/12/68

Location: New York, Saratoga County, on U. S. 4, 1.6 miles south of intersection with New York 146

Speed Limits: Cars; 50 Buses; 50 Trucks; 50

Visibility Distance through Site: 3,900 ft

Description: 11-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines, yellow line for northbound land begins 240 ft inside north end of site and extends north (curve), 3-ft gravel shoulder then steep ditch and large trees in narrow right-of-way, hazardous; foothills and mountains are surrounding terrain.

Site 2

Dates of Operation: Wednesday, 5/15/68 - Sunday, 5/19/68

Location: Maine, Sagadahoc County, on U. S. 1, 3.5 miles north of north intersection with Maine 127

Speed Limits: Cars; 55 Buses; 55 Trucks; 55

Visibility Distance through Site: 6,500 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline, 20-ft gravel shoulders, "controlled access," i.e., state permit must be secured for any intersecting lane or road; rolling coastal terrain.

Site 3

Dates of Operation: Wednesday, 1/31/68 - Thursday, 2/1/68
Friday, 2/23/68 - Sunday, 2/25/68

Location: Tennessee, Grainger County, on U. S. 11W, 4.5 miles west of west intersection with U. S. 25E

Speed Limits: Cars; 55 Buses; 55
Trucks under 4 tons; 55 Trucks over 4 tons; 50

Visibility Distance through Site: 2,800 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline, solid white reflective edge lines, 8-ft gravel shoulders; surrounding terrain is foothills and mountains.

Site 4

Dates of Operation: Thursday, 1/11/68 - Monday, 1/15/68

Location: Georgia, Dougherty County, on U. S. 82, 4.1 miles east of east city limit of Albany

Speed Limits: Cars; 50 Buses; 50 Trucks; 50

Visibility Distance through Site: 12,500 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline and solid white reflective edge lines, grassy shoulders; terrain of area is flat agricultural plain and forests.

Site 5

Dates of Operation: Thursday, 1/18/68 - Monday, 1/22/68

Location: Florida, Alachua County, on Florida 24, 5.8 miles north of intersection with Florida 232

Speed Limits: Cars; 55 Buses; 55 Trucks; 55

Visability Distance through Site: 4,900 ft

Description: 10-ft lanes, pcc slabs 40-ft long, comparatively high reflectance, broken white reflective centerline, some misalignment of slabs (vertically), 6-ft gravel shoulders; surrounding terrain flat and grassy, a few forests.

Site 6

Dates of Operation: Friday, 2/9/68 - Tuesday, 2/13/68

Location: Illinois, Tazewell County, on Illinois 121, 0.4 mile north of intersection with Dillon Road

Speed Limits: Cars; 65 Buses; 60
Trucks under 4 tons; 55 Trucks over 4 tons; 50

Visibility Distance through Site: 7,300 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines, 8-ft paved shoulders not used for travel; surrounding area is predominantly flat, agricultural, slight vertical "sag" toward center of site.

Site 7A

Dates of Operation: Friday, 2/16/68 - Tuesday, 2/20/68

Location: Michigan, Kent County, on Michigan 57, 4.5 miles east of intersection with U. S. 131

Speed Limits: Cars; 55 Buses; 55 Trucks; 55

Visibility Distance through Site: 15,000 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines, 10-ft gravel-over-asphalt shoulders; terrain generally flat, agricultural or forested.

Site 7B

Dates of Operation: Thursday, 5/23/68 - Monday, 5/27/68

Location: Michigan, Kent County, on Michigan 57, 4.5 miles east of intersection with U. S. 131

Speed Limits: Cars; 55 Buses; 55 Trucks; 55

Visibility Distance through Site: 15,000 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines, 10-ft gravel-over-asphalt shoulders; terrain generally flat, agricultural or forested.

Site 8

Dates of Operation: Wednesday, 4/10/68 - Sunday, 4/14/68

Location: Nebraska, Dodge County, on U. S. 77, 4.5 miles north of intersection with U. S. 30

Speed Limits: Cars; 60 Buses; 60 Trucks; 50

Visibility Distance through Site: 6,000 ft

Description: 12-ft lanes, weathered bituminous concrete (white aggregate exposed), moderate reflectance, badly worn broken white reflective center and solid white reflective edge lines, grassy shoulders; terrain generally flat-to-rolling, agricultural.

Site 9

Dates of Operation: Thursday, 4/18/68 - Monday, 4/22/68

Location: Louisiana, Jefferson Davis Parish, on U. S. 165, 2.4 miles north of Fenton (town)

Speed Limits: Cars; 60 Buses; 60 Trucks; 50

Visibility Distance through Site: 6,000 ft

Description: 12-ft lanes, bituminous resurfacing of pcc pavement, low reflectance, broken white reflective center and solid white reflective edge lines, 8-ft gravel shoulders, depressions (axial troughs) in driving lanes (hold water - many loss-of-control accidents in rain); flat terrain.

Site 10

Dates of Operation: Tuesday, 12/26/67 - Saturday, 12/30/67

Location: Texas, Bexar County, on Texas 16, 4.0 miles north of Helotes (town)

Speed Limits: Cars; 60 Buses; 60 Trucks; 60

Visibility Distance through Site: 2,500 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline, 8-ft gravel shoulders; terrain is rolling and grassy.

Site 11

Dates of Operation: Wednesday, 3/20/68 - Sunday, 3/24/68

Location: California, Stanislaus County, on California 132, 0.5 mile west of intersection with Paradise Gates Road

Speed Limits: Cars; 65 Buses; 65
Trucks under 4 tons; 65 Trucks over 4 tons; 55

Visibility Distance through Site: 7,000 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, solid white reflective edge lines, square (white) reflective "Stimsonite" and round (white) nonreflective "Top Five" buttons form centerline, 8-ft paved shoulders; terrain is flat, agricultural.

Site 12

Dates of Operation: Wednesday, 3/13/68 - Sunday, 3/17/68

Location: Arizona, Maricopa County, on U. S. 60 between mileposts 138.41 and 138.64 (northwest of Phoenix)

Speed Limits: Cars; 60 Buses; 60 Trucks; 60

Visibility Distance through Site: 6,500 ft

Description: 18-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline, 10-ft gravel shoulders; terrain flat, agricultural (valley)

Site 13

Dates of Operation: Wednesday, 3/27/68 - Sunday, 3/31/68

Location: Oregon, Linn County, on Oregon 22, 10.7 miles east of intersection with Oregon U. S. Interstate 5

Speed Limits: Cars; 65 Buses; 65
Trucks under 3 tons; 65 Trucks over 3 tons; 50

Visibility Distance through Site: 6,500 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines (white) reflective guideposts at 500-ft intervals, 10-ft paved shoulders; terrain hilly (foothills of cascade mountains), forested, some valley land under cultivation.

Site 14

Dates of Operation: Wednesday, 6/5/68 - Sunday, 6/9/68

Location: Colorado, Garfield County, on U. S. 6, 3.0 miles west of intersection with Colorado 13

Speed Limits: Cars; 70 Buses; 70 Trucks; 70

Visibility Distance through Site: 4,400 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective center and solid white reflective edge lines, 10-ft gravel shoulders; terrain mountainous-to-plateau, 5400-ft elevation, grazing land.

Site 15

Dates of Operation: Wednesday, 7/10/68 - Sunday, 7/14/68

Location: Texas, Bexar County, on Interstate 410, between Ingram Road and Culebra Road exits

Speed Limits: Cars; 65 Buses; 65 Trucks; 65

Visibility Distance through Site: 5,500 ft

Description: Four-lane divided with 50-ft depressed median, bituminous concrete, low reflectance, broken white reflective centerline, standard paved shoulders; gently rolling terrain.

Site 16

Dates of Operation: Friday, 7/19/68 - Monday, 7/22/68

Location: Maryland, on U. S. 5, 3.3 miles south of end of 4-lane section which intersects beltway (just south of Burch Road)

Speed Limits: Cars; 50 Buses; 50 Trucks; 50

Visibility Distance through Site: 2,200 ft

Description: 12-ft lanes, bituminous concrete, low reflectance, broken white reflective centerline, solid yellow reflective "no passing" line for southbound traffic begins 250 ft inside south end of site and extends south (hill), 15-ft gravel shoulders, site is tangent uphill toward south, area hilly, suburban-to-rural.

Site 17

Dates of Operation: Wednesday, 7/3/68 - Friday, 7/5/68

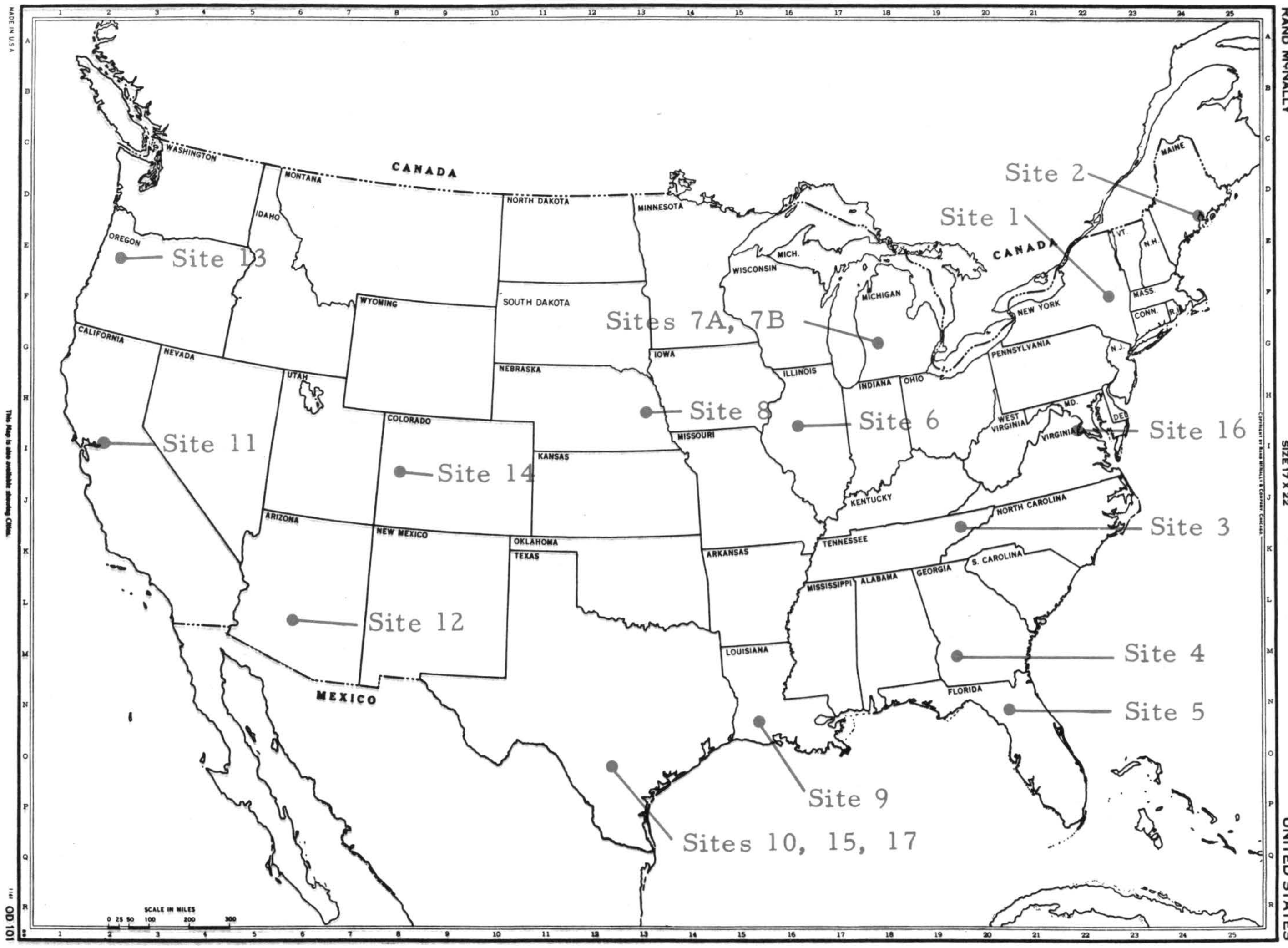
Location: Texas, San Antonio, on McCullough Avenue, south of Basse Road

Speed Limits: Cars; 35 Buses; 35 Trucks; 35

Visibility Distance through Site: 2,000 ft

Description: 18-ft lanes, bituminous concrete, overhead lighting; suburban area.

Pavement Illumination: 2.0 ft-candle maximum, 0.8 ft-candle minimum, 1.0 ft-candle average


RAND McNALLY
STATE-OUTLINE MAP
SIZE 17 X 22
UNITED STATES
OD 101
MADE IN U.S.A.
This Map is also available showing Cities.
CANADA
MEXICO
WASHINGTON
MONTANA
IDAHO
OREGON
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
WISCONSIN
MICH.
MICHIGAN
NEW YORK
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
N.J.
PENNSYLVANIA
CALIFORNIA
NEVADA
UTAH
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
COLORADO
KANSAS
MISSOURI
WEST VIRGINIA
VIRGINIA
MD.
DEL.
KENTUCKY
NORTH CAROLINA
TENNESSEE
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
S. CAROLINA
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
FLORIDA
SCALE IN MILES
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Sites 7A, 7B
Site 8
Site 9
Sites 10, 15, 17
Site 11
Site 12
Site 13
Site 14
Site 16

APPENDIX B

TABULATED DATA AND CALCULATIONS

Definitions of Terms Used in Appendix B

1. Open road situation: no opposing vehicle in test site and no leading vehicle within 600 ft

2. Meeting situation: meets an opposing vehicle in test site

3. Low beam meeting situation: meets an opposing vehicle in test site and uses low beam for at least final 1,000 ft of approach

4. High beam meeting situation: approaches an opposing vehicle within 1,000 ft while using high beam

5. Following situation: leading vehicle within 300 ft

6. Light truck: G. C. W. 1 ton or less

7. Heavy truck: G. C. W. over 1 ton

Note: Dimming distributions for sites 1, 3, and 14 show that some dimming actions occurred at distances in excess of maximum intercar visibility. The explanation is that visibility from observers' positions at these three sites exceeded that of the approaching drivers, so some dimming actions were recorded which were spontaneous and not in response to oncoming vehicles.

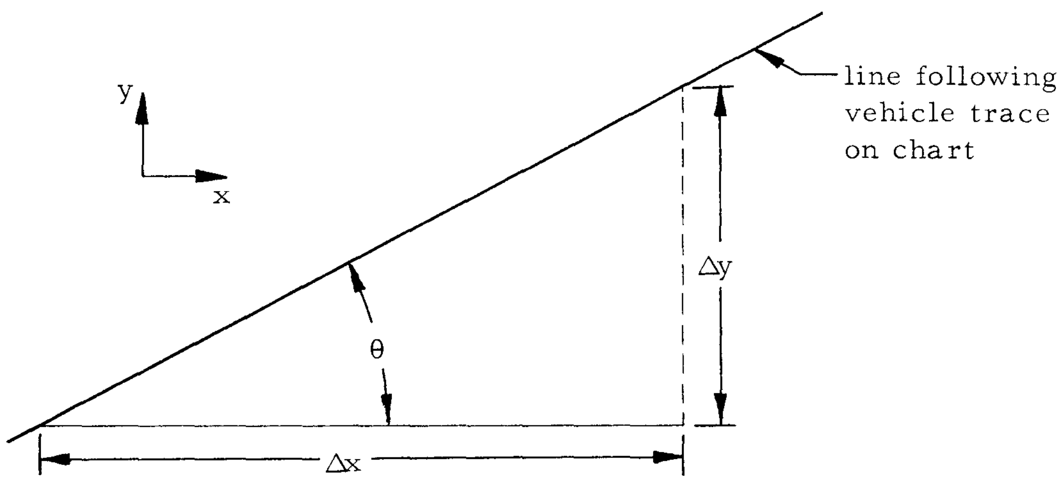
CALCULATIONS

To read speed of vehicle from recorder chart:

ΔP = change in position of vehicle, ft
ΔT = change in time, sec
Δy = change in position of vehicle trace on recorder chart in the direction perpendicular to chart motion, in.
Δx = change in position of vehicle trace on recorder chart in the direction parallel to chart motion, in.

$\Delta x/\Delta T$ (measured constant) = 1 in./4.76 sec
$\Delta y/\Delta P$ (measured constant) = 1 in./1059 ft

$$\text{speed of vehicle} = \Delta P/\Delta T \text{ ft/sec} = (\Delta y/\Delta x)(\Delta x/\Delta T) / (\Delta y/\Delta P)$$
$$= (\Delta y/\Delta x)(1059/4.76) \text{ ft/sec}$$



The sketch above shows that $\Delta y/\Delta x = \tan\theta$, so we can write:

$$\text{speed of vehicle} = (1059 \tan\theta/4.76) \text{ft/sec}$$

$$= 151.7 \tan\theta \text{ mph}$$

Hypothesis: Beam usage is independent of traffic situation for the meeting case.

Contingency Table

Traffic Situation	Low Beam	High Beam	Total
Open Road	17,476	5,700	23,176
Meeting	17,409	1,314	18,723
Total	34,885	7,014	41,899

$$X^2 = (n_{11} - a_{11})^2 / a_{11} + (n_{12} - a_{12})^2 / a_{12} + (n_{21} - a_{21})^2 / a_{21} + (n_{22} - a_{22})^2 / a_{22}$$

$X^2 = 2294.77$, and the hypothesis is rejected.

Hypothesis: Beam usage is independent of traffic situation for the following case.

Contingency Table

Traffic Situation	Low Beam	High Beam	Total
Open Road	17,476	5,700	23,176
Meeting	8,251	574	8,825
Total	25,727	6,274	32,001

$X^2 = 1326.59$, and the hypothesis is rejected.

Dimming Actions Completed in 100-ft Intervals of Intercar Distance from 5,000 ft to Meeting Point

Interval (ft)	Dimming Actions in Interval	Cumulative Fraction	Interval (ft)	Dimming Actions in Interval	Cumulative Fraction
4900-4999	1	0.0285	2400-2499	46	0.2299
4800-4899	8	0.0317	2300-2399	56	0.2524
4700-4799	2	0.0325	2200-2299	48	0.2717
4600-4699	5	0.0345	2100-2199	59	0.2953
4500-4599	7	0.0373	2000-2099	58	0.3184
4400-4499	4	0.0389	1900-1999	70	0.3467
4300-4399	15	0.0449	1800-1899	66	0.3732
4200-4299	3	0.0461	1700-1799	70	0.4013
4100-4199	4	0.0478	1600-1699	94	0.4390
4000-4099	17	0.0546	1500-1599	82	0.4719
3900-3999	9	0.0582	1400-1499	103	0.5132
3800-3899	9	0.0618	1300-1399	89	0.5490
3700-3799	18	0.0690	1200-1299	116	0.5955
3600-3699	11	0.0734	1100-1199	123	0.6449
3500-3599	16	0.0799	1000-1099	144	0.7026
3400-3499	20	0.0879	900-999	111	0.7472
3300-3399	26	0.0983	800-899	117	0.7941
3200-3299	23	0.1075	700-799	112	0.8391
3100-3199	32	0.1204	600-699	96	0.8776
3000-3099	34	0.1340	500-599	79	0.9093
2900-2999	26	0.1445	400-499	71	0.9378
2800-2899	30	0.1565	300-399	57	0.9607
2700-2799	30	0.1685	200-299	54	0.9823
2600-2699	53	0.1898	100-199	29	0.9940
2500-2599	54	0.2115	0-99	15	1.000

DATA SUMMARY	SITE 1	STATE NEW YORK	Sight Distance Through Site 3,900 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	899	28.72	69.10		
Open Road	High	402	12.84	30.90		
Meeting	Low	1047	33.45		91.28	
Meeting	High	100	3.19		8.72	
Following ≤ 300 ft	Low	589	18.82			97.68
Following ≤ 300 ft	High	14	.45			2.32

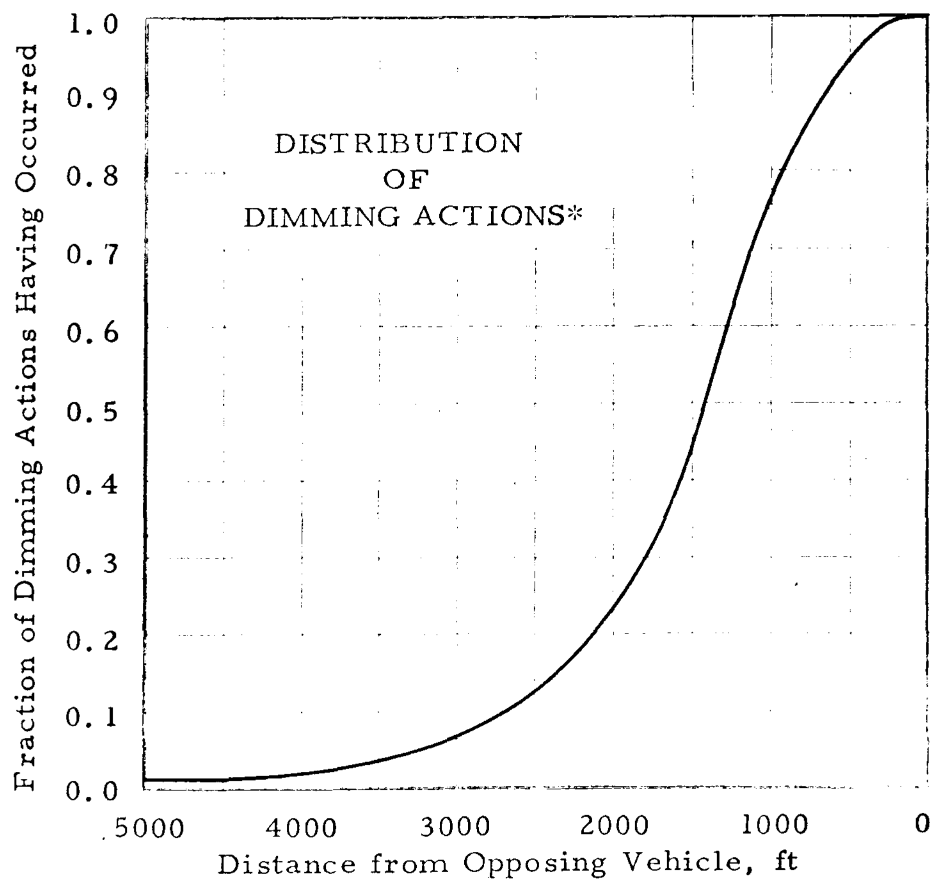
Date		Volume
Wed.	5/8/68	457
Thurs.	5/9/68	640
Fri.	5/10/68	795
Sat.	5/11/68	711
Sun.	5/12/68	527

Total Vehicles	3130	% Total
Passenger Cars	2979	95.18
Light Trucks	104	3.32
Heavy Trucks	47	1.50
4-Lamp Vehicles	2506	80.06
2-Lamp Vehicles	624	19.94

Traffic Situation	Beam	Avg Speed
All	All	48.67
Meeting	All	47.44
Open Road	Low	49.90
Open Road	High	51.30

Speed Limit (mph)	50
Vehicles Over Limit	1130
% Vehicles Over Limit	36.10

Number of Dimming Situations	257
Avg Dimming Distance, ft	1570
Standard Deviation, ft	884
No. of Vehicles Which Did Not Dim	30



*See note, p. 17

DATA SUMMARY	SITE	2	STATE	MAINE	Sight Distance Through Site	6, 500 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	867	24.74	73.72		
Open Road	High	309	8.82	26.28		
Meeting	Low	1435	40.94		89.63	
Meeting	High	166	4.74		10.37	
Following ≤ 300 ft	Low	733	20.91			97.60
Following ≤ 300 ft	High	18	.51			2.40

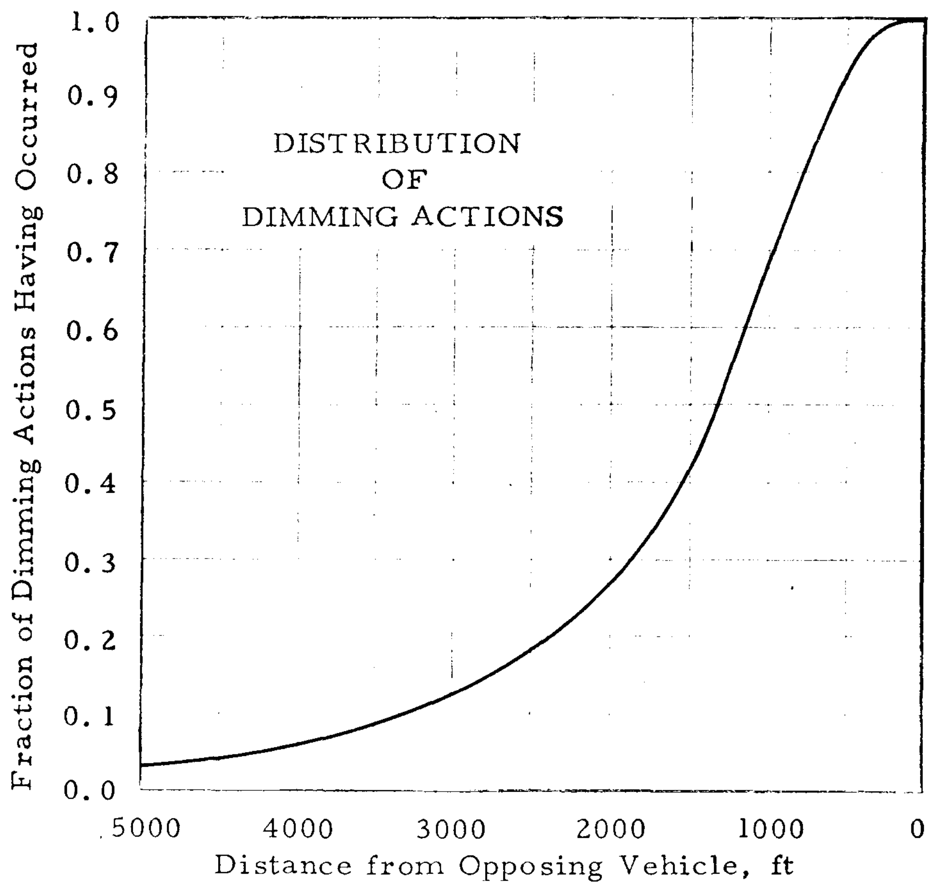
Date	Volume
Wed. 5/15/68	472
Thurs. 5/16/68	638
Fri. 5/17/68	831
Sat. 5/18/68	979
Sun. 5/19/68	585

Total Vehicles	3505	% Total
Passenger Cars	3120	89.02
Light Trucks	215	6.13
Heavy Trucks	170	4.85
4-Lamp Vehicles	2345	66.90
2-Lamp Vehicles	1160	33.10

Traffic Situation	Beam	Avg Speed
All	All	53.67
Meeting	All	53.00
Open Road	Low	55.31
Open Road	High	57.13

Speed Limit (mph)	55
Vehicles Over Limit	1365
% Vehicles Over Limit	38.94

Number of Dimming Situations	360
Avg Dimming Distance, ft	1624
Standard Deviation, ft	1195
No. of Vehicles Which Did Not Dim	38



DATA SUMMARY	SITE	3	STATE	TENNESSEE	Sight Distance Through Site	2,800 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	747	25.32	49.24		
Open Road	High	770	26.10	50.76		
Meeting	Low	709	24.03		76.57	
Meeting	High	217	7.36		23.45	
Following ≤ 300 ft	Low	307	10.41			65.32
Following ≤ 300 ft	High	163	5.53			34.68

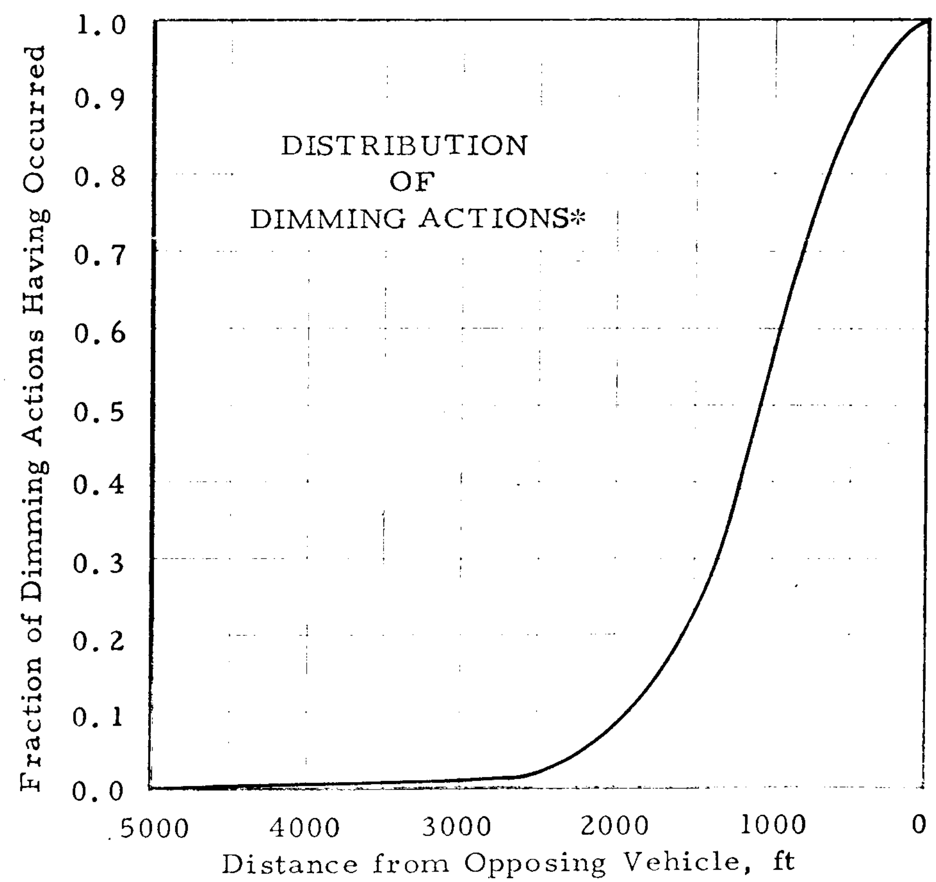
Date	Volume
Wed. 1/31/68	493
Thurs. 2/1/68	591
Fri. 2/23/68	491
Sat. 2/24/68	706
Sun. 2/25/68	669

Total Vehicles	2950	% Total
Passenger Cars	1663	56.37
Light Trucks	167	5.66
Heavy Trucks	1120	37.97
4-Lamp Vehicles	1467	49.73
2-Lamp Vehicles	1483	50.27

Traffic Situation	Beam	Avg Speed
All	All	56.48
Meeting	All	55.64
Open Road	Low	56.33
Open Road	High	57.49

Speed Limit (mph)	55
Vehicles Over Limit	1652
% Vehicles Over Limit	56.00

Number of Dimming Situations	278
Avg Dimming Distance, ft	1103
Standard Deviation, ft	595
No. of Vehicles Which Did Not Dim	98



*See note, p. 56

DATA SUMMARY	SITE 4	STATE GEORGIA	Sight Distance Through Site	12,500 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	855	30.14	59.62		
Open Road	High	579	20.41	40.38		
Meeting	Low	650	22.91		81.86	
Meeting	High	144	5.08		18.14	
Following ≤ 300 ft	Low	390	13.75			93.30
Following ≤ 300 ft	High	28	.99			6.70

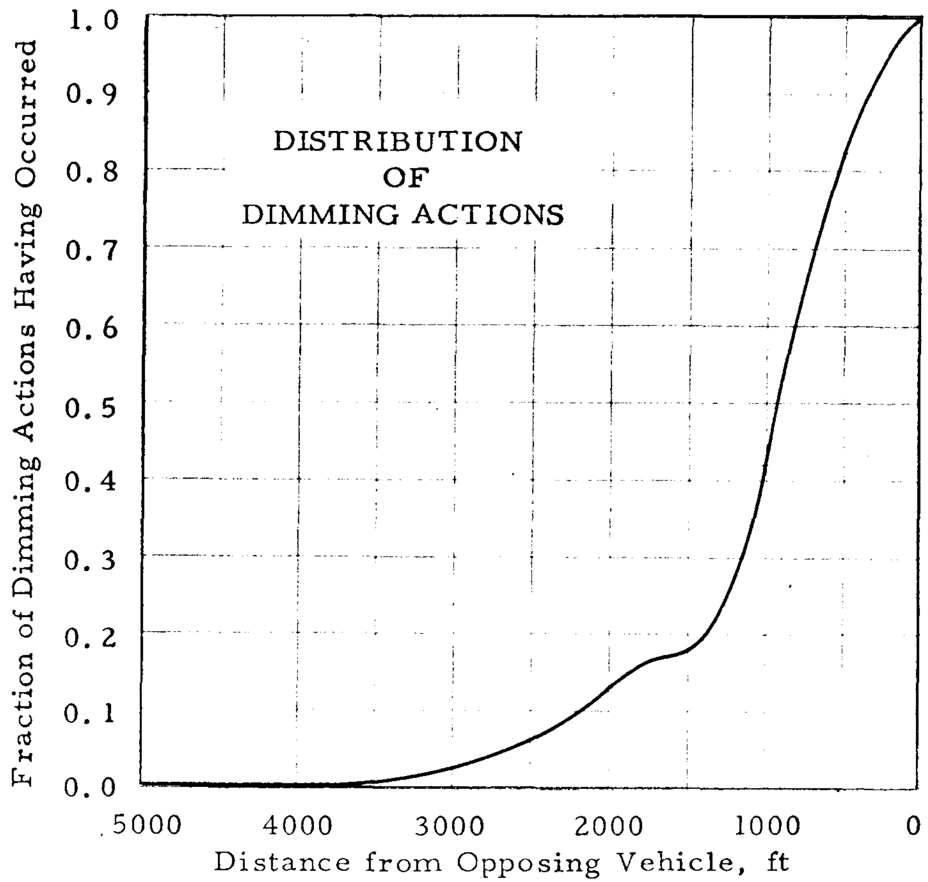
Date	Volume
Thurs. 1/11/68	270
Fri. 1/12/68	774
Sat. 1/13/68	649
Sun. 1/14/68	557
Mon. 1/15/68	587

Total Vehicles	2837	% Total
Passenger Cars	2416	85.16
Light Trucks	166	5.85
Heavy Trucks	255	8.99
4-Lamp Vehicles	1947	68.63
2-Lamp Vehicles	890	31.37

Traffic Situation	Beam	Avg Speed
All	All	55.86
Meeting	All	55.94
Open Road	Low	55.15
Open Road	High	57.22

Speed Limit (mph)	50
Vehicles Over Limit	2046
% Vehicles Over Limit	72.12

Number of Dimming Situations	207
Avg Dimming Distance, ft	1016
Standard Deviation, ft	715
No. of Vehicles Which Did Not Dim	32



DATA SUMMARY	SITE 5	STATE FLORIDA	Sight Distance Through Site	4,900 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1089	31.99	69.63		
Open Road	High	475	13.95	30.37		
Meeting	Low	1052	30.90		86.16	
Meeting	High	169	4.96		13.84	
Following ≤ 300 ft	Low	552	16.22			94.68
Following ≤ 300 ft	High	31	.91			5.32

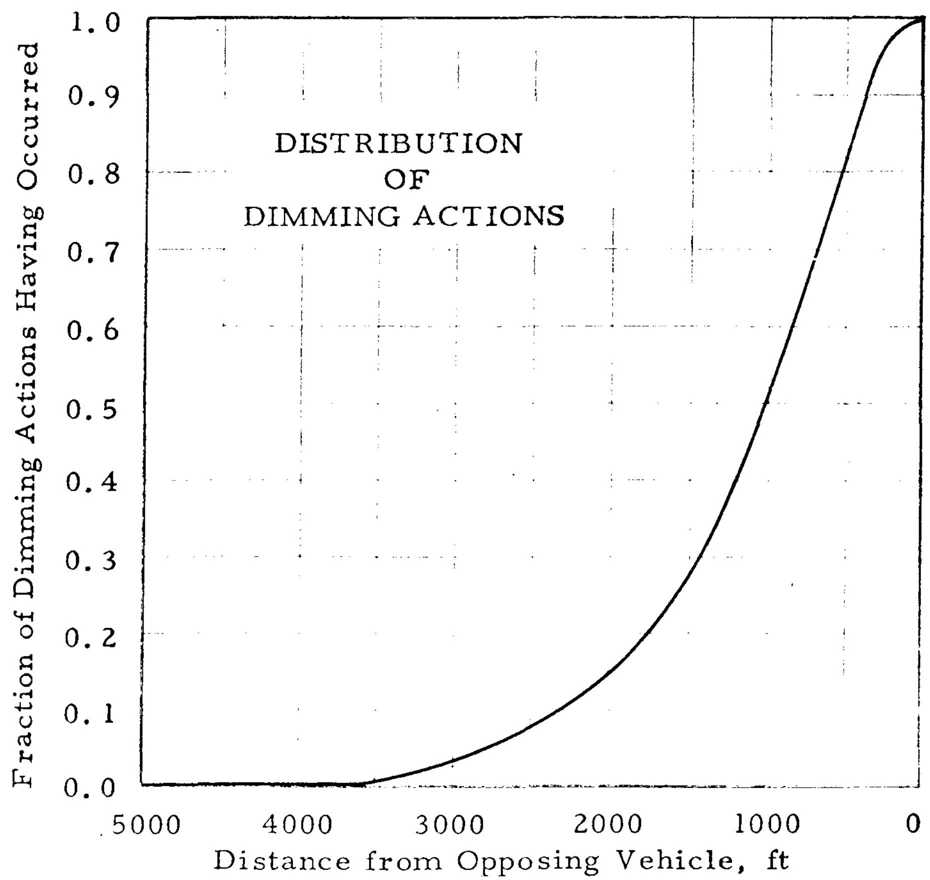
Date	Volume
Thurs. 1/18/68	354
Fri. 1/19/68	877
Sat. 1/20/68	903
Sun. 1/21/68	880
Mon. 1/22/68	390

Total Vehicles	3404	% Total
Passenger Cars	3103	91.16
Light Trucks	116	3.41
Heavy Trucks	185	5.43
4-Lamp Vehicles	2143	62.96
2-Lamp Vehicles	1261	37.04

Traffic Situation	Beam	Avg Speed
All	All	57.00
Meeting	All	56.31
Open Road	Low	57.83
Open Road	High	58.36

Speed Limit (mph)	55
Vehicles Over Limit	1954
% Vehicles Over Limit	57.40

Number of Dimming Situations	115
Avg Dimming Distance, ft	1150
Standard Deviation, ft	828
No. of Vehicles Which Did Not Dim	90



DATA SUMMARY	SITE 6	STATE ILLINOIS	Sight Distance Through Site 7,300 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1691	44.65	82.13		
Open Road	High	368	9.72	17.87		
Meeting	Low	1117	29.50		91.48	
Meeting	High	104	2.75		8.52	
Following ≤ 300 ft	Low	549	14.50			84.72
Following ≤ 300 ft	High	99	2.61			15.28

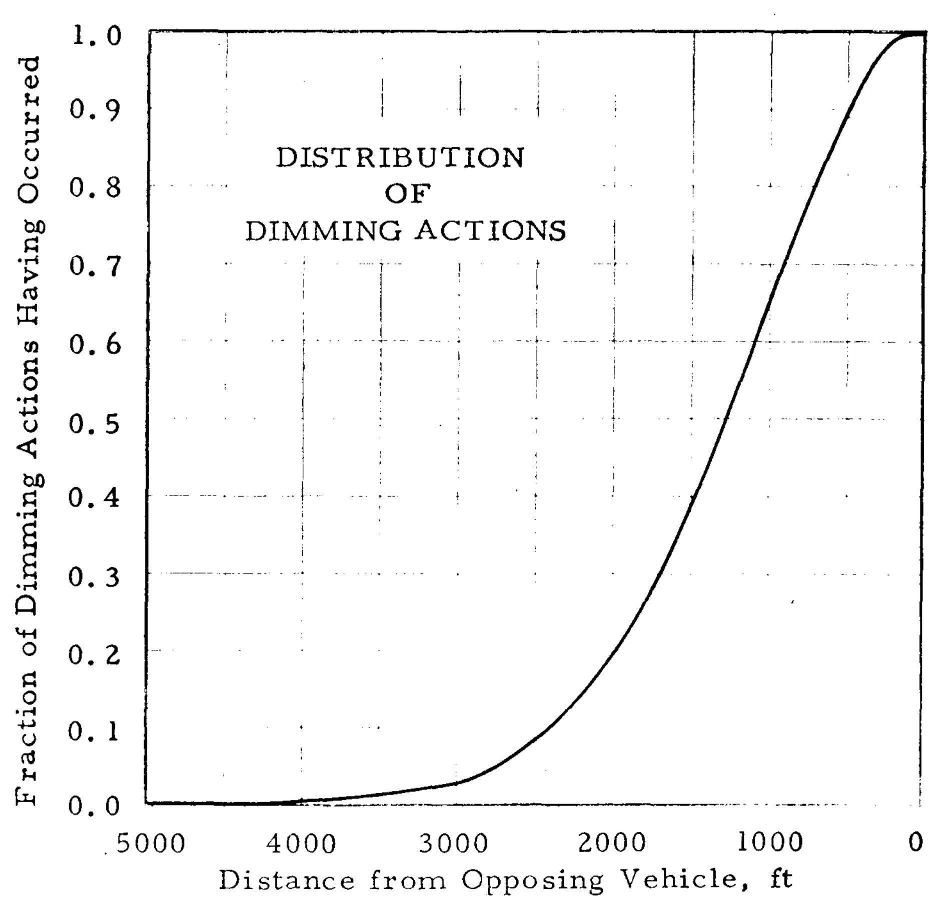
Date	Volume
Fri. 2/9/68	742
Sat. 2/10/68	695
Sun. 2/11/68	1064
Mon. 2/12/68	729
Tues. 2/13/68	557

Total Vehicles	3787	% Total
Passenger Cars	3163	83.52
Light Trucks	155	4.09
Heavy Trucks	469	12.38
4-Lamp Vehicles	2833	74.81
2-Lamp Vehicles	954	25.19

Traffic Situation	Beam	Avg Speed
All	All	62.28
Meeting	All	61.38
Open Road	Low	62.43
Open Road	High	64.90

Speed Limit (mph)	65
Vehicles Over Limit	1340
% Vehicles Over Limit	35.38

Number of Dimming Situations	162
Avg Dimming Distance, ft	1347
Standard Deviation, ft	750
No. of Vehicles Which Did Not Dim	46



DATA SUMMARY	SITE 7A	STATE MICHIGAN	Sight Distance Through Site 15,000 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1005	37.80	72.93		
Open Road	High	373	14.03	27.07		
Meeting	Low	809	30.42		94.73	
Meeting	High	45	1.69		5.27	
Following ≤ 300 ft	Low	357	13.43			80.04
Following ≤ 300 ft	High	89	3.35			19.96

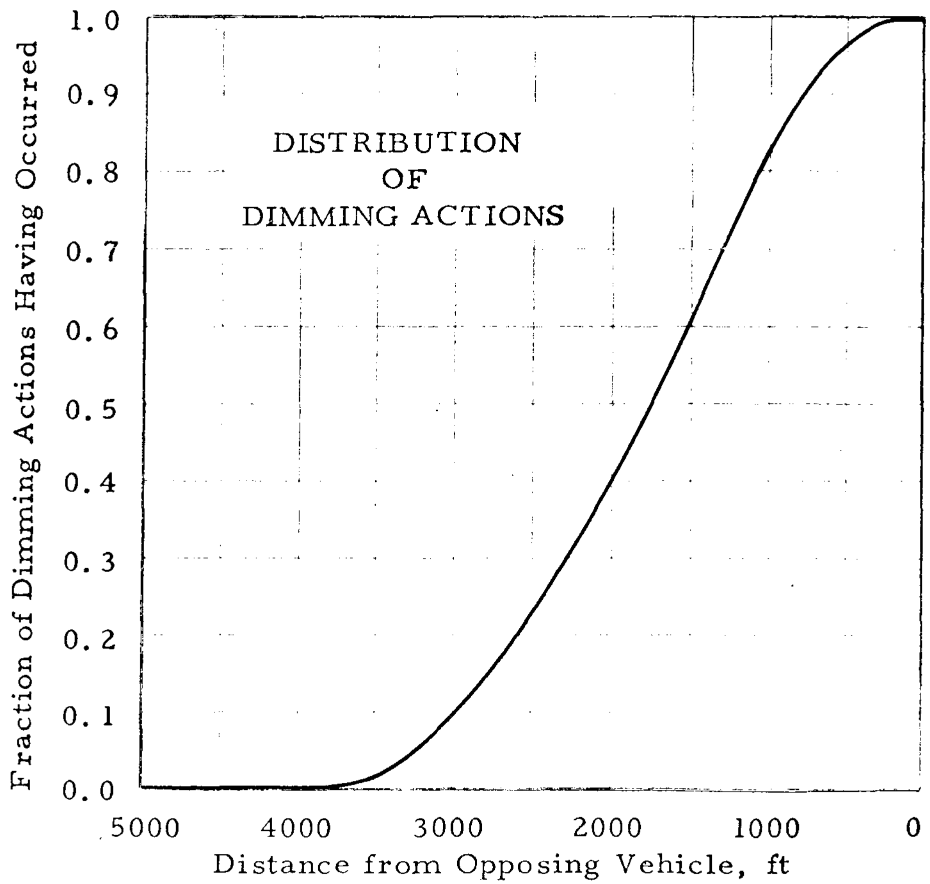
Date	Volume
Fri. 2/16/68	501
Sat. 2/17/68	621
Sun. 2/18/68	845
Mon. 2/19/68	385
Tues. 2/20/68	307

Total Vehicles	2659	% Total
Passenger Cars	2402	90.33
Light Trucks	175	6.58
Heavy Trucks	82	3.09
4-Lamp Vehicles	2154	81.01
2-Lamp Vehicles	505	18.99

Traffic Situation	Beam	Avg Speed
All	All	63.67
Meeting	All	63.36
Open Road	Low	63.67
Open Road	High	64.19

Speed Limit (mph)	55
Vehicles Over Limit	2192
% Vehicles Over Limit	82.44

Number of Dimming Situations	85
Avg Dimming Distance, ft	1840
Standard Deviation, ft	883
No. of Vehicles Which Did Not Dim	26



DATA SUMMARY	SITE	7B	STATE	MICHIGAN	Sight Distance Through Site	15,000 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1031	50.27	76.03		
Open Road	High	325	15.85	23.97		
Meeting	Low	387	18.87		93.03	
Meeting	High	29	1.41		6.97	
Following ≤ 300 ft	Low	169	8.24			98.83
Following ≤ 300 ft	High	2	.10			1.17

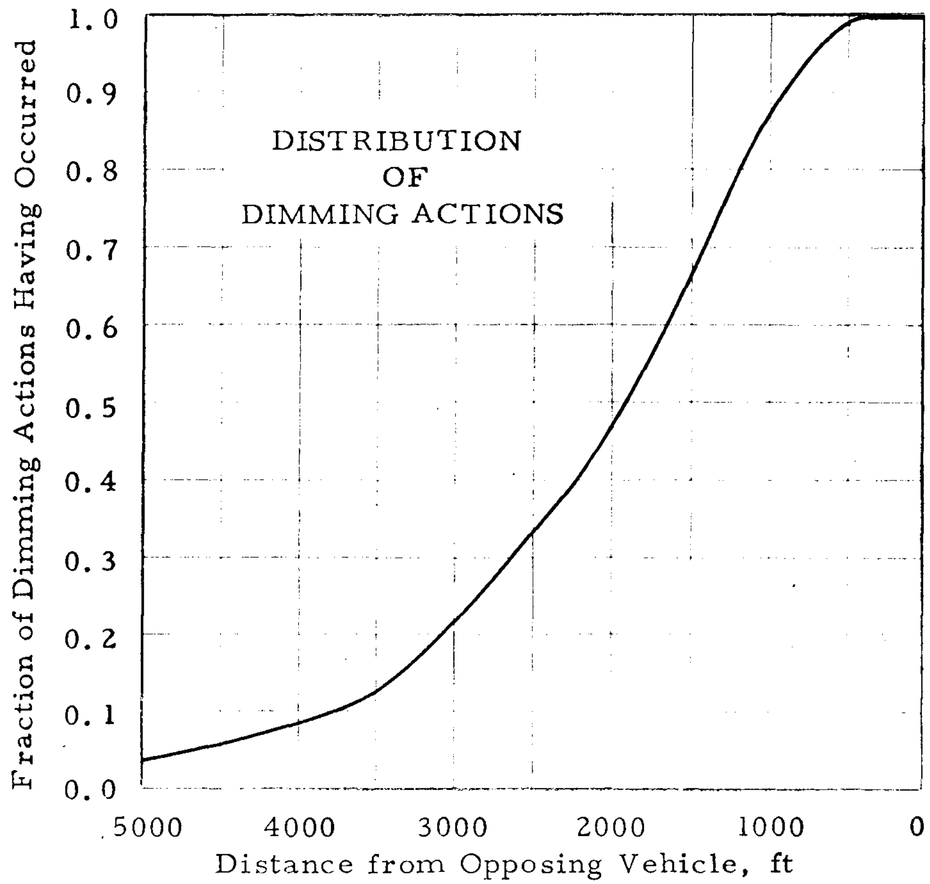
Date	Volume
Thurs. 5/23/68	284
Fri. 5/24/68	482
Sat. 5/25/68	591
Sun. 5/26/68	437
Mon. 5/27/68	257

Total Vehicles	2051	% Total
Passenger Cars	1860	90.69
Light Trucks	133	6.48
Heavy Trucks	58	2.83
4-Lamp Vehicles	1630	79.47
2-Lamp Vehicles	421	20.53

Traffic Situation	Beam	Avg Speed
All	All	64.00
Meeting	All	63.31
Open Road	Low	64.57
Open Road	High	64.56

Speed Limit (mph)	55
Vehicles Over Limit	1703
% Vehicles Over Limit	83.03

Number of Dimming Situations	79
Avg Dimming Distance, ft	2159
Standard Deviation, ft	1296
No. of Vehicles Which Did Not Dim	13



DATA SUMMARY	SITE	8	STATE	NEBRASKA	Sight Distance Through Site	6,000 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1461	29.41	87.64		
Open Road	High	206	4.15	12.36		
Meeting	Low	2473	49.79		98.68	
Meeting	High	33	.66		1.32	
Following ≤ 300 ft	Low	1166	23.47			99.32
Following ≤ 300 ft	High	8	.16			.68

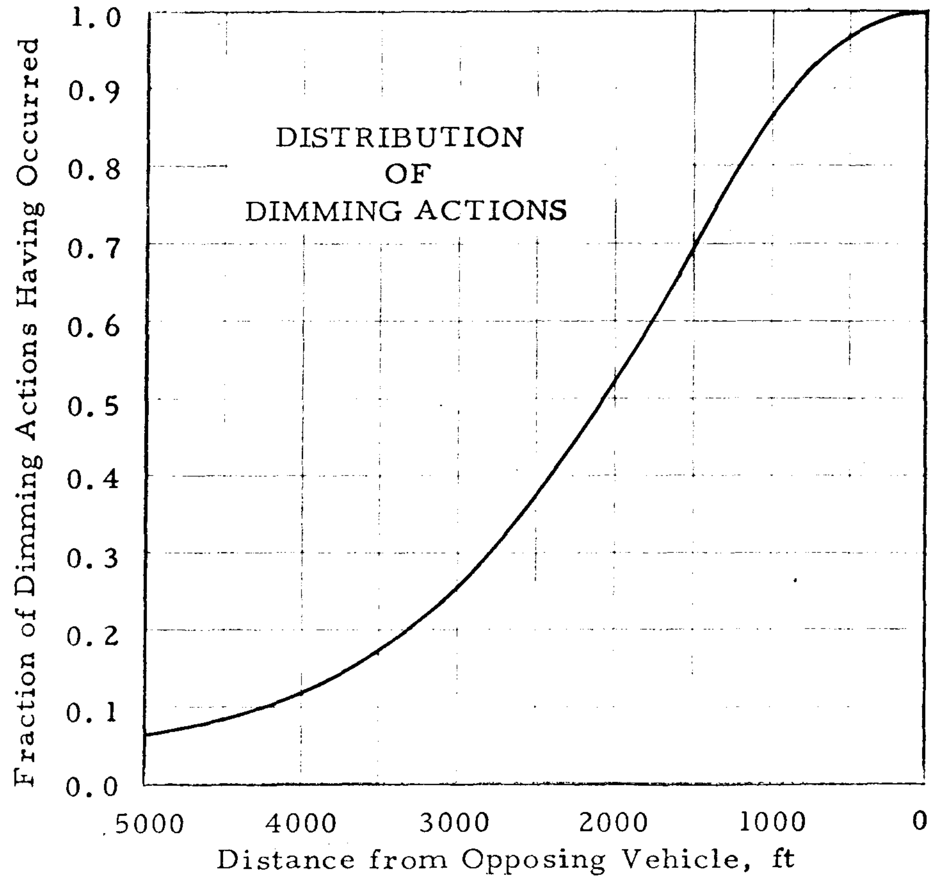
Date	Volume
Wed. 4/10/68	644
Thurs. 4/11/68	1070
Fri. 4/12/68	1099
Sat. 4/13/68	628
Sun. 4/14/68	1526

Total Vehicles	4967	% Total
Passenger Cars	4354	87.66
Light Trucks	189	3.81
Heavy Trucks	424	8.53
4-Lamp Vehicles	3988	80.29
2-Lamp Vehicles	979	19.71

Traffic Situation	Beam	Avg Speed
All	All	57.23
Meeting	All	56.38
Open Road	Low	57.99
Open Road	High	59.79

Speed Limit (mph)	60
Vehicles Over Limit	1732
% Vehicles Over Limit	34.87

Number of Dimming Situations	94
Avg Dimming Distance, ft	2 275
Standard Deviation, ft	1 345
No. of Vehicles Which Did Not Dim	18



DATA SUMMARY	SITE	9	STATE	LOUISIANA	Sight Distance Through Site	6,000 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	917	40.27	70.48		
Open Road	High	384	16.86	29.52		
Meeting	Low	507	22.27		87.26	
Meeting	High	74	3.25		12.74	
Following ≤ 300 ft	Low	189	8.30			95.94
Following ≤ 300 ft	High	8	.35			4.06

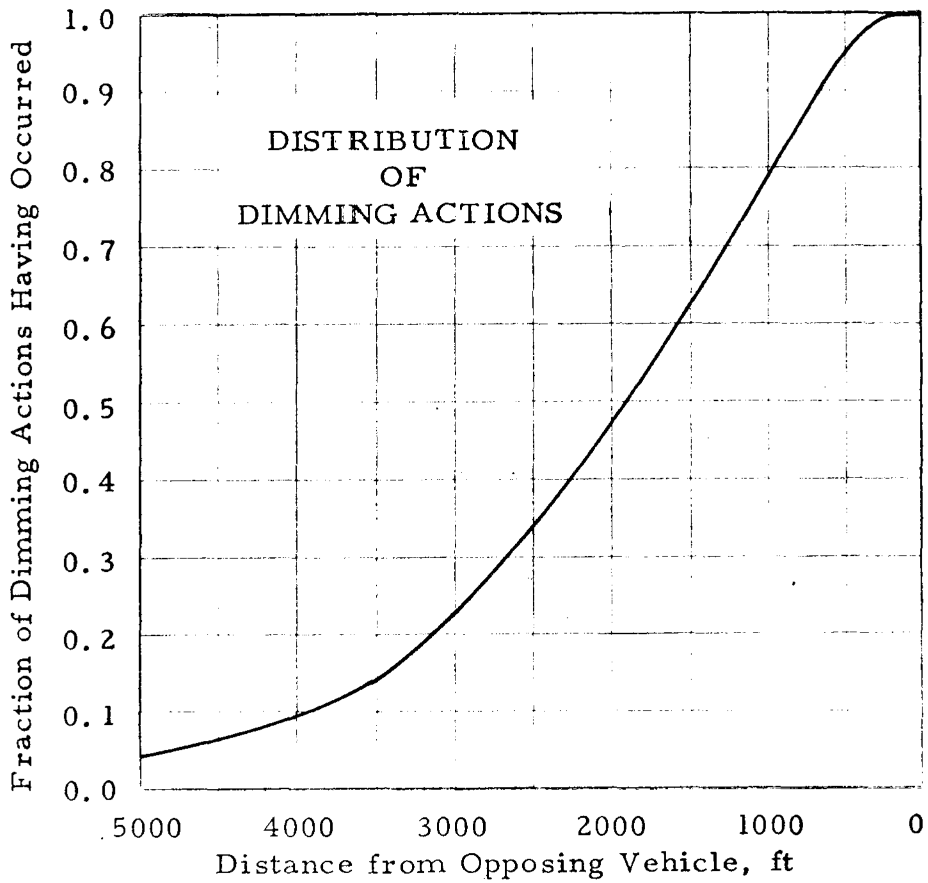
Date	Volume
Thurs. 4/18/68	282
Fri. 4/19/68	588
Sat. 4/20/68	562
Sun. 4/21/68	615
Mon. 4/22/68	230

Total Vehicles	2277	% Total
Passenger Cars	1768	77.65
Light Trucks	238	10.45
Heavy Trucks	271	11.90
4-Lamp Vehicles	1484	65.17
2-Lamp Vehicles	793	34.83

Traffic Situation	Beam	Avg Speed
All	All	64.23
Meeting	All	63.33
Open Road	Low	64.62
Open Road	High	65.67

Speed Limit (mph)	60
Vehicles Over Limit	1495
% Vehicles Over Limit	65.66

Number of Dimming Situations	216
Avg Dimming Distance, ft	2115
Standard Deviation, ft	1354
No. of Vehicles Which Did Not Dim	16



DATA SUMMARY	SITE	10	STATE	TEXAS	Sight Distance Through Site	2,500 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	104	10.12	14.65		
Open Road	High	606	58.95	85.35		
Meeting	Low	112	10.89		62.22	
Meeting	High	68	6.61		37.78	
Following ≤ 300 ft	Low	100	9.73			90.09
Following ≤ 300 ft	High	11	1.07			9.91

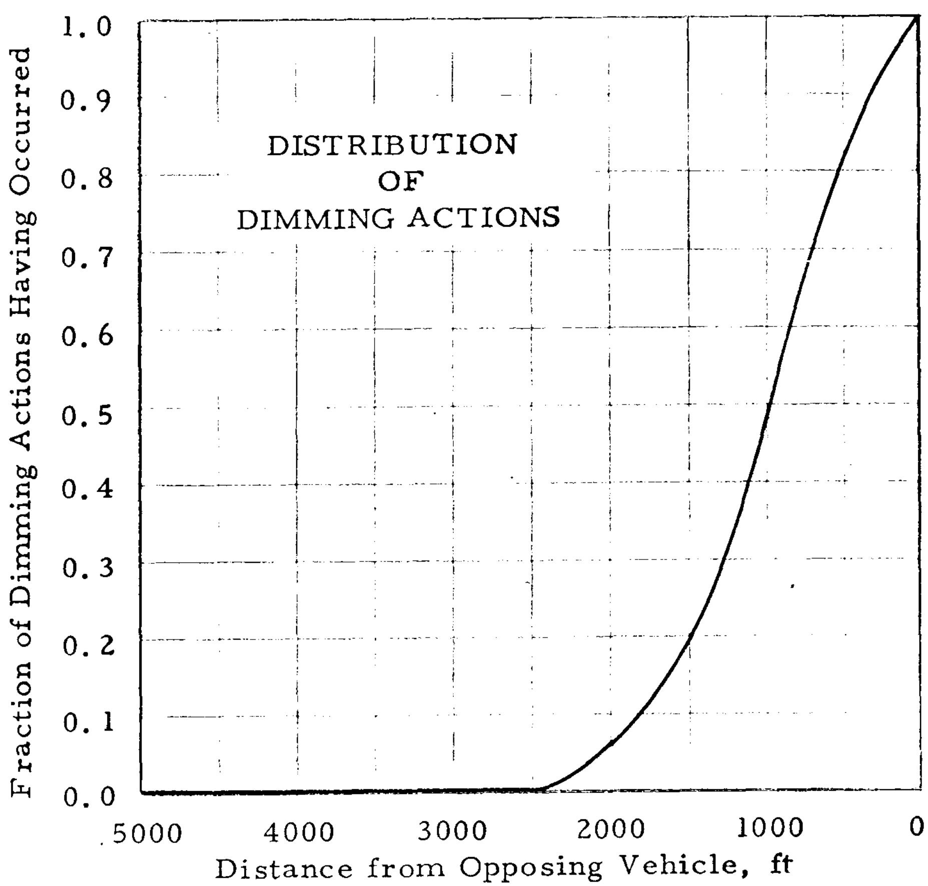
Date		Volume
Tues.	12/26/67	63
Wed.	12/27/67	233
Thurs.	12/28/67	94
Fri.	12/29/67	325
Sat.	12/30/67	313

Total Vehicles	1028	% Total
Passenger Cars	818	79.57
Light Trucks	206	20.04
Heavy Trucks	4	.39
4-Lamp Vehicles	530	51.56
2-Lamp Vehicles	498	48.44

Traffic Situation	Beam	Avg Speed
All	All	53.72
Meeting	All	53.20
Open Road	Low	51.69
Open Road	High	54.58

Speed Limit (mph)	60
Vehicles Over Limit	203
% Vehicles Over Limit	19.75

Number of Dimming Situations	85
Avg Dimming Distance, ft	974
Standard Deviation, ft	554
No. of Vehicles Which Did Not Dim	19



DATA SUMMARY	SITE	11	STATE	CALIFORNIA	Sight Distance Through Site	7,000 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	2680	37.07	96.72		
Open Road	High	91	1.26	3.28		
Meeting	Low	3504	48.47		99.49	
Meeting	High	18	.25		.51	
Following ≤ 300 ft	Low	1547	21.40			97.36
Following ≤ 300 ft	High	42	.58			2.64

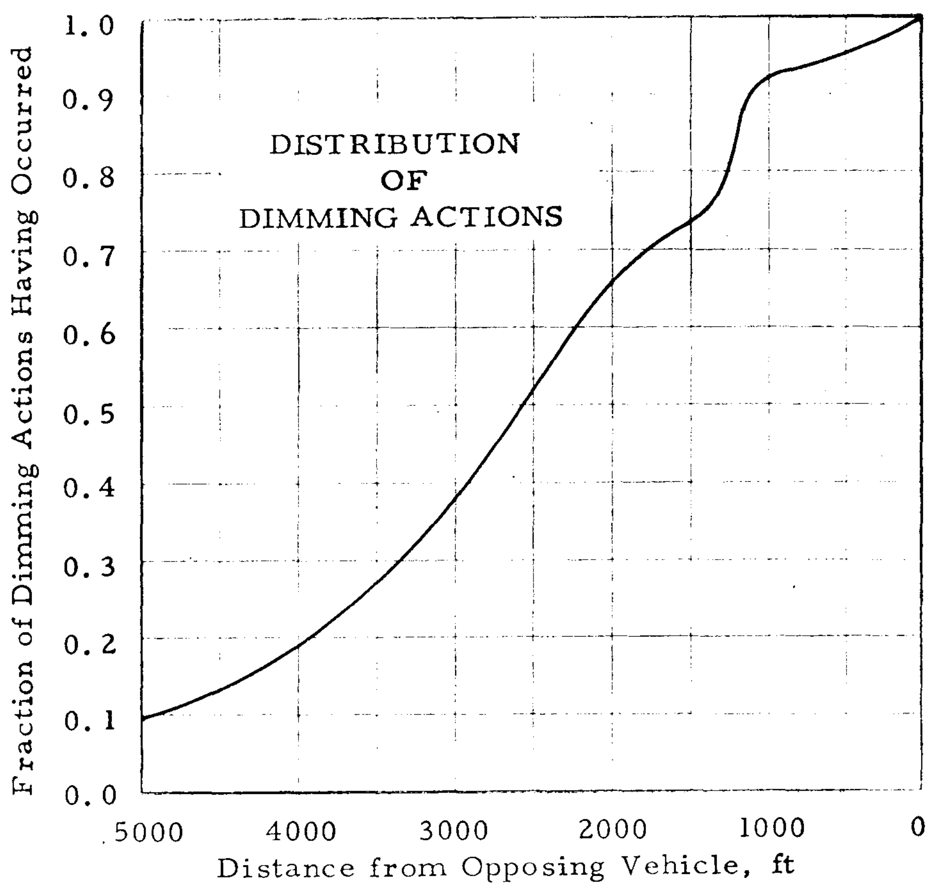
Date	Volume
Wed. 3/20/68	898
Thurs. 3/21/68	1202
Fri. 3/22/68	1529
Sat. 3/23/68	1502
Sun. 3/24/68	2098

		% Total
Total Vehicles	7229	
Passenger Cars	5470	75.67
Light Trucks	664	9.18
Heavy Trucks	1095	15.15
4-Lamp Vehicles	4218	58.35
2-Lamp Vehicles	3011	41.65

Traffic Situation	Beam	Avg Speed
All	All	67.12
Meeting	All	65.58
Open Road	Low	68.67
Open Road	High	70.26

Speed Limit (mph)	65
Vehicles Over Limit	4038
% Vehicles Over Limit	55.86

Number of Dimming Situations	64
Avg Dimming Distance, ft	2751
Standard Deviation, ft	1946
No. of Vehicles Which Did Not Dim	11



DATA SUMMARY	SITE	12	STATE	ARIZONA	Sight Distance Through Site	6,500 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	2305	41.02	96.36		
Open Road	High	87	1.55	3.64		
Meeting	Low	2431	43.26		98.22	
Meeting	High	44	.78		1.78	
Following ≤ 300 ft	Low	1124	20.00			96.32
Following ≤ 300 ft	High	43	.77			3.68

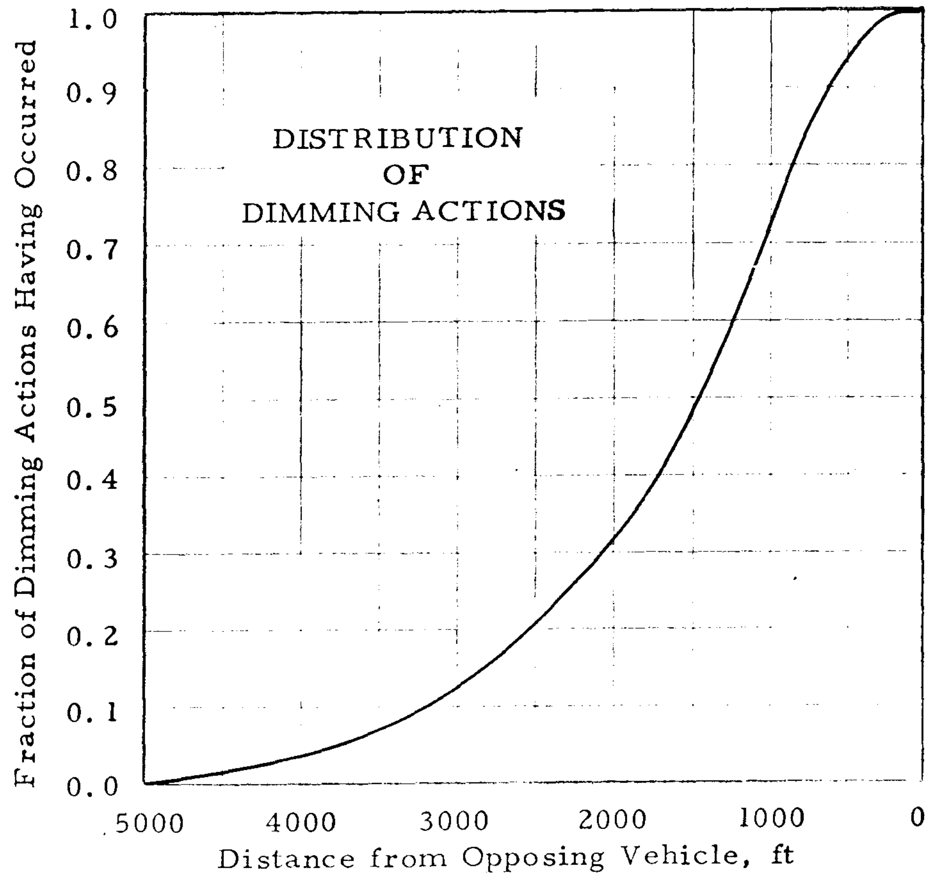
Date		Volume
Wed.	3/13/68	716
Thurs.	3/14/68	798
Fri.	3/15/68	1679
Sat.	3/16/68	1073
Sun.	3/17/68	1353

Total Vehicles	5619	% Total
Passenger Cars	3728	66.35
Light Trucks	771	13.72
Heavy Trucks	1120	19.93
4-Lamp Vehicles	3300	58.73
2-Lamp Vehicles	2319	41.27

Traffic Situation	Beam	Avg Speed
All	All	64.29
Meeting	All	63.67
Open Road	Low	64.95
Open Road	High	66.63

Speed Limit (mph)	60
Vehicles Over Limit	3906
% Vehicles Over Limit	69.51

Number of Dimming Situations	74
Avg Dimming Distance, ft	1669
Standard Deviation, ft	1051
No. of Vehicles Which Did Not Dim	15



DATA SUMMARY	SITE	13	STATE	OREGON	Sight Distance Through Site	6,500 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	1290	39.59	78.32		
Open Road	High	357	10.96	21.68		
Meeting	Low	944	28.97		92.10	
Meeting	High	81	2.49		7.90	
Following ≤ 300 ft	Low	434	13.32			96.66
Following ≤ 300 ft	High	15	.46			3.34

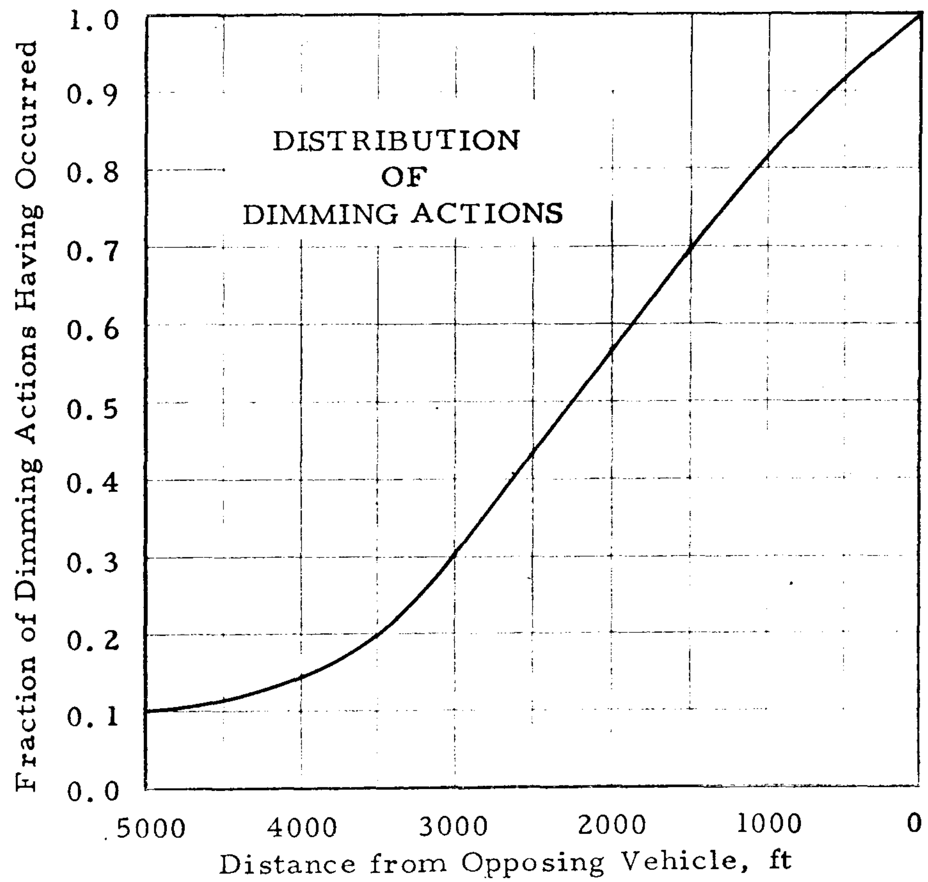
Date	Volume
Wed. 3/27/68	329
Thurs. 3/28/68	433
Fri. 3/29/68	831
Sat. 3/30/68	880
Sun. 3/31/68	785

Total Vehicles	3258	% Total
Passenger Cars	2762	84.78
Light Trucks	413	12.68
Heavy Trucks	83	2.54
4-Lamp Vehicles	2021	62.03
2-Lamp Vehicles	1237	37.97

Traffic Situation	Beam	Avg Speed
All	All	65.40
Meeting	All	64.43
Open Road	Low	66.39
Open Road	High	68.02

Speed Limit (mph)	65
Vehicles Over Limit	1759
% Vehicles Over Limit	53.99

Number of Dimming Situations	277
Avg Dimming Distance, ft	2532
Standard Deviation, ft	1862
No. of Vehicles Which Did Not Dim	30



DATA SUMMARY	SITE	14	STATE	COLORADO	Sight Distance Through Site	4,400 ft

Traffic Situation	Beam	Vehicles	% Total	% Open Road	% Meeting	% Following
Open Road	Low	535	40.23	59.25		
Open Road	High	368	27.67	40.75		
Meeting	Low	232	17.44		91.34	
Meeting	High	22	1.65		8.66	
Following ≤ 300 ft	Low	45	3.38			93.75
Following ≤ 300 ft	High	3	.23			6.25

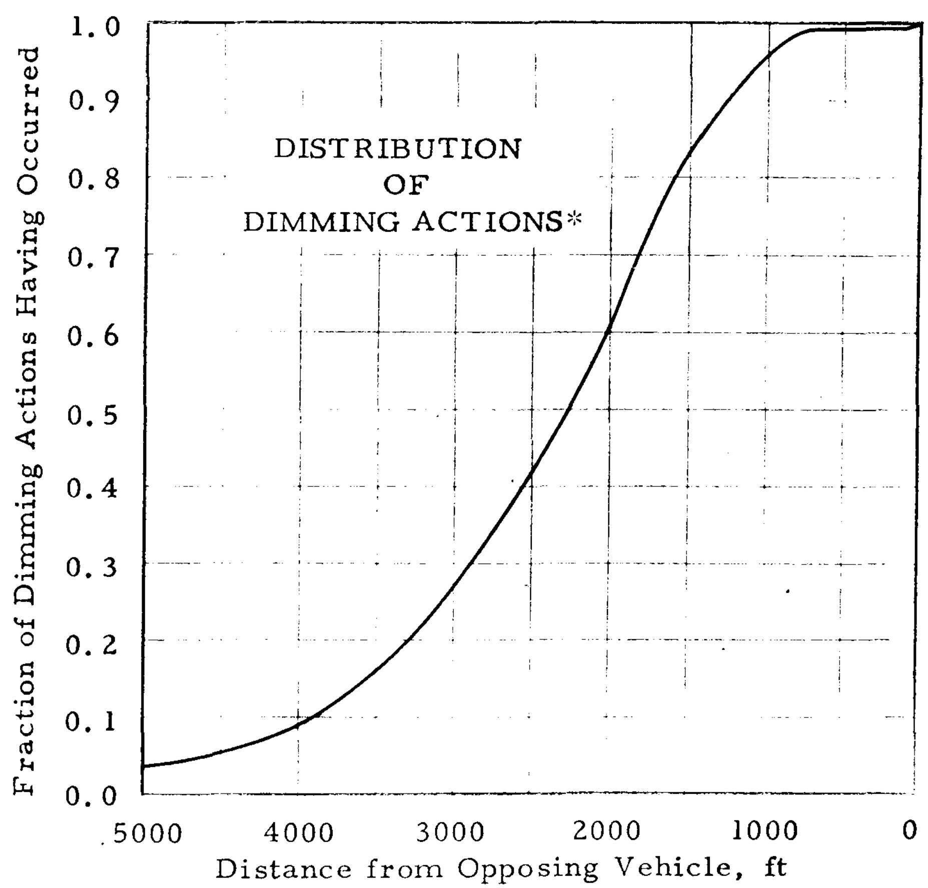
Date		Volume
Wed.	6/5/68	128
Thurs.	6/6/68	270
Fri.	6/7/68	377
Sat.	6/8/68	344
Sun.	6/9/68	211

Total Vehicles	1330	% Total
Passenger Cars	912	68.57
Light Trucks	225	16.92
Heavy Trucks	193	14.51
4-Lamp Vehicles	822	61.80
2-Lamp Vehicles	508	38.20

Traffic Situation	Beam	Avg Speed
All	All	65.53
Meeting	All	65.35
Open Road	Low	64.66
Open Road	High	67.32

Speed Limit (mph)	70
Vehicles Over Limit	333
% Vehicles Over Limit	25.04

Number of Dimming Situations	139
Avg Dimming Distance, ft	2400
Standard Deviation, ft	1112
No. of Vehicles Which Did Not Dim	13



*See note, p. 56

Site 15

Suburban, four-lane freeway with median

Dates of operation: Wednesday, 7/10/68 - Sunday, 7/14/68

Total number of vehicles observed	7,024
Percent passenger cars	90.58
Percent light trucks	7.30
Percent heavy trucks	2.12
Percent 4-lamp vehicles	62.41
Percent 2-lamp vehicles	37.59
Speed limit, mph	65
Percent vehicles exceeding speed limit	43.36
Percent on high beam, open road situation	20.99
Percent on high beam, meeting situation	7.94
Percent on high beam, following situation	2.93
Sight distance through test site, ft	5,500
Average intercar distance at dimming, ft	1,708
Number dimming for opposing vehicle	34
Number not dimming for opposing vehicle	44

Site 16

Suburban two-lane

Dates of operation: Friday, 7/19/68 - Monday, 7/22/68

Total number of vehicles observed	6,783
Percent passenger cars	94.66
Percent light trucks	4.07
Percent heavy trucks	1.27
Percent 4-lamp vehicles	73.26
Percent 2-lamp vehicles	26.74
Speed limit, mph	50
Percent vehicles exceeding speed limit	78.47
Percent on high beam, open road situation	12.81
Percent on high beam, meeting situation	4.21
Percent on high beam, following situation	1.38
Sight distance through test site, ft	2,200
Average intercar distance at dimming, ft	1,284
Number dimming for opposing vehicle	34
Number not dimming for opposing vehicle	20

Site 17

Suburban, two-lane with overhead lighting

Dates of operation: Wednesday, 7/3/68 - Friday, 7/5/68

Total number of vehicles observed: 7,099

Pavement illumination: 1.0 ft-candle average, 2.0 ft-candle maximum,
0.8 ft-candle minimum

Hour of night	9-10	10-11	11-12	12-1	1-2	2-3
Number of vehicles observed	2,078	1,539	1,350	1,079	692	361
Percent of high beam	1.52	0.41	0.89	0.99	0.97	1.17
Number of vehicles not dimming	0	0	0	0	0	0
Number of vehicles brightening	0	0	0	0	0	0

APPENDIX C

OBSERVERS' ORIENTATION SHEET

The purpose of the study in which you are participating is to determine how the average motorist uses his car's headlamps. The study will be conducted in fifteen areas of the U. S. during the next 6 months, and it is a portion of a nationwide research effort to reduce automobile accidents at night.

Figure 1 (see page 8) is a diagram of the test site at which you will be working. Please examine it at this time, before you read further.

Referring to Figure 1, the boxes at the left and right of the page marked "observer #1" and "observer #2" indicate positions of observers, one of which you will occupy. Your function is to observe vehicles coming toward you on the road to determine the following things about each one:

(1) Type of vehicle (car or truck)

(2) Number of headlamps the vehicle has (2 or 4)

(3) Headlamp beam the driver is using (high or low)

(4) The point at which the driver dims his headlamps, if he does so within the test section.

To record the data, you will be provided with a control panel which will be connected by electrical cable to a recorder in the control vehicle. A diagram of the control panel, Figure C. 1, is shown next. Please look at it before you continue reading.

Referring to Figure C. 1, across the top of the panel is a row of eight small, circular indicator lights, each of which is marked with a letter or number. Below each of the three pairs of lights to the left is a toggle switch, and below each of the two lights to the right is a push button. There is also a push button at the lower left marked "record data," as well as an intercom speaker/microphone at the lower right.

To illustrate the operation of the controls, consider an example:

> A 1966 Chevrolet sedan comes through the test section toward you. There is no other car in sight in either direction, and the Chevy has two headlamps burning.

The action you take is:

(1) Flip the left toggle switch to the left, indicating passage of a car (rather than a truck)

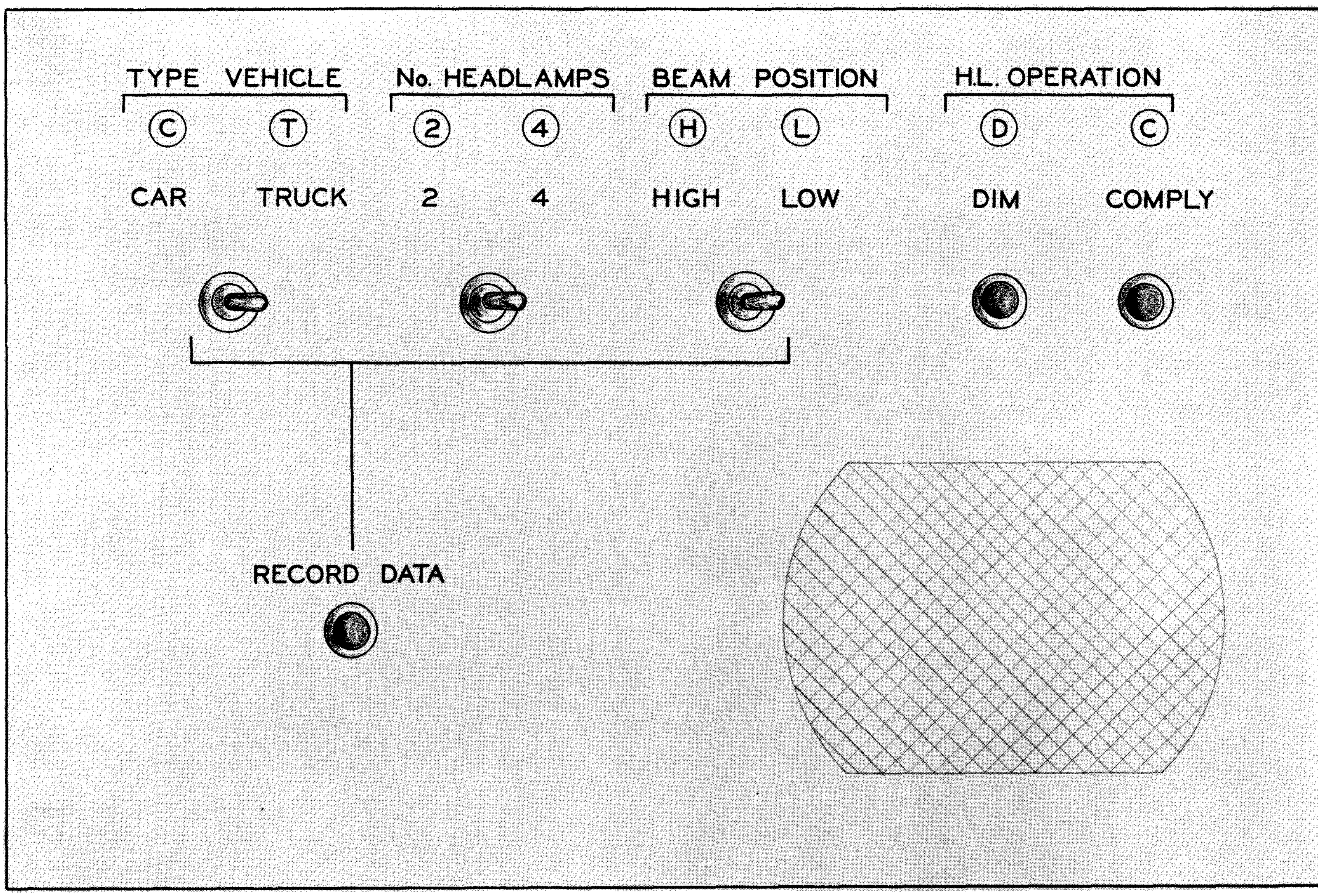


FIGURE C. 1. OBSERVER'S CONTROL PANEL

(2) Flip the middle toggle switch to the right, indicating that the vehicle is equipped with four headlamps

(3) Flip the right toggle switch to the right, indicating that the driver is using low beam (which he is, since only two headlamps are burning)

(4) As the vehicle passes your position, push the button marked "record data" and hold it down for 2 sec.

Here are some variations on the above example and the actions you are to take in each situation.

(1) If the vehicle had been anything other than a passenger car (a truck, pickup, or bus), you would have pushed the left toggle switch to the right.

(2) If the vehicle had been equipped with only two headlamps, you would have pushed the middle toggle switch to the left.

(3) If the driver had been using high beam, you would have pushed the right toggle switch to the left.

(4) If only one headlight is on, notify the crew chief by intercom, but indicate the proper beam position if it can be determined.

For the purposes of this study, all 2-wheel vehicles (bicycles, motorcycles, etc.) will be ignored.

Quite often, when a vehicle equipped with two headlamps comes toward you, it will be very difficult to tell whether the driver is using high beam or low beam. To help you in making your judgement in this case, there will be a sign beside the road in view of the drivers reading "please dim lights" (see Figure 1, points marked Ⓐ). If, while you are observing the vehicle, the driver responds to the sign by changing to low beam, you will know he was using high beam when he entered the test section and you will immediately push the button on the right of the control panel marked "comply," flip the "beam position" toggle switch to the left, and proceed as before. The "comply" button is to be pushed in all cases when the driver changes to low beam in response to the sign (that is, all cases in which there is no vehicle coming toward the one you are watching, and in those cases only). The "comply" button is pushed in the cases described above no matter what the type of vehicle or number of headlamps.

Now suppose the vehicle you are watching is meeting another car; that is, an oncoming car is within the driver's view. In this case, you will <u>not</u> use the "comply" button; you will instead push the "dim" button if the driver switches to low beam while he is in the test section. The "beam position" (right) toggle switch should be set to correspond to the headlamp beam the driver was using as he entered the test section, regardless of any changes he makes within the test section.

If, under any condition of traffic, a driver switches to high beam in the test section, you will immediately push the "dim" button. The data will show his action correctly because the "beam position" switch will indicate that he was using low beam when he entered the test section.

These few examples by no means cover all the possibilities, but they should serve to familiarize you with the operation of the control panel. The crew chief will go over this material with you on the first night of your employment, answer your questions, and explain the action you are to take, in certain situations not covered herein. The intercom shown in Figure C.1 will also help by allowing you to communicate with the crew chief and the other observer while operation is underway.

Your understanding of your function is very important to your performance in this program, and your performance is perhaps the most important factor controlling the validity of the data you will help collect, so please be sure that you understand fully what you have read. If any portion of the material is unclear or if you have any questions, please write them down right now in the space provided on the following pages, and bring this document with you when you report for your first night of employment.

Thank you for your cooperation, and I'll be looking forward to working with you.

Charles T. Hare
Project Crew Chief