NO-PASSING ZONE TREATMENTS
FOR
SPECIAL GEOMETRIC AND TRAFFIC OPERATIONAL SITUATIONS

FINAL REPORT -- TASK D
(Pilot Field Tests of Experimental No-Passing Zone Treatments)

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1. INTRODUCTION

BACKGROUND

This report represents the final report of one phase of the research project entitled, "No-Passing Zone Treatments for Special Geometric and Traffic Operational Situations." (Contract DOT-FH-11-9454). The report documents research conducted to pilot field test three experimental no-passing zone advance warning treatments that were developed in a previous study, "Passing and No-Passing Zones: Signs, Markings, and Warrants" (Report No. FHWA-RD-79-5) (1).

Contract DOT-FH-11-9164 included development of criteria, warrants, signs, and markings for passing, no-passing, and restrictive passing zones -- based on past research, state practices, accident study, human factors research, and analytical study of the factors and elements involved in the passing maneuver. The results and conclusions were reviewed by representatives of the Federal Highway Administration (FHWA), the National Advisory Committee (NAC), the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO), and the American Association of State Highway and Transportation Officials (AASHTO). Background information concerning the research and proposed treatments under Contract DOT-FH-11-9164 is presented in section 2 of this report.

The proposed experimental treatment (dotted marking and sign) indicated a high demonstrated level of driver understanding, favorable benefit cost ratio estimates for nationwide implementation, and in general, the concept was well reviewed by reviewers. Based on the conclusions of the study, it was decided that the concept warranted field evaluation.

The three experimental treatments included, (1) the NO-PASSING ZONE pennant sign (W14-3); (2) a short dotted line pattern extending upstream from the no-passing zone barrier stripe and adjacent to the dashed centerline marking; and (3) combination of the pennant and the advance dotted treatment. The experimental devices were installed at three locations on two-lane highways in each of three States: North Carolina, Texas, and Utah. Passing performance was measured for more than 2600 passing maneuvers executed in the nine study sites with conventional no-passing zone demarcation and with the experimental treatments.

The report contains background information regarding development of the experimental treatments, a description of the field study sites, data measurement techniques, data reduction process, and evaluation of passing performance for each of the experimental treatments. The report also presents an evaluation of driver understanding and opinions of the experimental treatments that is based on a separate Texas Transportation Institute study, the results of which were made available to this research project.

OBJECTIVE

The objective of the research reported herein was to develop plans for pilot field testing the experimental treatments and conduct pilot field tests and evaluations at a limited number of field sites. The pilot field tests were intended to provide results and conclusions that indicate the effectiveness of the proposed treatments and identify the treatments that warrant further evaluation by the States at additional locations where the feasibility of the treatment was not totally conclusive.

SCOPE

Contractual requirements specified that

three study sites be selected in each of three States (a total of nine sites), each sight containing at least 20 no-passing zones. One of the treatments was installed in each site in each State. The States selected were geographically distributed to reflect flat, rolling, and mountainous terrain. Three sites were located in North Carolina, three in Texas, and three in Utah. The individual sites are described in Section 3 of this report.

Operational data were measured on 2637 passing maneuvers -- 1543 maneuvers through the study sites with conventional no-passing zone demarcation (solid yellow stripe only), and 1094 maneuvers through study sites with the experimental treatment installed. Data were collected for daytime passing maneuvers at all nine sites. Nighttime data were collected at two Texas sites also.

Data measured during each maneuver included speed and time of passing and passed vehicle at several positions throughout the maneuver, position of an opposing vehicle, vehicle characteristic data (type, size, license plate, trailer, etc.) and positional information of all vehicles with respect to the no-passing zone location.

2. RESEARCH BACKGROUND

PROBLEM DESCRIPTION

No-passing zones conventionally have been established on the basis of sight distance along the highway to permit a driver to pass another vehicle in the face of an opposing vehicle. The demarcation system to designate length of roadway through which passing is prohibited has been a solid yellow line. To prohibit passing in one direction only, the yellow line is placed to the right of the highway centerline marking. A solid yellow double centerline line pattern is used to prohibit passing in both directions. (2)

The ultimate goal of any traffic control device is to provide a system that (1) drivers readily understand, (2) drivers accept and believe to be necessary to their safe vehicle operation, (3) is uniformly applied, and (4) provides the necessary information to elicit the intended driver response in sufficient time. This is particularly important in designating no passing zones because the potential for a severely hazardous collision is increased during the passing maneuver. Several factors contribute to the hazard -- the high speeds involved, the complexity of the driving task, and the basic fact that the passing vehicle is traveling in a lane normally reserved for vehicles traveling in the opposing direction. Even if a headon collision is avoided, the driver who is forced to abort a pass is afforded limited maneuvering space.

The use of the solid yellow line to denote no-passing zones satisfies the first two of the above traffic control device criteria quite well (3). It measures up fairly well to the third criterion at least with respect to the marking of zones on the roadway (solid yellow line is used by all States) but the "design" and "marking" concepts differ appreciably (4). It substantially fails to meet the fourth--and one of the most important--requirements (1), primarily because it cannot be seen at sufficient distance under certain geometric and environmental conditions.

Driver Understanding

A high level of understanding of the precise intent is a primary requisite of the effectiveness of a traffic control device. Without understanding, the driver is confused; in fact is "second guessing" in many cases. Thus, a high rate of compliance cannot be expected. Drivers "learn" the meaning of signs, pavement markings, and other traffic control devices through initial driver education in obtaining a driver's license, through continued exposure with driving experience and deduction, or sometimes through citation for traffic legal violation. Traffic engineers, have often erroneously assumed that drivers, in general, clearly understand the intended meaning of the majority of control devices present on the highway. Gordon (3) found this to be far from true; however, his study indicated that the solid yellow pavement marking on the right side of the pavement centerline marking was the most correctly understood pavement marking used. This finding alone suggests strongly that the solid yellow line should constitute the "core" of any demarcation system to designate no-passing zones. It offers one further desirable characteristic -- the length of the longitudinal marking distinctly delineates the length of roadway through which passing is prohibited. Drivers understand this and, when the solid yellow line is visible, can immediately decide where passing maneuvers should not be initiated. Conversely, when the pavement marking is dashed, the majority of drivers perceive that a passing maneuver may be

legally and safely initiated in the absence of an opposing vehicle.

Driver Acceptance

Drivers, in general, accept the constraints that are imposed by traffic control devices -- if the devices are installed rationally and appear to satisfy a need, either a need for safety or a need for right-of-way assignment. In many cases, drivers not only accept the constraints, they advocate the installation and expect to be warned of potential hazard. A study by Weaver and Woods (1) revealed that most drivers consider the designation of no-passing zones to be absolutely necessary to their safety. They believed that it should be continued, and in fact expressed the complaint that many "passing" zones were too short. They would prefer that these short "passing" zones between successive no-passing zones be closed up because the markings were creating a sense of false security. Drivers initiating a pass in the short sections were unable to complete the maneuver before reaching the beginning of the solid yellow line downstream. The study also indicated that a high majority of drivers believe that they should return to the right lane at or before reaching the solid yellow line. The primary complaint was that the beginning point of the solid yellow line was not visible at a distance upstream sufficient to complete the passing maneuver without encroaching into the no-passing zone ("clipping").

Uniformity of Application

The Weaver and Woods study (1) revealed several aspects of non-uniformity regarding establishment of no-passing zones and also in use of differing traffic control devices to designate the zones.

The solid yellow barrier stripe represents the primary technique to designate no-passing zones in all States. The sight distance criteria on which the barrier stripe is started and/or ended vary among States. All States employ the "short zone" marking concept; however, five States enforce passing operations on the "long zone" concept. Under the short zone concept advocated by the MUTCD, the no-passing zone barrier stripe is begun when downstream sight distance is less than minimum values specified in Section 3B-5. The upstream end of the stripe designates the location where the passing vehicle will be back in the right lane. The long zone concept is based on longer minimum sight distance values; hence the barrier stripe starts further upstream than under the short zone criteria for a given set of visibility constraints. Under the long zone philosophy a passing driver may complete a pass beyond the start of the solid line because a "buffer zone" is provided at the upstream end. No States were found to use the longer sight distance criteria that provide the long zone safety margin; hence, allowing the passing driver to operate the zones on the lone zone philosophy when the zones were in reality marked on the short zone criteria, represents a potentially hazardous situaton.

Other non-uniform State practices identified in the Weaver and Woods study are summarized below:

1. Four States specify minimum spacing between successive no-passing zones that are longer than the 400-foot (122 m) MUTCD specified minimum.
2. Two States permit minimum "passing" zones less than 400 feet (122 m) in mountainous areas.
3. Two States do not specify minimum passing zone length.
4. Only five States use the regulatory DO NOT PASS sign (Sign R4-1) as a general statewide practice, one of which uses it only because the pavement marking is not a regulatory device. At least 17 States

use the sign selectively for unique geometry, visibility during snow, and maintenance purposes.

5. One State uses the PASS WITH CAUTION sign in lieu of pavement markings in certain mountainous areas.
6. At least 34 States use the NO-PASSING ZONE pennant sign (Sign W14-3) with many States adopting its use within the past two years. Sixteen States use it statewide, 18 States use it selectively.

Satisfaction of Driving Task Needs

The current criteria for establishing the limits of passing and no-passing zones and the demarcation of the no-passing zones by merely the solid yellow line do not satisfy the passing driver's operational and informational needs in three respects: (1)

1. The "minimum passing sight distance" on which the no-passing zone is predicated is not measured from the point within the passing maneuver where the decision to abort or complete the maneuver is made.
2. The solid yellow line in many geometric situations is not visible back at the point where the maneuver decision is made; hence the passing driver is being advised of an approaching no-passing zone "after the fact."
3. The 400-foot (122 m) minimum distance between successive no-passing zones is inadequate to physically pass almost 98 percent of the vehicles traveling at only 20 mph (64 km/h). A minimum distance of 750 feet (229 m) was found to be necessary to allow about 85 percent of the vehicles to pass another vehicle traveling at only 20 mph (64 km/h).

The inadequacy of the solid yellow line as the sole traffic control device to designate no-passing zones has been borne out from several sources. The Weaver and Woods study reached this conclusion repeatedly:

1. Human factors studies and driver survey techniques revealed that low target visibility was the primary reason for "clipping."
2. Enforcement personnel assembled in a workshop agreed unanimously that voluntary compliance of no-passing zones would be enhanced when a driver approaching the start of the zone had a clear indication that the zone was ahead. They agreed that providing adequate advance visibility of the start of the zone was the most important improvement that could be made in current signing and marking system used for no-passing zones. Further, the information was necessary back at the position where the driver was making the decision to pass or abort under the existing conditions.
3. Actual measurements of visibility distance to the beginning of a painted yellow line on horizontal terrain revealed that the line could be seen from only about 400 feet (122 m) in daylight and from only about 250 feet (76 m) at night using low-beam headlights. These visibility distances are approximately 150 feet (46 m) less than needed for a 50-mph (80 km/h) pass in daytime and about 300 feet (91 m) short for a nighttime 50 mph (80 km/h) pass when compared to AASHTO passing maneuver operational data (4). The disparity is even worse when compared to measured operational passing distances in a study by Weaver and Glennon (5).

Minimum Passing Sight Distance Terminology

Another problem that confuses the no-passing zone subject pertains to the different definitions of the same term, "minimum passing sight distance," used by design engineers and by operations engineers when marking no-passing zones on highways in accordance with the Manual on Uniform Traffic Control Devices (2). A third definition of

"minimum passing sight distance" was developed by Weaver and Woods (1). Their definition integrated the sight distance components necessary to allow a passing driver to safely complete the maneuver from the point where the decision is made to abort or complete the pass.

MAGNITUDE OF THE PASSING-RELATED ACCIDENT PROBLEM

Passing-related accidents generally are one of the most severe type that occur because of the high speeds involved and the potential for head-on collision. Thus, public and highway officials are keenly aware of the passing safety problem.

Passing-related accidents, on a nationwide basis, comprise about 3 to 4 percent of the total annual number of highway fatalities (1). This might, by some individuals, be considered to represent a negligible problem; however, it represents a sizeable dollar amount in terms of personal injury. Based on 50,000 annual highway fatalities, this percentage represents about 1500 to 2000 fatalities per year. At current accident costs (9), passing-related accidents constitute an estimated 450 to 600 million dollar economic loss each year.

No traffic control device can be expected to eliminate all passing-related accidents. However, a 25 to 30 percent reduction was observed using only the NO-PASSING ZONE pennant sign (10). Accident reductions of this magnitude would reduce the annual number of passing-related fatalities by about 375 to 500 with an associated annual cost savings of 113 to 150 million dollars. This lower cost savings, assuming a 75-dollar pennant sign cost produces a benefit-cost ratio of 1.8 for fatalities alone. A treatment per zone costing as much as 135 dollars would still be cost beneficial on this basis. The 150 million dollar cost savings would justify a 390 dollar treatment cost per site. This simplistic analysis suggests that detailed study of alternate treatments of no-passing zones is warranted, particularly if a system could be developed that would be expected to reduce the accident rate by more than the 25 percent reduction demonstrated by the pennant sign alone.

The accident files from California and Texas for the years 1975 to 1977 were examined to identify passing-related accidents and determine if possible geometric or operational causative factors. It was found that an unusually high percentage (about 40 percent) of all passing-related accidents were intersection-related. The California data file indicated a 15 percent reduction in passing-related accidents between 1975 and 1977--the years before and after the national speed limit change to 55 mph (89 km/h). The reduction in Texas was 35 percent. While these reductions cannot be fully attributed to the speed limit change, they do parallel the general accident trend observed nationally for these years, and must be considered to be a significant factor.

The accident data files reveal only those accidents that were coded, "passing-related", these data do not identify the total magnitude of the passing accident problem. It may be conservatively assumed that these data represent the least probably estimate of the number of passing-related accidents.

EXPERIMENTAL TRAFFIC CONTROL DEVICES FOR NO-PASSING ZONES

The objective of the Weaver and Woods research study (1) was to develop improved criteria and guidelines for establishing passing and no-passing zones, regulatory traffic control devices and traffic regulations, and environment and legal requirements that could be uniformly applied

throughout the Nation for the safety and benefit of all drivers.

The Weaver and Woods study developed a concept for establishing no-passing zones based on "minimum passing sight distance" required to safely complete a pass -- the sight distance being measured from the point in the maneuver where the decision is made to abort or continue with the passing operation. In addition, alternative traffic control devices were evaluated on the basis of driver understanding, practicality of application, legality, and cost effctiveness to provide the informational needs to the passing driver -- back at the decision point -- that a no-passing zone was being approached. The suggested sight distances for various passing speeds were developed from measured passing operational distances (4,5,6,7).

Critical Position (P_c)

The decision to complete or abort the pass is made at the point in time and space where the passing vehicle in the left lane is adjacent to the vehicle in the right lane being passed. Weaver and Woods referred to this point as the "critical position." From measured vehicle performance (5,6,7), this relative position of vehicles occurs at approximately the one-third point of the left lane travel distance. Since it is at this position that the passing driver must decide to complete the maneuver or abort and return to a position behind the vehicle that was to be passed, it, therefore, defines the location at which information must be provided regarding the availability of safe passing distance remaining. An opposing vehicle that would conflict with the completion maneuver must be able to be perceived at this location. Minimum passing sight distance, thus, should be measured from this point, although the marked no-passing zone does not begin until a point downstream where the passing driver must return to the right lane.

Figure 1 illustrates the concept and defines terminology suggested in the Weaver and Woods study. Minimum passing sight distance (distance A-B, Figure 1) to an opposing vehicle that would conflict with safe pass completion is measured from the critical point at point A. The no-passing zone begins at point C, the point where the passing driver must legally return to the right lane under short zone marking and enforcement philosophy. The distance A-C, although part of the minimum passing sight distance, is not a no-passing zone; rather, it is a pass completion distance. It is a distance in which a vehicle can physically complete a pass from the critical position before reaching the start of the solid yellow no-passing barrier stripe. In effect, it is an advance warning distance to advise the passing driver that the "passing zone" will soon terminate and that a no-passing zone will start.

The concept developed by Weaver and Woods integrates the desirable attributes of the long and short zone concepts without the primary negative factors of each. It provides the "buffer zone" of the long zone concept (pass completion advance warning distance), but this distance is marked as a legal passing distance, not a no-passing distance as it would be under the long zone marking concept. The beginning point of the solid yellow barrier stripe is not moved upstream appreciably; therefore, the concept does not materially increase the length of roadway that is marked for no-passing under current MUTCD warrants. Further, it developed a system of terminology and distance elements based on operational practice to define "minimum passing sight distance" on the basis of passing safety to satisfy driver informational needs.

Suggested Experimental Traffic Control Devices

The concept appeared rational from the

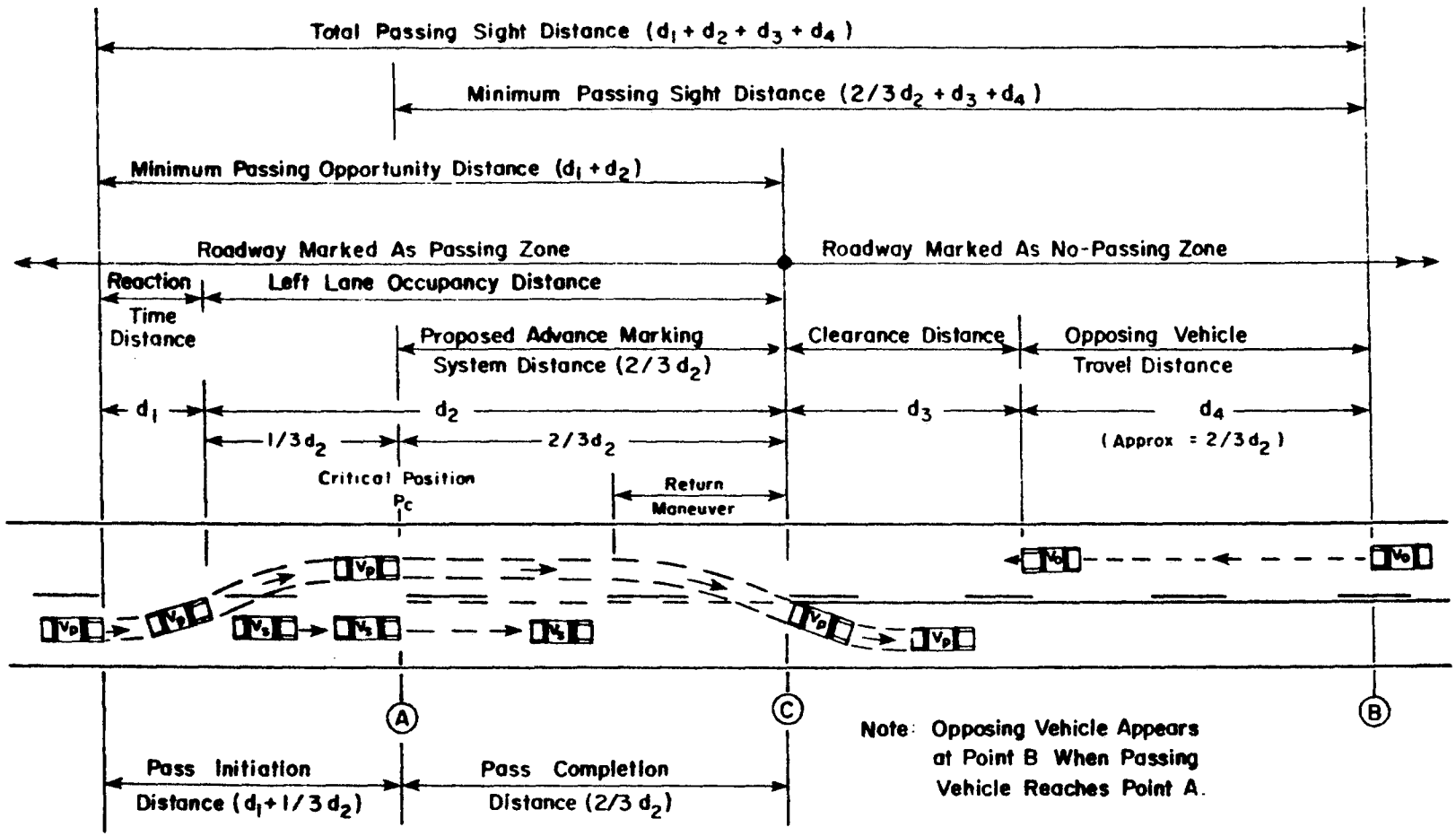

Figure 1. Suggested Distance Elements and Terminology to Define Passing and No-Passing Zone on Two-Lane Highways (Contract DOT-FH-11-9164) (1)

standpoint of operational safety needs the practicality of it, however, depends on the capability of a system of traffic control devices to inform the passing driver -- at a position upstream from the start of the no-passing zone equal to the required pass completion distance (i.e. at point A, Figure 1) -- that a no-passing zone is being approached. The traffic control system would need to convey three meanings:

1. A no-passing zone is located downstream.
2. A driver should not begin a passing maneuver beyond a designated point upstream from the beginning of the no-passing barrier strip, and
3. If a driver is in the act of passing when the designated point is reached, the maneuver may be safely completed and the driver should return to the right lane as expeditiously as possible to avoid encroaching into the prohibitive no-passing zone.

To accomplish this, in effect the system of traffic control devices used must translate the location of the beginning of the solid yellow line informational source back upstream a distance that is at least equal to the needed pass completion distance. A series of human factors studies produced three candidate traffic control techniques to satisfy the informational needs. The candidate system included the following:

1. A short dotted yellow line pattern adjacent to the centerline extending upstream from the solid yellow barrier stripe for a distance equal to the pass completion distance
2. A NO-PASSING ZONE pennant sign (W14-3) located in accordance with the MUTCD on the left side of the roadway at the beginning of the solid yellow no-passing barrier stripe, and
3. A combination of the advance dotted marking system and the NO-PASSING ZONE pennant sign.

SUMMARY OF FINDINGS FROM HUMAN FACTORS STUDIES

The concept of providing advance information through the use of the dotted line treatment, the NO-PASSING ZONE pennant sign, and the combination of the two treatments was developed and evaluated through extensive human factors laboratory testing in the research study (1). About 400 subjects participated in the studies to evaluate the experimental treatments in conveying the three intended meanings.

The basic system evaluated in the human factors studies was the dotted line treatment. Other study situations provided additional information to assist the deduction process through the addition of signs to the basic dotted marking system. The NO-PASSING ZONE pennant sign was one of the signs evaluated. All other conditions were compared to the basic dotted treatment to identify improvement in correct interpretation.

The pertinent findings of the human factors studies are summarized here to form a basis of comparison for the understanding levels demonstrated by surveyed drivers who observed the treatments actually placed on the roadway.

Understanding of Total Meaning

A major finding was that about two-thirds of the subjects correctly interpreted the advance dotted marking system alone to convey all three intended meanings. Eighty percent correctly interpreted that the advance dotted marking conveyed that a driver in the act of passing could legally continue passing beyond the beginning of the dotted markings, but should return before reaching the no-passing solid stripe. Only 7 percent believed that the advance dotted markings represented an upstrean extension of the conventional no-passing zone and that the passing driver must return before reaching the dotted markings.

"No-Passing Zone Ahead." The advance dotted markings alone (with no supplementary information or driver education) indicated to 68 percent of the subjects that this system meant that they were approaching a no-passing zone. It was strongly believed that the subjects correctly deduced its intent because it was a longitudinal marking placed to the right of the roadway centerline, a system well understood by drivers as indicating no-passing. The dotted pattern, evidently different than the conventional broken centerline immediately adjacent, apparently conveyed "transition" to the drivers.

With the addition of the NO-PASSING ZONE pennant sign, the percentage of subjects correctly interpreting that the system signified a no-passing zone ahead increased from 68 percent to 90 percent.

In summary, the advance dotted marking system alone produced a very acceptable level of understanding (68 percent), particularly considering that it was completely innovative and naive drivers interpreted its total intent without assistance from supplementary signing. Addition of the pennant sign was considered necessary, however, to produce a criteria performance level of 85 percent or more. Addition of the sign reduced the interpretation "means nothing" from 17 percent to only 2 or 3 percent. Although "means nothing" was an appropriate answer since no subjects had ever experienced this innovative marking system, it was believed that it would exhibit one-time learning (as was expected with the pennant sign) because drivers could soon associate the repetition of dotted markings transitioning into each already well understood solid yellow barrier stripe with "No-Passing Zone Ahead."

"Do Not Begin Passing." The second intent of the advance treatment was correctly interpreted by 61 percent of the subjects when shown only the dotted marking situation. The pennant produced a 65-percent understanding level of this meaning. Although these percentage levels represented a relatively good level of response, neither device conveyed the meaning at a desired 85-percent level.

"Continue Passing, But Return Before Barrier Stripe." The subjects generally understood that the dotted lines meant something different than the solid yellow line. The solid line, not the dotted line, represented the place where they should return to the right lane. Eighty percent believed that, if they were passing a vehicle, they could drive to the left of the more permissive dotted lines provided they could complete the pass before reaching the solid line. The addition of signs did not increase the percentage of correct responses.

Patterns of Interpretations. The percentage of subjects who selected all three (and only those three) correct interpretations was about equal for the marking-only treatment (40 percent) and the combination treatment (44 percent). A common pattern of interpretations included "no-passing zone ahead" and "continue passing, but return before solid line", but omitted "do not begin passing." (51 percent for marking-only, 66 percent for combination). The third most prevalent pattern of interpretations included selection of the three correct responses and the response, "must return before reaching the dotted line."

PILOT FIELD STUDIES

It was concluded that the proposed advance treatment system (sign and dotted markings) had a high probability of being cost-effective if used nationwide and that it would satisfy the driver informational needs for safe passing operations. The findings certainly indicated that such a system would be beneficial in areas of high passing-accident frequency and that a

thorough field trial of the concept was justified to evaluate the benefits directly.

In this regard, a subsequent contract was awarded by the Federal Highway Administration to pilot field test the proposed experimental advance treatment (dotted markings and pennant sign) in three States. The scope of the research was subsequently expanded to include pilot field testing of the advance dotted marking system alone and the NO-PASSING ZONE pennant sign alone.

The results of the pilot field testing of these three experimental traffic control systems are documented in this report.

3. RESEARCH APPROACH

GENERAL METHODOLOGY

The research methodology, in general, consisted of measurement and recording of traffic passing operational characteristics within the study site in the base marking condition ("before" treatment) and in the experimental condition ("after" treatment). Maneuver data were collected using a "floating vehicle" approach in which an instrumented vehicle traveled throughout the study site at about five miles per hour less than the normal running speed of the traffic stream. Speed, time, and positional data were recorded for all vehicles passing the research vehicle or for all vehicles directly ahead of the research vehicle that passed the vehicle ahead of them. In addition to measurement of operating characteristics, a separate in house study in driver understanding and opinion of the experimental treatments was conducted by a staff member of the Texas Transportation Institute as a special problem for a graduate Civil Engineering course. The results of this separate study were made available to this research effort to evaluate driver understanding and acceptance of the experimental devices. Only drivers who were observed passing in the study sites were surveyed. Passing accident data for the three-year period prior to installation of the treatments and for three years following the installation will be compiled to evaluate this very important consideration. The experimental treatments will be maintained for three years by the respective States and information on accidents occurring within the study sites will be transmitted to the contractor throughout the contract period. Since the research contract will terminate before the three-year period following treatment installation, the accident evaluation will be accomplished after the contract is completed, thus the accident investigation cannot be reported herein.

MEASURES OF EFFECTIVENESS

The intent of the experimental treatments is to improve safe passing operations by providing better driver advance information regarding the availability of passing distance ahead. Drivers assess passing distance in a reverse fashion. They look first for information that a no-passing zone is being approached. If no such information is received and there are no opposing vehicles, they convert this to the positive sense -- passing can be attempted. In this manner, making the no-passing zone more highly visible at a greater distance should ease the passing maneuver task; hence passing operations should be smoother and safer. The evaluation of the effectiveness of the treatment included determination of the following operational measures:

1. Is there a reduction in "clipping" occurrence?
2. Is there a reduction in "clipping" distance?
3. Is there a reduction in aborted passes?
4. Is there a reduction in pass initiation within the 1000-ft (305m) distance immediately prior to the no-passing zone?
5. Is there a reduction in total passing distance for vehicles initiating a pass within the downstream 1000-ft (305m) of a "passing" zone?
6. Is there a reduction in the number of passing zones traveled through prior to initiating a pass (with no opposing traffic)?
7. Do drivers demonstrate a high level of understanding of the intent of the experimental treatment?

The hypothesis for each of the above is that the experimental treatment will produce an affirmative answer to each question and that the differences are statistically significant. Each measure is considered to represent a desirable improvement in the exe-

cution of a passing maneuver, for safety or ease of operations. The 1000-ft (305m) distance prior to the start of the no-passing zone is considered to be the distance at which advance notification is necessary and effective, because, based on measured passing distances (5), passes within this region would be expected to result in completion beyond the start of the no-passing zone.

STUDY SITE SELECTION

Several Study site selection criteria were considered. They are summarized below.

1. The sites must be located in three States geographically distributed and containing flat, rolling, and mountainous terrain. This contractual requirement necessitated identifying three States that would agree to participate in the field studies.
2. Approval for installation of the experimental traffic control devices was obtained from the National Advisory Committee.
3. Each study site would contain at least 20 no-passing zones.
4. Study sites would be located on two-lane rural highways that had good quality surfaces, lane widths of 12 ft (3.7m), no paved shoulders, and a mixture of horizontal and vertical alignment constraints for which no-passing zones were marked.
5. Each site must be one for which accident data, traffic volume data, and geometric data could be obtained from State records.
6. Only sites which would undergo no alignment or cross-sectional changes for three years would be selected.

STUDY SITE LOCATIONS

Study sites were selected in North Carolina, Texas and Utah -- flat, rolling, and mountainous respectively. The general locations are illustrated in Figure 2. Table 1 presents site characteristic data. Sites are numbered with a 1, 2, or 3 designation in each State and include a State identification code (example, T-1 identifies Texas site number one). The sites with a "1" contained the combination experimental treatment (advance dotted marking and no-passing zone pennant sign). The no-passing pennant sign alone was installed at sites with a "2" designation; those with a "3" designation contained the advance dotted marking system only.

Study site lengths ranged from 10 to 34 miles (32 to 55 km). The number of no-passing zones within a study site varied from a minimum of 24 to a maximum of 48.

SITE PREPARATION

Several possible study sites that satisfied the selection criteria were identified in each State through the assistance of State personnel in each of the three States. The research team inspected all potential sites and measured the beginning and ending points of all no-passing zones in both travel directions within the potential site. Distances were recorded with an electronic distance measuring instrument (DMI) installed in a vehicle. The instrument, calibrated for a particular vehicle, measures distance to within an accuracy of about 5 ft (1.5 m) per mile.

The conventional markings, centerline and no-passing barrier stripes, were repainted on three of the nine selected sites where the markings were not in excellent condition. These sites were resurveyed to determine the position of all no-passing zones in both travel directions after remarking.

Each zone within a site was numbered on a plan sheet for reference during data collection. A "zone" includes the distance

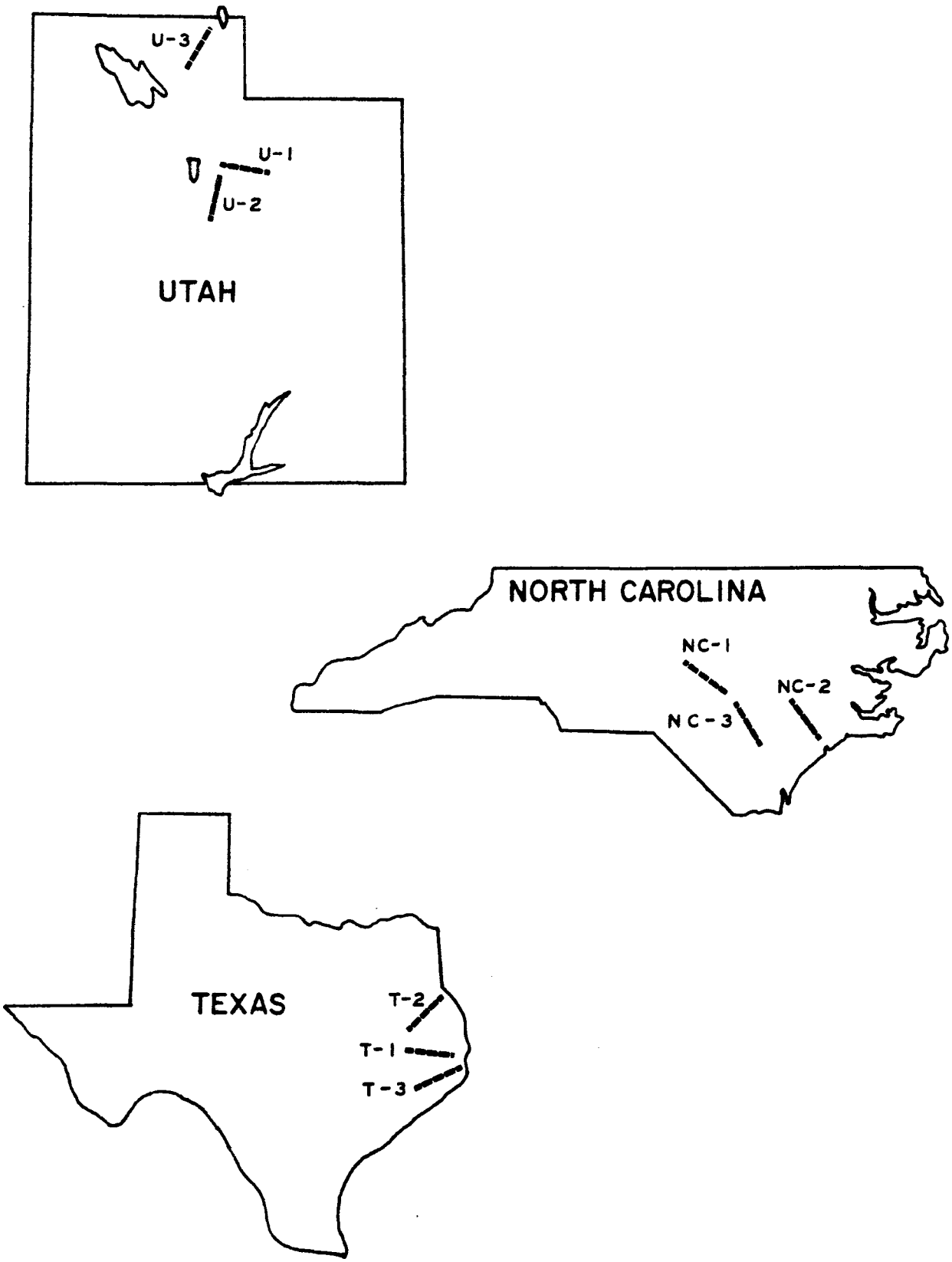

Figure 2. Field Study Site Locations

Table 1. Study Site Characteristics

Site	State	Highway Number	Site Endpoints	Nearest Large City	Number of Zones: In Travel Direction		Number of Zones: Total	Site Length (Miles): In Each Direction		Site Length (Miles): Total
NC-1	North Carolina	US 421	Spivey's Corner - Clinton	Fayetteville	S-18	N-18	36	S-14.42	N-15.08	29.5
NC-2	North Carolina	US 258 & SH 24	Jacksonville - Richlands	Fayetteville	S-12	N-12	24	S-10.40	N-10.56	20.9
NC-3	North Carolina	US 421	Clinton - Harrels	Fayetteville	S-16	N-18	34	S-16.89	N-17.42	34.3
T-1	Texas	SH 103	Jct. SH 147 - Jct. FM 1	Lufkin	E-17	W-19	36	E- 9.06	W-11.16	20.22
T-2	Texas	SH 7	Center - Joaquin	Lufkin	N-23	S-23	46	N-13.01	S-12.80	25.81
T-3	Texas	FM 83	Pineland - Memphill	Lufkin	E-16	W-16	32	E- 9.63	W- 9.49	19.12
U-1	Utah	SH 6	Thistle - Tucker	Provo	E-21	W-20	41	E-15.47	W-14.82	30.29
U-2	Utah	US 89 So.	Thistle - Indianola	Provo	N-23	S-22	45	N-14.26	S-12.63	26.89
U-3	Utah	US 89 No.	Logan - Garden City	Logan	W-24	E-24	48	W-16.08	E-16.95	33.03

from the downstream end of a no-passing zone to the downstream end of the next no-passing zone in the same travel direction. Therefore, a zone includes the "passing" zone and the no-passing zone following it. (See Figure 3)

Prior to data collection, a 2-ft (0.6 m) strip of reflectorized temporary pavement marking tape was placed laterally across the roadway centerline 1000-ft (305 m) upstream from the beginning of each no-passing zone. The distance was measured with a distance measuring wheel. A placard displaying the zone number in 6-inch numerals was placed in the grass about ten feet from the pavement edge adjacent to the tape marker. The tape marker and the zone number were very inconspicuous to drivers traveling through the site, but could be seen by the data collection team. The distance measuring device was rezeroed at each marker so that distance error was not accumulated. Each passing maneuver could be referenced to a particular no-passing zone using this referencing technique.

In addition to placing the tape marker at 1000 ft (305m), a small painted mark was placed on the centerline to denote the upstream end of the advance dotted marking system. This distance was 752 ft (229m) at the Texas sites and 552 ft (168m) at the sites in North Carolina and Utah. The no-passing zones in Texas are marked for 70-mph (113 km/h) operations whereas they are marked for 55 mph (86 km/h) in Utah and North Carolina; hence the shorter advance marking distance. The painted mark was placed as a guide for installing the experimental dotted marking.

PASSING MANEUVER MEASUREMENTS

Passing maneuver data were collected on every vehicle that passed the research vehicle within the study site, regardless of where the maneuver occurred with respect to the no-passing zone. The techniques used to measure passing operational data and reduce the data for analysis purposes are described in Appendix A. Passing maneuvers were classified in two categories: (1) "criterion" maneuvers and (2) "non-criterion" maneuvers. Non-criterion maneuvers were those in which a vehicle started the passing maneuver in a legal passing zone and returned to the right lane before reaching the 1000-ft (305m) marker. Criterion maneuvers included passes that met one or more of the following criteria:

1. Completed the pass beyond the 1000-ft (305m) marker, or
2. Completed the pass beyond the start of the solid yellow no-passing stripe ("clipped"), or
3. Initiated the passing maneuver beyond the 1000-ft (305m) marker.

These passing maneuvers were considered to represent the situations to which advance warning would offer informational benefit. A few passing maneuvers (38 of the 2637 total, or 1.4 percent) were observed (and measured) in which the passing vehicle traveled in the left lane completely through a no-passing zone and returned to the right lane in the following "passing" zone. These maneuvers were not included in the criterion data sample because it was considered that even advance notification would not influence this type of apparent disregard for traffic control devices.

A minimum of 50 criterion passes were measured at each study site for the "before" marking condition and for the experimental condition. The first five zones in each travel direction within a study site were considered to be training zones in which a driver was given an opportunity to recognize that the devices were in place. Only the passing maneuvers occurring in zones beyond the first five zones were included in the sample.

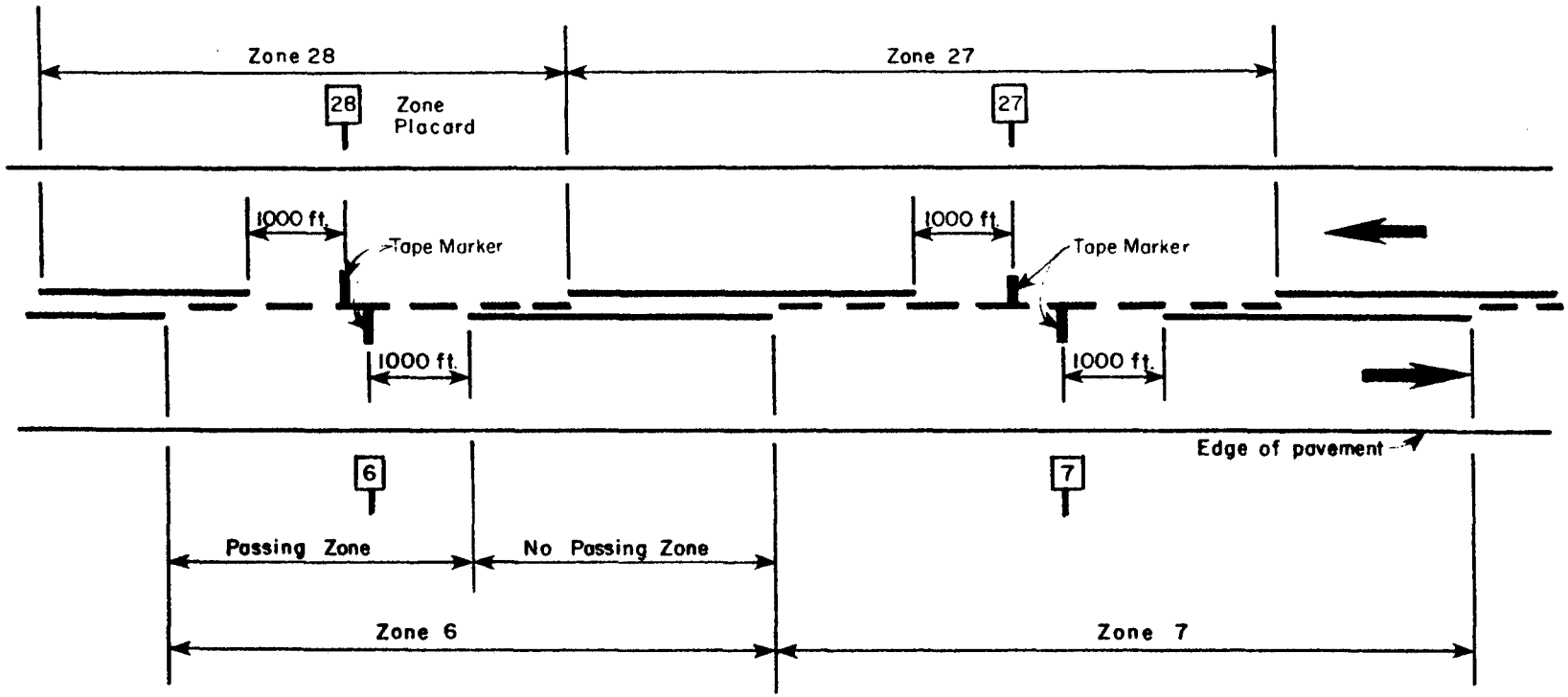

Figure 3. Typical Study Site Preparation Details and Zone Designation

The installation of the experimental treatments or the intent were not publicized in any way prior to data collection. The level of driver understanding measured in the laboratory studies during the conceptual development in the previous research study had been determined on the basis of no advance driver education regarding the intent. The objective of the pilot field studies was to obtain comparably non-biased data under real-world operating conditions. If driver understanding was high without education, it could be expected to be even higher after a public education campaign at a later date if desired.

Data Collection Team

All data were measured by a team of three researchers -- a driver, a "front recorder" and a "back recorder." To maintain consistency in collection methodology between the "before" and the "after" and among the three States, team members practiced the technique together prior to collection of any data. This assured that similar data were collected and times and vehicle positions were recorded in a consistent manner. For example, the same driver and front recorder were used at the same site for "before" and "after" data collection. Research vehicles of the same type were used at a given site in both study conditions. A senior research staff member supervised and participated in all site preparation and data collection.

Measured Data

A potential pass situation was established when a subject vehicle closed to within 200 ft (61m) behind the research vehicle or when the left front wheel of the trailing vehicle crossed the roadway centerline. All times measured throughout the passing maneuver were referenced to the time the trailing vehicle front left wheel crossed the centerline. All distance measurements were referenced to the position of the research vehicle (cumulative DMI reading) at that instant. Relative position of both vehicles at certain critical positions throughout the maneuver were recorded on the electronic distance measuring device in the research vehicle. All distance measurements and vehicle positions throughout the maneuver were then referenced to the no-passing zone marking through the reference markings placed on the roadway. The data that were measured or recorded during each passing maneuver are summarized below.

Distances. Four distances were measured during each passing maneuver. The situation in which the trailing vehicle passed the research vehicle is used in Figure 4 to illustrate the measurements.

The "trailing distance" is the distance from the rear of the research vehicle (Position 6, Figure 4) to the point where the passing vehicle's left front wheel crosses the centerline as it moves to the left lane to begin the pass (Position 2, Figure 4). This distance was estimated by the back recorder team member and was usually about 60 to 80 ft (18 to 24 m).

The "critical distance" is the distance traveled by the passing vehicle between positions 2 and 3, Figure 4. During this time, the research vehicle traveled from position 6 to position 7, Figure 4. The "critical position" occurred when the passing vehicle in the left lane was abreast of the research vehicle in the right lane, front bumpers being adjacent. At this point, a DMI reading was recorded; thus the distance traveled at constant speed by the research vehicle from position 6 to position 7 was determined.

The "total passing distance" is the left lane occupancy distance of the passing vehicle from position 2 to position 4, Figure 4. The position where the passing

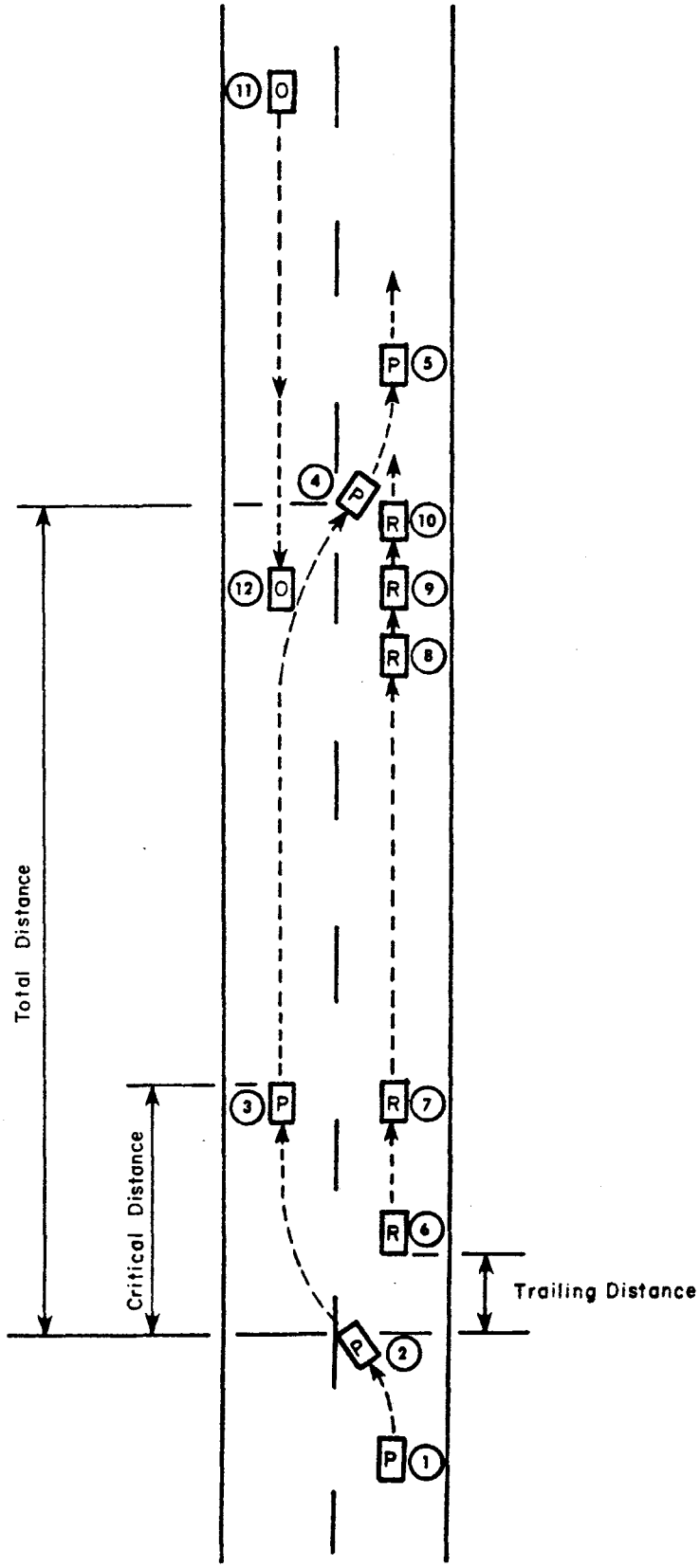

Figure 4. Schematic of Vehicle Positions During Passing Performance Measurements

vehicle's left rear tire crosses the roadway centerline on the return maneuver determines the end point of this distance. During the time that the passing vehicle travels from position 3 to position 4, the research vehicle travels at constant speed from position 7 to position 8. The front recorder team member "marked" the return position (usually a position on a roadway centerline stripe) and when the research vehicle had reached that point (position 10, Figure 4), a DMI reading was recorded. Thus, the roadway distance from position 6 to position 10 (also position 4 for the passing vehicle) was determined. The total passing distance (position 2 to position 4) was the sum of this distance and the trailing distance.

A "closeout distance" was measured to reference all vehicle positions to a known on-site reference position. The DMI generally was rezeroed at a 1000-ft (305m) tape marker prior to pass initiation; hence all recorded distances were referenced to this known position. In some maneuvers, the DMI was zeroed as the passing vehicle crossed the centerline (position 2, Figure 4); therefore, a closeout measurement was taken at another known downstream point, usually the next tape marker or the start of the solid yellow line. Zeroing the DMI at pass initiation was considered to be more accurate when the maneuver started near the downstream end of a long passing zone. Close out distance measurements were made in practically all maneuvers to assure that the maneuver could be referenced to the no-passing zone; the distance acting as a position calculation check with the beginning zero reading.

Times. Three times were measured throughout each maneuver using two split cumulative electronic stop-watches (0.01 second accuracy). All time measurements began when the passing vehicle reached position 2, Figure 4.

The "critical time" was the time interval in which the passing vehicle traveled from position 2 to the "critical position" (position 3, Figure 4).

The "total time" was the time interval during which the passing vehicle was occupying the left lane (position 2 to position 4, Figure 4).

The "opposing time" was used to estimate the distance to an opposing vehicle when the pass was initiated (passing vehicle at position 2, opposing vehicle at position 11, Figure 4). The cumulative stop-watch reading was recorded when the opposing vehicle and the research vehicle were abreast (positions 12 and 9 respectively, Figure 4). The distance traveled by the research vehicle at constant speed for a known time could be computed. Assuming that the opposing vehicle was traveling at the posted speed, the distance to the opposing vehicle from the point of pass initiation could be estimated. In addition, the opposing vehicle distance was estimated by the front recorder team member using known reference markings such as the beginning of the solid stripe ahead or the position of the vehicle within the highly visible advance dotted marking system if it was an "after" data collection process. These estimated distances were used as a check for estimating the opposing vehicle distance calculations.

Measured times and distances were used to compute average passing vehicle speeds throughout the various distance elements of the passing maneuvers.

Vehicle Data. Certain vehicle descriptive data were recorded to document each subject vehicle for future evaluation of operating performance by such factors as vehicle type (passenger car, pickup, bus, etc.), vehicle size (small car, medium car, semi-trailer truck, motorhome, etc.). Vehicle license plate data were recorded from

which engine size could be obtained from vehicle records if this was to be used in vehicle performance evaluation. Each subject passing vehicle was designated by a unique number regardless of whether it passed or not. A vehicle was considered to be a potential passing subject vehicle when it approached within 200 ft (61m) of a lead vehicle (either the research vehicle, or a vehicle ahead of it). Once a vehicle was considered to be a subject, it was monitored until it passed, turned off the study site roadway, or until it was definitely evident that the driver did not intend to pass (trailed through at least ten "passing" zones yet no opposing traffic was visible).

DRIVER UNDERSTANDING STUDIES

One of the primary requisites of a traffic control device is that drivers understand its intent. Although operational performance provides an indirect measure of demonstrated understanding, the true measure can be obtained best by direct communication with drivers who observe the device in a real-world roadway environment. Extensive driver understanding human factors studies were conducted in the previous developmental study (Contract DOT-FH-11-9164). The dotted line pattern and NO-PASSING ZONE pennant combination treatment exhibited a high level of understanding of the intent of the advance treatment for no-passing zones. Although not specifically required in the pilot field testing research effort, it was believed that a demonstrated understanding and expression of opinion of the experimental devices would provide an important ingredient in evaluating the feasibility of the treatments. A separate study to accomplish this was conducted by D.R. Hatcher, a staff member of the Texas Transportation Institute, as a special problem for a Civil Engineering course at Texas A&M University. The special problem was conducted under the supervision of D. L. Woods who was actively involved in the research project; therefore the experimental design could be tailored to produce data that would be applicable to the research herein and the results could be made available. The separate study is described briefly herein and pertinent parts are included in Appendices B, C, D, and E.

Driver Surveys

Three individual, but related, surveys were developed -- one each for drivers observed passing in each of the three study sites within the three States. The surveys are contained in Appendix C (combination treatment), Appendix D (NO-PASSING ZONE pennant sign only), and Appendix E (advance dotted line only). A total of 561 surveys were sent out to drivers who were observed passing in the three States. Vehicle license plate information recorded during all passing maneuver measurements was used to obtain driver addresses. Surveys were sent to all addresses except those of rental car agencies or those for which an address was not yet on file (example: a new automobile with registration in process; hence not on motor vehicle registration file yet), or those addresses indicating commercial equipment (example: buses, trailer licenses of semi-trailer trucks etc.). Some surveys were returned postmarked "undeliverable", and a few surveys were returned uncompleted. The distribution and return rate are summarized in Table 2.

Survey Format

The survey was developed to determine what meanings drivers ascribed to the experimental devices. Closed form questions were asked (multiple choice) and where possible, drivers were asked to rank numerically how strongly they agreed or disagreed with statements regarding the usefulness of the devices in assisting them in executing passing maneuvers under various circumstances. All questions included space for open-ended comment by a subject to insert other mean-

Table 2. Driver Survey Distribution

Site	Number of Surveys				Effective Response (%)
	Mailed	Undeliverable	Returned Blank	Returned Answered	
NC-1	76	4	3	27	39
NC-2	56	1	2	14	26
NC-3	77	3	3	27	38
T-1	67	7	1	14	24
T-2 (day)	48	2	1	8	23
T-2 (night)	20	1	1	5	28
T-3 (day)	52	2	1	13	27
T-3 (night)	33	2	3	4	14
U-1	47	5	1	15	37
U-2	59	7	0	15	29
U-3	36	5	1	17	57
TOTALS					
Day	508	36	13	150	33
Night	53	3	4	9	20
ALL	561	39	17	159	31

comment by a subject to insert other meanings if desired or to write additional comments or suggestions.

The first three questions were identical in all three surveys. They were used as "control" questions to determine if the responding subject understood the meaning of the conventional solid no-passing zone stripe and if they understood the legal intent with respect to "clipping" or "jumping" (beginning a pass over the solid yellow line). Thereafter, the questions pertained to understanding or opinion of the particular experimental treatment.

The survey was developed to determine how well the subject understood the intended meanings of the advance treatment and also what other meanings they ascribed to the devices. The three intended meanings included:

1. A no-passing zone is coming up ahead,
2. A passing maneuver should not be initiated beyond a certain point near the downstream end of a "passing" zone, and
3. If a driver is in the act of passing near the downstream end of the "passing" zone, the maneuver should be completed expeditiously to avoid "clipping."

In addition to evaluating how well drivers perceived the intended meanings, it is also important to ascertain if they believed the dotted section to be a no-passing zone. Did they realize that it represented a pass completion distance; hence it differed from the solid yellow no-passing zone? Did they recognize that the dotted treatment always preceded the solid line or that the NO-PASSING ZONE pennant sign was placed at the beginning of the solid yellow line? How quickly did they recognize that a unique treatment was installed at every no-passing zone? How soon did they deduce its meaning? Under what conditions (geometric, operational, and environmental) would the device(s) be helpful? How strongly did drivers believe that the device(s) should be installed by the State Department of Transportation?

Subjects were asked to rate their responses on a scale from "totally disagree" to "totally agree" (scale of 1 to 13) so that opinions could be evaluated objectively.

DRIVER UNDERSTANDING DATA REDUCTION

All survey answers were assigned a numerical code so that all answers could be identified using computerized sorting techniques. In this way, the answer to any question a survey could be compared to any other related question from another survey. For example, the number of subjects recognizing that the device(s) meant that they were approaching a no-passing zone could be compared among those who traveled through any one of the three experimental treatments. The degree to which either the sign or the dotted marking conveyed this meaning could be determined individually as well as collectively for those seeing the combination treatment. "Correct" responses are marked with an "X" in each survey (Appendices B, C, D, and E). The driver responses and the analyses of the responses are presented in Appendix F. The findings are discussed in Chapter 4.

4. FINDINGS

INTRODUCTION

This chapter presents a summary of the findings from the analysis of passing maneuver measurements and from the driver survey responses. Statistical analyses of passing performance data are documented in Appendix G. The surveys, driver responses, and analyses of the driver survey responses are documented in Appendices A through F of this report.

FINDINGS--PASSING PERFORMANCE MEASUREMENTS

Analyses of variance (ANOVA) were conducted to identify any passing operational effects among States (terrain environment) and treatments on each of the performance measures. Only one performance measure exhibited a statistically significant effect on passing performance--altering clipping distance. Although definitive trends toward modified passing behavior were apparent in most measures, the effects were not statistically significant. As mentioned previously, the desired effect of the treatment(s) was to produce a reduction in each of the operational measures of effectiveness, preferably a statitically significant reduction, even though the studies represented pilot tests to investigate feasibility of the treatments.

The findings with respect to the effect of the individual treatments on the measures are summarized in Tables 3 through 7.

Table 3. Effect of Treatments on Clipping Distance*

	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Increase
Utah	Increase	Increase	Increase

*Statistically significant

Table 4. Effect of Treatments on Clipping Frequency

	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Decrease	Decrease
Texas	Decrease	Increase	Decrease
Utah	Decrease	Decrease	Increase

Table 5. Effect of Treatments on Number of Passes Initiated Within 1000 ft of the No-Passing Zone

	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Decrease	Decrease
Texas	Decrease	Decrease	Decrease
Utah	Decrease	Increase	Decrease

Table 6. Effect of Treatments on Total Passing Distance of Vehicles Initiating a Pass Within 1000 ft of the No-Passing Zone

	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Decrease
Utah	Decrease	Increase	Increase

Table 7. Effect of Treatments on the Number of "Passing" Zones Through Which Vehicles Trailed Prior to Initiating a Pass

	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Increase
Utah	Decrease	Decrease	Decrease

Of the 2637 total passing maneuvers measured during the study, only 35 involved aborted passes (1.3 percent). These data were too small to warrant statistical analyses; therefore, this measure of effectiveness could not be evaluated.

From statistical t-analyses, statistically significnt differences were observed between four situations containing the experimental treatments. The t-analyses were conducted to identify differences between treatments with a given State (terrain) and between States for a given treatment. Statistically differences were found for four comparisons with respect to clipping distance:

NC-1 (Combination) vs. NC-2 (Pennant)
NC-1 (Combination) vs. U-1 (Combination)
NC-3 (Marking) vs. U-3 (Marking)
T-2 (Pennant) vs. T-3 (Marking)

Two findings from the t-analyses are significant:

1. Both treatments containing the dotted marking system produced a significantly

shorter clipping distance than did the pennant alone.

2. Both treatments containing the dotted marking produced significantly shorter clipping distances in the flat terrain environment (North Carolina) than in the mountainous terrain.

In addition to the statistically significant effects mentioned above, several influencing trends can be identified from Tables 8 through 10:

1. The combination treatment exhibited a decrease in all measures for all terrain types with only one exception--clipping distance in mountainous terrain.

2. In general, the combination treatment and the marking-alone treatment exhibited the desired reduction in most of the measures more so than merely the pennant alone.

3. The pennant-alone treatment exhibited an increase in 10 of the 15 treatment/ terrain situations.

4. The combination treatment and the marking-alone treatment exhibited clipping distances that were at least 100 ft (30 m) shorter than those observed with the pennant-alone treatment, and in three cases the clipping distance was 150 ft (46 m) shorter. These reductions were evident in the flat and rolling terrain environments only; the mountainous terrain sites did not reflect this reduction.

Table 8. Effect of NO-PASSING ZONE Pennant On Passing Performance Measures

Operational Measure	North Carolina	Texas	Utah
Clipping Distance	Increase	Increase	Increase
Clipping Frequency	Decrease	Increase	Decrease
Number of Passes Initiated	Decrease	Decrease	Increase
Total Passing Distance	Increase	Increase	Increase
Number of Zones Trailed Through	Increase	Increase	Decrease

With the pennant-only treatment, 5 measures indicated a decrease, 10 indicated an increase.

Table 9. Effect of Dotted Marking Treatment On Passing Performance Measures

Operational Measure	North Carolina	Texas	Utah
Clipping Distance	Decrease	Increase	Increase
Clipping Frequency	Decrease	Decrease	Increase
Number of Passes Initiated	Decrease	Decrease	Decrease
Total Passing Distance	Decrease	Decrease	Increase
Number of Zones Trailed Through	Decrease	Increase	Decrease

With the marking-only treatment, a decrease in 10 operational measures was indicated. Only 5 measures indicated an increase.

Table 10. Effect of Combination Treatment On Passing Performance Measures

Operational Measure	North Carolina	Texas	Utah
Clipping Distance	Decrease	Decrease	Increase
Clipping Frequency	Decrease	Decrease	Decrease
Number of Passes Initiated	Decrease	Decrease	Decrease
Total Passing Distance	Decrease	Decrease	Decrease
Number of Zones Trailed Through	Decrease	Decrease	Decrease

With the combination treatment, a decrease was indicated for all operational measures except one.

Night Studies

Night passing maneuvers were measured at Texas sites T-2 (pennant alone) and T-3 (dotted marking alone).

Clipping frequency was the only measure exhibiting a statistically significant difference when comparing day/night versus "before"/"after" using ANOVA analysis. This analysis indicated that there was some difference between the "before" condition (MUTCD markings) and the "after" condition (pennant) and some difference between day and night effects; however, ANOVA analysis does not identify the reason for the differences, it merely indicates that some statistically significant difference exists. Chi-Square statistical analyses were then conducted to compare day versus night operations and site treatments for the "before" and for the "after" conditions. The Chi-Square analysis indicated also that there were differences between day and night or between treatments in both the "before" and the "after" condition. Hence, Chi-Square analyses were conducted to compare day versus night and treatments (pennant versus dotted marking) for both "before" and "after" conditions. This analysis would indicate if the difference was related to day versus night and/or site treatment for both "before" and "after". The findings are summarized:

1. Drivers pass differently at night than in the daytime when the roadway is marked conventionally. The clipping frequency increases at night (in some cases as much as 50 percent).

2. Clipping frequency was lower for the dotted marking (site T-3) than for the pennant (site T-2) during the day and for nighttime passes.

Although not statistically significant, other trends were apparent from the nighttime studies.

1. Clipping distance both day and night was appreciably less for the dotted marking treatment than for the pennant alone.

2. In general, nighttime passing exhibits an increase in clipping distance, clipping frequency, and total passing distance. Negligible differences were observed for the number of passes initiated in the last 1000 ft (305 m) of the "passing" zone and for the number of passing zones through which the vehicles trailed before passing.

SUMMARY OF TREATMENT EFFECTS

Based on the evaluation of the limited number of passing operational measurements in these pilot field tests, several conclusions are drawn:

1. The dotted marking is a very important element of the conceptual advance treatment system in achieving the desirable operational effects.

2. The marking elicits the desired operational response better than the pennant alone; however, the combination of the two devices is more effective than either device alone.

3. The treatment(s) appear to be more effective in the flat and rolling terrain environment than in the mountainous environment.

4. With the exception of the mountainous terrain, the combination treatment exhibited no negative effects on any of the measures of effectiveness; all trends were toward positive effects (i.e., decrease in measures). Neither device alone produced this effect.

FINDINGS—FIELD STUDY DRIVER SURVEYS

The findings from the driver surveys are summarized here from Appendix F.

Demonstrated Understanding

The percentage of drivers who demonstrated total understanding of the marking treatments was less in the field studies than in the laboratory studies. (24 percent versus about 40 percent). These drivers responded correctly to only those responses that were defined as being "correct". They did not check any other responses as being correct. The subjects who were interpreting the meaning under a passing situation demonstrated about a three fold understanding level above the non-passing drivers (those who were driving through the study site but did not execute a pass).

The most common misinterpretation of the pennant sign was that drivers believed they should not begin a pass beyond the point where they could first see the sign. Although this produces a safety margin, it does reduce the length of safe passing opportunity along the roadway. The pennant can be seen for about 1200 feet (366 m) whereas only about 750 feet (229 m) is needed to safely complete a high-speed pass from the critical position.

The most common misinterpretation of the dotted marking was that subjects believed that they should return to the right lane before reaching the start of the marking system. This was interpreted as meaning that they believed it to be an upstream extension of the no-passing zone. Since the dotted marking is totally unique, having never been used in this country, it is understandable that it might be confused with a no-passing zone. It is placed on the right side of the centerline where a no-passing zone stripe would be expected. At long low- angle visibility distances, it appears to be a faint solid line; when approached it becomes very evident that it is a broken line pattern. The concept that a broken line is permissive apparantly did not overshadow the fact that it was a line placed to the right of the centerline to these subjects -- the primary aspect of a conventional no-passing zone stripe. It is evident that education would be necessary to explain the subtle differences between placement and pattern.

More than half the subjects observing the combination treatment (55 percent) recognized that the pennant sign designated the beginning of the no-passing zone. Of those subjects in the pennant-only study

study sites, 54 percent recognized this feature. Only 18 percent of the combination treatment subjects recognized that the no-passing zone started immediately at the far end of the dotted marking treatment. This percentage increased to 30 percent for those subjects who traveled through the marking-only study site.

Both the pennant and the marking alone conveyed the desired meaning "approaching a no-passing zone," about equally; however, the combination treatment produced a higher level of understanding of this meaning (marking only, 47 percent; pennant only, 50 percent; and combination, 61 percent).

No subject drivers were presented advance information regarding the presence or the meaning of the experimental treatments. Therefore, demonstrated understanding was deduced by the drivers. Even at this, driver understanding levels of the primary meaning--"approaching a no-passing zone"--were highly favorable in that at least half of the naive drivers recognized this. It would be expected that this level of understanding would be increased through education and further exposure.

Driver Opinion Ratings

Subjects were asked to rate (rank) the degree to which they agreed or disagreed with statements in the survey. The rating technique permits numerical analysis of a subjective opinion. The rating scale was linear with five categories between "totally disagree" and "totally agree". The numerical values from 1 to 13 were assigned to the categories for analysis purposes--no codes were shown on the surveys. Rating values were:

1. Totally Disagree
3. Strongly Disagree
5. Moderately Disagree
7. Undecided
9. Moderately Agree
11. Strongly Agree
13. Totally Agree

The subject was asked to place an "X" on the rating-scale line beside each statement to indicate how well he (she) agreed or disagreed with the statement. The "X" could be placed anywhere along the line--on a numbered "tick mark" or between "tick marks". Therefore, the mid-point of each category was assigned a numerical rank to achieve greater accuracy in calculations.

Evaluation of Solid Yellow Line

Surveyed drivers did not rate the solid yellow line highly in terms of adequately supplying their informational needs. Almost one-third of the subjects were within the "Totally Disagree" to "Undecided" range of opinion, with 24 percent being in the "Moderately to Totally Disagree" ranking category. About 55 percent of the subjects at best only "Moderately Agreed" that it was adequate.

Assistance of Experimental Treatment in Passing Situations

Drivers were asked to rate how well they thought each treatment would assist passing under fourteen specific geometric or operational conditions.

The marking treatment and the pennant alone received higher average ratings than the combination treatment for providing assistance in the passing situations. The marking alone and the pennant alone received equal ratings for "passing a truck" (10.4 rating). The marking alone received the highest rating for "night" (11.0 rating), "fog" (10.3 rating), "right curve" (10.5 rating), and "left curve" (10.0 rating. The pennant alone received the highest ratings-for the remaining nine situations:

1. passing one car (9.5 rating),

2. passing more than one car (10.5 rating),
3. daytime passing (10.2 rating),
4. passing at dusk or dawn (10.5 rating),
5. passing in rain (10.6 rating),
6. passing in snow (10.6 rating),
7. sun glare (9.7 rating),
8. approaching hill (10.3 rating), and
9. hidden dip (10.1 rating).

Recognition of Treatments

Drivers indicated a high rating (10.3 rating) for capability of recognizing rapidly that there was a difference between the dotted line pattern and a conventional centerline pattern. The exact meaning was not totally clear to them, but after observing it at each successive no-passing zone, it soon became apparent that it was not merely a "painting error" according to the driver comments.

After initial education through seeing several pennants, drivers stated that subsequent pennant signs were easily recognizeable long before they were close enough to read the legend (10.7 rating). The unique shape, and left-side placement apparently contribute significantly to target value and recognition. The fact that the sign can be recognized at the considerable visibility distance is a positive attribute because this feature, coupled with a high level of understanding, transfers the start of the no-passing zone information source at least 1200 ft (366 m) upstream, if the sign is seen.

Driver Opinion Regarding Installation of Devices

Surveyed drivers indicated a highly ranked opinion in favor of installing the experimental treatments.

Drivers who observed the combination treatment were asked to rate their opinion regarding installation of the marking alone, the pennant alone, and the combination treatment. The ratings were 6.3, 6.4, and 9.8 respectively indicating a 50 percent increased preference for the combinatin treatment over each component. It is important to note, however, that those drivers who observed only one of the individual treatments rated the individual device almost as highly as the combination treatment subjects rated the combination treatment (9.4 pennant-only, 9.4 marking-only, 9.8 combination). These ratings are within the "Moderately to Strongly Agree" rating category.

SUMMARY OF FINDINGS FROM DRIVER SURVEYS

The salient findings are summarized.

1. The NO-PASSING ZONE pennant more clearly defined the precise beginning of the no-passing zone than did the dotted marking alone.

2. Both individual treatments convey very well that a no-passing zone is being approached.

3. Both individual treatments convey the meaning that a pass should not be initiated. The pennant, although not designating a precise point on the roadway beyond which the pass should not be initiated, apparently conveys this indirectly. Drivers believed that they should not begin a pass beyond the point where they could first see the pennant. A sizeable percentage believed this of the marking alone also. The visibility distance of the pennant is about 1200 ft (366 m). The dotted marking extends 750 ft (229 m) upstream and exhibits a visibility distance (on level roadway) of about 400 ft (122 m). Therefore if drivers believe that they should not begin a pass beyond the "first sight" position, the pennant and the dotted marking differ only by about 50 ft (15 m).

4. After initial education through viewing the pennant, drivers stated that they could clearly recognize subsequent pennants at distances greater than the legibility distance--the unique shape and placement provided the needed information without the need for message reading.

5. The pennant alone and the dotted markings alone received about equal ratings for installation when viewed either singly or as the combination treatment; however, the combination treatment received a 50 percent higher rating than either component alone by those drivers who observed the full complement of devices.

5. APPRAISAL OF RESULTS

BASIS OF APPRAISAL

The pilot field studies were conducted to evaluate, in a real-world environment, a conceptual system of traffic control devices that had been shown through human factors and economic studies to exhibit desirable features in providing advance notification of upcoming no-passing zones on rural two-lane highways. The observed effects of the experimental treatments on passing performance and driver understanding (Chapter 4) are interpreted herein with respect to the feasibility of the treatments in achieving safer passing operations. In this respect, negative aspects that could create safety problems in passing operations are identified as well as the positive attributes and the associated benefits to safety.

NO-PASSING ZONE Pennant Sign

The NO-PASSING ZONE pennant sign is currently used either Statewide or at selected no-passing zone locations by about 70 percent of the States. Its unique shape and left-side placement offer very desirable target value and recognition qualities. On the basis of the driver understanding studies in this research, it performs very satisfactorily as a highly visible device to designate the beginning of a no-passing zone in most environmental conditions. Limited nighttime studies indicated that it is highly visible at night and that drivers initiating a pass were prone to abort the maneuver when seeing the reflective sign downstream after moving to the left lane.

The pennant sign was not found to reduce "clipping" (completing the pass in the no-passing zone); conversely it exhibited an increased "clipping" occurrence at all three study sites. This might be attributed to the primary weakness of the pennant sign -- driver inability to accurately judge distance and execute a maneuver within that distance at high speeds under complex driving task situations.

Although the pennant does identify the beginning of the no-passing zone well (high target value), it does not clearly delineate a point on the roadway upstream beyond which a driver should not initiate a pass. This point must be judged by the driver. In inclement weather such as rain, snow or fog which mask the visibility characteristics, the distance judgment capability is further degraded. Conversely, the pennant sign performs admirably when the roadway surface is obliterated by snow or ponded water, and is not as susceptible to visibility degradation as painted marking erosion from traffic.

The pennant sign received high opinion ratings as a device to provide information that would assist in passing under a variety of selected geometric, operational, and environmental situations.

The pennant sign was found to elicit desired passing operations more favorably in flat-to-rolling terrain than in severe mountainous terrain. This indicates that traffic control devices are a more important information source to drivers when the roadway geometry does not immediately provide the necessary visual cues than when alignment makes it easily recognizable that passing is unsafe. Drivers were observed to execute a passing maneuver very aggressively in the mountainous study sites, probably because they were offered relatively short passing opportunities at infrequent intervals. It is understandable that drivers, familiar with these constraints, would accept passing opportunities with greater risk factors since it would be the only opportunity for several miles. It is believed that drivers in this terrain accept passing opportunities on primarily on

the criterion of no visible approaching vehicle; hence, use of additional traffic control devices at these locations may not be necessary for other than maintaining demarcation uniformity (legal purposes). The presence of a no-passing zone downstream is clearly designated by the severe terrain sight restrictions.

In summary, the pennant sign alone offers several desirable features with respect to signifying the presence of a no-passing zone. It is a control device that is superior to the solid yellow line alone in providing advance notification of the no-passing zone; however, it did not significantly reduce undesirable passing performance measures.

Dotted Marking Treatment

The advance dotted treatment, a unique device to all drivers who traveled through the study sites, was shown to convey the primary meaning -- "Approaching a no-passing zone" -- quite well. It received an equal rating with the pennant sign regarding drivers' opinion that it should be installed (both ratings were 9.8 on a 1-to-13 opinion scale).

The dotted line treatment understanding level of the three intended meanings, although not unsatisfactory since it is totally unique, appears to need additional driver education in one aspect. Drivers apparently did not readily associate the broken line pattern with "permissive movement". They quickly recognized that it was different than a conventional centerline marking pattern; however, about 30 percent of the surveyed subjects thought that they must complete their pass before reaching the dotted section. This would infer that they are placing greater emphasis on the placement of the dotted line (to the right of the centerline) and associating this with their past experience with no-passing zone markings which are the only markings adjacent to the centerline. It is believed, however, that driver education would materially improve the understanding level.

The dotted treatment was rated highly by drivers as a device to provide necessary advance information at night and for horizontal alignment no-passing zone establishment.

The dotted treatment overcomes the primary deficiency of the pennant sign. The marking physically designates the length of roadway upstream for the start of the no-passing zone in which passing should not be initiated; it therefore alleviates the need to estimate remaining distance to the no-passing zone. Also, it can be used successfully where the start of the no-passing zone is located slightly beyond the point of horizontal curvature where the pennant is obscured by trees. Several no-passing zones in the nine field sites began in long curves and on barn-roof crest vertical curves. Thus, the beginning of the zone was not apparent to an approaching driver. At many of these sites, the pennant was not visible because visibility was blocked by trees or by the first shallow vertical curve. The dotted treatment extended back to the tangent section and was highly visible.

The dotted marking alone affected the passing performance considerably better than the pennant alone; thus, it is believed to be a very important element of the conceptual advance treatment system. It does, however, exhibit one negative feature--being completely unique, additional exposure and education is considered necessary before its full meaning will be understood by most drivers. The dotted marking alone, like the pennant alone, did not totally produce the desired reduction in operational measures; however, it appreciably improved the performance above the solid yellow line marking system and the pennant.

Combination of Pennant and Dotted Line Treatment

The combination treatment (dotted marking and pennant) produced almost total desired effect on all performance measures--reduction in all situations. Clipping distance in the mountainous terrain was the only exception.

The combination treatment incorporates the favorable aspects of both markings and signs. Each component compliments the other to overcome the individual deficiencies in all environmental conditions. The sign is highly visible (under most geometric situations) when the pavement is obscured. The marking is visible when the sign is obscured. In addition, the marking specifically identifies a point on the roadway and a length of roadway to the no-passing zone which overcomes inept distance judgement if its meaning is understood. The combination treatment represents a fairly inexpensive treatment, costing only about forty dollars per mile of roadway for installation in this study. The combination treatment also provides redundancy -- if a pennant is knocked down, the marking remains, if the markings are obscured (snow, worn paint, etc.) the pennant will provide a large part of the necessary information.. From merely this legal liability aspect, the combination treatment offers favorable consideration.

The combination treatment offers redundancy in another respect also. After observing several thousand passing maneuvers and evaluating the driver survey responses, it is believed that some drivers "key" on the sign and some on the marking. The combination treatment would be expected to assist a greater percentage of drivers by providing both visual cues.

CONCLUSIONS

Based on the results of the performance measures and driver understanding surveys, the following conclusions are presented.

1. Each of the individual treatments exhibits favorable characteristics with respect to providing advance information that a no-passing zone is being approached; however, the combination of the pennant and dotted marking accomplishes this better than either device alone.

2. The treatment(s) appear to be more effective in flat or rolling terrain than in mountainous terrain. Extending the target value of the no-passing zone 550 to 750 ft (168 to 229 m) in mountainous terrain where geometry already indicates unsafe passing very conspicuously may not be needed for purely safety reasons.

3. No negative safety effects on passing performance can be expected from use of the experimental dotted marking system.

4. The marginal cost of installing the combination treatment rather than only one of the individual treatments should be considered carefully in selecting a preferred system. The combination treatment, while not costing appreciably more than either individual treatment, offers favorable legal liability considerations through providing redundancy, and produces more desirable passing operations.

5. Drivers need, and want, better advance notification of the no-passing zone. These treatments provide this information in a way in which they can effectively use the information.

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APPENDICES

A. Passing Maneuver Data Collection and Reduction

B. Driver Survey Information

C. Driver Survey -- Combination Treatment

D. Driver Survey -- No-Passing Zone Pennant Sign Only

E. Driver Survey -- Advance Dotted Line Treatment Only

F. Driver Survey Responses

G. Passing Maneuver Measurement

APPENDIX A

Passing Maneuver Data Collection and Reduction

The techniques used to collect and reduce the passing maneuver operational data are discussed in this appendix. Also included are examples of the various data recording forms used, computer coding information, and processed output of the data as illustrated in Exhibits A-1 through A-6.

DATA COLLECTION TECHNIQUE

All operational data were measured and recorded by a three-person team. Data were recorded on cassette tape continuously throughout each maneuver by the front recorder who supervised the data collection. Both the driver and the back recorder team member operated the electronic stop-watches in addition to other duties.

The driver's primary responsibility was to maintain constant vehicle speed throughout the data measurement phase and to concentrate on the safety aspects of the driving task. The back recorder's responsibilities included recording of trailing vehicle information, providing advance warning to the team that the trailing vehicle was moving into a pass initiation position, and designating the time when the left front wheel crossed the centerline and recording the estimated trailing distance at this point. This signal initiated all measurements. The back recorder stop-watch and the driver's stop-watch were both started on this signal. If the DMI was rezeroed on pass initiation rather than on a previously crossed tape marker, this was done on this signal also. The back recorder was also responsible for designating the time that an opposing vehicle reached the research vehicle.

The front recorder was responsible for operating the DMI and assuring that all readings (time, distance, and presence of opposing vehicle) were recorded on the tape. Since several DMI readings were taken during each maneuver (within about 10 seconds usually), the same person operated the DMI constantly to maintain efficiency.

The sequence of events for a typical maneuver is presented below for a situation in which the DMI was zeroed at a tape mark and then rezeroed on pass initiation.

1. The research vehicle is traveling along the highway at about 45 mph (72 Km/h)
2. As the front wheels pass over a tape marker, the front recorder rezeroes the DMI and notes the zone placard number on cassette tape (typical message: "Rezero, marker 3")
3. A trailing vehicle closes on the research vehicle. The back recorder signals when the vehicle approaches within 200 ft (61m) by counting centerline stripes (40-ft pattern) (12m) or by using a set of stadia marks etched on the rear window. The distance can be checked by zeroing the DMI as the research vehicle passes over a tape mark and reading the instrument when the trailing vehicle passes over the same mark.
4. The back recorder alerts the team that the trailing vehicle is moving over toward the centerline. The signal "Get ready!" is given as the left front tire approaches the centerline. The signal "Now!" is given as the wheel crosses the centerline.
5. The rezero button on the DMI is held in a depressed mode throughout the warning time, then released on the "Now!" signal and noted on the tape. At the same time, both stop-watches are started.
6. The front recorder signals the time at which the critical position is reached and depresses the memory button on the DMI (the unit continues to measure distance but the reading is locked on the display panel for recording purposes). A typical message would be, "Critical position coming up --- Now!" The warning prepares the driver who stops the stop-watch on the "Now!" signal. At the same time, the recorder depresses the DMI memory button and records the reading on the cassette tape, then releases the button so that the cumulative distance reading is again being displayed.

7. The front recorder signals the return position with a typical message, "Return maneuver coming up --- Now!" The back recorder is also watching, and on the signal "Now", stops one channel of the split cumulative stop-watch and records the total time on the data form. The front recorder "marks" the return position and as the front wheels of the research vehicle passes the point, depresses the memory button on the DMI. The DMI reading is recorded on tape and the memory button is released.
8. If an opposing vehicle was in sight during the maneuver, the time that it reached the research vehicle is recorded by the back recorder on the second channel of the split cumulative stop-watch.
9. A closeout DMI is recorded by the DMI operator as the research vehicle passes over a known reference mark and noted on the tape.
10. The three measured times and the trailing distance are recorded on the tape.
11. The type of passing maneuver (criterion or non-criterion) is noted on the tape along with "clipping" information or other notations such as a multiple pass, obvious disregard for markings, etc.
12. The notations made on data recording forms by both the back and front recorders are checked to assure that all necessary data coincided.
13. The DMI and both stop-watches are cleared and the next consecutive number is assigned to the next subject in preparation for data collection.
14. The above sequence is repeated for each subject vehicle.

MANEUVER DATA REDUCTION

All data were transcribed from cassette tape and recording forms to individual maneuver data forms so that vehicle data, operational data and other information could be formatted for computer entry. Examples of data recording forms, coding information and sample output are illustrated in Exhibits A-2 through A-5.

1. Data from front and back recorder forms and vehicle operational data from the cassette tapes were transcribed to individual passing maneuver forms (see Exhibit A-1).

2. Passing distances (critical, total, etc.), opposing vehicle distance, and "clipping" distance were computed.
3. Speeds of the passing vehicle throughout the various maneuver distance elements were computed using time/distance relationships.
4. Relative positions of each passing maneuver with respect to the no-passing zone were computed using operational distance data and the study site survey plan sheets.
5. All data were coded on computer entry forms.
6. The coded data were keypunched and verified for accuracy.
7. The coded data were processed through the Statistical Analysis System (SAS) program to identify frequency of occurrence for the many variables.

The computerized data file provided the capability to investigate operational performance from a number of aspects. An examples of the type of sorting techniques is presented in Exhibit A-6.

Exhibit A-1. Example of Field Study Site Inventory

FIELD STUDY SITE INVENTORY
RF 3828

Highway Number: SH 103 Travel Direction: East Bound (Lufkin) Date Inventoried: 6/14/79

ITEM	DMI READINGS (REFERENCE STATIONS)							LENGTHS (FEET)			COMMENTS
	Start Passing Zone	1000 ft. Advance Marker	750 ft. Advance Marker	Start NPZ	End of NPZ	Other Begin	Other End	Passing Zone	No-Passing Zone	Other	
West End of Site	-	-	-	0	1113			-	1113		Begins At "Rest Area 1 Mile" Sign on Right Side Highway Marked For No-Passing
ZONE 1	1113	1099	1349	2099	3071			986	972		
ZONE 2	3071	3528	3778	4528	5659			1457	1131		
						4143	-			-	Rest Area On Right
ZONE 3	5659	5493	5743	6493	7297			834	804		
ZONE 4	7297	6787	7037	7787	8203			490	416		
ZONE 5	8203	10925	11175	11925	13104			3722	1179		
						8203	-			-	Intersection of FM 705
						10580	11154			574	Bridge
ZONE 6	13104	15246	15496	16246	16980			3142	734		
ZONE 7	16980	16833	17083	17833	18801			853	968		

Exhibit A-2. Example of Front-Recorder Data Form

PASSING MANEUVER DATA
RF 3828

(Data Recorded from Front of Vehicle)

☐ "Before" Data

☒ "After" Data

Traffic Control Combination

Page 1 of 8

Date 8-16-79

Location T-1
SH 103

Veh No.	Tape Count	Vehicle Passed In Zone	Comments
1	2		Truck
2	47	9	Return within dotted marking, Criterion
3	78		Vehicle turned off on US 96
4	119	21	Clip - zone 21, Criterion
5		23	Return in dotted zone, no clip, zone 23, Criterion
6	189		Truck - completed before dots, zone 10
7	223		Car - LA. plate, outside zone (truck passed him and us first, no data)
8	294	21	Dodge Colt Wagon - clip, Criterion
9	328		
10	369	28	Return in dots, Criterion
11	387		Return before dots & before 1000', barely
12	405		Veh. did not pass before Jct. 147 - end of zone
13	422	2	Completed in dots, Criterion (Sedan)
14	441		Completed before 1000' to zone, Pickup
15	462		Turned off
16	490	14	Illinois, Criterion
17	520+		Passed beyond zone 17
18	558	20	Clip, Criterion, started in dots after oppos. veh. passed

Exhibit A-3. Example of Back-Recorder Data Form

PASSING MANEUVER DATA
RF 3828

(Data Recorded from Back of Vehicle)

☐ "Before" Data
☒ "After" Data
Traffic Control Combination

Page 1 of 8
Date 1-16-79
Location T-1
SH 103

Veh No.	Tape Count	License Plate	Vehicle Type	Total Time	Opp. Time	Trail Dist.	Comments
1	0	PO 3751	Semi.	15.01		40'	
2	47	STW 555	T.Bird	14.46		40'	
3		TX MDV 796	Chev. Malibu	-		-	turned right
4	119	TX RZD 221	Chev. Sedan	10.89		20'	
5		TX QHL 174	Pontiac Sedan	11.31		40'	
6	189	no plate	Mack Truck	16.28		60'	log truck
7	223	41H 177	4Dr. Dodge Sedan	14.47		80'	
8	294	6387-DV	Dodge Colt Station Wagon	9.84		60'	West bound
9	328	317G114	Olds 4Dr. Delta 88	11.90		45'	
10		TX FZ-4058	Ford Van	11.31		30'	
11	387	P47-952	2Dr. Ford Sedan	11.35		80'	
12	405	TX MDW-922	Chev. 2Dr.	-		-	
13	422	TX TYO-737	Pheonix Pontiac 2Dr.	10.41		50'	
14		TX Truck FY-309	Pickup Ford Ranger	11.96		25'	
15	462	PDL-258	2Dr. Ford LTD.	-		-	turned left
16		KY-9188	Olds 4Dr. Delta 88	15.65		30'	
17		TX NZX-656	Ford LTD.	15.15		85'	
18	558	TX QHL-311	Ford LTD.	9.41		70'	West bound

Exhibit A-4. Example of Data Reduction and Computation Form

SITE: T-2 ; SH 7 — No. 9

FROM: Center, TX

TO: Joaquin, TX

DAYTIME DATA

RF 3828 (TEXAS SITE)

"BEFORE DATA RECORDING"

Tape Count 350

Passing Vehicle Type and License Number Monte Carlo TX - MOC-403

Direction of Travel: N (S) E W

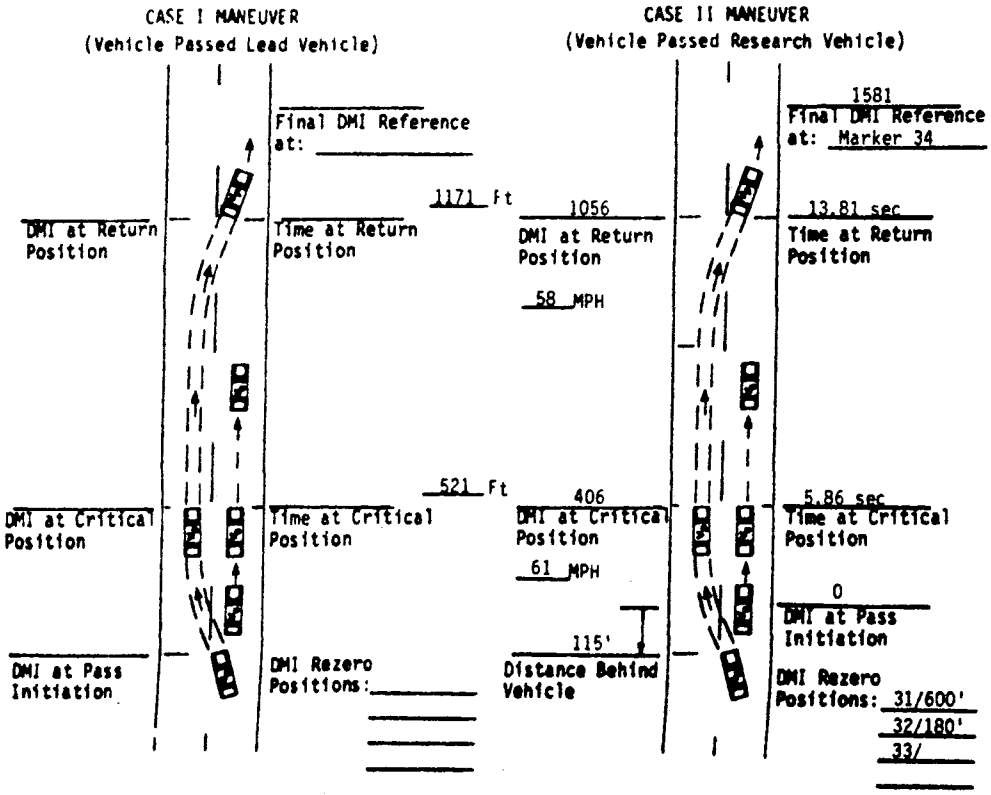
Passed Vehicle Type and License Number Station Wgn. TX - 317-308

Zone Number 33

Speed of Passing Vehicle ----

Date 4/27/80

Speed of Passed Vehicle 45 mph



Passing Vehicle Clipped: (Yes) No Comments: Criterion Pass; Clip Distance = 42'

Opposing Time: 20.11 seconds --- 2956 feet

Opposing Traffic in Zones: 32 No Aborted Pass Attempts

Passing Opportunities Rejected: None

Exhibit A-5. Coding Information for Passing Maneuver Data

ITEM	COLUMNS	CODING INFORMATION
CARD I		
1. Vehicle Number	3	Vehicle Number From Forms
2. Study Site	1	NC1 = 1 NC2 = 2 NC3 = 3 T1 = 4 T2 = 5 T3 = 6 U1 = 7 U2 = 8 U3 = 9
3. Data Type	1	Before = 1 After = 2
4. Demaraction System	1	MUTCD = 1 TTI marking only = 2 TTI marking & pennant = 3 Pennant Only = 4
5. Passing Vehicle Type	2	Compact passenger Vehicle = 1 Mid-Size Passenger Vehicle = 2 Full Size Passenger Vehicle = 3 High Performance Vehicle = 4 Compact Pickup = 5 Regular Pickup = 6 Van = 7 R. V. Camper = 8 R. V. Motor Home = 9 Bus (Greyhound Type) = 10 Single Unit Truck = 11 Semi Truck/Trailer = 12 Logging Truck (Loaded Only) = 13

ITEM	COLUMNS	CODING INFORMATION
6. Trailer Type	1	None = 0
		Empty = 1
		U-Haul = 2
		Boat = 3
		Horse = 4
		Cattle = 5
		Camper = 6
7. Passing Vehicle-State	2	(2) Two Letter Abbreviation
8. Passing Vehicle-License	6	License Number
9. Direction Of Travel	1	North = 1
		South = 2
		East = 3
		West = 4
10. Passed Vehicle Type	1	Passenger Vehicle = 1
		Station Wagon = 2
		Van = 3
11. Passed Vehicle-State	2	Two Letter Abbreviation
12. Passed Vehicle-License	6	License Number
13. Zone Pass Initiated In	2	Zone Number
14. Average Speed Of Passing Vehicle Through 1/3 d_2	2	In MPH (Calculated From Time And Critical Distance)
15. Average Speed Of Passing Vehicle Throughout d_2	2	In MPH (Calculated From Time And Return Distance)
16. Study Date	6	Example - 10 22 79
17. Speed of Passed Vehicle	2	In MPH
18. Maneuver Type	1	CASE I = 1
		CASE II = 2
19. Total Passing Distance	4	In Feet
20. Total Passing Time	4	00.00 Seconds
21. Distance To Critical Point	4	In Feet
22. Time To Critical Point	4	00.00 Seconds (Time At Critical Position)

ITEM	COLUMNS	CODING INFORMATION
23. Trailing Distance Of Passing Vehicle	3	In Feet (Distance Behind Vehicle)
24. Beginning Point Of Pass	1	Jump = 1 Before 1000' Zone = 2 Within 1000' Zone = 3 Within Dashed System = 4
25. End Point Of Pass	1	Before 1000' Zone = 1 Within 1000' Zone = 2 Within Dased System = 3 Clip = 4 Ended In Following Zone = 5
26. Clip Distance	3	In Feet
27. Demarcation System Installation Date	6	Example - 10 22 79 (Obtain From Files)
28. Opposing Vehicle Distance	4	Unknown = Blank No Opposing Vehicle = 0 Opposing Vehicle = Distance In Feet
CARD II		
29. Trailing Information	50	Each Column Represents a Column Number Coding By Zone: Blank = Did Not Trail 1 = Trailed And Rejected Opportunity To Pass 2 = Trailed - No Opportunity To Pass Because Of Limited Sight Distance 3 = Trailed - No Opportunity To Pass Due To Opposing Traffic 4 = Aborted Pass

ITEM	COLUMNS	CODING INFORMATION
30. Vehicle Number	3	Vehicle Number From Forms
31. Study Site	1	Same As Item 2
32. Data Type	1	Before = 1
		After = 2

Exhibit A-6. Sample Output of Sorted Maneuver Data

TEXAS SITE 2 NIGHT TIME BEFORE DATA GOOD PASSES ONLY

TIMECRPT	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
0996	1	57	1.639	93.443
1015	1	58	1.639	95.082
1065	1	59	1.639	96.721
1296	1	60	1.639	98.361
1621	1	61	1.639	100.000

TRDIST	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
055	4	4	6.557	6.557
065	3	7	4.918	11.475
070	5	12	8.197	19.672
075	1	13	1.639	21.311
080	1	14	1.639	22.951
085	3	17	4.918	27.869
090	2	19	3.279	31.148
095	5	24	8.197	39.344
105	4	28	6.557	45.902
115	7	35	11.475	57.377
125	6	41	9.836	67.213
135	4	45	6.557	73.770
140	2	47	3.279	77.049
145	1	48	1.639	78.689
165	4	52	6.557	85.246
175	1	53	1.639	86.885
190	1	54	1.639	88.525
215	3	57	4.918	93.443
235	2	59	3.279	96.721
295	1	60	1.639	98.361
315	1	61	1.639	100.000

PASBEGPT	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
1	2	2	3.279	3.279
2	31	33	50.820	54.098
3	7	40	11.475	65.574
4	21	61	34.426	100.000

PASENDPT	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
2	5	5	8.197	8.197
3	17	22	27.869	36.066
4	39	61	63.934	100.000

APPENDIX B

DRIVER SURVEY INFORMATION

Each survey included a descriptive letter, a driver information form, a map designating the location of the test site, and the survey to be completed. A stamped return envelope was also included.

This Appendix contains examples of a typical cover letter, a typical driver information form, and the site location maps for the nine study sites.

TEXAS A&M UNIVERSITY
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION TEXAS 77843

Transportation Systems Division

Exhibit B-1. Typical Cover Letter

Dear Motorist:

The Texas State Department of Highways and Public Transportation is working cooperatively with the Texas Transportation Institute in a research study to evaluate roadway markings and/or signs installed in several sections of rural two-lane roadway in the State of Texas.

Your vehicle was observed traveling through one of the test sections. Therefore, we would appreciate your answering the attached questions.

Your name is not requested on the survey form that you are being asked to complete. In this way, all answers will remain confidential and data will be used for statistical analysis purposes only.

Your mailing address was obtained from the Texas license plate records. If an error was made in reading the license plate and your vehicle was not driven through the test section, please just return the uncompleted survey form in the enclosed postage-paid envelope.

Thank you for your cooperation and assistance.

Sincerely,

Texas Transportation Institute

Exhibit B-2. Typical Driver Information Form

TEXAS DRIVER INFORMATION

(Test Site 1)

6 1. Age: 16-18 [1] 25-34 [3] 45-54 [5] Over 64 [7]
19-24 [2] 35-44 [4] 55-64 [6]

7 2. Sex: M [1] F [2]

8,9 3. Educational Background: (Circle Highest Grade Completed)

Elementary	High School	College	Graduate School
1 2 3 4 5 6 7 8	9 10 11 12	1 2 3 4 13 --- 16	1 2 3 4 17 --- 20

10 Master's 1 Ph.D 2 Others 3 _____

11 4. Occupation NO ANSWER -- 0 ANSWER -- 1 _____

12,13 5. How many years have you been driving? -- -- years

14 6. How many miles do you drive per year? 1 a. less than 10,000 per year
2 b. 10,000-20,000 per year
3 c. Over 20,000 per year

15 7. Approximately how many times have you driven on State Highway 103 between FM 147 and U. S. Highway 96 (east of Lufkin, Texas) since June 1979? (See map on reverse side of this page.)

[1] Only once
[2] 2-5 times
[3] 6-20 times
[4] more than 20 (estimate number) _____

.....

Survey begins on next page. Please answer all questions in the order presented. DO NOT READ AHEAD. Please do not go back to a completed question to change your original answer -- we wish to obtain your first thoughts on each question.

Thank you. This information and all data obtained during this study program will be held in strict confidence and used for statistical purposes only.

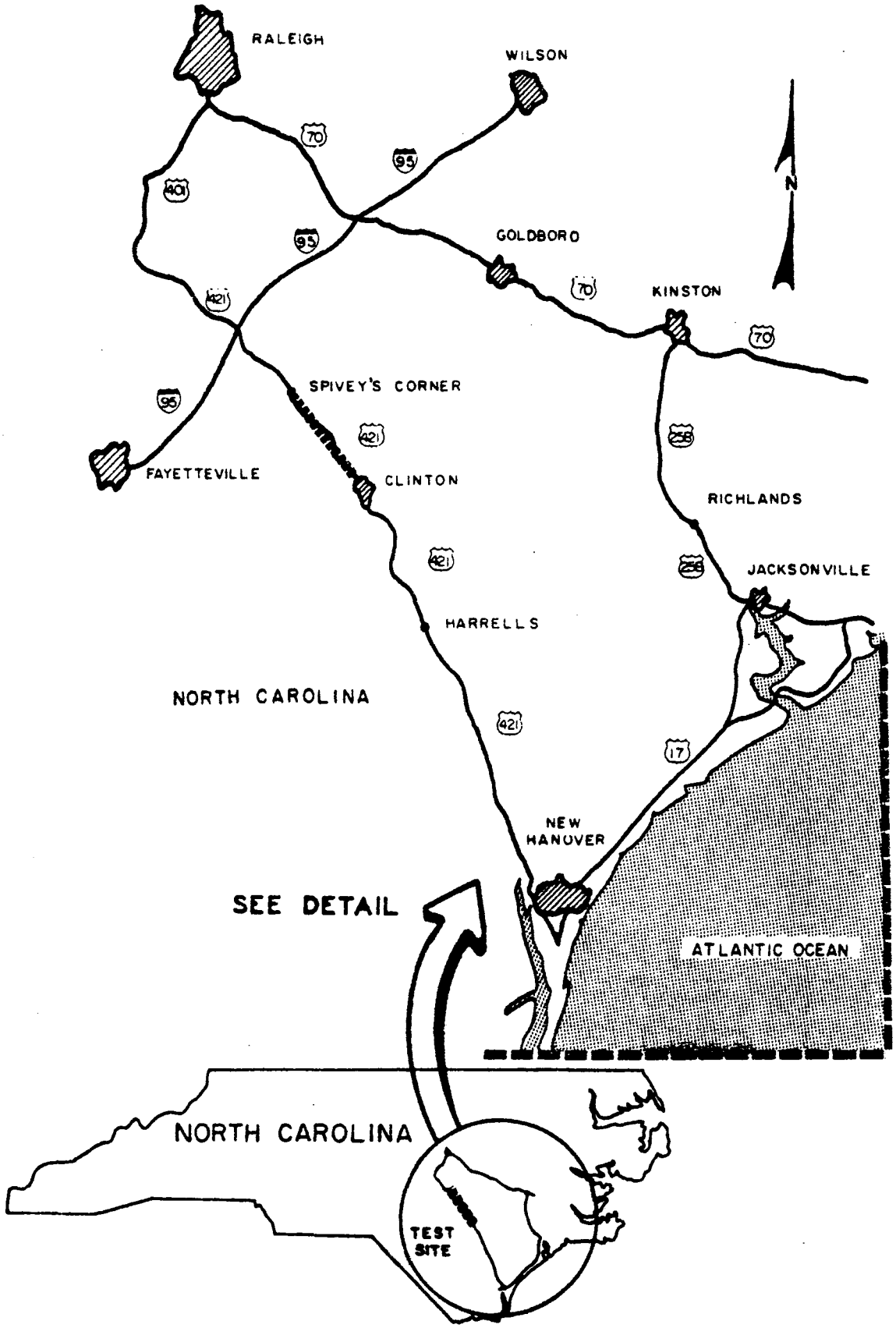


Exhibit B-3. Site Map -- Study Site NC-1 (Combination Treatment)

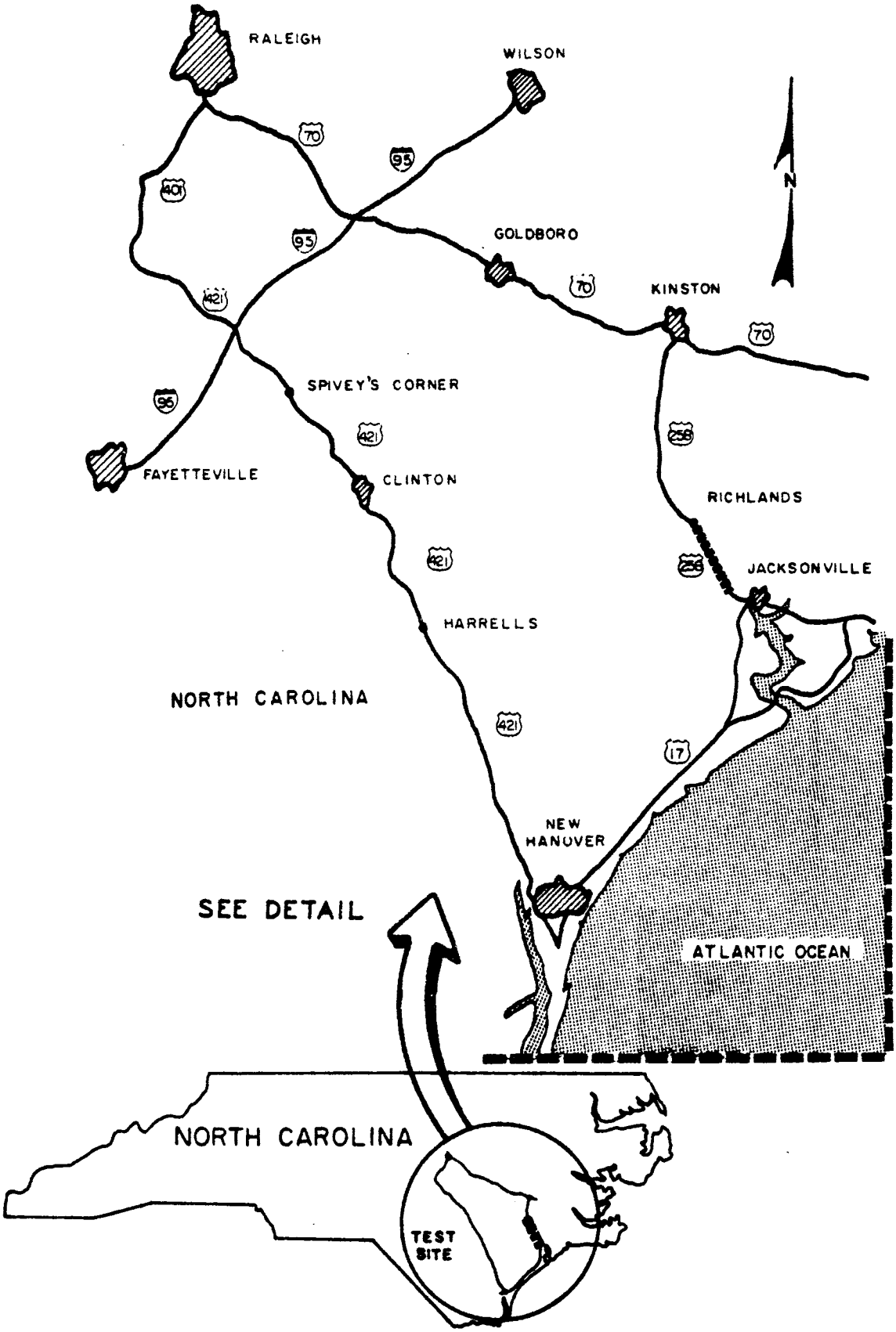


Exhibit B-4. Site Map -- Study Site NC-2 (Pennant Sign Only)

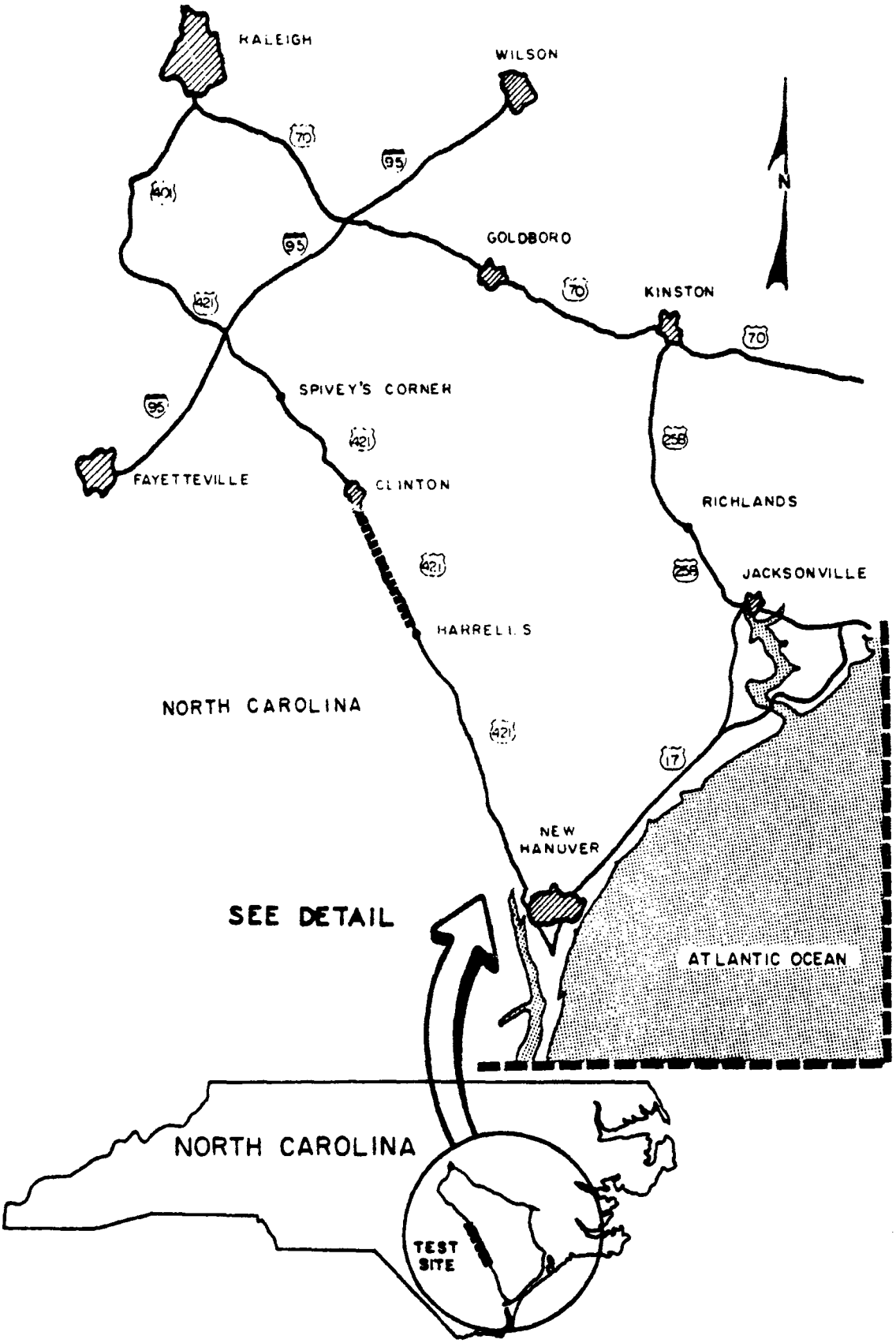


Exhibit B-5. Site Map -- Study Site NC-3 (Dotted Treatment Only)

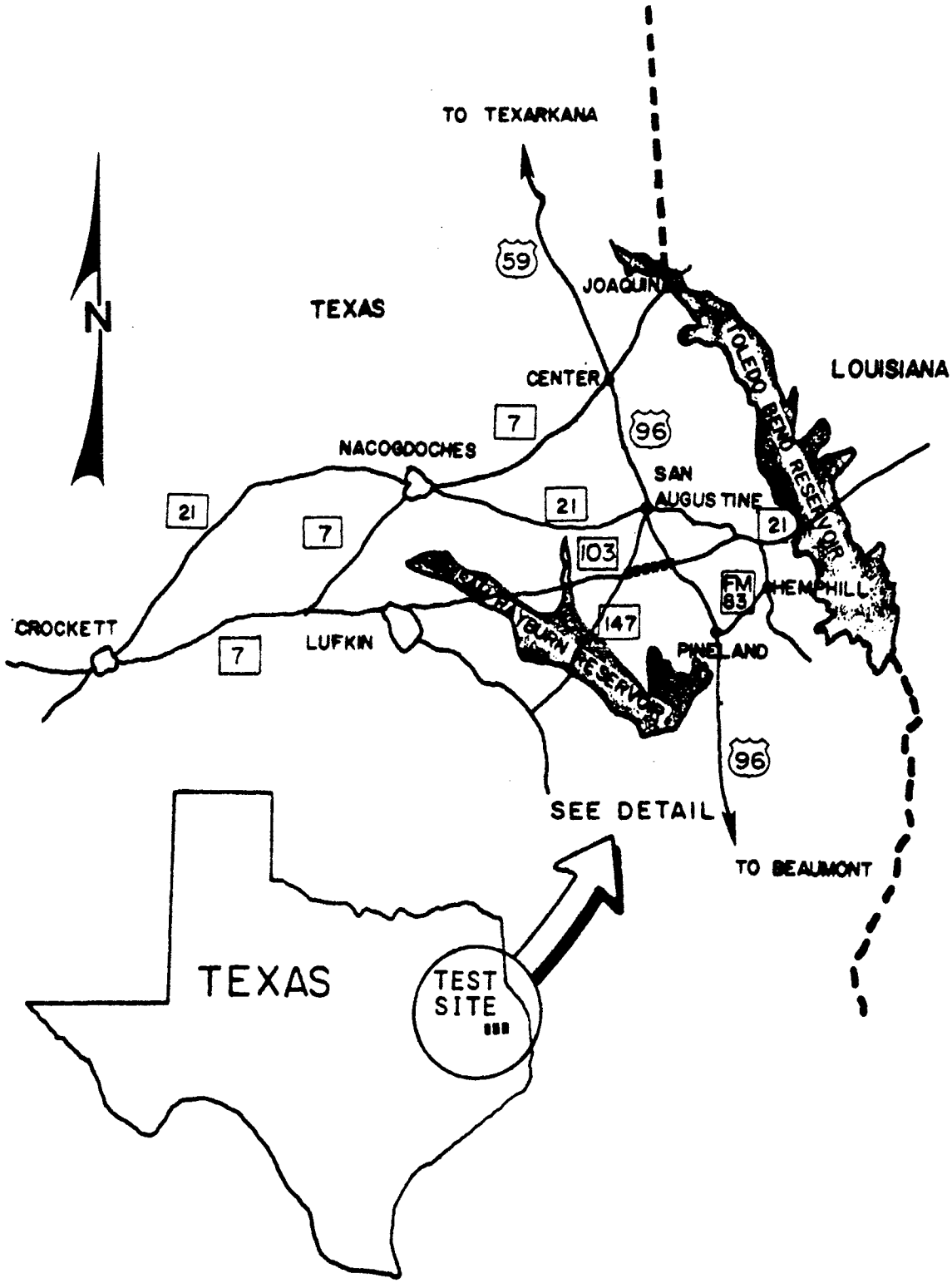


Exhibit B-6. Site Map -- Study Site T-1 (Combination Treatment)

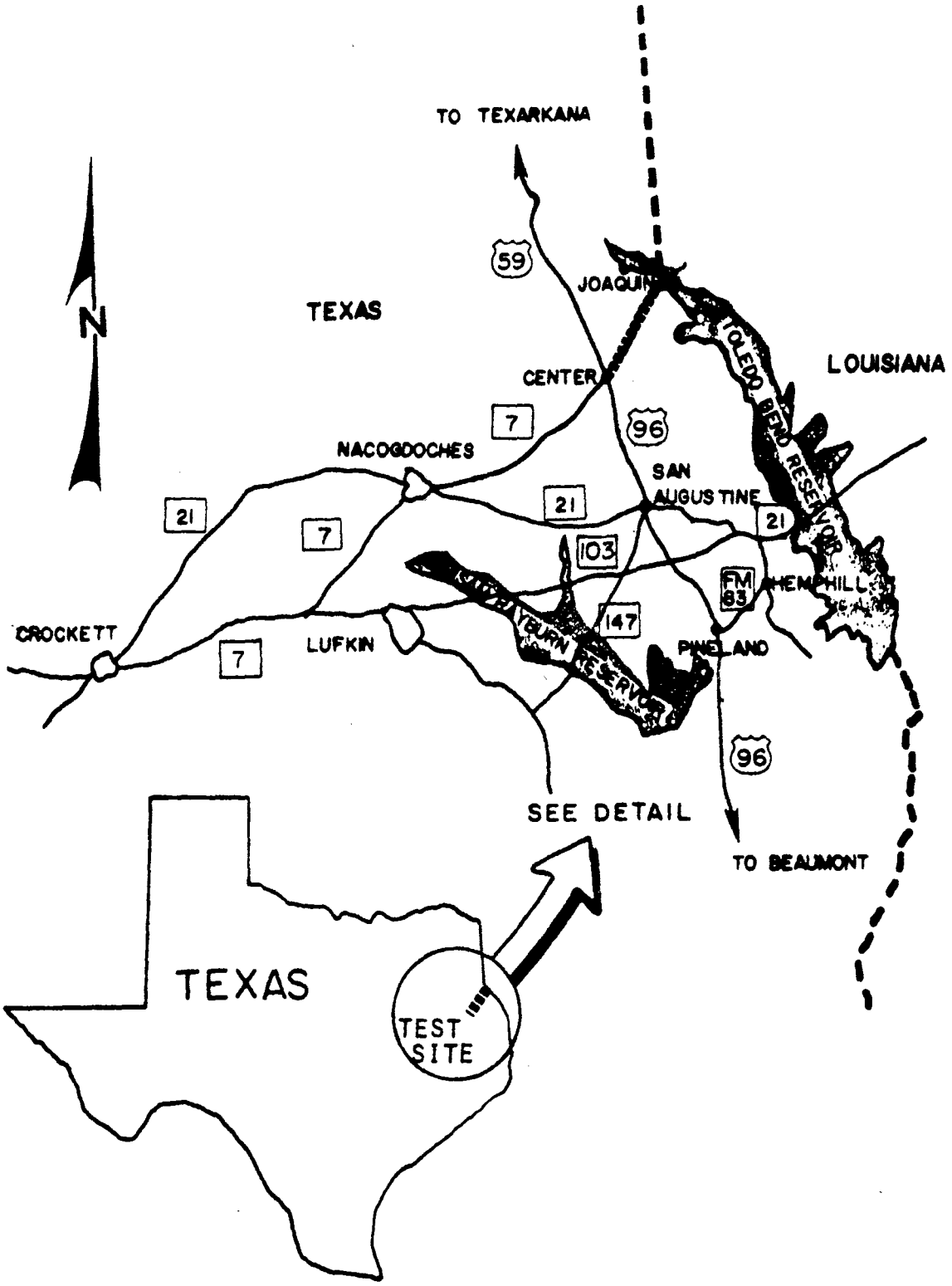


Exhibit B-7. Site Map -- Study Site T-2 (Pennant Sign Only)

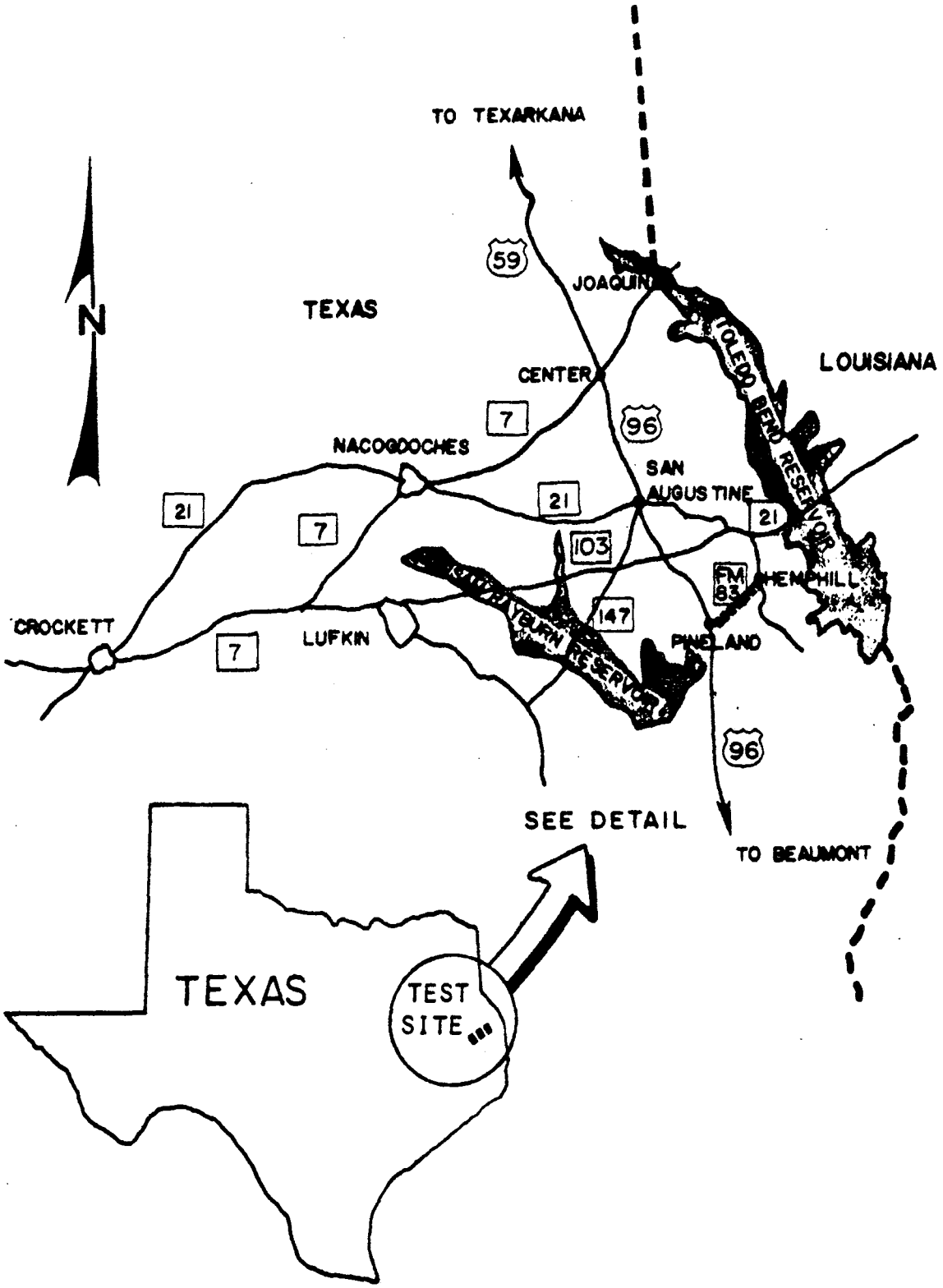


Exhibit B-8. Site Map -- Study Site T-3 (Dotted Treatment Only)

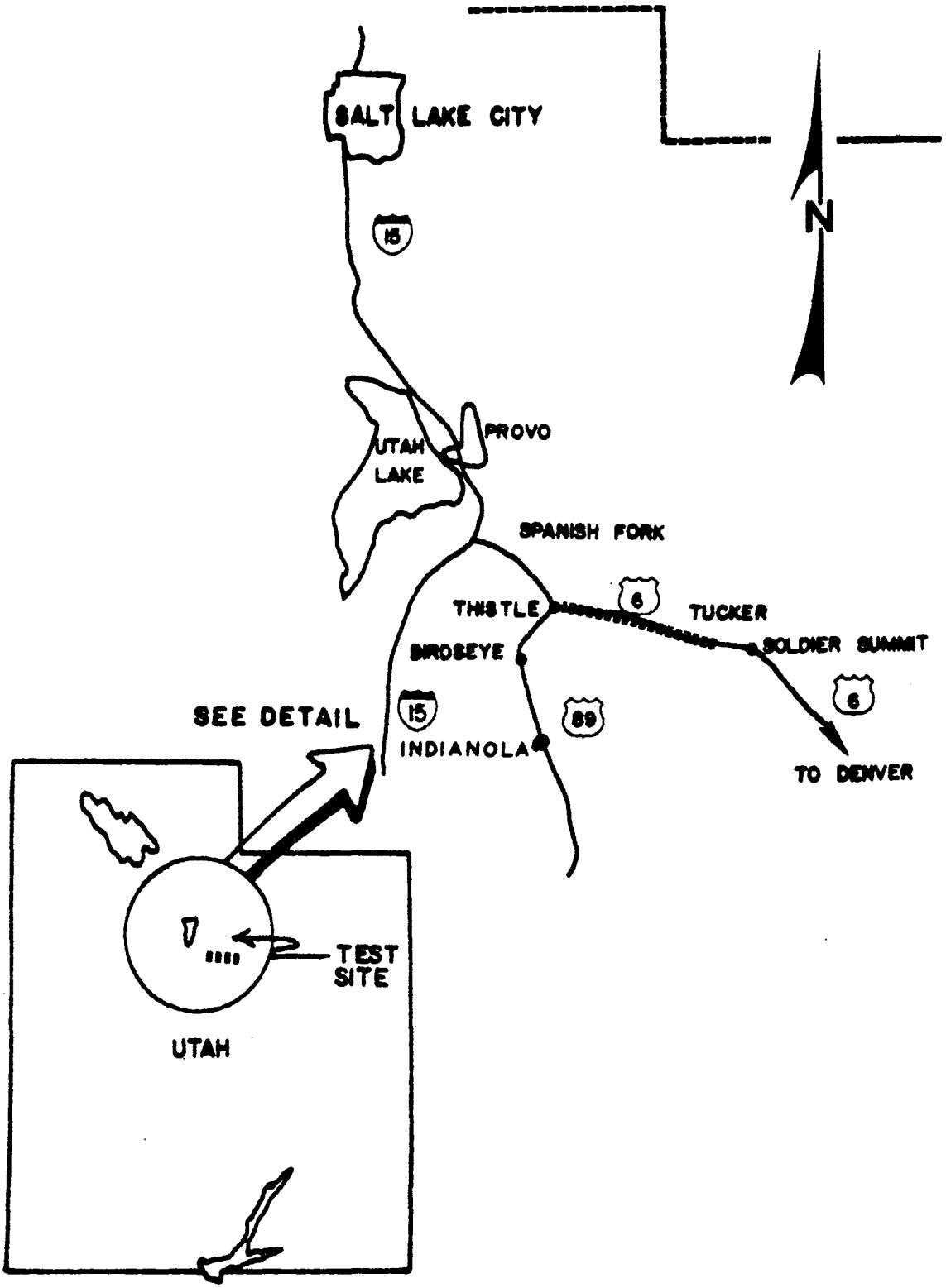


Exhibit B-9. Site Map -- Study Site U-1 (Combination Treatment)

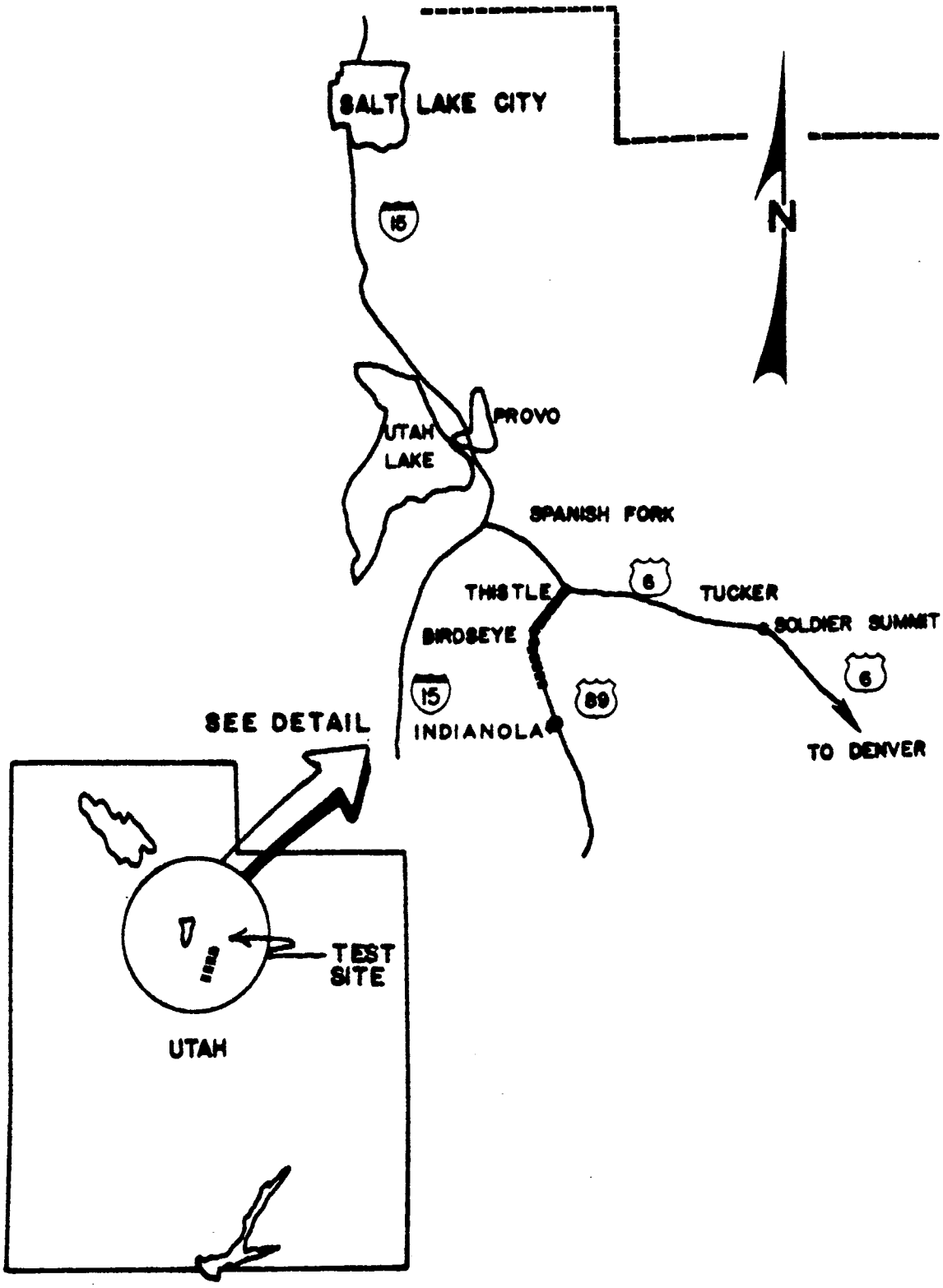


Exhibit B-10. Site Map -- Study Site U-2 (Pennant Sign Only)

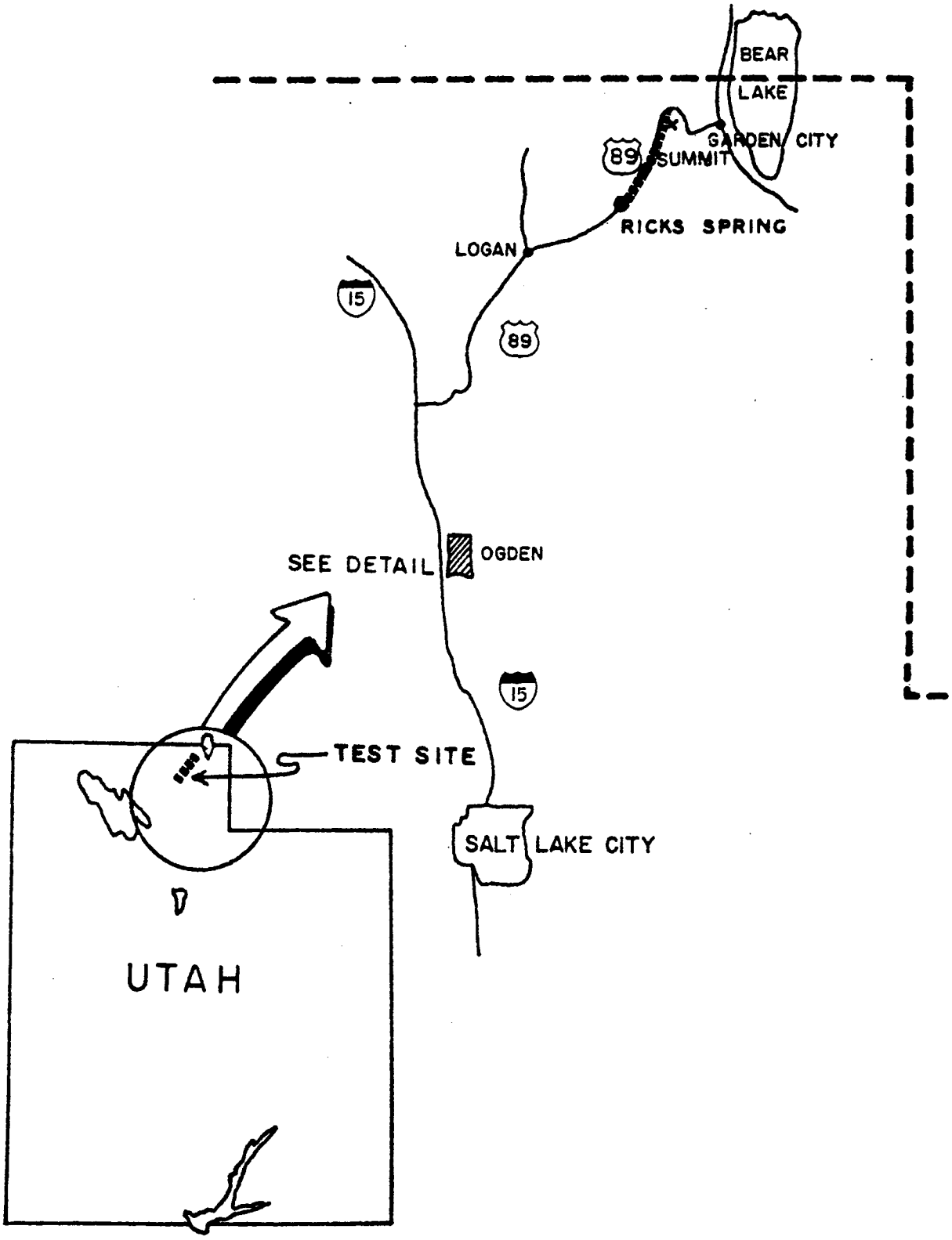


Exhibit B-11. Site Map -- Study Site U-3 (Dotted Treatment Only)

APPENDIX C

DRIVER SURVEY -- COMBINATION TREATMENT

This Appendix contains the driver survey that was sent to drivers who were observed executing a passing maneuver in the three study sites containing the advanced dotted line treatment and the NO-PASSING ZONE pennant sign. Surveys were received from 27 subjects at site NC-1, 14 subjects at site T-1, and 15 subjects at site U-1.

Exhibit C-1. Driver Survey - Combination Treatment (Advance) Dotted Line and NO-PASSING ZONE Sign)

Please answer the following questions (use ballpoint pen, not pencil). Your name is not requested, and all answers will remain confidential; therefore, please answer the questions as frankly as you can.

Situation No. 1

Assume that you are driving along a two-lane rural highway (one lane in each travel direction) and you see the roadway pavement markings as shown in Figure 1. The dashed centerline (indicated by the letter "a" in Figure 1) is yellow; ahead, you see a solid yellow line (indicated by the letter "b" beginning at point 1 in Figure 1).

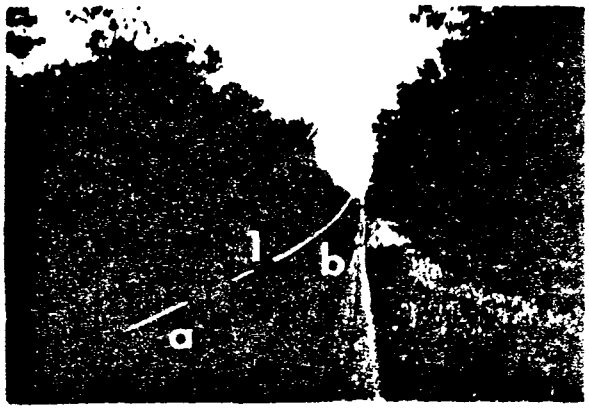


Figure 1

Question No. 1

What does the solid yellow line mean to you? (In other words, what is its legal intent?)
(Please write your answer below.)

16 Meaning of Solid Yellow Line: NO ANSWER -- 0

CORRECT ANSWER -- 1

INCORRECT ANSWER -- 2

Use this space to write additional comments if necessary:

17 Comments: NO COMMENT -- 0

COMMENT -- 1

(Survey continues on next page)

Situation No. 2

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 2). You are passing another vehicle in Region "a" when you see a solid line ahead of you (indicated by the letter "b" beginning at point (1) in Figure 2.)

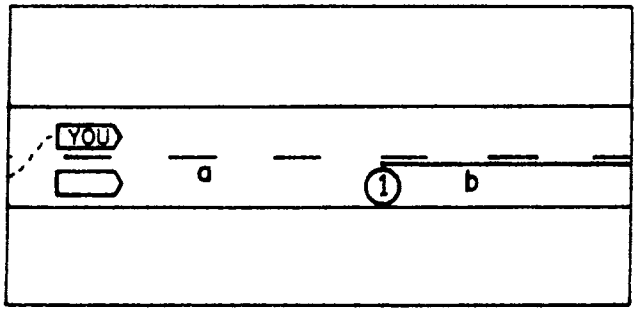


Figure 2

Question No. 2

Please check the answer below that you think is correct. (Check only one and write in any comments you wish to add regarding your answer choice).

18 ☐ I may legally complete my pass beyond point (1)

19 ☒ I should return to the right lane at or before reaching point (1) .

20 Comments: _____

_____

_____

_____

(Survey continues on next page)

Situation No. 3

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 3). You are traveling in Region "b" behind another vehicle.

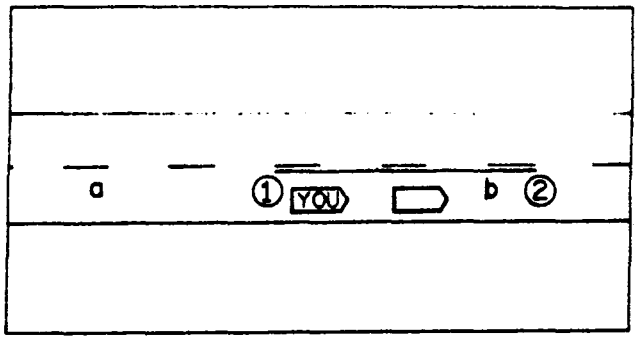


Figure 3

Question No. 3

Please check the answer below that you think is correct (Check only one answer and write in any comments you wish to add regarding your answer choice).

21 ☐ I may legally begin a pass before reaching point (2) .

22 ☒ I should begin a pass only after reaching point (2) .

23 Comments: _____

_____

_____

_____

(Survey continues on next page)

Situation No. 4

Assume that you are driving along in the right lane of the two-lane rural highway. Ahead, you see a pennant-shaped sign (Figure 4) facing you on the left side of the roadway and a series of short dashed lines on the right of the roadway centerline (indicated by the letter "c" in Figure 5).

Figure 4

Figure 5

Question No. 4

What does this series of short dashed lines and this sign mean to you? (Please check all answers that you think are correct.)

24 ☐ I do not have any idea what the short dashed lines mean.

25 ☐ I do not have any idea what the sign means.

26 ☐ I must not be in the left lane beyond the start of the short dashed lines.

27 ☒ I must not be in the left lane beyond the sign.

28 ☒ A no-passing zone is coming up ahead of me.

29 ☒ I must not begin to pass after reaching the start of the short dashed lines.

30 ☐ I must not begin to pass beyond the point where I can first see the sign.

31 ☐ I must not begin to pass beyond the point where I can first see the short dashed lines.

32 ☒ A no-passing zone will start at the sign.

33 ☐ A no-passing zone will start shortly beyond the sign.

34 ☒ I must not begin to pass after reaching the sign.

35 ☐ I may legally complete my pass beyond the sign.

36 ☐ A no-passing zone will start at the beginning of the short dashed lines.

37 ☒ A no-passing zone will start immediately at the far end of the short dashed lines.

38 ☐ A no-passing zone will start shortly beyond the far end of the short dashed lines.

39 ☐ Other meanings: (write your own) _____

_____

_____

40 Explanation of your answer(s) is desired: _____

_____

_____

(Survey Continues on Next Page)

Situation No. 5

Assume that you are in the act of passing another vehicle on the rural highway when you first see the short dashed lines and the pennant-shaped sign ahead. (You are in the left lane.)

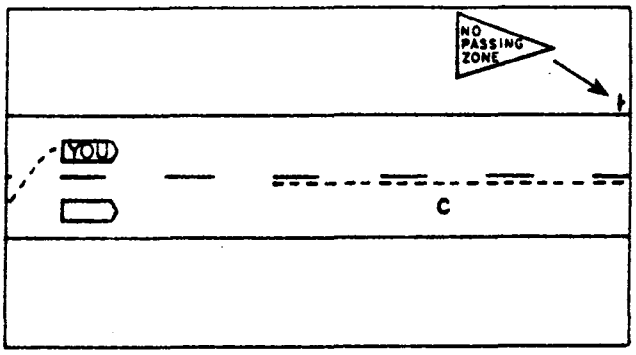


Figure 6

Question No. 5

What does this series of short dashed lines and this sign mean to you? (Please check all answers that you think are correct.)

41 ☐ I do not have any idea what the sign means.

42 ☐ I do not have any idea what the short dashed lines mean.

43 ☐ The sign does not apply to me because I am already passing.

44 ☐ I must complete my pass at or before reaching the start of the short dashed lines.

45 ☒ I must complete my pass at or before reaching the sign.

46 ☐ I may legally continue my pass and complete it beyond the sign.

47 ☐ The short dashed lines do not apply to me because I am already passing.

48 ☒ I may continue my pass beyond the start of the short dashed lines, but I must complete it at or before reaching the far end of the short dashed lines.

49 ☐ I may legally complete my pass beyond the far end of the short dashed lines.

50 ☒ A no-passing zone is coming up ahead of me.

51 ☐ Other meanings: (write your own) _____

_____

_____

_____

52 Explanation of your answer(s) is desired: _____

_____

_____

_____

(Survey continues on next page)

The pennant-shaped NO-PASSING ZONE sign and the short dashed line pavement markings are not widely used in your State. Your vehicle was observed traveling through a section of highway in which they were installed for test evaluation.

We would like your opinion of the advantages or disadvantages of using the sign and the short dashed lines on two-lane rural highways in your State.

Please place an "X" on the ranking scale line beside each statement to indicate how well you agree (or disagree) with the statement. The "X" may be placed anywhere along the line -- at a "tick-mark" or between "tick-marks."

	Totally Disagree	Strongly Disagree	Moderately Disagree	Undecided	Moderately Agree	Strongly Agree	Totally Agree
	1 2	3 4	5 6	7	8 9	10 11	12 13
53,54 Question No. 6							
The current method of marking no-passing zones (solid yellow line) is adequate for my passing information needs.							
Question No. 7							
The short dashed lines and the pennant sign are helpful to me when I am passing:							
55,56 (a) only one car ahead of me.							
57,58 (b) more than one car ahead of me.							
59,60 (c) a large truck.							
61,62 (d) at night.							
63,64 (e) during the day.							
65,66 (f) at dusk or dawn.							
67,68 (g) in rain.							
69,70 (h) in fog.							
71,72 (i) when it is snowing.							
73,74 (j) while looking into bright sun glare.							
75,76 (k) on a curve to the right.							
77,78 (l) on a curve to the left.							
79,80 (m) when approaching a hill.							
81,82 (n) when approaching a hidden dip in the road.							

	Totally Disagree		Strongly Disagree		Moderately Disagree		Undecided		Moderately Agree		Strongly Agree		Totally Agree
	1	2	3	4	5	6	7	8	9	10	11	12	13

33,84 Question No. 8

I soon recognized that the short dashed marking system meant something different than the normal dashed roadway centerline.

35,86 Question No. 9

After reading the message, NO-PASSING ZONE, on the first few signs, remaining pennant shaped signs were easily recognized long before I was close enough to read the message.

37,88 Question No. 10

I soon recognized that the short dashed marking system was intended to warn me that I was approaching a no-passing zone.

39,90 Question No. 11

I soon recognized that the pennant shaped sign was intended to warn me that I was approaching a no-passing zone.

	Totally Disagree		Strongly Disagree		Moderately Disagree		Undecided		Moderately Agree		Strongly Agree		Totally Agree
	1	2	3	4	5	6	7	8	9	10	11	12	13

Question No. 12

The Department of Transportation in my state should install, at all no-passing zones:

91,92 (a) Short dashed lines only

93,94 (b) Pennant-shaped signs only

95,96 (c) Both markings and signs

97 Question No. 13

Please add any additional comments you wish in the space below: _____

_____

_____

_____

(Use reverse side of page if additional space is needed).

Thank you for your cooperation and assistance.

Please return the completed survey in the enclosed postage-paid envelope to:

The Texas Transportation Institute
Texas A & M University
College Station, Texas 77843

APPENDIX D

DRIVER SURVEY -- NO-PASSING ZONE PENNANT SIGN ONLY

This Appendix contains the driver survey that was sent to drivers who were observed executing a passing maneuver in the three study sites containing the NO-PASSING ZONE pennant only. Surveys were received from 14 subjects at site NC-2, none from T-2 (not included in data sample), and 15 subjects from site U-2.

Exhibit D-1. Driver Survey - NO-PASSING ZONE Pennant Sign Only

Please answer the following questions (use ballpoint pen, not pencil). Your name is not requested, and all answers will remain confidential; therefore, please answer the questions as frankly as you can.

Situation No. 1

Assume that you are driving along a two-lane rural highway (one lane in each travel direction) and you see the roadway pavement markings as shown in Figure 1. The dashed centerline (indicated by the letter "a" in Figure 1) is yellow; ahead, you see a solid yellow line (indicated by the letter "b" beginning at point 1 in Figure 1).

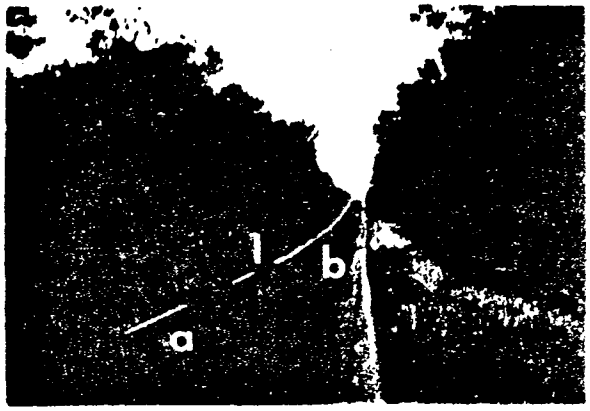


Figure 1

Question No. 1

What does the solid yellow line mean to you? (In other words, what is its legal intent?)
(Please write your answer below.)

16 Meaning of Solid Yellow Line: NO ANSWER -- 0

CORRECT ANSWER -- 1

INCORRECT ANSWER -- 2

17 Use this space to write additional comments if necessary:

Comments: NO COMMENT -- 0

COMMENT -- 1

(Survey Continued on Next Page)

Situation No. 2

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 2). You are passing another vehicle in Region "a" when you see a solid line ahead of you (indicated by the letter "b" beginning at point (1) in Figure 2.)

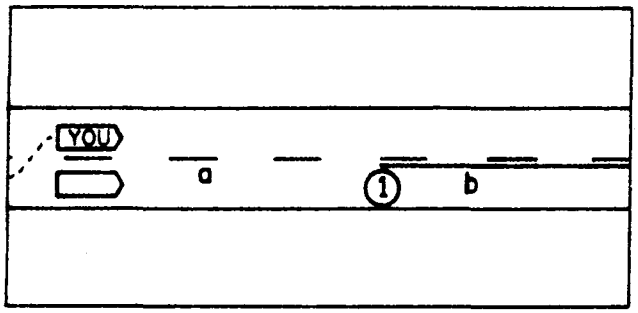


Figure 2

Question No. 2

Please check the answer below that you think is correct. (Check only one and write in any comments you wish to add regarding your answer choice).

18 ☐ I may legally complete my pass beyond point (1)

19 ☒ I should return to the right lane at or before reaching point (1)

20 Comments: _____

_____

_____

_____

(Survey Continued on Next Page)

Situation No. 3

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 3). You are traveling in Region "b" behind another vehicle.

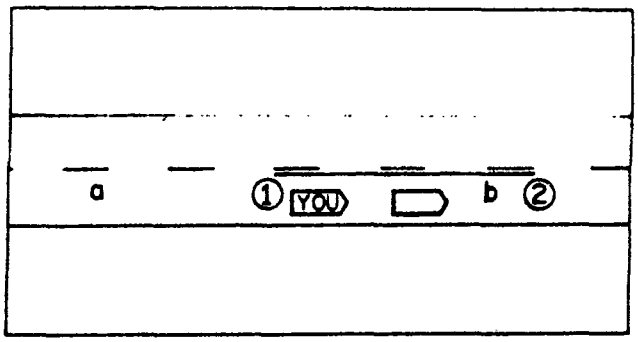


Figure 3

Question No. 3

Please check the answer below that you think is correct (Check only one answer and write in any comments you wish to add regarding your answer choice).

21 ☐ I may legally begin a pass before reaching point (2) .

22 ☒ I should begin a pass only after reaching point (2) .

23 Comments: _____

_____

_____

_____

(Survey Continued on Next Page)

Situation No. 4

Assume that you are driving along in the right lane of the two-lane rural highway. Ahead, you see a pennant-shaped sign (Figure 4) facing you on the left side of the roadway.

Figure 4

Question No. 4

What does this sign mean to you? (Please check all answers that you think are correct).

25 ☐ I do not have any idea what the sign means.

32 ☒ A no-passing zone will start at the sign.

33 ☐ A no-passing zone will start shortly beyond the sign.

34 ☒ I must not begin to pass after reaching the sign.

30 ☐ I must not begin to pass beyond the point where I can first see the sign.

28 ☒ A no-passing zone is coming up ahead of me.

39 ☐ Other meanings: (Write your own) _____

_____

_____

40 Explanation of your answer(s) is desired: _____

_____

_____

(Survey Continued on Next Page)

Situation No. 5

Assume that you are in the act of passing another vehicle on the rural highway when you first see the pennant-shaped sign ahead of you on the left side of the road. (You are in the left lane).

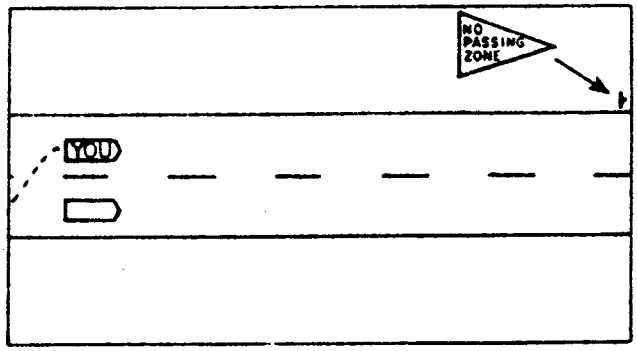


Figure 5

Question No. 5

What does this sign mean to you? (Please check all answers that you think are correct.)

41 ☐ I do not have any idea what the sign means.

43 ☐ The sign does not apply to me because I am already passing.

45 ☒ I must complete my pass at or before reaching the sign.

46 ☐ I may legally continue my pass and complete it beyond the sign.

50 ☒ A no-passing zone is coming up ahead of me.

51 ☐ Other meanings: (Write your own) _____

_____

_____

_____

52 Explanation of your answer(s) is desired: _____

_____

_____

_____

(Survey Continued on Next Page)

The pennant-shaped NO-PASSING ZONE sign is not widely used in your State. Your vehicle was observed traveling through a section of highway in which it was installed for test evaluation.

We would like your opinion of the advantages or disadvantages of using the pennant shaped sign on two-lane rural highways in your State.

Please place an "X" on the ranking scale line beside each statement to indicate how well you agree (or disagree) with the statement. The "X" may be placed anywhere along the line -- at a "tick-mark" or between "tick-marks."

		1 Totally Disagree	2	3 Strongly Disagree	4	5 Moderately Disagree	6	7 Undecided	8	9 Moderately Agree	10	11 Strongly Agree	12	13 Totally Agree
53,54	Question No. 6													
	The current method of marking no-passing zones (solid yellow line) is adequate for my passing information needs.													
	Question No. 7													
	The pennant-shaped sign is helpful to me when I am passing:													
55,56	(a) only one car ahead of me.													
57,58	(b) more than one car ahead of me.													
59,60	(c) a large truck.													
61,62	(d) at night.													
63,64	(e) during the day.													
65,66	(f) at dusk or dawn.													
67,68	(g) in rain.													
69,70	(h) in fog.													
71,72	(i) when it is snowing.													
73,74	(j) while looking into bright sun glare.													
75,76	(k) on a curve to the right.													
77,78	(l) on a curve to the left.													
79,80	(m) when approaching a hill.													
81,82	(n) when approaching a hidden dip in the road.													

	Totally Disagree		Strongly Disagree		Moderately Disagree		Undecided		Moderately Agree		Strongly Agree		Totally Agree
	1	2	3	4	5	6	7	8	9	10	11	12	13

85,86 Question No. 8

After reading the message, NO-PASSING ZONE, on the first few signs, remaining pennant shaped signs were easily recognized long before I was close enough to read the message.

89,90 Question No. 9

I soon recognized that the pennant shaped sign was intended to warn me that I was approaching a no-passing zone.

93,94 Question No. 10

The pennant shaped sign should be installed by the State Department of Transportation at all no-passing zones in my state.

97 Question No. 11

Please add any additional comments you wish in the space below: _____

_____

_____

_____

(Use reverse side of page if additional space is needed).

Thank you for your cooperation and assistance.

Please return the completed survey in the enclosed postage-paid envelope to:

The Texas Transportation Institute
Texas A & M University
College Station, Texas 77843

APPENDIX E

DRIVER SURVEY -- ADVANCE DOTTED LINE TREATMENT ONLY

This Appendix contains the driver survey that was sent to drivers who were observed executing a passing maneuver in the three study sites containing the advanced dotted treatment only. Surveys were received from 27 subjects at site NC-3, none from T-3 (not included in data sample), and 17 subjects at site U-3.

Exhibit E-1. Driver Survey - Advanced Dotted Line Only

Please answer the following questions (use ballpoint pen, not pencil). Your name is not requested, and all answers will remain confidential; therefore, please answer the questions as frankly as you can.

Situation No. 1

Assume that you are driving along a two-lane rural highway (one lane in each travel direction) and you see the roadway pavement markings as shown in Figure 1. The dashed centerline (indicated by the letter "a" in Figure 1) is yellow; ahead, you see a solid yellow line (indicated by the letter "b" beginning at point 1 in Figure 1).

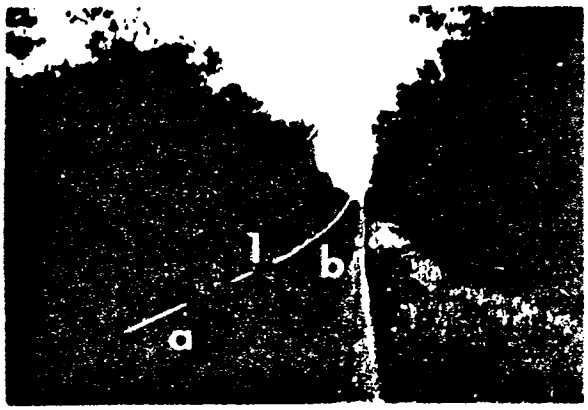


Figure 1

Question No. 1

What does the solid yellow line mean to you? (In other words, what is its legal intent?)
(Please write your answer below.)

16 Meaning of Solid Yellow Line: NO ANSWER--0

CORRECT ANSWER--1

INCORRECT ANSWER--2

17 Use this space to write additional comments if necessary:

Comments: NO COMMENT--0

COMMENT--1

(Survey continues on next page)

Situation No. 2

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 2). You are passing another vehicle in Region "a" when you see a solid line ahead of you (indicated by the letter "b" beginning at point 1 in Figure 2.)

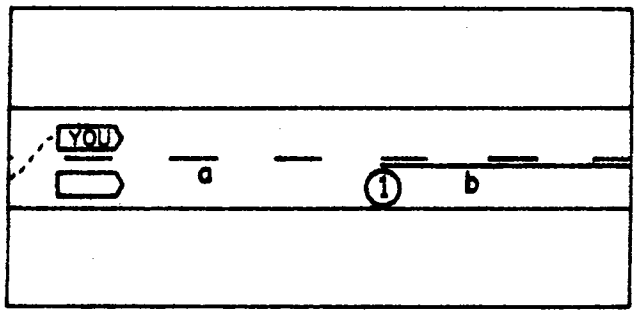


Figure 2

Question No. 2

Please check the answer below that you think is correct. (Check only one and write in any comments you wish to add regarding your answer choice).

18 ☐ I may legally complete my pass beyond point 1

19 ☒ I should return to the right lane at or before reaching point 1 .

20 Comments: _____

_____

_____

_____

(Survey continues on next page)

Situation No. 3

Assume that you are driving along the same two-lane rural highway (pavement markings as shown in Figure 3). You are traveling in Region "b" behind another vehicle.

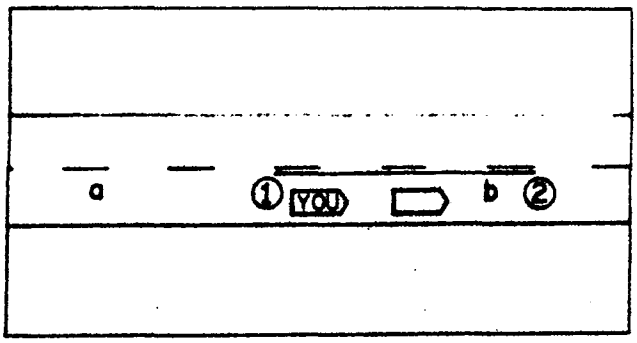


Figure 3

Question No. 3

Please check the answer below that you think is correct (Check only one answer and write in any comments you wish to add regarding your answer choice).

21 ☐ I may legally begin a pass before reaching point (2).

22 ☒ I should begin a pass only after reaching point (2).

23 Comments: _____

_____

_____

_____

(Survey continues on next page)

The short dashed line pavement marking system is not widely used in your State. Your vehicle was observed traveling through a section of highway in which it was installed for test evaluation.

We would like your opinion of the advantages or disadvantages of using the short dashed line pavement markings on two-lane rural highways in your State.

Please place an "X" on the ranking scale line beside each statement to indicate how well you agree (or disagree) with the statement. The "X" may be placed anywhere along the line -- at a "tick-mark" or between "tick-marks."

	Totally Disagree	Strongly Disagree	Moderately Disagree	Undecided	Moderately Agree	Strongly Agree	Totally Agree
	1 2	3 4	5 6	7	8 9	10 11	12 13
53,54 Question No. 6							
The current method of marking no-passing zones (solid yellow line) is adequate for my passing information needs.							
Question No. 7							
The short dashed marking system is helpful to me when I am passing:							
55,56 (a) only one car ahead of me.							
57,58 (b) more than one car ahead of me.							
59,60 (c) a large truck.							
61,62 (d) at night.							
63,64 (e) during the day.							
65,66 (f) at dusk or dawn.							
67,68 (g) in rain.							
69,70 (h) in fog.							
71,72 (i) when it is snowing.							
73,74 (j) while looking into bright sun glare.							
75,76 (k) on a curve to the right.							
77,78 (l) on a curve to the left.							
79,80 (m) when approaching a hill.							
81,82 (n) when approaching a hidden dip in the road.							

	Totally Disagree	Strongly Disagree	Moderately Disagree	Undecided	Moderately Agree	Strongly Agree	Totally Agree
	1 2	3	4 5	6 7	8 9	10 11	12 13

13,84 Question No. 8

I soon recognized that the short dashed marking system meant something different than the normal dashed roadway centerline.

17,88 Question No. 9

I soon recognized that the short dashed marking system was intended to warn me that I was approaching a no-passing zone.

1,92 Question No. 10

The short dashed marking system should be installed by the State Department of Transportation at all no-passing zones in my state.

97 Question No. 11

Please add any additional comments you wish in the space below: _____

_____

_____

_____

(Use reverse side of page if additional space is needed).

Thank you for your cooperation and assistance.

Please return the completed survey in the enclosed postage-paid envelope to:

The Texas Transportation Institute
Texas A & M University
College Station, Texas 77843

APPENDIX F

DRIVER SURVEY RESPONSES

CONTROL QUESTIONS

Questions 1, 2, 3 in each survey were identical and were used to determine how subject drivers interpreted the conventional solid yellow no-passing zone stripe and to identify their operational behavior with respect to "clipping" and "jumping." In all three States, the solid yellow line is used to designate no-passing zones; hence driving to the left of this line is illegal. Also, all three States establish and enforce no-passing zones on the short zone concept; hence drivers should complete the passing maneuver at or before reaching the solid line (i.e., no "clipping" allowed). "Jumping" is prohibited in all three States.

All surveys in which subject drivers answered any of questions 1, 2, or 3 incorrectly were ommitted from the sample because it was believed that if they did not correctly interpret conventional markings, they could not correctly deduce the meaning of the experimental treatments. Of the 150 surveys returned, 46 subjects incorrectly answered at least one of the three control questions. Thirteen were disqualified because they incorrectly interpreted the meaning of the solid yellow line (Question 1). Only two were disqualified because they indicated that "jumping" was legal (Question 3). The remainder of the 46 were disqualified because they indicated that "clipping" was legal (Question 2). The sample, therefore, included 104 surveys from all three States. Of the nine surveys returned from those drivers observed in sites T-2 and T-3 at night, only six answered the three control questions correctly. These surveys were not included in the driver survey evaluation due to the small sample size.

SURVEY RESEARCH CODING

Each survey response was assigned a coding number corresponding to a computer column number. Columns 1 through 5 are reserved for computer job control. The driver information is coded in columns 6 through 15 (Exhibit B-2, Appendix B). Columns 16 through 97 include all coded responses for questions in the combination treatment survey (Appendix C, Exhibit C-1).

Questions in the other two surveys that are identical to one in the combination survey are assigned identical codes to facilitate computer analysis. An example is presented: The fifth response to question number 4 in the combination survey (Appendix C) is, "A no-passing zone is coming up ahead of me." This same statement appears as response number 6 to question 4 in the sign-only survey (Apendix D) and as response number 2 to question 4 in the marking-only survey (Appendix E). All three responses are designated as Code 28.

All coding was added after surveys were received. The subjects' surveys contained no coding numbering.

DEFINITION OF TERMS IN DATA SUMMARY TABLES

Response Code

The term "Response Code" refers to the numerical code assigned to each survey response and located adjacent to the survey responses in Appendices B, C, D and E. These codes are used in some tabular data so that the reader may refer to the particular question or sub-element of a question in the survey.

"N" Term

The term "N" represents the number of surveys received or the number of responses to a particular question within a survey. Since every subject did not necessarily complete all questions within a survey (either by oversight, refusal to answer, etc), the N-values for a question containing several parts may be different within the total question responses.

Response Ratings

Subjects were asked to rate (rank) the degree to which they agreed or disagreed with statements in the survey. The rating technique permits numeri-

cal analysis of a subjective opinion. The ranking scale was linear with five categories between "totally disagree" and "totally agree". The numerical values from 1 to 13 (see Appendix C, questions 6 through 12) were assigned to the categories for analysis purposes -- no codes were shown on the surveys. Ranking values were:

1. Totally Disagree
3. Strongly Disagree
5. Moderately Disagree
7. Undecided
9. Moderately Agree
11. Strongly Agree
13. Totally Agree

The subject was asked to place an "X" on the ranking scale line beside each statement to indicate how well he (she) agreed or disagreed with the statement. The "X" could be placed anywhere along the line -- a "tick mark" or between "tick marks." Therefore, the mid-point of each category was assigned a numerical rank to achieve greater accuracy in calculation.

RESPONSES TO QUESTIONS

Tables F-1 through F-17 present summarized responses for all questions in the surveys that were received. Responses to each question are discussed individually. The combination treatment survey (Appendix C) in each State contained all questions that were included in the sign-only survey and the marking-only survey, although identical questions in the two separate treatment surveys are numbered differently than those in the combination treatment survey. Therefore, the questions are discussed according to the combination treatment survey designation (Appendix C) with appropriate cross-reference to the individual surveys (Appendices D and E).

Question Format

The human factors studies in the previous no-passing zone study (2) had contained open-ended questions in the first series, followed by an extensive

series of closed questions (objective multiple choice format) as patterns of responses developed. The questions in this survey were all objective type although space was provided for additional comments for each question. In addition, many of the questions contained the rating scales to quantify response conviction.

QUESTIONS 1, 2, AND 3 -- CONTROL QUESTIONS

As discussed previously, the first three questions were identical on all surveys. The objective of these questions was to determine if a subject understood the intent of the conventional solid yellow line with respect to "clipping", "jumping", and prohibition of passing throughout the length of the yellow line. Those subjects who responded incorrectly to these questions were removed from further evaluation. Forty-six of the 150 surveys received were eliminated from the sample due to incorrect responses to at least one of the control questions leaving a sample of 104 surveys.

CORRECT INTERPRETATION OF EXPERIMENTAL TREATMENTS (Table F-1)

Questions 4 and 5 of each survey were included to determine subjects' interpretation of the meaning(s) of the experimental treatment. It was desired to determine:

1. How many subjects deduced the three specific meanings (and only these),
2. How many subjects misinterpreted the treatment meaning, and
3. How many subjects recognized the position of the no-passing zone with respect to the device.

The situation in Question 4 under which subjects were to evaluate the meaning was one in which the driver was not passing -- merely driving along the highway and observing the treatment. All drivers who were surveyed had traveled through at least five no-passing zones before being considered as a subject. Only drivers who executed a passing maneuver or were presented ample opportunity to pass within the treated site were considered as subjects.

Table F-1 summarizes the number of subjects who totally understood the intended meaning of the experimental treatment and those who deduced the three meanings but also checked at least one incorrect meaning. None of the 33 combination survey subjects correctly responded to only the "correct" answers to Question 4 (i.e., they did not check any incorrect responses).

Six of the 28 sign-only survey subjects responded absolutely correctly (no incorrect responses), and 4 of the 43 marking-only survey subjects checked all "correct" rsponses. Therefore, slightly less than 10 percent (9.6 percent) of the 104 subjects demonstrated total understanding of the three intended meanings of the experimental treatments. An additional six subjects checked all "correct" responses plus at least one "incorrect" response. The common "incorrect" response for these six subjects was misinterpretation of where the no-passing zone started with respect to the device and that they could not begin to pass beyond the point where they could first see the device. They indicated that the no-passing zone started shortly beyond the device (rather than immediately at the device. One of the six subjects also indicated that he (she) shouldn't be in the left lane beyond the start of the dotted lines (response code 26). None of the "incorrect" responses represent a serious misinterpretation. Although these responses are technically incorrect, from a safety aspect, operations under these interpretations would not be severely affected. Since the pennant sign can be seen at about 1200 ft (366 m), "not beginning a pass beyond the point where the sign can first be seen" (Response 30) produces a slight safety margin. It does, however, increase the length of safe passing distance by about 500 ft (152 m) when this interpretation is made.

The interpretation that "a no-passing zone will start shortly beyond the sign" (Response 33) represents a subjective evaluation of the term "shortly beyond." If these subjects interpreted "shortly beyond" to mean merely a few feet (meaning that sign position and start of yellow line were not exactly aligned) the net effect on operation would be negligible.

Table F-1. Summary of "Correct" Responses to Questions 4 and 5 -- Driver Interpretation of Meaning

	North Carolina (N=41)						Texas (N=10)						Utah (N=35)					
	Combination		Sign		Marking		Combination		Sign		Marking		Combination		Sign		Marking	
	13 Surveys		8 Surveys		20 Surveys		10 Surveys		8 Surveys		10 Surveys		10 Surveys		12 Surveys		13 Surveys	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Question 4																		
Only all Correct Responses (1)	0	0	1	13	3	15	0	0	2	25	0	0	0	0	3	25	1	8
All Correct plus some Incorrect Responses (2)	1	8	1	13	2	10	0	0	0	0	1	10	0	0	1	8	0	0
Question 5																		
Only all Correct Responses (1)	1	8	4	50	7	35	2	20	2	25	2	20	0	0	6	50	1	8
All Correct plus Some Incorrect Responses (2)	0	0	0	0	0	0	0	0	0	0	0	0	1	10	1	8	1	8

NOTES:

(1) These subjects checked only the "correct" responses and no other incorrect responses.

(2) These subjects checked the "correct" responses and at lease one incorrect response. The "all-correct-only" subjects are not included in this sample.

The situation in Question 5 under which the subjects were to evaluate the meaning was one in which the subject observed the treatment while in the act of passing another vehicle. The "correct" responses and "correct" plus at least one "incorrect" responses to Question 5 are summarized in Table F-1. Twenty-five of the 104 subjects (24 percent) checked only the correct responses in the applicable surveys -- almost a threefold increase in demonstrated total understanding over the Question 4 driving situation. Only 3 additional subjects checked all "correct" responses plus at least one additional "incorrect" response. One of the three thought that he (she) must complete the pass before the dotted treatment (combination survey). The sign-only subject stated that it was legal to complete the pass beyond the sign. The marking-only subject stated that the pass could be completed beyond the far end of the dotted treatment. The former is a safe misinterpretation; the latter two indicated either that the subjects did not recognize the position of the solid yellow line or that they believed clipping was permitted.

Three sign-only subjects answered all parts correctly but include some incorrect answers (at least one). One checked Response Code 30 (incorrect) and two subjects checked Response Code 33 (incorrect). Although these responses are technically incorrect, from a safety aspect, operations under these interpretations would not be severely affected. Since the pennant sign can be seen at about 1200 ft (366 m), "not beginning a pass beyond the point where the sign can first be seen" (Response 30) produces a slight safety margin. It does, however, increase the length of safe passing distance by about 500 ft (152 m) when this interpretation is made.

The interpretation that "a no-passing zone will start shortly beyond the sign" (Response 33) represents a subjective evaluation of the term "shortly beyond." If these subjects interpreted "shortly beyond" to mean merely a few feet (meaning that sign position and start of yellow line were not exactly aligned) the net effect on operation would be negligible.

Table F-2 contains a summary of responses to question 4 by the subjects from all States who received the three surveys categorized by individual survey (Columns 1 through 10) and by total responses to identical questions in Columns 11 through 14. By comparing responses from subjects who observed the combination treatment with responses to identical questions by subjects who observed only the sign treatment or only the marking treatment, the relative effect of the individual components can be estimated. Intuitively, it would be expected that the level of understanding of a particular question (meaning) would be greater for those subjects who observed the combination treatment than for those subjects who observed only the sign treatment or only the marking treatment. This can be evaluated by comparison of identical question responses in Columns 11 through 12 and 13 through 14 with the appropriate combination question responses in Columns 1 through 10 in Table F-2.

Tables F-3, F-4, and F-5 present similar response data categorized by individual State so that differences in interpretation among drivers in the three States can be identified. Tables F-3, F-4, and F-5 contain response information by subjects from North Carolina, Texas and Utah, respectively.

Combination Treatment Survey Responses (All 104 Subjects)

The six "correct" responses (Codes 27, 28, 29, 32, 34, and 37) were in general well understood. (See Column 4, Table F-2.) With the exception of response Code 37, at least half of the subjects checked all the correct responses. Only 18 percent of the subjects recognized that the no-passing zone began at the far end of the dotted marking whereas 55 percent of the subjects recognized that it began at the pennant sign.

The most significant misinterpretations by a substanital percent of the subjects involved Response Codes 31 (33 percent) and 36 (42 percent). The misinterpretation of Response Code 36 infers that these subjects are considering that the length of roadway containing the dotted lines is a no-passing zone rather than a pass completion zone. Although this would improve passing safety, it also decreases the length of roadway in which passing could be safely executed.

Table F-2. Responses to Question 4 -- Driver Understanding of Treatments (All States, 104 Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=33)			Sign-Only Treatment Survey (Ref. Appendix D) (N=28)			Marking-Only Treatment Survey (Ref. Appendix E) (N=43)			Total Responses to Identical Questions on Combination Treatment & Sign-Only Surveys (N=61)		Total Responses to Identical Questions on Combination Treatment & Marking-Only Surveys (N=76)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
24	4.1	8	24	NA	--	--	4.1	15	35	NA	--	23	30
25	4.2	2	6	4.1	1	4	NA	--	--	3	5	NA	--
26	4.3	14	44	NA	--	--	NA	--	--	NA	--	NA	--
27	4.4*	20	61	NA	--	--	NA	--	--	NA	--	NA	--
28	4.5*	20	61	4.6*	14	50	4.2*	20	47	34	56	40	53
29	4.6*	16	49	NA	--	--	4.3*	18	42	NA	--	34	45
30	4.7	15	46	4.5	8	29	NA	--	--	23	38	NA	--
31	4.8	11	33	NA	--	--	4.6	10	23	NA	--	21	28
32	4.9*	18	55	4.2*	15	54	NA	--	--	33	54	NA	--
33	4.10	10	30	4.3	5	18	NA	--	--	15	25	NA	--
34	4.11*	21	64	4.4*	15	54	NA	--	--	36	59	NA	--
35	4.12	1	3	NA	--	--	NA	--	--	NA	--	NA	--
36	4.13	14	42	NA	--	--	4.4	9	21	NA	--	23	30
37	4.14*	6	18	NA	--	--	4.5*	13	30	NA	--	19	25
38	4.15	0	0	NA	--	--	4.7	5	12	NA	--	5	7

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses/N) x 100 %
Astrices indicate "correct" responses

Table F-3. Responses to Question 4 -- Driver Understanding of Treatments (North Carolina Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=13)			Sign-Only Treatment Survey (Ref. Appendix D) (N= 8)			Marking-Only Treatment Survey (Ref. Appendix E) (N=20)			Total Responses to Identical Questions on Combination Treatment & Sign-Only Surveys (N=21)		Total Responses to Identical Questions on Combination Treatment & Marking-Only Surveys (N=33)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
24	4.1	2	15	NA	-	-	4.1	5	25	-	-	7	21
25	4.2	0	0	4.1	0	0	NA	-	-	0	0	-	-
26	4.3	5	39	NA	-	-	NA	-	-	-	-	-	-
27	4.4*	8	62	NA	-	-	NA	-	-	-	-	-	-
28	4.5*	9	69	4.6*	5	63	4.2*	13	65	14	67	22	67
29	4.6*	7	54	NA	-	-	4.3*	9	45	-	-	16	48
30	4.7	8	62	4.5	4	50	NA	-	-	12	57	-	-
31	4.8	6	46	NA	-	-	4.6	6	30	-	-	-	-
32	4.9*	6	46	4.2*	3	38	NA	-	-	9	43	-	-
33	4.10	4	31	4.3	2	25	NA	-	-	6	29	-	-
34	4.11*	9	69	4.4*	2	25	NA	-	-	11	52	-	-
35	4.12	0	0	NA	-	-	NA	-	-	-	-	-	-
36	4.13	4	31	NA	-	-	4.4	4	20	-	-	8	24
37	4.14*	5	39	NA	-	-	4.5*	9	45	-	-	14	42
38	4.15	0	0	NA	-	-	4.7	2	10	-	-	2	6

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses/N) x 100 %
Astrices indicate "correct" responses

Table F-4. Responses to Question 4 -- Driver Understanding of Treatments (Texas Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=10)			Sign-Only Treatment Survey (Ref. Appendix D) (N=8)			Marking-Only Treatment Survey (Ref. Appendix E) (N=10)			Total Responses to Identical Questions on Combination Treatment & Sign-Only Surveys (N=18)		Total Responses to Identical Questions on Combination Treatment & Marking-Only Surveys (N=20)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
24	4.1	2	20	NA	--	--	4.1	3	30	NA	--	5	25
25	4.2	1	10	4.1	0	0	NA	--	--	1	6	NA	--
26	4.3	2	20	NA	--	--	NA	--	--	NA	--	NA	--
27	4.4*	5	50	NA	--	--	NA	--	--	NA	--	NA	--
28	4.5*	5	50	4.6*	2	25	4.2*	2	20	7	39	7	35
29	4.6*	5	50	NA	--	--	4.3*	5	50	NA	--	10	50
30	4.7	3	30	4.5	1	13	NA	--	--	4	22	NA	--
31	4.8	1	10	NA	--	--	4.6	3	30	NA	--	4	20
32	4.9*	6	60	4.2*	4	50	NA	--	--	10	56	NA	--
33	4.10	2	20	4.3	1	13	NA	--	--	3	17	NA	--
34	4.11*	6	60	4.4*	6	75	NA	--	--	12	67	NA	--
35	4.12	1	10	NA	--	--	NA	--	--	NA	--	NA	--
36	4.13	4	40	NA	--	--	4.4	3	30	NA	--	7	35
37	4.14*	1	10	NA	--	--	4.5*	1	10	NA	--	2	10
38	4.15	0	0	NA	--	--	4.7	1	10	NA	--	1	5

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses/N) x 100 %
Astrices indicate "correct" responses

Table F-5. Responses to Question 4 -- Driver Understanding of Treatments (Utah Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=10)			Sign-Only Treatment Survey (Ref. Appendix D) (N=12)			Marking-Only Treatment Survey (Ref. Appendix E) (N=13)			Total Responses to Identical Questions on Combination Treatment & Sign-Only Surveys (N=22)		Total Responses to Identical Questions on Combination Treatment & Marking-Only Surveys (N=23)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
24	4.1	4	40	NA	-	0	4.1	7	54	-	-	11	48
25	4.2	1	10	4.1	1	8	NA	-	-	2	3	-	-
26	4.3	7	70	NA	-	-	NA	-	-	-	-	-	-
27	4.4*	7	70	NA	-	-	NA	-	-	-	-	-	-
28	4.5*	6	60	4.6*	7	58	4.2*	5	39	13	59	11	48
29	4.6*	4	40	NA	-	-	4.3*	4	31	-	-	8	35
30	4.7	4	40	4.5	3	25	NA	-	-	7	32	-	-
31	4.8	4	40	NA	-	-	4.6	1	8	-	-	5	27
32	4.9*	6	60	4.2*	8	67	NA	-	-	14	64	-	-
33	4.10	4	40	4.3	2	17	NA	-	-	6	27	-	-
34	4.11*	6	60	4.4*	7	58	NA	-	-	13	59	-	-
35	4.12	0	0	NA	-	-	NA	-	-	-	-	-	-
36	4.13	6	60	NA	-	-	4.4	2	15	-	-	8	35
37	4.14*	0	0	NA	-	-	4.5*	3	23	-	-	3	13
38	4.15	0	0	NA	-	-	4.7	2	15	-	-	2	9

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses/N) x 100 %
Astrices indicate "correct" responses

Although Response Code 26 received a 44-percent misinterpretation, it is believed that the subjects may have misunderstood the question. The situation was one in which they were not passing (as opposed to question 5); therefore, they would have no reason to be in the left lane. Hence, checking this response would be a viable answer. This interpretation is not an anticipated proper response, it is not an unsafe response and might be a logical answer under the driving situation. Operation under this interpretation would not affect passing opportunity distance.

The 46-percent response rate to Response Code 30 coupled with the 55-percent response rate to Response Code 32 indicates that the subjects were using the visibility distance to the pennant sign to estimate remaining passing distance. Although the visibility distance is actually greater than the needed pass completion distance for 55 to 70 mph (89 to 113 km/h) operations, this distance assessment would enhance passing safety. It would also reduce passing opportunity distance.

Considerably more subjects stated that they had no idea what the short dashed lines meant than what the sign meant. This is understandable because the dotted line treatment is absolutely unique having never been used in the country whereas the pennant, although not used to any great extent in the three study States, is used in more than half the States. It also displays a word message, NO-PASSING ZONE, which aids understanding. It is entirely probable that some subjects had observed the pennant sign while driving in other States where it is used.

Sign-Only Treatment Responses (Table F-2)

The three "correct meanings" (Codes 28, 32, and 34) were fairly well understood (50 percent being the lowest, with 54 percent being the highest); however, no single response was as well understood as the complimentary question in the combination survey, although Code 32 was rated almost even. (Compare Columns 4 and 7, Table F-2).

Again, a fairly large percentage (29 percent) of the subjects interpreted Response Code 30 as being one of the intended meanings.

Marking-Only Survey (Table F-2)

The three "correct meanings" (Codes 28,29, and 37) received the highest response frequency. Forty-two percent of the subjects recognized that the dotted line meant not to begin a pass (Code 29). The percentage of subjects that recognized that the no-passing zone began at the far end of the dotted treatment increased (from 18 to 30 percent) when only the marking treatment rather than the combination treatment was observed.

The percentage of subjects checking "I do not have any idea what the short dashed lines mean" (Code 24) was higher for the markings only treatment than for the combination treatment. This was expected because it is a truly unique device and is based on knowledge of a broken line pattern intent plus position with respect to the centerline. Also, the pennant sign in the combination would aid in deduction of intent.

Combination and Sign-Only Survey - Identical Questions

Comparing Columns 4 and 11 indicates that when all applicable data were merged, producing a sample of 53 responses for identical questions, no significant differences in response selection were evident.

Combination and Marking-Only - Identical Questions

When responses for all parts of question 4 pertaining to the meaning of the marking treatment were merged (Column 13, Table F-2), no appreciable changes in response patterns were evident, except in the identification of the beginning of the no-passing zone with respect to the dots. (Comparison of Columns 4 and 14.)

The responses to Code 36 illustrate that those drivers in the combination zones were more likely (42 percent to 30 percent) to believe that the no-passing zone began at the beginning of the dots as were those drivers in the marking-only zone. Those drivers in the marking-only zones were more likely (25 percent to 18 percent) to recognize that the no-passing zone began at the end of the markings.

Combination Treatment Comparison of Individual State Responses

Comparison of responses to similar questions indicates that subjects in all three States did not differ appreciably in their interpretation of meanings. Correct responses are indicated by astrices in Tables F-3, F-4, and F-5. There was no appreciable difference between State responses to Response Codes 27, 28, 29, 32, and 34 with the exception that North Carolina subjects indicated only a 46-percent understanding level whereas about 60 percent of the other two State subject samples recognized that a no-passing zone would start at the sign (Response Code 32).

Also, the understanding level for Response Code 37 was unusually low in all three States (range from 0 to 39 percent). Only one Texas subject and no Utah drivers indicated that they recognized that the no-passing zone started at the far end of the dotted treatment.

About twice as many Utah drivers as other survey subjects indicated that they did not know what the dotted lines meant (Response Code 24).

Sign-Only Treatment Comparison of Individual State Responses

Comparison of responses to identical questions about the intended meaning of the sign revealed a few differences between the states. In Texas only 25 percent of the drivers surveyed responded correctly to, "a no-passing zone is coming up ahead," (Code 28) whereas both North Carolina and Utah rated over 50 percent understanding level to the question.

Both Texas and Utah demonstrated an understanding level of over 50 percent to the knowledge that the no-passing zone started at the sign (Codes 32 and 34), but North Carolina demonstrated less than a 40 percent understanding level.

Marking-Only Treatment Comparison of Individual State Responses

Comparisons of similar questions concerning the intended meaning of the marking reveals that twice as many subjects in North Carolina understood that

the no-passing zone started at the end of the marking (Code 37), as did the subjects in both Texas and Utah.

Also, the understanding level for Response Code 28 varied widely between the States, with 65 percent of the North Carolina subjects understanding that the marking warned of an approaching no-passing zone, and only 20 percent of the Texas drivers displayed this understanding. Utah subjects were in the middle of that range with 39 percent demonstrating knowledge of the upcoming no-passing zone.

QUESTION 5 -- MEANING OF EXPERIMENTAL TREATMENT

Question 5 differed from question 4 in that it was developed to elicit drivers' interpretation of the meaning of the experimental treatment when they observed it while executing a passing maneuver rather than merely driving along the highway. The "correct responses" to question 5 are indicated by astrices in Tables F-6 through F-9.

By checking Response Codes 45, 61 percent of the subjects recognized that they must complete their pass before reaching the sign. This coupled with a 73 percent response level of subjects that recognized that the treatment indicated an upcoming no-passing zone, indicates that the subjects demonstrated a good understanding of the location end meaning of the pennant sign. (See Column 4, Table F-6.) This is further amplified by the fact that 86 percent and 57 percent understanding levels were demonstated for the same responses by subjects observing only the pennant sign treatment (Column 7, Table F-6). Without the sign, only 51 percent of the subjects (Column 10, Table F-6) responded correctly to Response Code 50.

The third correct answer in the combination survey (Code 48) received a low rating of understanding (21 percent), but 40 percent of the marking-only subjects recognized this meaning. A fairly high percentage (26 percent of marking-only subjects, Column 10, and 42 percent of combination subjects, Column 4) erroneously interpreted Response Code 44. This indicates that they believed the dotted treatment to be a no-passing zone rather than a pass completion zone.

Table F-6. Responses to Question 5 -- Driver Understanding of Treatments (All States, 104 Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=33)			Sign-Only Treatment Survey (Ref. Appendix D) (N=28)			Marking-Only Treatment Survey (Ref. Appendix E) (N=43)			Total Responses to Identical Questions on Combination Survey & Sign-Only Survey (N=61)		Total Responses to Identical Questions on Combination Survey & Marking-Only Survey (N=76)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
41	5.1	2	6	5.1	0	0	NA	--	--	2	3	NA	--
42	5.2	5	15	NA	--	--	5.1	12	28	NA	--	17	22
43	5.3	2	6	5.2	0	0	NA	--	--	2	3	NA	--
44	5.4	14	42	NA	--	--	5.3	11	26	NA	--	25	33
45	5.5*	20	61	5.3*	24	86	NA	--	--	44	72	NA	--
46	5.6	1	3	5.4	3	11	NA	--	--	4	7	NA	--
47	5.7	1	3	NA	--	--	5.2	0	0	NA	--	1	1
48	5.8*	7	21	NA	--	--	5.4*	17	40	NA	--	24	32
49	5.9	2	6	NA	--	--	5.5	1	2	NA	--	3	4
50	5.10*	24	73	5.5*	16	57	5.6*	22	51	40	66	46	61

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses / N) x 100 %
Astrices indicate "correct" responses.

Table F-7. Responses to Question 5 -- Driver Understanding of Treatments (North Carolina Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=13)			Sign-Only Treatment Survey (Ref. Appendix D) (N= 8)			Marking-Only Treatment Survey (Ref. Appendix E) (N= 20)			Total Responses to Identical Questions on Combination Survey & Sign-Only Survey (N= 21)		Total Responses to Identical Questions on Combination Survey & Marking-Only Survey (N= 33)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
41	5.1	0	0	5.1	0	0	NA	-	-	0	0	-	-
42	5.2	2	15	NA	-	-	5.1	5	25	-	-	7	21
43	5.3	0	0	5.2	0	0	NA	-	-	0	0	-	-
44	5.4	7	54	NA	-	-	5.3	4	20	-	-	11	33
45	5.5*	10	77	5.3*	7	88	NA	-	-	17*	81	-	-
46	5.6	0	0	5.4	1	13	NA	-	-	1	5	-	-
47	5.7	0	0	NA	-	-	5.2	0	0	-	-	0	0
48	5.8*	3	23	NA	-	-	5.4*	10	50	-	-	13*	39
49	5.9	0	0	NA	-	-	5.5	0	0	-	-	0	0
50	5.10*	10	77	5.5*	5	63	5.6*	11	55	15*	71	21*	64

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses / N) x 100 %
Astrices indicate "correct" responses

Table F-8. Responses to Question 5 -- Driver Understanding to Treatments (Texas Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=10)			Sign-Only Treatment Survey (Ref. Appendix D) (N=8)			Marking-Only Treatment Survey (Ref. Appendix E) (N=10)			Total Responses to Identical Questions on Combination Survey & Sign-Only Survey (N=18)		Total Responses to Identical Questions on Combination Survey & Marking-Only Survey (N=20)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
41	5.1	1	10	5.1	0	0	NA	--	--	1	6	NA	--
42	5.2	1	10	NA	--	--	5.1	2	20	NA	--	3	15
43	5.3	1	10	5.2	0	0	NA	--	--	1	6	NA	--
44	5.4	2	20	NA	--	--	5.3	4	40	NA	--	6	30
45	5.5*	6	60	5.3*	6	75	NA	--	--	12	67	NA	--
46	5.6	1	10	5.4	1	13	NA	--	--	2	12	NA	--
47	5.7	1	10	NA	--	--	5.2	0	0	NA	--	1	5
48	5.8*	3	30	NA	--	--	5.4*	4	40	NA	--	7	35
49	5.9	2	20	NA	--	--	5.5	0	0	NA	--	2	10
50	5.10*	7	70	5.5*	3	38	5.6*	5	50	10	56	12	60

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses / N) x 100 %
Astrices indicate "correct" responses

Table F-9. Responses to Question 5 -- Driver Understanding to Treatments (Utah Subjects)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Response Code	Combination Treatment Survey (Ref. Appendix C) (N=10)			Sign-Only Treatment Survey (Ref. Appendix D) (N=12)			Marking-Only Treatment Survey (Ref. Appendix E) (N=13)			Total Responses to Identical Questions on Combination Survey & Sign-Only Survey (N=22)		Total Responses to Identical Questions on Combination Survey & Marking-Only Survey (N=23)	
	Question	Responses	%	Question	Responses	%	Question	Responses	%	Responses	%	Responses	%
41	5.1	1	10	5.1	0	0	NA	0	0	1	5	-	-
42	5.2	2	20	NA	-	-	5.1	5	39	-	-	7	30
43	5.3	1	10	5.2	0	0	NA	-	-	1	5	-	-
44	5.4	5	50	NA	-	-	5.3	3	23	-	-	8	35
45	5.5	4	40	5.3	11	92	NA	-	-	15	70	-	-
46	5.6	0	0	5.4	1	8	NA	-	-	1	5	-	-
47	5.7	0	0	NA	-	-	5.2	13	100	-	-	13	57
48	5.8	1	10	NA	-	-	5.4	3	23	-	-	4	17
49	5.9	0	0	NA	-	-	5.5	1	8	-	-	1	4
50	5.10	7	70	5.5	8	67	5.6	6	46	15	70	13	57

Notes

N = Number of completed surveys received
Responses = Number of responses checked by subject for a given statement in survey
% = (Number of responses / N) x 100 %

When responses to identical questions (Columns 11 through 14, Table F-6) were merged, the ability of either device to denote that a no-passing zone was being approached (Code 50) was 66 percent for combination and sign-only and 61 percent for combination and marking-only. It appears that the pennant was understood better than the dotted line treatment to denote where the pass should be completed (72 percent versus 32 percent, Column 12, Code 45 and Column 14, Code 48 respectively).

In comparing differences among States (Tables F-7 through F-9), subjects from all States equally understood that the experimental treatment indicated an upcoming no-passing zone (Column 4, Code 50). North Carolina and Texas subjects generally recognized that they must complete the pass at or before reaching the sign (code 45), but only 40 percent of Utah subjects recognized this meaning. Similarly, half of the Utah and North Carolina subjects misinterpreted the dotted line as being a no-passing zone (Code 44).

More than two-thirds of the subjects who saw only the sign treatment in all three States understood they were to complete their pass at or before the pennant sign (Column 7, Code 45). Less than 40 percent of the Texas subjects understood that the sign meant they were approaching a no-passing zone (Code 50), but more than 60 percent of the subjects in both North Carolina and Utah understood the intended meaning.

About one half of the subjects in the three States that saw the marking only treatment, understood that the marking was intended to warn them that they were approaching a no-passing zone (Column 10, Code 50). One half of the North Carolina subjects understood they could pass in the markings but had to complete their pass before the end of the marking (Code 48), whereas 40 percent of the Texas subjects and only 23 percent of the Utah subjects understood this meaning. None of the Texas or North Carolina subjects responded that the marking did not apply because they were already passing (Column 10, Code 47). Every Utah subject responded that the marking did not apply to them while they were in the act of passing.

QUESTION 6 -- EVALUATION OF SOLID YELLOW LINE (Table F-10)

Question 6 was asked in all surveys to determine how well subject drivers thought that the conventional solid yellow line satisfied their passing informational needs. Table F-10 presents the weighted response rankings (scale 1 to 13) for the subjects from each State responding to the question in each survey and the composite rankings of all subjects.

The overall weighted agreement to the statement for each State was in the "Undecided" to "Moderately Agree" range. Almost one third of the responses (30 percent) were in the "Totally Disagree" to "Undecided" range, with 24 percent being within the "Moderately to Totally Disagree" ranking category. Forty-five percent "Strongly Agreed" or "Totally Agreed" that the current demarcation system was adequate. About 55 percent of the subjects at best only "Moderately Agreed" that it was adequate.

QUESTION 7 -- ASSISTANCE OF EXPERIMENTAL TREATMENT IN PASSING SITUATIONS.

Question 7 contained 14 situations (operational, environmental, geometric) which subjects were asked to rate their opinion regarding the degree of assistance the particular experimental treatment would offer them. The weighted response rankings for each survey are presented in Table F-11.

The situations presented in the surveys, with the exception of "approaching a hill" (item 7(m)) represented situations in which the solid line above is believed to be somewhat inadequate. Many of the situations were identified in the previous passing study (1) as creating visibility (hence, operational) problems to passing drivers. The intent of the question, therefore, was to determine quantitatively the relative weaknesses of the solid line for each situation and to objectively determine the strengths of the experimental treatments toward alleviating the problem.

Table F-10. Responses to Question 6 -- Opinion Rating of Solid Yellow Line to Denote No-Passing Zone

1	2	3	4	5	6	7	8	9
Survey	Response Rating							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Combination Treatment	11	7.9	9	11.0	10	8.5	30	9.0
Sign Only Survey	7	8.6	7	9.3	12	7.9	26	8.5
Marking Only Survey	18	8.8	6	10.2	12	9.8	36	9.4
Average	36	8.5	22	10.2	34	8.7	92	9.0

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

Table F-11. Responses to Question 7 -- Treatment Assistance in Passing Situations

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Combination Survey								Sign-Only Survey								Marking-Only Survey							
	N. Carolina		Texas		Utah		Average		N. Carolina		Texas		Utah		Average		N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R	N	R
(a) One Car	8	10.4	8	7.4	10	8.8	26	8.9	7	9.3	5	9.2	10	9.7	22	9.5	14	9.9	3	5.0	9	8.3	26	8.8
(b) One Car	8	10.8	8	7.1	7	8.9	23	8.9	6	12.5	6	8.5	10	10.5	22	10.5	15	10.8	4	10.3	9	8.9	28	10.1
(c) Truck	9	10.9	8	8.0	9	10.3	26	9.8	7	11.0	6	9.5	10	10.5	23	10.4	16	10.9	5	11.0	10	9.3	31	10.4
(d) Night	10	9.4	8	10.1	9	10.3	27	9.9	7	10.4	7	9.7	10	10.7	24	10.3	16	12.1	5	11.6	10	8.9	31	11.0
(e) Day	8	9.5	8	8.0	10	8.3	26	8.6	7	10.1	7	10.0	10	10.5	24	10.2	15	10.4	3	10.3	10	7.9	28	9.5
(f) Dusk/Dawn	10	10.1	8	9.1	9	10.0	27	9.8	7	10.7	7	10.0	10	10.7	24	10.5	14	9.9	3	10.3	10	9.1	27	9.6
(g) Rain	11	9.4	8	8.5	9	10.3	28	9.4	7	10.7	7	9.6	10	11.3	24	10.6	15	10.6	4	11.0	10	9.5	29	10.3
(h) Fog	10	9.5	8	9.0	9	11.2	27	9.9	6	11.2	6	8.2	10	10.7	22	10.2	16	10.4	5	11.4	10	9.5	31	10.3
(i) Snowing	11	9.7	8	9.5	9	11.1	28	10.1	7	11.1	7	9.1	10	11.4	24	10.6	15	9.2	1	12.0	9	8.6	25	9.1
(j) Sun Glare	9	9.8	8	9.3	9	10.0	26	9.7	6	10.8	6	7.5	10	10.3	22	9.7	15	9.7	3	10.7	10	8.4	28	9.3
(k) Curve Rt.	9	8.2	8	9.8	9	10.1	26	9.4	6	10.8	6	9.2	11	10.2	23	10.1	15	11.5	4	10.0	10	9.1	29	10.5
(l) Curve Left	10	8.3	8	9.8	9	10.1	27	9.3	6	10.5	6	8.7	11	9.5	23	9.6	15	11.3	4	10.0	10	8.1	29	10.0
(m) Hill	9	9.4	8	9.5	9	9.7	26	9.5	7	10.4	6	9.8	10	10.6	23	10.3	16	9.9	5	11.8	10	7.9	31	9.6
(n) Hidden Dip	10	9.9	8	8.8	9	9.1	27	9.3	7	10.4	6	9.5	11	10.2	24	10.1	16	10.3	5	11.0	10	8.5	31	9.8

Note

N = Number of subjects responding to question
R = Rating (See Appendices C,D,E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C,D,E)
Average is weighted average on scale of 1 to 13 (See Appendices C,D,E)

On the basis of average ratings (Columns 9, 17, and 25, Table F-11) the "pennant-only" survey revealed the highest average rating for all situations except four which were received by the marking-only survey. The marking-only received slightly higher ratings for "night", "fog" and "right and left curve" situations. The "truck" situation tied for the highest rating in both the pennant-only and marking-only. The individual treatments received higher average ratings than the combination treatment.

The situations that consistantly received high ratings (agreement that the treatment would be helpful) included "truck", "night", "rain", "fog", and "snowing". These situations received a rating of at least 10.0 which is slightly less than "strongly agree." The geometric situations received ratings between 9 and 10 which indicates that these situations pose less operational problems. Apparently drivers receive better visual cues from these features regarding safe passing operations.

QUESTION 8 -- RECOGNITION OF DIFFERENCE BETWEEN DOTTED LINE AND CENTERLINE

The concept of the dotted line treatment is based on the premise that drivers recognize that a solid line is "prohibitive" whereas a broken line is "permissive". If the short dotted line was to be placed to the right of a normal centerline pattern, it was important that it be highly recognizable as being different. If it appeared to be merely another painted line similar to the stripe/gap pattern of a normal centerline, it could be confused with a "painting error" or a divided two lane highway which is being used experimentally by one State to provide greater separation between opposing vehicles. Question 8 was intended to quantify how rapidly subject drivers recognized that it was not a "painting error" as they traveled through successive zones containing the experimental markings.

Table F-12 presents the responses to this question. The overall average response ratings of 10.1 and 10.3 for the two treatments containing the marking indicate that the desired recognition was quite rapidly achieved.

Table F-12. Responses to Question 8 (Combination Treatment Survey) and Question 8 (Marking Only Survey) -- Recognition of Difference Between Dotted Line and Centerline

1	2	3	4	5	6	7	8	9
Treatment	Response Ratings							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Combination Treatment	11	10.8	10	9.0	9	10.3	30	10.1
Marking Only Treatment	18	9.9	6	11.8	10	10.1	34	10.3

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

Table F-13. Responses to Question 9 (Combination Treatment Survey) and Question 8 (Sign Only Survey) -- Recognition of NO-PASSING ZONE Pennant Signs

1	2	3	4	5	6	7	8	9
Treatment	Response Ratings							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Combination Treatment	12	11.0	10	10.4	9	10.8	31	10.7
Sign Only Treatment	7	11.9	7	9.4	12	10.4	26	10.5

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

QUESTION 9 -- RECOGNITION OF NO-PASSING ZONE PENNANT SIGNS (Table F-13)

The NO-PASSING ZONE pennant sign is unique in signing principle in two aspects -- unique shape and unique placement. It is the only sign approved for solely left-side placement. Its unique aspects, both of which are conducive to visibility and recognition, are highly desirable. It has been advocated by many traffic engineers that the word message, NO-PASSING ZONE, is not absolutely necessary. It is believed that the sign is a "one-time learning" device and that, after education, the meaning is conveyed by the unique shape and placement characteristics. To test this hypothesis, question 9 was included in the combination survey (question 8 in the sign-only survey). If the sign is highly recognizable at visibility distances well beyond the message legibility distance, two important considerations are offered. The sign intent can be clearly conveyed at considerable distance upstream, and sign fabrication costs could be reduced eventually by omission of the message as is being done with other symbolic signs.

The high response rating (10.7 for combination and 10.5 for sign-only) in Table F-13 (Column 9) indicate that, after early education, drivers easily recognize the pennant sign at distances greater than the legibility distance of the word message on the sign.

QUESTION 10 -- RECOGNITION THAT DOTTED LINES MEANT "APPROACHING A NO-PASSING ZONE" (Table F-14)

One of the most important intended meanings of the advance treatments was that they convey to the driver that " a no-passing zone was being approached". Question 10 (combination treatment survey) and question 9 (marking-only survey) were asked to objectively determine the relative capability of the dotted line to convey this meaning. Table F-14 presents the response ratings for the subjects' assessment of the capability to convey this meaning. The generally high ratings, 9.3 for combination and 10.2 for marking-only treatment, agree with the responses to this meaning indicated in questions 4 and 5. Of the three intended meanings, this was the most clearly understood.

Table F-14. Responses to Question 10 (Combination Treatment Survey) and Question 9 (Marking-Only Survey) -- Recognition that Dotted Lines Meant "Approaching a No-Passing Zone"

1	2	3	4	5	6	7	8	9
Survey	Response Ratings							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Combination Treatment	11	9.0	10	9.1	9	9.8	30	9.3
Marking Only Treatment	17	10.6	6	9.0	11	10.3	34	10.2

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

Table F-15. Responses to Question 11 (Combination Treatment Survey) and Question 9 (Sign Only Survey) -- Recognition that Pennant Sign Meant "Approching a No-Passing Zone"

1	2	3	4	5	6	7	8	9
Survey	Response Ratings							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Combination Treatment	12	9.9	10	9.6	9	10.2	31	9.9
Sign Only Treatment	8	11.1	7	9.4	12	11.4	27	10.8

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

QUESTION 11 -- RECOGNITION THAT THE PENNANT SIGN MEANT "APPROACHING A NO-PASSING ZONE" (Table F-15)

Since the pennant sign displays the message, "NO-PASSING ZONE", it was anticipated that the device would receive a high rating for its ability to convey that it designated the start of a no-passing zone. To convey "approaching a no-passing zone" is dependent on the upstream distance at which it is recognizable, once the sign is seen and understood. The generally high response ratings, 9.9 for combination and 10.8 for pennant-only treatment, in Table F-15 indicate that drivers could quickly recognize that the pennant conveys this intended meaning very satisfactorily.

Comparison of the respective ratings for the dotted line and the pennant (Table F-14 versus Table F-15) indicates that the meaning was more quickly recognizable with the pennant than with the dotted line treatment.

QUESTION 12 -- OPINION RATING FOR COMBINED INSTALLATION (Table F-16)

The combination treatment survey concluded with a question to determine how strongly subjects thought that the sign alone, the marking alone, or the combination treatment should be installed by their State Department of Transportation. The response ratings are presented in Table F-16. Subjects' opinion ratings were between "Moderately Agree" and "Strongly Agree" for installation of the combination treatment. The ratings for both individual treatments were in the "Undecided to Moderately Disagree" ranking category.

It is to be anticipated that subjects would rank "combination" higher than either of the individual components merely because "if both components are favorable, the sum of the two must be more favorable." Therefore, the relative difference in rating values becomes more important than the absolute value. The responses to question 12 in the combination survey (where each subject observed the whole treatment) must be evaluated with respect to the responses of those who saw <u>only</u> one of the individual elements. Table F-17 presents these responses.

Table F-16. Responses to Question 12 (Combination Treatment Survey) -- Opinion Rating for Installation of Sign, Marking or Combination by State Department of Transportation

1	2	3	4	5	6	7	8	9
Treatment	Response Ratings							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
(a) Dotted Line Only	3	5.7	5	6.2	4	6.8	12	6.3
(b) Pennant Sign Only	4	5.8	5	8.2	5	5.2	14	6.4
(c) Dotted Line & Sign	8	11.1	10	8.2	9	10.4	27	9.8

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

Table F-17. Responses to Question 10 (Signs Only Survey) and Question 10 (Marking Only Survey) -- Opinion Rating for Installation of Only Sign or Marking by State Department of Transportation

1								
Treatment	Response Rating							
	N. Carolina		Texas		Utah		Average	
	N	R	N	R	N	R	N	R
Pennant Sign Only	8	9.6	7	9.9	12	9.3	27	9.5
Dotted Lines Only	17	10.6	6	9.0	11	7.5	34	9.3

Notes

N = Number of subjects responding to question
R = Rating (See Appendices C, D, E)
Ratings are weighted ratings on scale of 1 to 13 (See Appendices C, D, E)
Average is weighted average on scale of 1 to 13 (See Appendices C, D, E)

QUESTION 10 -- OPINION RATING FOR INDIVIDUAL INSTALLATION (Table F-17)

The final question on the sign-only survey and the marking-only survey was asked to determine how strongly subjects thought that an individual treatment should be installed. These subjects saw only one component of the combination treatment; therefore, their response ratings would reflect comparison to conventional marking (solid line) only.

Table F-17 presents response ratings for each treatment. Both received ratings in the "Moderately to Strongly Agree" ranking category. As indicated in Table F-16, each element received about equal rating; however, the "sum of both" principle can be ignored in the Table F-17 response ratings because neither group of subjects observed the combination treatment.

The rating for the combination treatment (Table F-16) was higher than the ratings for either the sign-only or marking-only treatments (Table F-17). The sign-only treatment received a slight margin of preference over the marking-only treatment.

APPENDIX G

PASSING MANEUVER MEASUREMENTS

INTRODUCTION

The passing performance characteristics were measured to obtain data with which to evaluate the influence of the experimental treatments on passing performance with respect to the measures of effectiveness listed:

1. Is there a reduction in "clipping" occurrence?
2. Is there a reduction in "clipping" distance?
3. Is there a reduction in aborted passes?
4. Is there a reduction in passes initiated within 1000 ft (305 m) of the no-passing zone.
5. Is there a reduction in total passing distance for vehicles initiating a pass within 1000 ft (305 m) of the no-passing zone?
6. Is there a reduction in the number of passing zones through which a passing vehicle trailed before initiating a pass?

This Appendix contains tabulated passing maneuver characteristics with which the above questions were evaluated.

PASSING MANEUVER TYPES

The number of passing maneuvers that were measured in the three States are listed in Table G-1. "Criterion passes" include those maneuvers in which:

1. The pass was initiated within 1000 ft (305 m) of the beginning of the no-passing zone, or
2. The pass ended within 1000 ft (305 m) of the no-passing zone, or
3. The pass involved a "clip" (returned to the right lane beyond the start of the solid yellow no-passing stripe).

These passes were considered to represent the only types at which the advance warning treatment could be expected to benefit the driver.

Table G-1. Summary of Passing Maneuvers Observed

1	2	3	4	5
	Before Data		After Data	
SITE	No. of Vehicles Total	No of Vehicles Criterion	No of Vehicles Total	No of Vehicles Criterion
NC-1 (Day)	247	52	140	56
NC-2 (Day)	187	54	112	53
NC-3 (Day)	164	55	159	45
T-1 (1) (Day)	104	52	117	52
T-2 (1) (Day)	87	56	-	-
T-3 (1) (Day)	88	56	-	-
T-2 (2) (Day)	100	63	82	49
T-3 (2) (Day)	68	52	70	56
T-2 (2) (Night)	115	61	77	54
T-3 (2) (Night)	64	56	65	56
U-1 (Day)	99	54	98	52
U-2 (Day)	108	60	85	52
U-3 (Day)	112	52	89	55
TOTAL	1543	723	1094	580

Notes:

(1) Initial daytime passing data measured at Texas sites.

(2) Data re-collected at Texas sites prior to night data collection.

Although all maneuvers in which subject vehicle passed the research vehicle anywhere within the study site were measured, only criterion passes were used to evaluate the effectiveness of the experimental treatment(s) except in evaluating the number of zones through which a vehicle trailed before passing. The methodology by which the data were collected, and descriptions of the study sites are discussed in Section 3 of the report.

Table G-1 contains two sets of daytime "before" data for Texas sites T-2 and T-3. The "before" data at these sites were collected early in the research effort. Later, the scope of the project was expanded to include day and night evaluation of the pennant sign and the dotted marking individually at these two field sites. The first data had been collected approximately one year before the nighttime data were to be collected; hence new daytime data were collected shortly before the nighttime data to assure consistency in sequencing the "before" and "after" data collection. Only the second data sets for sites T-2 and T-3 daytime data were used in the analysis, although there were no appreciable differences between the two data sets. Merging the data would bias the sample size between comparisons of treatments.

MEASURED DATA

Tables G-2 through G-12 contain "before" and "after" data and the corresponding changes. These data represent the values which were used in the statistical evaluations. The tables are listed:

Table G-2	Clipping Occurrence (All Passing Maneuvers)
Table G-3	Clipping Occurrence (Criterion Passing Maneuvers)
Table G-4	Average Clipping Distance (All Passing Maneuvers)
Table G-5	Average Clipping Distance (Criterion Passing Maneuvers)
Table G-6	Aborted Passing Maneuvers (All Passing Maneuvers)
Table G-7	Aborted Passing Maneuvers (Criterion Passing Maneuvers)
Table G-8	Pass Initiations Within 1000 Ft of The No-Passing Zone (All Passing Maneuvers)
Table G-9	Pass Initiations Within 1000 Ft of The No-Passing Zone (Criterion Passing Maneuvers)

Table G-10	Total Passing Distance For Vehicles Initiating A Pass Within 1000 Ft of The No-Passing Zone (Criterion Passing Maneuver)
Table G-11	Number of Passing Zones Through Which Vehicles Trailed Prior to Initiating A Pass (All Passing Maneuvers)
Table G-12	Number of Passing Zones Through Which Vehicles Trailed Prior to Initiating A Pass (Criterion Passing Maneuvers)

DATA ANALYSIS

Five questions were examined using analysis of variance (ANOVA) techniques. Statistical analysis was not conducted on "aborted pass" data because very few aborted passes were observed (about 1 percent of observed maneuvers). The ANOVA statistical technique permits comparison of more than two samples by comparison of variances. The purpose is to determine how two or more independent variable conditions affect the outcome. Statistical F-tests were used to determine whether or not treatments or States exhibited a significant effect on the performance measure. The F-tests compared the variances of two samples to determine if they represent different populations. The calculated F-value is compared to a tabulated F-value. Treatments and States were analyzed to determine if they exhibited significant effects on the performance measure.

ANOVA CONCEPT

The ANOVA matrix tables were developed to contain Treatments (columns) and States (rows). The three treatments were Site 1 (Combination of NO-PASSING ZONE pennant sign and dotted marking), Site 2 (NO-PASSING ZONE pennant sign alone), and Site 3 (dotted marking alone). The differences between the "before" and "after" data for each State/site combination, X_{ij}, were computed and placed in the appropriate matrix cell for that variable.

The ANOVA technique and the F-test used are described below. An example is presented following the general description. Table G-13 illustrates general ANOVA matrix table nomenclature.

Table G-2. Clipping Occurrence (All Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
	No. of Veh Total	No. of Veh Clipping	Percent	No. of Veh Total	No. of Veh Clipping	Percent	Number of Vehicles	Percent	Number of Vehicles	Percent
NC-1 (Day)	152	27	17.8	138	17	12.3	-	-	10	5.5
NC-2 (Day)	158	17	10.7	111	14	12.6	-	1.9	3	-
NC-3 (Day)	136	17	12.5	156	18	11.5	1	-	-	1.0
T-1 (Day)	80	18	22.5	93	13	14.0	-	-	5	8.5
T-2(1)(Day)	82	25	30.5	-	-	-	-	-	-	-
T-3(1)(Day)	72	16	22.2	-	-	-	-	-	-	-
T-2(2)(Day)	100	26	26.0	82	26	31.7	0	5.7	-	-
T-3(2)(Day)	58	20	34.5	66	16	24.2	-	-	4	10.3
T-2(2)(Ngt)	115	41	35.7	66	38	57.6	-	21.9	3	-
T-3(2)(Ngt)	57	22	38.6	61	21	34.4	-	-	1	4.2
U-1 (Day)	77	31	40.3	76	29	38.2	-	-	2	2.1
U-2 (Day)	83	24	28.9	72	18	25.0	-	-	6	3.9
U-3 (Day)	84	13	15.5	72	20	27.8	7	12.3	-	-

Table G-3. Clipping Occurrence (Criterion Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
Site	No. of Veh Criterion	No. of Veh Clipping	Percent	No. of Veh Criterion	No. of Veh Clipping	Percent	Number of Vehicles	Percent	Number of Vehicles	Percent
NC-1 (Day)	52	21	40.4	56	17	30.4	-	-	4	10.0
NC-2 (Day)	54	17	31.5	53	11	20.8	-	-	6	10.7
NC-3 (Day)	55	17	30.9	45	12	26.7	-	-	5	4.2
T-1 (Day)	52	17	32.7	52	12	23.1	-	-	5	9.6
T-2(1)(Day)	56	24	42.9	-	-	-	-	-	-	-
T-3(1)(Day)	56	16	28.6	-	-	-	-	-	-	-
T-2(2)(Day)	63	25	39.7	49	22	44.9	-	5.2	3	-
T-3(2)(Day)	52	19	36.5	56	16	28.6	-	-	3	7.9
T-2(Night)	61	39	63.9	54	37	68.5	-	4.6	2	-
T-3(Night)	55	22	40.0	56	21	37.5	-	-	1	2.5
U-1 (Day)	54	30	55.6	52	28	53.8	-	-	2	1.8
U-2 (Day)	60	23	38.3	52	17	32.7	-	-	6	5.6
U-3 (Day)	52	12	23.1	55	18	32.7	6	9.6	-	-

Table G-4. **Average Clipping Distance (All Passing Maneuvers)**

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
Site	No. of Veh Total	No. of Veh Clipping	Avg. Clip Dist. (ft)	No. of Veh Total	No. of Veh Clipping	Avg. Clip Dist. (ft)	Number of Vehicles	Avg. Clip Dist. (ft)	Number of Vehicles	Avg. Clip Dist. (ft)
NC-1 (Day)	152	27	386.0	138	17	158.4	-	-	10	227.6
NC-2 (Day)	158	17	301.3	111	14	433.2	-	131.9	3	-
NC-3 (Day)	136	17	241.1	156	18	382.2	1	141.1	-	-
T-1 (Day)	80	18	314.0	93	13	284.1	-	-	5	29.9
T-2(1)(Day)	82	25	363.2	-	-	-	-	-	-	-
T-3(1)(Day)	72	16	313.9	-	-	-	-	-	-	-
T-2(2)(Day)	100	26	321.3	82	26	454.4	0	133.1	-	-
T-3(2)(Day)	58	20	267.4	66	16	251.0	-	-	4	16.4
T-2(2)(Ngt)	115	41	418.5	66	38	537.2	-	118.7	3	-
T-3(2)(Ngt)	57	22	335.6	61	21	252.4	-	-	1	83.2
U-1 (Day)	77	31	346.7	76	29	404.5	-	57.8	2	-
U-2 (Day)	83	24	269.7	72	18	370.2	-	100.5	6	-
U-3 (Day)	84	13	337.9	72	20	426.4	7	88.5	-	-

Table G-5. **Average Clipping Distance (Criterion Passing Maneuvers)**

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
Site	No. of Veh Criterion	No. of Veh Clipping	Avg. Clip Dist. (ft)	No. of Veh Criterion	No. of Veh Clipping	Avg. Clip Dist. (ft)	Number of Vehicles	Avg. Clip Dist. (ft)	Number of Vehicles	Avg. Clip Dist. (ft)
NC-1 (Day)	52	21	290.7	56	17	163.8	-	-	4	126.9
NC-2 (Day)	54	17	301.3	53	11	365.0	-	63.7	6	-
NC-3 (Day)	55	17	241.1	45	12	222.3	-	-	5	18.8
T-1 (Day)	52	17	296.6	52	12	224.5	-	-	5	72.1
T-2(1)(Day)	56	24	351.6	-	-	-	-	-	-	-
T-3(1)(Day)	56	16	313.9	-	-	-	-	-	-	-
T-2(2)(Day)	63	25	295.6	49	22	365.9	-	70.3	3	-
T-3(2)(Day)	52	19	242.7	56	16	251.0	-	8.3	3	-
T-2(2)(Ngt)	61	39	389.1	54	37	529.1	-	140.0	2	-
T-3(2)(Ngt)	55	22	335.6	56	21	252.4	-	-	1	83.2
U-1 (Day)	54	30	324.9	52	28	383.3	-	58.4	2	-
U-2 (Day)	60	23	241.3	52	17	344.5	-	103.2	6	-
U-3 (Day)	52	12	321.4	55	18	382.6	6	61.2	-	-

Table G-6. Aborted Passing Attempts (All Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	No. of Veh Total	No. Passes Aborted	Percent	No. of Veh Total	No. Passes Aborted	Percent	No. Passes Aborted	Percent	No. Passes Aborted	Percent
NC-1 (Day)	152	7	4.6	138	0	0.0	-	-	7	4.6
NC-2 (Day)	158	1	0.6	111	0	0.0	-	-	1	0.6
NC-3 (Day)	136	0	0.0	156	0	0.0	-	-	0	0.0
T-1 (Day)	80	0	0.0	93	0	0.0	-	-	0	0.0
T-2(1)(Day)	82	1	1.2	-	-	-	-	-	-	-
T-3(1)(Day)	72	0	0.0	-	-	-	-	-	-	-
T-2(2)(Day)	88	0	0.0	65	1	1.5	1	1.5	-	-
T-3(2)(Day)	58	0	0.0	66	2	3.0	2	3.0	-	-
T-2(2)(Ngt)	81	0	0.0	66	7	10.6	7	10.6	-	-
T-3(2)(Ngt)	58	2	3.4	61	1	1.6	-	-	1	1.1
U-1 (Day)	77	2	2.6	76	2	2.6	-	-	0	0.0
U-2 (Day)	83	4	4.8	72	0	0.0	-	-	4	4.8
U-3 (Day)	84	4	4.8	72	2	2.7	-	-	2	2.1

Table G-7. Aborted Pass Attempts (Criterion Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	No. of Veh Criterion	No. Passes Aborted	Percent	No. of Veh Criterion	No. Passes Aborted	Percent	No. Passes Aborted	Percent	No. Passes Aborted	Percent
NC-1 (Day)	52	4	7.0	56	0	0.0	-	-	4	7.0
NC-2 (Day)	54	1	1.9	53	0	0.0	-	-	1	1.9
NC-3 (Day)	55	0	0.0	45	0	0.0	-	-	0	0.0
T-1 (Day)	52	0	0.0	52	0	0.0	-	-	0	0.0
T-2(1)(Day)	56	0	0.0	-	-	-	-	-	-	-
T-3(1)(Day)	56	0	0.0	-	-	-	-	-	-	-
T-2(2)(Day)	63	0	0.0	49	1	2.0	1	2.0	-	-
T-3(2)(Day)	52	0	0.0	56	2	3.6	2	3.6	-	-
T-2(2)(Ngt)	61	0	0.0	54	5	9.2	5	9.2	-	-
T-3(2)(Ngt)	56	2	3.5	56	1	1.8	-	-	1	1.7
U-1 (Day)	54	0	0.0	52	1	1.9	1	1.9	-	-
U-2 (Day)	60	3	5.0	52	0	0.0	-	-	3	5.0
U-3 (Day)	52	0	0.0	55	2	3.6	2	3.6	-	-

Table G-8. Pass Initiations Within 1000 Ft of The No-Passing Zone (All Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	No. of Veh Total	No. of Veh Initiating	Percent	No. of Veh Total	No. of Veh Initiating	Percent	No. of Veh Initiating	Percent	No. of Veh Initiating	Percent
NC-1 (Day)	152	31	20.3	138	23	16.7	-	-	8	3.7
NC-2 (Day)	158	23	14.5	111	17	15.3	-	0.8	7	-
NC-3 (Day)	136	21	15.5	156	21	13.4	-	-	0	2.1
T-1 (Day)	80	19	23.8	93	5	5.4	-	-	14	18.4
T-2(1)(Day)	82	28	34.2	-	-	-	-	-	-	-
T-3(1)(Day)	72	19	26.4	-	-	-	-	-	-	-
T-2(2)(Day)	88	33	37.5	65	22	33.8	-	-	11	3.7
T-3(2)(Day)	58	17	29.3	66	16	24.2	-	-	1	5.1
T-2(2)(Ngt)	81	29	35.8	66	29	43.9	0	8.9	-	-
T-3(2)(Ngt)	58	17	29.3	61	14	23.0	-	-	3	6.3
U-1 (Day)	77	32	41.6	76	29	38.1	-	-	3	3.5
U-2 (Day)	82	22	26.8	72	19	26.4	-	-	3	0.4
U-3 (Day)	84	13	15.5	72	14	19.4	1	3.9	-	-

Table G-9. Pass Initiations Within 1000 Ft of The No-Passing Zone (Criterion Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	No. of Veh Criterion	No. of Veh Initiating	Percent	No. of Veh Criterion	No. of Veh Initiating	Percent	No. of Veh Initiating	Percent	No. of Veh Initiating	Percent
NC-1 (Day)	52	25	48.1	56	23	41.1	-	-	2	7.0
NC-2 (Day)	54	23	42.6	53	15	28.3	-	-	8	14.3
NC-3 (Day)	55	21	38.2	45	16	35.7	-	-	5	2.6
T-1 (Day)	52	18	34.7	52	5	9.6	-	-	13	25.1
T-2(1)(Day)	56	27	48.2	-	-	-	-	-	-	-
T-3(1)(Day)	56	19	33.9	-	-	-	-	-	-	-
T-2(2)(Day)	63	32	50.8	49	21	42.9	-	-	11	7.9
T-3(2)(Day)	52	16	30.8	56	16	28.6	-	-	0	2.2
T-2(2)(Ngt)	61	28	45.9	54	28	51.9	0	6.0	-	-
T-3(2)(Ngt)	56	17	30.4	56	13	23.2	-	-	4	7.2
U-1 (Day)	54	31	57.4	52	28	53.8	-	-	3	3.6
U-2 (Day)	59	21	35.6	52	19	36.5	3	0.9	-	-
U-3 (Day)	52	12	23.0	55	12	21.8	-	-	0	1.2

Table G-10. Total Passing Distance for Vehicles Initiating a Pass Within 1000 Ft of The No-Passing Zone (Criterion Passing Manuevers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	No. of Veh Criterion	No. of Veh Initiating	Passing Dist. (ft)	No. of Veh Criterion	No. of Veh Initiating	Passing Dist. (ft)	No. of Veh Initiating	Passing Dist. (ft)	No. of Veh Initiating	Passing Dist. (ft)
NC-1 (Day)	52	25	793.9	56	23	794.0	-	0.1	2	-
NC-2 (Day)	54	23	833.6	53	15	885.3	-	51.7	8	-
NC-3 (Day)	55	21	849.7	45	16	841.4	-	-	5	8.3
T-1 (Day)	52	17	893.0	52	5	821.0	-	-	12	72.0
T-2(1)(Day)	56	27	944.0	-	-	-	-	-	-	-
T-3(1)(Day)	56	19	856.1	-	-	-	-	-	-	-
T-2(2)(Day)	63	32	888.7	49	21	930.3	-	41.6	11	-
T-3(2)(Day)	52	16	936.4	56	16	890.9	-	-	0	45.5
T-2(2)(Ngt)	61	28	1022.6	54	28	1195.0	0	172.4	-	-
T-3(2)(Ngt)	56	17	997.0	56	13	987.8	-	-	4	9.2
U-1 (Day)	54	31	884.8	52	28	856.6	-	-	3	28.2
U-2 (Day)	59	21	873.6	52	19	898.7	-	25.1	2	-
U-3 (Day)	52	12	771.3	55	12	870.7	0	99.4	-	-

Table G-11. Number of Passing Zones Through Which Vehicles Trailed Prior to Initiating A Pass (All Passing Maneuvers)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	Number of Vehicles Total	Number of Zones Trailed In	Zones Trailing Per Veh.	Number of Vehicles Total	Number of Zones Trailed In	Zones Trailing Per Veh.	No. Zones Trailed In	Zones Trailing*	No. Zones Trailed In	Zones Trailing*
NC-1 (Day)	152	206	1.36	138	141	1.02	-	-	65	0.34
NC-2 (Day)	158	179	1.13	111	136	1.22	-	0.09	43	-
NC-3 (Day)	136	150	1.10	156	171	1.10	-	-	21	0.00
T-1 (Day)	80	136	1.70	93	134	1.44	-	-	2	0.26
T-2(1)(Day)	82	100	1.21	-	-	-	-	-	-	-
T-3(1)(Day)	72	90	1.25	-	-	-	-	-	-	-
T-2(2)(Day)	88	118	1.34	65	84	1.29	-	-	34	0.05
T-3(2)(Day)	58	67	1.15	66	96	1.45	29	0.30	-	-
T-2(2)(Ngt)	81	92	1.14	66	91	1.38	-	0.24	1	-
T-3(2)(Ngt)	58	68	1.17	61	72	1.18	4	0.01	-	-
U-1 (Day)	77	99	1.28	76	96	1.26	-	-	3	0.02
U-2 (Day)	83	175	2.11	72	80	1.11	-	-	95	1.00
U-3 (Day)	84	133	1.58	72	104	1.44	-	-	29	0.14

Notes:

*Per Vehicle

Table G-12. Number of Passing Zones Through Which Vehicles Trailed Prior to Initiating A Pass (Criterion Passing Maneuver)

1	2	3	4	5	6	7	8	9	10	11
	Before Data			After Data			Change			
							Increase		Decrease	
SITE	Number of Vehicles Criterion	Number of Zones Trailed In	Zones Trailing Per Veh.	Number of Vehicles Criterion	Number of Zones Trailed In	Zones Trailing Per Veh.	No. Zones Trailed In	Zones Trailing*	No. Zones Trailed In	Zones Trailing*
NC-1 (Day)	52	73	1.40	56	57	1.01	-	-	16	0.39
NC-2 (Day)	54	61	1.13	53	67	1.26	6	0.13	-	-
NC-3 (Day)	55	62	1.13	45	50	1.11	-	-	12	0.02
T-1 (Day)	52	81	1.56	52	69	1.33	-	-	12	0.23
T-2(1)(Day)	56	69	1.23	-	-	-	-	-	-	-
T-3(1)(Day)	56	72	1.29	-	-	-	-	-	-	-
T-2(2)(Day)	63	83	1.32	49	66	1.35	-	0.03	17	-
T-3(2)(Day)	52	61	1.17	56	76	1.36	11	0.19	-	-
T-2(2)(Ngt)	61	69	1.13	54	72	1.33	3	0.20	-	-
T-3(2)(Ngt)	56	66	1.18	56	67	1.20	1	0.02	-	-
U-1 (Day)	54	67	1.24	52	63	1.21	-	-	4	0.03
U-2 (Day)	60	121	2.01	52	58	1.11	-	-	63	0.90
U-3 (Day)	52	87	1.67	55	78	1.41	-	-	9	0.26

Notes:

*Per Vehicle

Table G-13. General ANOVA Matrix Table

State	Treatment			Sum (Σ)
	Site 1	Site 2	Site 3	
North Carolina	X_{11}	X_{12}	X_{13}	X_{1J}
Texas	X_{21}	X_{22}	X_{23}	X_{2J}
Utah	X_{31}	X_{32}	X_{33}	X_{3J}
Sum (Σ)	X_{I1}	X_{I2}	X_{I3}	X_{IJ}

General ANOVA Equations (8)

a = Number of rows in Matrix

b = Number of columns in Matrix

$$\text{Correction to Sum of Squares, Corr} = \frac{(X_{IJ})^2}{ab}$$

$$\text{Total Sum of Squares, Total} = \Sigma\,(X_{ij})^2 - \text{Corr}$$

$$\text{Treatment Sum of Squares, } T_{SS} = \frac{(X_{I1})^2 + (X_{I2})^2 + (X_{I3})^2}{a} - \text{Corr}$$

$$\text{States Sum of Squares, } S_{SS} = \frac{(X_{1J})^2 + (X_{2J})^2 + (X_{3J})^2}{b} - \text{Corr}$$

$$\text{Error Sum of Squares, } E_{SS} = \text{Total} - (T_{SS} + S_{SS})$$

Degrees of freedom for Treatment, $T_{df} = b - 1$

Degrees of freedom for State, $S_{df} = a - 1$

Degrees of freedom for Error, $E_{df} = T_{df} \times S_{df}$

Treatment Mean Square, $T_{MS} = T_{SS}/T_{df}$

State Mean Square, $S_{MS} = S_{SS}/S_{df}$

Error Mean Square, $E_{MS} = E_{SS}/E_{df}$

F-Test Equations (8)

$$F_{treatment} = \frac{T_{MS}}{E_{MS}}$$

$$F_{state} = \frac{S_{MS}}{E_{MS}}$$

The calculated F-values for Treatment and State were compared to the F-values found in the F-table for a 90 percent confidence level. If the calculated F-value was less than or equal to the tabulated F-value, the variable was said to have no significant effect on reduction. If, on the other hand, the calculated F-value was larger than the tabulated F-value, the effect was said to be significant and would require further analysis.

EXAMPLE STATISTICAL EVALUATION

The following example is presented to illustrate the statistical methods used to analyze the performance data. The example concerns the variable, clipping occurrence. All variables were analyzed using this technique.

Original Data

The first step in the analysis involved reduction of the original data to the format necessary for the ANOVA table. Two variables, Clipping Distance and Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone, were analyzed on the basis of average distance measurements. Frequency data were used to analyze the other three variables.

Table G-14 presents the original data for this example including the "before" and "after" data and resulting differences.

Table G-14. Passing Maneuver Measurements -- Clipping Occurrence

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
State	Site 1 (Combination)							Site 2 (Sign Only)							Site 3 (Markings Only)						
	Before			After			Chg.	Before			After			Chg.	Before			After			Chg.
	C	N	%	C	N	%	%	C	N	%	C	N	%	%	C	N	%	C	N	%	%
North Carolina	21	52	40.4	17	56	30.4	-10.0	17	54	31.5	11	53	20.8	-10.7	17	55	30.9	12	45	26.7	- 4.2
Texas	17	52	32.7	12	52	23.1	- 9.6	25	63	39.7	22	49	44.9	+ 5.2	19	52	36.5	16	56	28.6	-7.9
Utah	30	54	55.6	28	52	53.8	- 1.8	23	60	38.3	17	52	32.7	- 5.6	12	52	23.1	18	55	32.7	+ 9.6

Notes:

C = Number of vehicles that clipped during a criterion passing maneuver

N = Number of Criterion passes

(+) Denotes an increase in the number of vehicles that clipped

(-) Denotes a decrease in the number of vehicles that clipped

ANOVA Table & Analysis

The differences between the before and after data are then placed in the appropriate cells of the ANOVA matrix, Table G-15. Rows and columns are summed.

Table G-15. ANOVA Matrix - Clipping Occurrence (Percent)

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
N. Carolina	-10.0	-10.7	- 4.2	-24.9
Texas	- 9.6	+ 5.2	- 7.9	-12.3
Utah	- 1.8	- 5.6	+ 9.6	+ 2.2
Sum (Σ)	-21.4	-11.1	- 2.5	- 35.0

Notes:

(+) Denotes an increase in the number of vehicles that clipped during a criterion pass

(-) Denotes a decrease in the number of vehicles that clipped during a criterion pass.

$$\text{Corr} = \frac{(-35.0)^2}{9} = 136.1$$

$$\text{Total} = (-10.0)^2 + (-10.7)^2 + (-4.2)^2 + (-9.6)^2 + (+5.2)^2 + (-7.9)^2 + (-1.8)^2 + (-5.6)^2 + (+9.6)^2 - 136.1 = 404.4$$

$$T_{SS} = \frac{(-21.4)^2 + (-11.1)^2 + (-2.5)^2}{3} - 136.1 = 59.7$$

$$S_{SS} = \frac{(-24.9)^2 + (-12.3)^2 + (+2.2)^2}{3} - 136.1 = 122.6$$

$$E_{SS} = 404.4 - (59.7 + 122.6) = 222.1$$

$T_{MS} = 59.7/2 = 29.9$

$S_{MS} = 122.6/2 = 61.3$

$E_{MS} = 222.1/4 = 55.5$

$$F_{treatment} = \frac{29.9}{55.5} = 0.54$$

$$F_{state} = \frac{61.3}{55.5} = 1.10$$

$F_{2,3}$, the tabulated F-value needed for the comparison, was found on the F-table for 90 percent confidence level, see Table G-16.

$F_{2,3} = 4.32$

$F_{treatment} < F_{2,3}$

$F_{state} < F_{2,3}$

Therefore, it can be said, with a 90% confidence level, that Treatments and States have no significant effect on reduction of clips.

Table G-16. 10 Percentage Points of The F Distribution*

Table of $F_{0.10;\nu_1,\nu_2}$

Degrees of freedom for the denominator (n)	Degrees of freedom for the numerator (m): 1	2	3	4	5	6	7	8	9	10	15	20	30	60	100	200	500	∞
1	39.9	49.5	53.6	55.8	57.2	58.2	58.9	59.4	59.9	60.2	61.2	61.7	62.3	62.7	63.0	63.2	63.3	63.3
2	8.53	9.00	9.16	9.24	9.29	9.33	9.35	9.37	9.38	9.39	9.42	9.44	9.46	9.47	9.48	9.49	9.49	9.49
3	5.54	5.46	5.39	5.34	5.31	5.28	5.27	5.25	5.24	5.23	5.20	5.18	5.17	5.15	5.14	5.14	5.14	5.13
4	4.54	4.32	4.19	4.11	4.05	4.01	3.98	3.95	3.94	3.92	3.87	3.84	3.82	3.80	3.78	3.77	3.76	3.76
5	4.06	3.78	3.62	3.52	3.45	3.40	3.37	3.34	3.32	3.30	3.24	3.21	3.17	3.15	3.13	3.12	3.11	3.10
6	3.78	3.46	3.29	3.18	3.11	3.05	3.01	2.98	2.96	2.94	2.87	2.84	2.80	2.77	2.75	2.73	2.73	2.72
7	3.59	3.26	3.07	2.96	2.88	2.83	2.78	2.75	2.72	2.70	2.63	2.59	2.56	2.52	2.50	2.48	2.48	2.47
8	3.46	3.11	2.92	2.81	2.73	2.67	2.62	2.59	2.56	2.54	2.46	2.42	2.38	2.35	2.32	2.31	2.30	2.29
9	3.36	3.01	2.81	2.69	2.61	2.55	2.51	2.47	2.44	2.42	2.34	2.30	2.25	2.22	2.19	2.17	2.17	2.16
10	3.28	2.92	2.73	2.61	2.52	2.46	2.41	2.38	2.35	2.32	2.24	2.20	2.16	2.12	2.09	2.07	2.06	2.06
11	3.23	2.86	2.66	2.54	2.45	2.39	2.34	2.30	2.27	2.25	2.17	2.12	2.08	2.04	2.00	1.99	1.98	1.97
12	3.18	2.81	2.61	2.48	2.39	2.33	2.28	2.24	2.21	2.19	2.10	2.06	2.01	1.97	1.94	1.92	1.91	1.90
13	3.14	2.76	2.56	2.43	2.35	2.28	2.23	2.20	2.16	2.14	2.05	2.01	1.96	1.92	1.88	1.86	1.85	1.85
14	3.10	2.73	2.52	2.39	2.31	2.24	2.19	2.15	2.12	2.10	2.01	1.96	1.91	1.87	1.83	1.82	1.80	1.80
15	3.07	2.70	2.49	2.36	2.27	2.21	2.16	2.12	2.09	2.06	1.97	1.92	1.87	1.83	1.79	1.77	1.76	1.76
16	3.05	2.67	2.46	2.33	2.24	2.18	2.13	2.09	2.06	2.03	1.94	1.89	1.84	1.79	1.76	1.74	1.73	1.72
17	3.03	2.64	2.44	2.31	2.22	2.15	2.10	2.06	2.03	2.00	1.91	1.86	1.81	1.76	1.73	1.71	1.69	1.69
18	3.01	2.62	2.42	2.29	2.20	2.13	2.08	2.04	2.00	1.98	1.89	1.84	1.78	1.74	1.70	1.68	1.67	1.66
19	2.99	2.61	2.40	2.27	2.18	2.11	2.06	2.02	1.98	1.96	1.86	1.81	1.76	1.71	1.67	1.65	1.64	1.63
20	2.97	2.59	2.38	2.25	2.16	2.09	2.04	2.00	1.96	1.94	1.84	1.79	1.74	1.69	1.65	1.63	1.62	1.61
22	2.95	2.56	2.35	2.22	2.13	2.06	2.01	1.97	1.93	1.90	1.81	1.76	1.70	1.65	1.61	1.59	1.58	1.57
24	2.93	2.54	2.33	2.19	2.10	2.04	1.98	1.94	1.91	1.88	1.78	1.73	1.67	1.62	1.58	1.56	1.54	1.53
26	2.91	2.52	2.31	2.17	2.08	2.01	1.96	1.92	1.88	1.86	1.76	1.71	1.65	1.59	1.55	1.53	1.51	1.50
28	2.89	2.50	2.29	2.16	2.06	2.00	1.94	1.90	1.87	1.84	1.74	1.69	1.63	1.57	1.53	1.50	1.49	1.48
30	2.88	2.49	2.28	2.14	2.05	1.98	1.93	1.88	1.85	1.82	1.72	1.67	1.61	1.55	1.51	1.48	1.47	1.46
40	2.84	2.44	2.23	2.09	2.00	1.93	1.87	1.83	1.79	1.76	1.66	1.61	1.54	1.48	1.43	1.41	1.39	1.38
50	2.81	2.41	2.20	2.06	1.97	1.90	1.84	1.80	1.76	1.73	1.63	1.57	1.50	1.44	1.39	1.36	1.34	1.33
60	2.79	2.39	2.18	2.04	1.95	1.87	1.82	1.77	1.74	1.71	1.60	1.54	1.48	1.41	1.36	1.33	1.31	1.29
80	2.77	2.37	2.15	2.02	1.92	1.85	1.79	1.75	1.71	1.68	1.57	1.51	1.44	1.38	1.32	1.28	1.26	1.24
100	2.76	2.36	2.14	2.00	1.91	1.83	1.78	1.73	1.70	1.66	1.56	1.49	1.42	1.35	1.29	1.26	1.23	1.21
200	2.73	2.33	2.11	1.97	1.88	1.80	1.75	1.70	1.66	1.63	1.52	1.46	1.38	1.31	1.24	1.20	1.17	1.14
500	2.72	2.31	2.10	1.96	1.86	1.79	1.73	1.68	1.64	1.61	1.50	1.44	1.36	1.28	1.21	1.16	1.12	1.09
∞	2.71	2.30	2.08	1.94	1.85	1.77	1.72	1.67	1.63	1.60	1.49	1.42	1.34	1.26	1.18	1.13	1.08	1.00

Example: $P(F_{.10;8,20} < 2.00) = 90\%$.

$F_{.90;\nu_1,\nu_2} = 1/F_{.10;\nu_2,\nu_1}$. Example: $F_{.90,8,20} = 1/F_{.10;20,8} = 1/2.42 = 0.413$.

Approximate formula for m and n larger than 30: $\log_e F_{.10;\nu_1,\nu_2} \cong \frac{1.1131}{\sqrt{h} - 0.77} - 0.527\left(\frac{1}{m} - \frac{1}{n}\right)$,

where $\frac{1}{h} = \frac{1}{2}\left(\frac{1}{m} + \frac{1}{n}\right)$.

* This table is abridged from A. Hald, *Statistical Tables and Formulas*, John Wiley and Sons, Inc., New York, a major part of which has been abridged from "Tables of Percentage Points of the Inverted Beta (F) Distribution," computed by M. Merrington and C. M. Thompson, *Biometrika* Vol. 33, 1943, pp. 73-88, by permission of the proprietors, or reproduced from Table V of R. A. Fisher and F. Yates, *Statistical Tables*, Oliver and Boyd, Edinburgh, by permission of the authors and the publishers.

Clipping Occurrence

Data in the ANOVA matrix, Table G-17, represent the percent change in clipping occurrence as shown in Table G-14 for before and after conditions.

Table G-17. ANOVA Matrix -- Clipping Occurrence (Percent)

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
North Carolina	-10.0	-10.7	- 4.2	-24.9
Texas	- 9.6	+ 5.2	-7.9	-12.3
Utah	- 1.8	- 5.6	+ 9.6	+ 2.2
Sum (Σ)	-21.4	-11.1	- 2.5	-35.0

Notes:

(+) Denotes an increase in the number of vehicles that clipped

(-) Denotes a decrease in the number of vehicles that clipped

Analysis Computations

Corr = 136.1

Total = 404.4

T_{SS} = 59.7

S_{SS} = 122.6

E_{SS} = 222.1

T_{MS} = 29.9

S_{MS} = 61.3

E_{MS} = 55.5

$$\left.\begin{array}{ll} F_{treatment} & = 0.54 \\ F_{state} & = 1.10 \\ F_{2,3} & = 4.32 \end{array}\right\} \quad F_{treatment} \text{ and } F_{state} \text{ are Not Significant}$$

Clipping Distance

Data in ANOVA Matrix, Table G-18, represent the change in the average clipping distance as shown in Table G-19 for before and after conditions.

Table G-18. ANOVA Matrix - Clipping Distance (feet)

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
N. Carolina	- 126.9	+ 63.7	- 18.8	- 82.0
Texas	- 72.1	+ 70.3	+ 8.3	+ 6.5
Utah	+ 58.4	+ 103.2	+ 61.2	+ 222.8
Sum (Σ)	- 140.6	+ 237.2	+ 50.7	+ 147.3

Notes:

(+) Denotes an increase in the average clipping distance.

(-) Denotes a decrease in the average clipping distance.

Analysis Computations

Corr = 2410.8

Total = 46119.6

T_{SS} = 23790.1

S_{SS} = 16391.2

E_{SS} = 5938.2

T_{MS} = 11895.1

S_{MS} = 8195.6

E_{MS} = 1484.6

$$\left.\begin{array}{ll} F_{treatment} = & 8.01 \\ F_{state} = & 5.52 \\ F_{2,3} = & 4.32 \end{array}\right\}$$

$F_{treatment}$ was Significant

F_{state} was Significant

Table G-19. Passing Maneuver Measurements -- Clipping Distance

1	2	3	4	5	6	7	8	9	10
State	Site 1 (Combination)			Site 2 (Sign Only)			Site 3 (Markings Only)		
	Before	After	Change	Before	After	Change	Before	After	Change
North Carolina	290.7'	163.8'	- 126.9'	301.3'	365.0'	+ 63.7'	241.1'	222.3'	- 18.8'
Texas	296.6'	224.5'	- 72.1'	295.6'	365.9'	+ 70.3'	242.7'	251.0'	+ 8.3'
Utah	324.9'	383.3'	+ 58.4'	241.3'	344.5'	+ 103.2'	321.4'	382.6'	+ 61.2'

Notes:

(+) Denotes an increase in the average clipping distance
(-) Denotes a decrease in the average clipping distance

Number of Aborted Passes

Statistical analysis was not conducted on "aborted pass" data because very few aborted passes were observed (about 1 percent of observed maneuvers). The data are shown in Table G-20.

Number of Passes Initiated Within 1000 Ft of the No-Passing Zone

Data in the ANOVA matrix, Table G-21, represent the percent change in the number of passes initiated within 1000 ft of the no-passing zone as shown in Table G-22 for before and after conditions.

Table G-20. Passing Maneuver Measurements -- Number of Aborted Passes

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
State	Site 1 (Combination)							Site 2 (Sign Only)							Site 3 (Markings Only)						
	Before			After			Chg.	Before			After			Chg.	Before			After			Chg.
	C	N	%	C	N	%	%	C	N	%	C	N	%	%	C	N	%	C	N	%	%
North Carolina	4	52	7.7	0	56	-	-	1	54	1.9	0	53	-	-	0	55	-	0	45	-	-
Texas	0	52	-	0	52	-	-	0	63	-	1	49	2.0	-	0	52	-	2	56	3.6	-
Utah	0	54	-	1	52	1.9	-	3	60	5.0	0	52	-	-	0	52	-	2	55	3.6	-

Notes:

C = Number of vehicles that aborted

N = Number of criterion passes

(+) Denotes an increase in the number of aborted passes

(-) Denotes a decrease in the number of aborted passes.

Table G-21. ANOVA Matrix - Number of Passes Initiated Within 1000 Ft of No-Passing Zone (Percent)

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
N. Carolina	- 7.0	- 14.3	- 2.6	- 23.9
Texas	-25.1	- 7.9	- 2.2	- 35.2
Utah	- 3.6	+ 0.9	- 1.2	- 3.9
Sum (Σ)	-35.7	- 21.3	- 6.0	- 63.0

Notes:

(+) Denotes an increase in the number of passes initiated within 1000 ft of the no-passing zone

(-) Denotes a decrease in the number of passes initiated within 1000 ft of the no passing zone

Analysis Computations

Corr = 441.0

Total = 531.7

T_{SS} = 147.1

S_{SS} = 167.5

E_{SS} = 217.1

T_{MS} = 73.6

S_{MS} = 83.8

E_{MS} = 54.3

Table G-22. Passing Maneuver Measurement -- Number of Passes Initiated Within 1000 Ft of The No-Passing Zone

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
State	Site 1 (Combination)							Site 2 (Sign Only)							Site 3 (Markings Only)						
	Before			After			Chg.	Before			After			Chg.	Before			After			Chg.
	C	N	%	C	N	%	%	C	N	%	C	N	%	%	C	N	%	C	N	%	%
North Carolina	25	52	48.1	23	56	41.1	- 7.0	23	54	42.6	15	53	28.3	-14.3	21	55	38.2	16	45	35.7	- 2.6
Texas	18	52	34.7	5	52	9.6	-25.1	32	63	50.8	21	49	42.9	- 7.9	16	52	30.8	16	56	28.6	- 2.2
Utah	31	54	57.4	28	52	53.8	- 3.6	21	59	35.6	19	52	36.5	+ 0.9	12	52	23.0	12	55	21.8	- 1.2

Notes:

C = Number of passes initiated within 1000 ft of the no-passing zone

N = Number of criterion passes

(+) Denotes an increase in the number of passes initiated within 1000 ft of the no-passing zone

(-) Denotes a decrease in the number of passes initiated within 1000 ft of the no-passing zone

$$\left.\begin{array}{lcl} F_{treatment} & = & 1.36 \\ F_{state} & = & 1.54 \\ F_{2,3} & = & 4.32 \end{array}\right\}$$

$F_{treatment}$ and F_{state} are Not Significant

Total Passing Distance For Vehicles Initiating A Pass Within 1000 Ft of The No-Passing Zone

Data in the ANOVA matrix, Table G-23 represent the change in the average total passing distance for vehicles initiating a pass within 1000 ft of the no-passing zone as shown in Table G-24 for before and after conditions.

Table G-23. ANOVA Matrix - Total Passing Distance For Vehicles Initiating A Pass Within 1000 Ft of The No-Passing Zone (feet)

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
North Carolina	+ 0.1	+ 51.7	- 8.3	+ 43.5
Texas	- 72.0	+ 41.9	-45.5	-75.6
Utah	- 28.2	+ 25.1	+ 99.4	+ 96.3
Sum (Σ)	-100.1	+118.7	+ 45.6	+ 64.2

Notes:

(+) Denotes an increase in the total passing distance for vehicles initiating a pass within 1000 ft of the no-passing zone.

(-) Denotes a decrease in the total passing distance for vehicles initiating a pass within 1000 ft of the no-passing zone.

Table G-24. Passing Maneuver Measurements -- Total Passing Distance For Vehicles Initiating A Pass Within 1000 Ft of The No-Passing Zone

1	2	3	4	5	6	7	8	9	10
State	Site 1 (Combination)			Site 2 (Sign Only)			Site 3 (Markings Only)		
	Before	After	Change	Before	After	Change	Before	After	Change
North Carolina	793.9'	794.0'	+ 0.1'	833.6'	885.3'	+ 51.7'	849.7'	841.4'	- 8.3'
Texas	893.0'	821.0'	- 72.0'	888.7'	930.6'	+ 41.9'	936.4'	890.9'	- 45.5'
Utah	884.8'	856.6'	- 28.2'	873.6'	898.7'	+ 25.1'	771.3'	870.7'	+ 99.4'

Notes:

(+) Denotes an increase in the total passing distance for vehicles initiating a pass within 1000 ft of the no-passing zone.

(-) Denotes a decrease in the total passing distance for vehicles initiating a pass within 1000 ft of the no-passing zone.

Analysis Computations

$$Corr = 458.0$$

$$Total = 22599.3$$

$$T_{SS} = 8271.7$$

$$S_{SS} = 5169.1$$

$$E_{SS} = 9158.5$$

$$T_{MS} = 4135.9$$

$$S_{MS} = 2584.6$$

$$E_{MS} = 2289.6$$

$$\left.\begin{aligned} F_{treatment} &= 1.81 \\ F_{state} &= 1.13 \\ F_{2,3} &= 4.32 \end{aligned}\right\}$$

$F_{treatment}$ and F_{state} are Not Significant

Number of Zones Through Which Vehicle Trailed Prior to Initiating A Pass

Data in the ANOVA matrix, Table G-25, represent the change in zones in which vehicles trailed prior to initiating a pass (expressed in zones per vehicle). Table G-26 contains the data on which the differences are predicated.

Table G-25. ANOVA Matrix - Number of Zones Through Which Vehicle Trailed Prior to Initiating A Pass

1	2	3	4	5
State	Site 1	Site 2	Site 3	Sum (Σ)
N. Carolina	-0.39	+0.13	-0.02	-0.28
Texas	-0.23	+0.03	+ .19	-0.01
Utah	-0.03	-0.90	-0.26	-1.19
Sum (Σ)	-0.65	-0.74	-0.09	-1.48

Notes:

(+) Denotes an increase in zones per vehicle

(-) Denotes a decrease in zones per vehicle

Analysis Computations

Corr = 0.24

Total = 0.90

T_{SS} = 0.09

S_{SS} = 0.26

E_{SS} = 0.55

T_{MS} = 0.05

S_{MS} = 0.13

E_{MS} = 0.14

Table G-26. Passing Maneuver Measurements -- Zones Through Which Vehicle Trailed Prior to Pass Initiation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
State	Site 1 (Combination)							Site 2 (Sign Only)							Site 3 (Markings Only)						
	Before			After			Chg. in Z	Before			After			Chg. in Z	Before			After			Chg. in Z
	C	N	Z	C	N	Z		C	N	Z	C	N	Z		C	N	Z	C	N	Z	
North Carolina	73	52	1.40	57	56	1.01	-0.39	61	54	1.13	67	53	1.26	+0.13	62	55	1.13	50	45	1.11	-0.02
Texas	81	52	1.56	69	52	1.33	-0.23	83	63	1.32	66	49	1.35	+0.03	61	52	1.17	76	56	1.36	+0.19
Utah	67	54	1.24	63	52	1.21	-0.03	121	60	2.01	58	52	1.11	-0.90	87	52	1.67	78	55	1.41	-0.26

Notes:

C = Number of zones trailed

N = Number of criterion vehicles passing

Z = Number of zones per vehicle, C/N

(+) Denotes an increase in zones per vehicle

(-) Denotes a decrease in zones per vehicle

$$\left.\begin{array}{lcl} F_{treatment} & = & 0.36 \\ F_{state} & = & 0.93 \\ F_{2,3} & = & 4.32 \end{array}\right\} \quad F_{treatment} \text{ and } F_{state} \text{ are Not Significant}$$

The ANOVA analysis indicated some significance in the reduction of clipping distances due to Treatments and States. A T-test was performed to determine which treatment or treatments and which state or states had a significant effect.

T-Test (8)

The T-test is used to compare the mean, $\bar{x}$, of two normally distributed samples. By comparing a calculated t-value to a tabulated t-value, it can be determined if the samples are from two different populations.

For this test, the mean, $\bar{x}$, and variance, S^2, for each before-after-state-site data set were calculated. The before data sets and after data sets, within each state were compared separately. The comparisons were: Site-1 to Site-2, Site-1 to Site-3, and Site-2 to Site-3, within each state; and North Carolina site to Texas site, North Carolina site to Utah site, and Texas site to Utah site, within each treatment.

Since each data set had a different sample size and different standard deviation, the usual t-test had to be somewhat altered. For this analysis, the tabulated t-value had to be weighted by two tabulated t-values. The tabulated t-value was determined with the following equation:

$$10\% \text{ level } t = \frac{\Sigma S_{\bar{x}}^2 \, t_{.10}}{\Sigma S_{\bar{x}}^2}$$

Example T-Analysis

To illustrate the t-test procedure, the calculations used to compare Site 1 to Site 2 for Texas - after data will be given in Table G-27 and then in the following computations.

Table G-27 Texas - After

Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	12	11	1.796	224.5	70604.9	5883.74
Site 2	22	21	1.721	365.9	35465.9	1612.09

n = Number of vehicles that clipped

d.f. = Degrees of freedom = n - 1

$t_{.10}$ = Tabulated t-values at a 90% confidence level (see Table G-28)

$\bar{x}$ = Sample mean

S^2 = Sample variance

$$\bar{x}_1 - \bar{x}_2 = 224.5 - 365.9 = -141.4$$

$$S_{\bar{x}_1 - \bar{x}_2}^2 = S_{\bar{x}_1}^2 + S_{\bar{x}_2}^2 = 5883.74 + 1612.09 = 7495.83$$

$$S_{\bar{x}_1 - \bar{x}_2} = \sqrt{S_{\bar{x}_1 - \bar{x}_2}^2} = \sqrt{7495.83} = 86.58$$

$$t' = (\bar{x}_1 - \bar{x}_2)/S_{\bar{x}_1 - \bar{x}_2} = -141.4/86.58 = -1.63$$

The absolute value of t' will be used in the comparison since it does not matter whether the comparison is between Site-1 to Site-2 or Site-2 to Site-1. The question is whether or not there is a difference between the two.

$$t@\ 10\% = \frac{\Sigma S_{\bar{x}}^2\ t_{.10}}{\Sigma S_{\bar{x}}^2} = \frac{(5883.74)(1.796) + (1612.09)(1.721)}{5883.74 + 1612.09}$$

$$= 1.78$$

$t' < t_{.10}$ Therefore, it can be said that at 10% confidence level, there is no significant difference between Site 1 and Site 2 treatments.

All other data sets were tested following this example. A summary of the means and variances for the original data may be found in Table G-29.

Table G-28 The Distribution of t*

Degrees of Freedom	Probability of a Larger Value, Sign Ignored								
	0.500	0.400	0.200	0.100	0.050	0.025	0.010	0.005	0.001
1	1.000	1.376	3.078	6.314	12.706	25.452	63.657		
2	.816	1.061	1.886	2.920	4.303	6.205	9.925	14.089	31.598
3	.765	.978	1.638	2.353	3.182	4.176	5.841	7.453	12.941
4	.741	.941	1.533	2.132	2.776	3.495	4.604	5.598	8.610
5	.727	.920	1.476	2.015	2.571	3.163	4.032	4.773	6.859
6	.718	.906	1.440	1.943	2.447	2.969	3.707	4.317	5.959
7	.711	.896	1.415	1.895	2.365	2.841	3.499	4.029	5.405
8	.706	.889	1.397	1.860	2.306	2.752	3.355	3.832	5.041
9	.703	.883	1.383	1.833	2.262	2.685	3.250	3.690	4.781
10	.700	.879	1.372	1.812	2.228	2.634	3.169	3.581	4.587
11	.697	.876	1.363	1.796	2.201	2.593	3.106	3.497	4.437
12	.695	.873	1.356	1.782	2.179	2.560	3.055	3.428	4.318
13	.694	.870	1.350	1.771	2.160	2.533	3.012	3.372	4.221
14	.692	.868	1.345	1.761	2.145	2.510	2.977	3.326	4.140
15	.691	.866	1.341	1.753	2.131	2.490	2.947	3.286	4.073
16	.690	.865	1.337	1.746	2.120	2.473	2.921	3.252	4.015
17	.689	.863	1.333	1.740	2.110	2.458	2.898	3.222	3.965
18	.688	.862	1.330	1.734	2.101	2.445	2.878	3.197	3.922
19	.688	.861	1.328	1.729	2.093	2.433	2.861	3.174	3.883
20	.687	.860	1.325	1.725	2.086	2.423	2.845	3.153	3.850
21	.686	.859	1.323	1.721	2.080	2.414	2.831	3.135	3.819
22	.686	.858	1.321	1.717	2.074	2.406	2.819	3.119	3.792
23	.685	.858	1.319	1.714	2.069	2.398	2.807	3.104	3.767
24	.685	.857	1.318	1.711	2.064	2.391	2.797	3.090	3.745
25	.684	.856	1.316	1.708	2.060	2.385	2.787	3.078	3.725
26	.684	.856	1.315	1.706	2.056	2.379	2.779	3.067	3.707
27	.684	.855	1.314	1.703	2.052	2.373	2.771	3.056	3.690
28	.683	.855	1.313	1.701	2.048	2.368	2.763	3.047	3.674
29	.683	.854	1.311	1.699	2.045	2.364	2.756	3.038	3.659
30	.683	.854	1.310	1.697	2.042	2.360	2.750	3.030	3.646
35	.682	.852	1.306	1.690	2.030	2.342	2.724	2.996	3.591
40	.681	.851	1.303	1.684	2.021	2.329	2.704	2.971	3.551
45	.680	.850	1.301	1.680	2.014	2.319	2.690	2.952	3.520
50	.680	.849	1.299	1.676	2.008	2.310	2.678	2.937	3.496
55	.679	.849	1.297	1.673	2.004	2.304	2.669	2.925	3.476
60	.679	.848	1.296	1.671	2.000	2.299	2.660	2.915	3.460
70	.678	.847	1.294	1.667	1.994	2.290	2.648	2.899	3.435
80	.678	.847	1.293	1.665	1.989	2.284	2.638	2.887	3.416
90	.678	.846	1.291	1.662	1.986	2.279	2.631	2.878	3.402
100	.677	.846	1.290	1.661	1.982	2.276	2.625	2.871	3.390
120	.677	.845	1.289	1.658	1.980	2.270	2.617	2.860	3.373
∞	.6745	.8416	1.2816	1.6448	1.9600	2.2414	2.5758	2.8070	3.2905

* Parts of this table are reprinted by permission from R. A. Fisher's *Statistical Methods for Research Workers*, published by Oliver and Boyd, Edinburgh (1925–1950); from Maxine Merrington's "Table of Percentage Points of the *t*-Distribution," Biometrika, 32:300 (1942); and from Bernard Ostle's *Statistics in Research*, Iowa State College Press (1954).

Table G-29. Passing Maneuver Measurements -- Means and Variance for the Criterion Data

1	2	3	4	5	6	7	8	9	10	11
State	Treatment	Site 1 (Combination)			Site 2 (Sign Only)			Site 3 (Marking Only)		
		N	$\bar{X}$	S^2	N	$\bar{X}$	S^2	N	$\bar{X}$	S^2
North Carolina	Before	21	290.7	29,183.8	17	301.3	55,123.6	17	241.1	22,839.1
	After	17	163.8	15,362.7	11	365.0	74,685.3	12	222.3	27,088.6
Texas	Before	17	296.6	26,652.2	25	295.6	45,466.4	19	253.2	45,584.0
	After	12	224.5	70,604.9	22	365.9	35,465.9	16	251.0	40405.8
Utah	Before	30	324.9	44,447.3	23	241.3	16,436.1	12	321.4	61,189.1
	After	28	383.3	65,848.8	17	344.5	47,858.4	18	382.6	73,410.5

Notes:

*Estimated Value

N = Number of criterion passes which clipped

$\bar{X}$ = Sample mean (Average Clipping Distance)

S^2 = Sample variance of clipping distance

Comparison of "Before" Clipping Distance (Site NC-1 and NC-2)

The t-analysis matrix to compare North Carolina sites (NC-1 and NC-2) is presented in Table G-30.

Table G-30 T-Analysis Comparing NC-1 to NC-2 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 - S^2/n$
Site 1	21	20	1.725	290.7	29183.8	1389.70
Site 2	17	16	1.746	301.3	55123.6	3242.57
				10.6		4632.27

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 68.06$ $t' = 0.16$ $t = 1.74$ N. S.

Comparison of "Before" Clipping Distance (Sites NC-1 and NC-3)

The t-analysis matrix to compare North Carolina site NC-1 to NC-3 is presented in Table G-31.

Table G-31 T-Analysis Comparing NC-1 to NC-3 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 - S^2/n$
Site 1	21	20	1.725	290.7	29183.8	1389.70
Site 3	17	16	1.746	241.1	22839.1	1343.48
				49.6		2733.18

t-Analysis Computation

$S_{\bar{x}_1 - \bar{x}_2}$ = 52.28 t' = 0.95 t = 1.74 N. S.

Comparison of "Before" Clipping Distance (Sites NC-2 and NC-3)

The t-analysis matrix to compare North Carolina site NC-2 to NC-3 is presented in Table G-32.

Table G-32 T-Analysis Comparing NC-2 to NC-3 For the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	17	16	1.746	301.3	55123.6	3242.56
Site 3	17	16	1.746	241.1	22839.1	1343.48
				60.2		4586.04

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 67.72 t' = 0.89 t = 1.75 N.S.

Comparison of "After" Clipping Distance (Sites NC-1 and NC-2)

The t-analysis matrix to compare North Carolina site NC-1 to NC-2 is presented in Table G-33.

Table G-33 T-Analysis Comparing NC-1 to NC-2 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	17	16	1.746	163.8	15362.7	903.69
Site 2	11	10	1.812	365.0	74685.3	6789.57
				201.2		7693.26

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 87.71 t' = 2.29 t = 1.80 Sign.

Comparison of "After" Clipping Distance (Sites NC-1 and NC-3)

The t-analysis matrix to compare North Carolina sites NC-1 to NC-3 is presented in Table G-34.

Table G-34 T-Analysis Comparing NC-1 to NC-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	17	16	1.746	163.8	15362.7	903.69
Site 3	12	11	1.796	222.3	27088.6	2257.38
				58.5		3161.07

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 56.22 t' = 1.04 t = 1.78 N.S.

Comparison of "After" Clipping Distance (Sites NC-2 and NC-3)

The t-analysis matrix to compare North Carolina sites NC-2 to NC-3 is presented in Table G-35.

Table G-35 T-Analysis Comparing NC-2 to NC-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	11	10	1.812	365.0	74685.3	6789.57
Site 3	12	11	1.796	222.3	27088.6	2257.38
				142.7		9046.95

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 95.12 t' = 1.50 t = 1.81 N.S.

Comparison of "Before" Clipping Distance (Sites T-1 and T-2)

The t-analysis matrix to compare Texas site T-1 to T-2 is presented in Table G-36.

Table G-36 T-Analysis Comparing T-1 to T-2 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	17	16	1.746	296.6	26652.2	1567.78
Site 2	25	24	1.711	295.6	45466.4	1818.66
				1.0		3386.44

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 58.19 t' = 0.02 t = 1.73 N.S.

Comparison of "Before" Clipping Distance (Sites T-1 and T-3)

The t-analysis matrix to compare Texas site T-1 to T-3 is presented in Table G-37.

Table G-37 T-Analysis Comparing T-1 to T-3 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	17	16	1.746	296.6	26652.2	1567.78
Site 3	19	18	1.734	253.2	45584.0	2399.16
				43.4		3966.94

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 62.98 t' = 0.69 t = 1.74 N.S.

Comparison of "Before" Clipping Distance (Sites T-2 and T-3)

The t-analysis matrix to compare Texas site T-2 to T-3 is presented in Table G-38.

Table G-38 T-Analysis Comparing T-2 to T-3 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	25	24	1.711	295.6	45466.4	1818.66
Site 3	19	18	1.734	253.2	45584.0	2399.16
				42.4		4217.82

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 64.94$ $t' = 0.65$ $t = 1.72$ N.S.

Comparison of "After" Clipping Distance (Sites T-1 and T-2)

The t-analysis matrix to compare Texas sites T-1 to T-2 is presented in Table G-39.

Table G-39 T-Analysis Comparing T-1 to T-2 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	12	11	1.796	224.5	70604.9	5883.74
Site 2	22	21	1.721	365.9	35465.9	1612.09
				141.4		7495.83

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 86.58$ $t' = 1.63$ $t = 1.78$ N.S.

Comparison of "After" Clipping Distance (Sites T-1 to T-3)

The t-analysis matrix to compare Texas site T-1 to T-3 is presented in Table G-40.

Table G-40 T-Analysis Comparing T-1 to T-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	12	11	1.796	224.5	70604.9	5883.74
Site 3	16	15	1.753	251.0	40405.75	2525.36
				26.5		8409.10

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 91.70$ $t' = 0.29$ $t = 1.78$ N.S.

Comparison of "After" Clipping Distance (Sites T-2 and T-3)

The t-analysis matrix to compare Texas site T-2 to T-3 is presented in Table G-41.

Table G-41 T-Analysis Comparing T-2 to T-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	22	21	1.721	365.9	35465.9	1612.09
Site 3	16	15	1.753	251.0	40405.75	2525.36
				114.9		4137.45

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 64.32 t' = 1.79 t = 1.74 Sign.

Comparison of "Before" Clipping Distance (Sites U-1 and U-2)

The t-analysis matrix to compare Utah site U-1 to U-2 is presented in Table G-42.

Table G-42 T-Analysis Comparing U-1 to U-2 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	30	29	1.699	324.9	44447.3	1481.6
Site 2	23	22	1.717	241.3	16436.1	714.6
				83.6		2196.2

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2}$ = 46.86 t' = 1.78 t = 1.70 Sign.

Comparison of "Before" Clipping Distance (Sites U-1 and U-3)

The t-analysis matrix to compare Utah site U-1 to U-3 is presented in Table G-43

Table G-43 T-Analysis Comparing U-1 to U-3 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	30	29	1.699	324.9	44447.3	1481.58
Site 3	12	11	1.796	321.4	61189.1	5099.09
				3.5		6580.67

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 81.12$ $t' = 0.04$ $t = 1.77$ N.S.

Comparison of "Before" Clipping Distance (Sites U-2 and U-3)

The t-analysis matrix to compare Utah site U-2 to U-3 is presented in Table G-44

Table G-44 T-Analysis Comparing U-2 to U-3 For The "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	23	22	1.717	241.3	16436.1	714.61
Site 3	12	11	1.796	321.4	61189.1	5099.09
				80.1		5813.70

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 76.25$ $t' = 1.05$ $t = 1.79$ N.S.

Comparison of "After" Clipping Distance (Sites U-1 and U-2)

The t-analysis matrix to compare Utah site U-1 to U-2 is presented in Table G-45

Table G-45 T-Analysis Comparing U-1 to U-2 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	28	27	1.703	383.3	65848.8	2351.74
Site 2	17	16	1.746	344.5	47858.4	2815.20
				38.8		5166.94

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 71.88$ $t' = 0.54$ $t = 1.73$ N.S.

Comparison of "After" Clipping Distance (Sites U-1 and U-3)

The t-analysis matrix to compare Utah sites U-1 to U-3 is presented in Table G-46

Table G-46 T-Analysis Comparing U-1 to U-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 1	28	27	1.703	383.3	65848.8	2351.74
Site 3	18	17	1.740	382.6	73410.5	4078.40
				0.7		6430.10

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 80.19$ $t' = 0.01$ $t = 1.73$ N.S.

Comparison of "After" Clipping Distance (Sites U-2 and U-3)

The t-analysis matrix to compare Utah site U-2 to U-3 is presented in Table G-47

Table G-47 T-Analysis Comparing U-2 to U-3 For The "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
Site 2	17	16	1.746	344.5	47858.4	2815.20
Site 3	18	17	1.740	382.6	73410.5	4078.36
				38.1		6893.56

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}_2} = 83.03$ $t' = 0.46$ $t = 1.74$ N.S.

Comparison of "Before" Clipping Distance (Site NC-1 and T-1)

The t-analysis matrix to compare North Carolina site NC-1 to Texas site T-1 is presented in Table G-48.

Table G-48. T-Analysis Comparing NC-1 to T-1 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-1	21	20	1.725	290.7	29183.8	1389.70
T-1	17	16	1.746	296.6	26652.2	1567.78
				5.9		2957.48

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 54.38 t' = 0.11 t = 1.74 N.S.

Comparison of "Before" Clipping Distance (Site NC-1 and U-1)

The t-analysis matrix to compare North Carolina site NC-1 to Utah site U-1 is presented in Table G-49.

Table G-49. T-Analysis Comparing NC-1 to U-1 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-1	21	20	1.725	290.7	29183.8	1389.70
U-1	30	29	1.697	324.9	44447.3	1481.58
				34.2		2871.28

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 53.58 t' = 0.638 t = 1.711 N.S.

Comparison of "Before" Clipping Distance (Site T-1 and U-1)

The t-analysis matrix to compare Texas site T-1 to Utah site U-1 is presented in Table G-50.

Table G-50. T-Analysis Comparing T-1 to U-1 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-1	17	16	1.746	296.6	26652.2	1567.78
U-1	30	29	1.699	324.9	44447.3	1481.58
				28.3		3049.36

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 55.22$ $t' = 0.512$ $t = 1.723$ N.S.

Comparison of "After" Clipping Distance (Site NC-1 and T-1)

The t-analysis matrix to compare North Carolina site NC-1 to Texas site T-1 is presented in Table G-51.

Table G-51. T-Analysis Comparing NC-1 to T-1 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-1	17	16	1.746	163.8	15362.7	903.69
T-1	12	11	1.796	224.5	70604.9	5883.74
				60.7		6787.43

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 82.39$ $t' = 0.74$ $t = 1.79$ N.S.

Comparison of "After" Clipping Distance (Site NC-1 and U-1)

The t-analysis matrix to compare North Carolina site NC-1 to Utah site U-1 is presented in Table G-52.

Table G-52. T-Analysis Comparing NC-1 to U-1 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-1	17	16	1.746	163.8	15362.7	903.69
U-1	28	27	1.703	383.3	65848.8	2351.74
				219.5		3255.43

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 57.06$ $t' = 3.85$ $t = 1.71$ Sign.

Comparison of "After" Clipping Distance (Site T-1 and U-1)

The t-analysis matrix to compare Texas site T-1 to Utah site U-1 is presented in Table G-53.

Table G-53. T-Analysis Comparing T-1 to U-1 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-1	12	11	1.796	224.5	70604.9	5883.74
U-1	28	27	1.703	383.3	65848.8	2351.74
				158.8		8235.48

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 90.75$ $t' = 1.750$ $t = 1.77$ N.S.

Comparison of "Before" Clipping Distance (Site NC-2 and T-2)

The t-analysis matrix to compare North Carolina site NC-2 to Texas site T-2 is presented in Table G-54.

Table G-54. T-Analysis Comparing NC-2 to T-2 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-2	17	16	1.746	301.3	55123.6	3242.56
T-2	25	24	1.711	295.6	45466.4	1818.66
				5.7		5061.22

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 71.14 t' = 0.080 t = 1.733 N.S.

Comparison of "Before" Clipping Distance (Site NC-2 and U-2)

The t-analysis matrix to compare North Carolina site NC-2 to Utah site U-2 is presented in Table G-55.

Table G-55. T-Analysis Comparing NC-2 to U-2 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-2	17	16	1.746	301.3	55123.6	3242.56
U-2	23	22	1.717	241.3	16436.1	714.61
				60.0		3957.17

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 62.91 t' = 0.95 t = 1.74 N.S.

Comparison of "Before" Clipping Distance (Site T-2 and U-2)

The t-analysis matrix to compare Texas site T-2 to Utah site U-2 is presented in Table G-56.

Table G-56. T-Analysis Comparing T-2 to U-2 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-2	25	24	1.711	295.6	45466.4	1818.66
U-2	23	22	1.717	241.3	16436.1	714.61
				54.3		2533.27

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 50.33$ $\quad t' = 1.08$ $\quad t = 1.71$ N.S.

Comparison of "After" Clipping Distance (Site NC-2 and T-2)

The t-analysis matrix to compare North Carolina site NC-2 to Texas site T-2 is presented in Table G-57.

Table G-57. T-Analysis Comparing NC-2 to T-2 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-2	11	10	1.812	365.0	74685.3	6789.57
T-2	22	21	1.721	365.9	35465.9	1612.09
				0.9		8401.66

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 91.66$ $\quad t' = 0.01$ $\quad t = 1.79$ N.S.

Comparison of "After" Clipping Distance (Site NC-2 and U-2)

The t-analysis matrix to compare North Carolina site 2 to Utah site U-2 is presented in Table G-58.

Table G-58. T-Analysis Comparing NC-2 to U-2 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-2	11	10	1.812	365.0	74685.3	6789.57
U-2	17	16	1.746	344.5	47858.4	2815.20
				20.5		9604.77

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 98.00$ $\quad t' = 0.209$ $\quad t = 1.79$ $\quad$ N.S.

Comparison of "After" Clipping Distance (Site T-2 and U-2)

The t-analysis matrix to compare Texas site T-2 to Utah U-2 is presented in Table G-59.

Table G-59. T-Analysis Comparing T-2 to U-2 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-2	22	21	1.721	365.9	35465.9	1612.09
U-2	17	16	1.746	344.5	47858.4	2815.20
				21.4		4427.29

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 66.54$ $\quad t' = 0.322$ $\quad t = 1.74$ $\quad$ N.S.

Comparison of "Before" Clipping Distance (Site NC-3 and T-3)

The t-analysis matrix to compare North Carolina site NC-3 to Texas site T-3 is presented in Table G-60.

Table G-60. T-Analysis Comparing NC-3 to T-3 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-3	17	16	1.746	241.1	22839.1	1343.48
T-3	19	18	1.734	253.2	45584.00	2399.16
				12.1		3742.64

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 61.18 t' = 0.20 t = 1.74 N.S.

Comparison of "Before" Clipping Distance (Site NC-3 and U-3)

The t-analysis matrix to compare North Carolina site NC-3 to Utah site U-3 is presented in Table G-61.

Table G-61. T-Analysis Comparing NC-3 to U-3 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-3	17	16	1.746	241.1	22839.1	1343.48
U-3	12	11	1.796	321.4	61189.1	5099.09
				80.3		6442.57

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}}$ = 80.27 t' = 1.00 t = 1.79 N.S.

Comparison of "Before" Clipping Distance (Site T-3 and U-3)

The t-analysis matrix to compare Texas site T-3 to Utah site U-3 is presented in Table G-62.

Table G-62. T-Analysis Comparing T-3 to U-3 for the "Before" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-3	19	18	1.734	253.2	45584.0	2399.16
U-3	12	11	1.796	321.4	61189.1	5099.09
				68.2		7498.25

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 86.59$ $\quad t' = 0.79$ $\quad t = 1.78$ $\quad$ N.S.

Comparison of "After" Clipping Distance (Site NC-3 and T-3)

The t-analysis matrix to compare North Carolina site NC-3 to Texas site T-3 is presented in Table G-63.

Table G-63. T-Analysis Comparing NC-3 to T-3 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-3	12	11	1.796	222.3	27088.6	2257.38
T-3	16	15	1.753	251.0	40405.75	2525.36
				28.7		4782.74

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 69.16$ $\quad t' = 0.41$ $\quad t = 1.77$ $\quad$ N.S.

Comparison of "After" Clipping Distance (Site NC-3 and U-3)

The t-analysis matrix to compare North Carolina site NC-3 to Utah site U-3 is presented in Table G-64.

Table G-64. T-Analysis Comparing NC-3 to U-3 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
NC-3	12	11	1.796	222.3	27088.6	2257.38
U-3	18	17	1.740	382.6	73410.5	4078.36
				160.3		6335.74

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 79.60$ $\quad t' = 2.01$ $\quad t = 1.76$ Sign.

Comparison of "After" Clipping Distance (Site T-3 and U-3)

The t-analysis matrix to compare Texas site T-3 to Utah site U-3 is presented in Table G-65.

Table G-65. T-Analysis Comparing T-3 to U-3 for the "After" Condition

1	2	3	4	5	6	7
Site	n	d.f.	$t_{.10}$	$\bar{x}$	S^2	$S_{\bar{x}}^2 = S^2/n$
T-3	16	15	1.753	251.0	40405.75	2525.36
U-3	18	17	1.740	382.6	73410.5	4078.36
				131.6		6603.72

t-Analysis Computations

$S_{\bar{x}_1 - \bar{x}} = 81.26$ $\quad t' = 1.62$ $\quad t = 1.74$ N.S.

Summary of ANOVA and T-Analysis

From the ANOVA Analysis, Clipping Distance was indicated as the only measure with any statistical reduction. The statistical significance was found to be between States and Treatments.

A summary of the increases or decreases in the "before" and "after" data are summarized in the following tables.

Table G-66. Clipping Distance

Table G-67. Clipping Occurrence

Table G-68. Number of Passes Initiated within 1000 Feet of the No-Passing Zone

Table G-69. Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone

Table G-70. Number of Zones through which Vehicle Trailed Prior to Initiating a Pass

The decreases and increases for Clipping Distance are statistically significant. The decreases and increases for the other measures were not statistically significant; they were considered apparent trends.

Table G-66. Clipping Distance*

1	2	3	4
	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Increase
Utah	Increase	Increase	Increase

* Statistically significant

Table G-67. Clipping Occurrence

1	2	3	4
	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Decrease	Decrease
Texas	Decrease	Increase	Decrease
Utah	Decrease	Decrease	Increase

Table G-68. Number of Passes Initiated within 1000 Feet of the No-Passing Zone

1	2	3	4
	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Decrease	Decrease
Texas	Decrease	Decrease	Decrease
Utah	Decrease	Increase	Decrease

Table G-69. Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone

1	2	3	4
	Treatment		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Decrease
Utah	Decrease	Increase	Increase

Table G-70. Number of Zones through which Vehicle Trailed Prior to Initiating a Pass

1	2	3	4
	Treatments		
State	Combination	Pennant	Marking
North Carolina	Decrease	Increase	Decrease
Texas	Decrease	Increase	Increase
Utah	Decrease	Decrease	Decrease

The T-Analysis indicated only one incidence of significance in the "before" data, between Utah sites -- U-1 and U-2 (Table G-42). With the standard MUTCD markings, there was some significant differences between the average clipping distance at these two Utah sites.

Statistical significance was found for four "after" data test.

NC-1 (combination)	vs	NC-2 (pennant)-(Ref. Table G-33)
T-2 (pennant)	vs	T-3 (marking)-(Ref. Table G-41)
NC-1 (combination)	vs	U-1 (combination)-(Ref. Table G-52)
NC-3 (marking)	vs	U-3 (marking)-(Ref. Table G-64)

A lower average clipping distance was exhibited for North Carolina site NC-1 than for North Carolina site NC-2. A lower average clipping distance for Texas site T-3 than for Texas site T-2 was also exhibited.

Lower average clipping distances were observed for North Carolina sites NC-1 and NC-3 than for the corresponding Utah sites.

Nighttime Statistical Analysis

ANOVA Analysis was used to determine any significant differences in the day and nighttime performances for the five measures. F-tests were performed for Before-After and Day-Night.

Clipping Occurrences

Data in the ANOVA Matrix, Table G-71, are for Texas site T-2. Data for Texas site T-3 are found in the ANOVA matrix, Table G-72. The data in these tables represent the day and night clipping occurrence for the before and after conditions, as shown in Table G-73.

Table G-71. ANOVA Matrix - Texas site T-2, Clipping Occurrence (percent)

1	2	3	4
T-2	Day	Night	Sum (Σ)
Before	39.7	63.9	103.6
After	44.9	68.5	113.4
Sum (Σ)	84.6	132.4	217.0

Analysis Computations

Corr = 11772.3

Total = 595.3

T_{SS} = 571.2

S_{SS} = 24.0

E_{SS} = 0.1

T_{MS} = 571.2

S_{MS} = 24.0

E_{MS} = 0.1

F_{D-N} = 5712.0
F_{B-A} = 240.0
F_{table} = 39.9

$F_{Day-Night}$
$F_{Before-After}$ $\therefore$ Significant

Table G-72. ANOVA Matrix - Texas site T-3, Clipping Occurrence (percent)

1	2	3	4
T-3	Day	Night	Sum (Σ)
Before	36.5	40.0	76.5
After	28.6	37.5	66.1
Sum (Σ)	65.1	77.5	142.6

Analysis Computation

Corr = 5083.7

Total = 72.8

T_{SS} = 38.4

S_{SS} = 27.0

E_{SS} = 7.4

T_{MS} = 38.4

S_{MS} = 27.0

E_{MS} = 7.4

F_{D-N} = 5.19
F_{B-A} = 3.65
F_{table} = 39.90

$F_{Day-Night}$
$F_{Before-After}$ $\therefore$ Not Significant

Table G-73. Passing Maneuver Measurements -- Clipping Occurrence

1	2	3	4	5	6	7	8	9	10	11	12	13
	Texas T-2						Texas T-3					
	Day			Night			Day			Night		
	C	N	%	C	N	%	C	N	%	C	N	%
Before	25	63	39.7	39	61	63.9	19	52	36.5	22	55	40.0
After	22	49	44.9	37	54	68.5	16	56	28.6	21	56	37.5

Notes: C = Number of vehicles that clipped during a criterion passing maneuver
N = Number of criterion passes

Clipping Distance

Data in the ANOVA Matrix, Table G-74, are for Texas site T-2. Data for Texas site T-3 are found in the ANOVA matrix, Table G-75. The data in these tables represent the day and night average clipping distance for the before and after conditions, as shown in Table G-76.

Table G-74. ANOVA Matrix - Texas site T-2, Clipping Distance (feet)

1	2	3	4
T-2	Day	Night	Sum (Σ)
Before	295.6	389.1	684.7
After	365.9	529.1	895.0
Sum (Σ)	661.5	918.2	1579.7

Analysis Computations

Corr = 623863.0

Total = 28744.8

T_{SS} = 16473.7

S_{SS} = 11056.5

E_{SS} = 1214.6

T_{MS} = 16473.7

S_{MS} = 11056.5

E_{MS} = 1214.6

$$\left.\begin{array}{ll} F_{D-N} = & 13.56 \\ F_{B-A} = & 9.10 \\ F_{table} = & 39.90 \end{array}\right\} \begin{array}{l} F_{Day-Night} \\ F_{Before-After} \end{array} \quad \therefore \quad \text{Not Significant}$$

Table G-75. ANOVA Matrix - Texas Site T-3, Clipping Distance (feet)

1	2	3	4
T-3	Day	Night	Sum (Σ)
Before	242.7	335.6	578.3
After	251.0	252.4	503.4
Sum (Σ)	493.7	588.0	1081.7

Analysis Computations

Corr = 292518.7

Total = 5718.7

T_{SS} = 2223.1

S_{SS} = 1402.5

E_{SS} = 2093.1

T_{MS} = 2223.1

S_{MS} = 1402.5

E_{MS} = 2093.1

$$\left.\begin{array}{l} F_{D-N} = 1.06 \\ F_{B-A} = 0.67 \\ F_{table} = 39.90 \end{array}\right\} \quad \begin{array}{l} F_{Day-Night} \\ F_{Before-After} \end{array} \quad \therefore \text{ Not Significant}$$

Table G-76. Passing Maneuver Measurements -- Clipping Distance

1	2	3	4	5
	Texas T-2		Texas T-3	
	Day	Night	Day	Night
Before	295.6	389.1	242.7	335.6
After	365.9	529.1	251.0	252.4

Number of Passes Initiated within 1000 Feet of the No-Passing Zone

Data in the ANOVA Matrix, Table G-77, are for Texas site T-2. Data for Texas site T-3 are found in the ANOVA Matrix, Table G-78. The data in these tables represent the day and night number of passes initiated within 1000 feet of the no-passing zone for the before and after conditions, as shown in Table G-79.

Table G-77. ANOVA Matrix - Texas site T-2, Number of Passes Initiated Within 1000 Ft. of No-Passing Zone (Percent)

1	2	3	4
T-2	Day	Night	Sum (Σ)
Before	50.8	45.9	96.7
After	42.9	51.9	94.8
Sum (Σ)	93.7	97.8	191.5

Analysis Computations

$$Corr = 9168.1$$

$$Total = 53.4$$

$$T_{SS} = 4.2$$

$$S_{SS} = 0.9$$

$$E_{SS} = 48.3$$

$$T_{MS} = 4.2$$

$$S_{MS} = 0.9$$

$$E_{MS} = 48.3$$

$$\left.\begin{array}{l} F_{D-N} = 0.09 \\ F_{B-A} = 0.02 \\ F_{table} = 39.90 \end{array}\right\} \begin{array}{l} F_{Day-Night} \\ F_{Before-After} \end{array} \therefore \text{ Not Significant}$$

Table G-78. ANOVA Matrix - Texas site T-3, Number of Passes Initiated within 1000 Feet of No-Passing Zone (Percent)

1	2	3	4
T-3	Day	Night	Sum (Σ)
Before	30.8	30.4	61.2
After	28.6	23.2	51.8
Sum (Σ)	59.4	53.6	113.0

Analysis Computations

$$Corr = 3192.3$$

$$Total = 36.7$$

$$T_{SS} = 8.36$$

$$S_{SS} = 22.0$$

$$E_{SS} = 6.34$$

$$T_{MS} = 8.36$$

$$S_{MS} = 22.0$$

$$E_{MS} = 6.34$$

$$\left.\begin{array}{l} F_{D-N} = 1.34 \\ F_{B-A} = 3.53 \\ F_{table} = 39.9 \end{array}\right\} \begin{array}{l} \text{Day-Night} \\ \text{Before-After} \end{array} \quad \therefore \quad \text{Not Significant}$$

Table G-79. Passing Maneuver Measurement -- Number of Passes Initiated within 1000 Feet fo the No-Passing Zone (percent)

1	2	3	4	5	6	7	8	9	10	11	12	13
	Texas T-2						Texas T-3					
	Day			Night			Day			Night		
	C	N	%	C	N	%	C	N	%	C	N	%
Before	32	63	50.8	28	61	45.9	16	52	30.8	17	56	30.4
After	21	49	42.9	28	54	51.9	16	56	28.6	13	56	23.2

Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone

Data in the ANOVA Matrix, Table G-80, are for Texas site T-2. Data for Texas site T-3 are found in the ANOVA Matrix, Table G-81. The data in these tables represent the day and night total passing distance for vehicles initiating a pass within 1000 feet of the no-passing zone for the before and after conditions, as shown in Table G-82.

Table G-80. ANOVA Matrix - Texas site T-2, Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone (feet)

1	2	3	4
T-2	Day	Night	Sum (Σ)
Before	888.7	1022.6	1911.3
After	930.3	1195.0	2125.3
Sum (Σ)	1819.0	2217.6	4036.6

Analysis Computation

Corr = 4073534.9

Total = 55446.6

T_{SS} = 39720.5

S_{SS} = 11449.0

E_{SS} = 4277.1

T_{MS} = 39720.5

S_{MS} = 11449.0

E_{MS} = 4277.1

F_{D-N} = 9.29
F_{B-A} = 2.68
F_{table} = 39.90

$F_{Day-Night}$
$F_{Before-After}$ $\therefore$ Not Significant

Table G-81. ANOVA Matrix - Texas site T-3, Total Passing Distance for Vehicles Initiating a Pass within 1000 Feet of the No-Passing Zone (feet)

1	2	3	4
T-3	Day	Night	Sum (Σ)
Before	936.4	997.0	1933.4
After	890.9	987.9	1878.8
Sum (Σ)	1827.3	1984.9	3812.2

Analysis Computations

Corr = 3633217.2

Total = 7286.0

T_{SS} = 6209.5

S_{SS} = 745.3

E_{SS} = 331.2

T_{MS} = 6209.5

S_{MS} = 745.3

E_{MS} = 331.2

F_{D-N} = 18.75
F_{B-A} = 2.25
F_{table} = 39.90

$F_{Day-Night}$
$F_{Before-After}$ $\therefore$ Not Significant

Table G-82. Passing Maneuver Measurements -- Total Passing Distance For Vehicles Initiating A Pass Within 1000 Ft. of the No-Passing Zone

1	2	3	4	5
	Texas T-2		Texas T-3	
	Day	Night	Day	Night
Before	888.7	1022.6	936.4	997.0
After	930.3	1195.0	890.9	987.9

Number of Zones through which Vehicle Trailed Prior to Pass Initiation

Data in the ANOVA Matrix, Table G-83, are for Texas site T-2. Data for Texas site T-3 are found in the ANOVA Matrix, Table G-84. The data in these tables represent the day and night number of zones through which vehicle trailed prior to pass initiation for the before and after conditions, as shown in Table G-85.

Table G-83. ANOVA Matrix - Texas site T-2, Number of Zones through which Vehicle Trailed Prior to Initiating a Pass

1	2	3	4
T-2	Day	Night	Sum (Σ)
Before	1.32	1.13	2.45
After	1.35	1.33	2.68
Sum (Σ)	2.67	2.46	5.13

Analysis Computations

$Corr = 6.58$

$Total = 0.031$

$T_{SS} = 0.01$

$S_{SS} = 0.012$

$E_{SS} = 0.009$

$T_{MS} = 0.010$

$S_{MS} = 0.012$

$E_{MS} = 0.009$

$$\left.\begin{array}{l} F_{D-N} = 1.11 \\ F_{B-A} = 1.33 \\ F_{table} = 39.90 \end{array}\right\} \quad \begin{array}{l} F_{Day-Night} \\ F_{Before-After} \end{array} \quad \therefore \quad \text{Not Significant}$$

Table G-84. Texas site T-3, Number of Zones through which Vehicle Trailed Prior to Initiating a Pass

1	2	3	4
T-3	Day	Night	Sum (Σ)
Before	1.17	1.18	2.35
After	1.36	1.20	2.56
Sum (Σ)	2.53	2.38	4.91

Analysis Computation

$Corr = 6.027$

$Total = 0.021$

$T_{SS} = 0.003$

$S_{SS} = 0.011$

$E_{SS} = 0.007$

$T_{MS} = 0.003$

$S_{MS} = 0.011$

$E_{MS} = 0.007$

$$\left.\begin{array}{l} F_{D-N} = 0.429 \\ F_{B-A} = 1.571 \\ F_{table} = 39.900 \end{array}\right\} \begin{array}{l} F_{Day-Night} \\ \\ F_{Before-After} \end{array} \quad \therefore \quad \text{Not Significant}$$

Table G-85. Passing Maneuver Measurements -- Number of Zones through which Vehicle Trailed Prior to Pass Initiation

1	2	3	4	5	6	7	8	9	10	11	12	13
	Texas T-2						Texas T-3					
	Day			Night			Day			Night		
	C	N	%	C	N	%	C	N	%	C	N	%
Before	83	63	1.32	69	61	1.13	61	52	1.17	66	56	1.18
After	66	49	1.35	72	54	1.33	76	56	1.36	67	56	1.20

Notes: C = Number of zones trailed
N = Number of criterion vehicles passing

The ANOVA Analysis revealed statistical significance for Clipping Occurrence at Texas site T-2. Significance was indicated for both Day-Night and Before-After. Chi-square tests were conducted to further evaluate this measure.

Chi-Square

The chi-square test involved a 2 x 4 contingency table to determine row or column effects in Clipping Occurrence. If this test proved significant, then 2 - 2 x 2 tables were tested to determine Day-Night or Site effects. Before and after data were tested separately.

To test for Day-Night effects, daytime data from Texas site T-2 and T-3 were combined into one value. Similarly, nighttime data were combined.

Testing for site effects required the combination of daytime data and nighttime data from Texas site T-2 into one value. Texas site T-3 data were similarly combined.

The chi-square analysis revealed significance between sites and between Day-Night for both the "before" and "after" conditions.

To Test Row and Column Effects for the "Before" Condition

Data in Table G-86 were used to test for row and column effects for the "before" condition.

Table G-86. 2 x 4 Contingency Table for the "Before" Condition

1	2	3	4	5	6	7
		Texas T-2		Texas T-3		TOTAL
		Day	Night	Day	Night	
% Clip	f	39.68	63.93	36.54	40.00	180.15
	F	45.04	45.04	45.04	45.04	
	f-F	-5.36	18.89	-8.50	-5.04	
% No Clip	f	60.32	36.07	63.46	60.00	219.85
	F	54.96	54.96	54.96	54.96	
	f-F	5.36	-18.89	8.50	5.04	
TOTAL		100.00	100.00	100.00	100.00	400.00

Note:

$$F = \frac{(\text{row total})\ (\text{column total})}{n}$$

n = 400 (sum, column 7)

Analysis Computations

$$x^2_{cal} = \Sigma \left(\frac{f-F}{F}\right)^2$$

$$= \frac{(5.325)^2}{45.025} + \frac{(18.875)^2}{45.025} + \ldots + \frac{(5.025)^2}{54.975}$$

$$= 19.52$$

$$d.f. = (R-1)\ (C-1) = (2-1)\ (4-1) = 3$$

$$x^2_{tab} \ @\ 10\% = 6.25$$

$$x^2_{cal} > x^2_{tab} \qquad \therefore \qquad \text{Significant}$$

To Test Day and Night Effects for the "Before" Condition

Data in Table G-87 were used to test day and night effects for the "before" condition.

Table G-87. Day and Night Effects for the "Before" Condition

1	2	3	4	5
		Day	Night	TOTAL
% Clip	f	38.26	52.59	90.85
	F	45.43	45.43	
	f-F	-7.17	7.16	
% No Clip	f	61.74	47.41	109.15
	F	54.58	54.58	
	f-F	7.16	-7.17	
TOTAL		100.00	100.00	200.00

Note:

$$F = \frac{\text{(row total) (column total)}}{n}$$

n - 200 (sum, column 5)

Day = Texas site T-2 day + Texas site T-3 day

Night = Texas site T-2 night + Texas site T-3 night

Analysis Computations

$$\left.\begin{array}{l} x^2_{cal} = 4.14 \\ d.f. = 1 \\ x^2_{tab} = 2.71 \end{array}\right\} \quad x^2_{cal} > x^2_{tab} \quad \therefore \quad \text{Significant}$$

To Test Site Effects for the "Before" Condition

Data in Table G-88 were used to test site effects for the "before" condition.

Table G-88. Site Effects for the "Before" Condition

1	2	3	4	5
		Site 2	Site 3	TOTAL
% Clip	f	51.61	38.32	89.93
	F	44.97	44.97	
	f-F	6.64	-6.65	
	f	48.39	61.68	110.07
	F	55.04	55.04	
	f-F	-6.65	6.64	
TOTAL		100.00	100.00	200.00

Note:

$$F = \frac{\text{(row total) (column total)}}{n}$$

n = 200 (sum, column 5)

Site 2 = Texas site T-2 day + Texas site T-2 night

Site 3 = Texas site T-3 day + Texas site T-3 night

Analysis Computations

$$\left.\begin{array}{l} x^2_{cal} = 3.57 \\ d.f. = 1 \\ x^2_{tab} = 2.71 \end{array}\right\} \quad x^2_{cal} > x^2_{tab} \quad \therefore \quad \text{Significant}$$

To Test for Row and Column Effects for the "After" Condition

Data in Table G-89 were used to test for row and column effects for the "after" condition.

Table G-89. 2 x 4 Contingency Table for the "After" Condition

1	2	3	4	5	6	7
		Texas T-2		Texas T-3		Total
		Day	Night	Day	Night	
% Clip	f	44.90	68.52	28.57	37.50	179.49
	F	44.87	44.87	44.87	44.87	
	f-F	0.03	23.65	-16.30	-7.37	
% No Clip	f	55.10	31.48	71.43	62.50	220.51
	F	55.13	55.13	55.13	55.13	
	f-F	-0.03	-23.65	16.30	7.37	
Total		100.00	100.00	100.00	100.00	400.00

Note: $F = \frac{(\text{row table})(\text{column total})}{n}$

n = 400(sum column 7)

Analysis Computations

$$\left.\begin{array}{l} x^2_{cal} = 35.55 \\ d.f. = 3 \\ x^2_{tab} = 6.25 \end{array}\right\} \quad x^2_{cal} > x^2_{tab} \quad \therefore \quad \text{Significant}$$

To Test Day and Night Effects for the "After" Condition

Data from Table G-90 were used to test for day and night effects for the "after" condition.

Table G-90. Day and Night Effects for the "After" Condition

1	2	3	4	5
		Day	Night	Total
% Clip	f	36.19	52.73	88.92
	F	44.46	44.46	
	f-F	-8.27	8.27	
% No Clip	f	63.81	47.27	111.08
	F	55.54	55.54	
	f-F	8.27	-8.27	
Total		100.00	100.00	200.00

Note: $F = \frac{(\text{row total})(\text{column total})}{n}$

n = 200 (sum column 5)

Day = Texas site T-2 day + Texas site T-3 day.

Night = Texas site T-2 night + Texas site T-3 night.

Analysis Computations

$$\left.\begin{array}{l} x^2_{cal} = 5.54 \\ d.f. = 1 \\ x^2_{cal} = 2.71 \end{array}\right\} \quad x^2_{cal} > x^2_{tab} \quad \therefore \quad \text{Significant}$$

To Test Site Effects for the "After" Condition

Data from Table G-91 were used to test for site effects for the "after" condition.

Table G-91. Site Effects for the "After" Condition

1	2	3	4	5
		Site 2	Site 3	Total
% Clip	f	57.28	33.04	90.32
	F	45.16	45.16	
	f-F	12.12	-12.12	
% No Clip	f	42.72	66.96	109.68
	F	54.84	54.84	
	f-F	-12.12	12.12	
Total		100.00	100.00	200.00

Note: $F = \frac{(\text{row total})(\text{column total})}{n}$

n = 200 (sum column 5)

Site 2 = Texas site T-2 day + Texas site T-2 night

Site 3 = Texas site T-3 day + Texas site T-3 night

Analysis Computations

$$\left.\begin{array}{l} x^2_{cal} = 11.86 \\ d.f. = 1 \\ x^2_{tab} = 2.71 \end{array}\right\} \quad x^2_{cal} > x^2_{tab} \quad \therefore \quad \text{Significant}$$