A Study of Roadside Delineator Effectiveness On an Interstate Highway

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This research was initiated to determine if post-mounted reflective delineators placed along Interstate highways were effective and valuable enough as a traffic control device to warrant their installation and maintenance.

The primary investigation consisted of the measurement of vehicle speed and placement at a single point within each of 4 test sections, 2 tangents and 2 curves, located on a single segment of Interstate 10 in southwest Louisiana. These measurements were made with a radar speed meter and a Bureau of Public Roads placement tape for a minimum sample of 100 independent passenger-car vehicles for each combination of experimental conditions: daylight vs nighttime, nondelineated vs post-delineated vs edge-stripe delineation, eastbound vs westbound direction of travel, and tangent vs curve geometrics, a total of 24 combinations. In addition, supplementary speed and placement, nighttime driver interview and test-vehicle distance-lapse film studies were conducted to help verify primary investigations.

Analysis of the principal study data showed mean speeds to be some 2 mph lower under delineated conditions than under nondelineated conditions but this difference was not considered to be significant from a practical standpoint. Also there was no significant effect of delineation on vehicle placement. (In general it was shown that vehicles travel closer to the centerline at nighttime as compared to daytime and at speeds over 64 mph as compared with traveling at speeds less than 55 mph.) Driver interviews provided origin-and-destination data on vehicles using the test sections at night and yielded an almost unanimous approval of delineation by drivers.

Analysis of test-vehicle distance-lapse films provided placement profiles for individual vehicles or drivers and determined a new traffic characteristic, the Placement Profile Smoothness Index; however, the limited number of such studies obtained did not provide a positive basis for distinguishing the effectiveness of roadside delineation.

•THE manual on Uniform Traffic Control Devices (1) contains the specification for the placement of reflective delineators along Interstate highways. In general, it is required that the delineators be placed 2 ft off the edge of shoulders or 2 ft outside the face of barrier curbs at 200-ft longitudinal intervals on tangent sections. The delineator faces should also be 4 ft above the near pavement edge (Fig. 1a).

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Experience with these delineators on sections of I-20 has led the Louisiana Department of Highways to seriously question their value. A high incidence of vandalism and damage from vehicles made the maintenance costs much higher than usually claimed for this type of delineation. Also, when placed off the shoulder edge, the delineator posts become obstacles for mowing machines requiring additional time and expense for hand clipping around the post.

The Department of Highways therefore posed this question. Are these delineators effective and valuable enough as a traffic control device to warrant their installation and maintenance? To answer this question the Division of Engineering Research of Louisiana State University entered into a research contract with the Louisiana Department of Highways financed in part by Federal-aid funds through the cooperation of the U.S. Bureau of Public Roads.

BACKGROUND

Opinion Surveys

In the past two years there have been two questionnaires relative to delineator use on Interstate highways sent to the highway departments of the 50 states and the District of Columbia. The first was the AASHO questionnaire of November 1962 (2); the second was sent out by the Alabama State Highway Department in December 1963 (3).

Based on 44 replying departments, the AASHO study showed 68 percent favoring the use of these delineators on the entire Interstate System while the others felt that the use of delineators was desirable and necessary on horizontal curves, interchanges, or at special locations. Only 20.4 percent of the respondents favored the use of the standard 200-ft spacing of delineators; 34.1 percent preferred 264 ft, 1/20th mile spacing, 11.4 percent preferred 264 ft-400 ft, 27.3 percent preferred 400 ft, and 6.8 percent preferred over 400-ft spacing.

The Alabama survey had 46 replies with only one, Alaska, in this group reporting no Interstate highways. The results of this survey showed the following based on the indicated number of definite responses to each question.

1. Of 40, 82.5 percent indicated that delineators constitute a maintenance problem.
2. Of 41, 48.8 percent indicated that the general Manual spacing of delineators (200 ft) is too close (plus 9.7 percent say too close on tangents).
3. Of 31, 35.5 percent recommend 400 ft or greater spacing in general (plus 6.5 percent recommend 400 ft on tangent).
4. Of 41, 70.7 percent use edge striping on Interstate highways with 100 percent of edge striping done with solid line.
5. Motorist preference in 23 states showed 30.4 percent preferring edge striping, 8.7 percent preferring delineators, and 60.9 percent preferring the combination of edge strips and delineators.
6. Of 39, 69.2 percent believe the delineator's value is doubtful in lighted sections.
7. Of 43, 67.5 percent believe that AASHO should reconsider its policy on delineators.

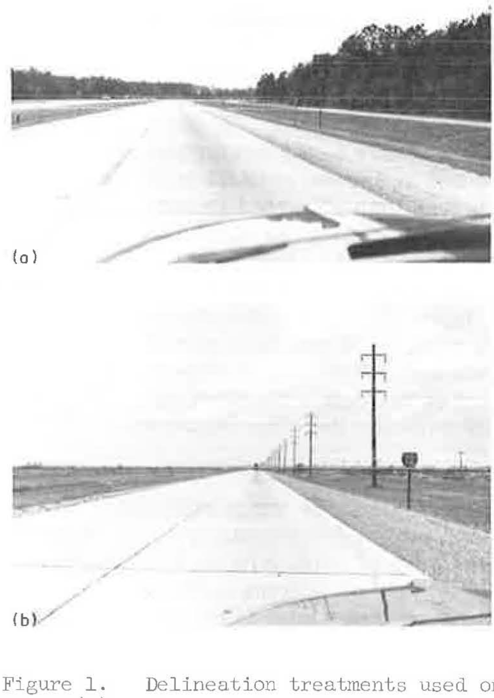

Figure 1. Delineation treatments used on I-10: (a) post-mounted reflective delineators, (b) edge striping.

Other Delineation Research

In considering this research, the literature was searched for similar studies in an attempt to determine what methodology would be most applicable to this study.

A study initiated in 1958 and reported by Taragin and Rudy (4) evaluated the effectiveness of highway illumination and roadside delineation in interchange areas of the Connecticut Turnpike. Under nine different combinations of illumination and delineation, the effects on accident rate, vehicle speeds, lateral placement, headways, lane use, and utilization of acceleration and deceleration lanes were measured. The Bureau of Public Roads Mobile Traffic Analyzer was used to record data for a total of some 183,000 vehicles. Analysis of these data showed no significant relationship of average speed or lateral placement to the nine study conditions. However, based on lane-use analysis, they concluded that the results pointed up the value of roadside delineation with or without illumination in the interchange area.

Another study conducted in Connecticut was reported by Williston (5) in 1960. This study also measured speed and placement of vehicles on three 2-lane highways and one 4-lane divided highway under nondelineated and edge-striped conditions. They found that edge striping increased nighttime speeds and tended to move vehicles farther from the centerline of the highway.

The Louisiana Department of Highways has conducted two studies of traffic operation characteristics on sections delineated by edge stripes. Equipment of the Bureau of Public Roads was used to measure speed and placement of vehicles through several test sections 2.5 to 4 miles long. In the 1956 research reported by Thomas (6), there were few significant results obtained from speed and placement data; there was a tendency for vehicles to be closer to the centerline with edge striping than without, especially at night. The main benefit of the edge stripes was found to be psychological, as 86 percent of all drivers interviewed in one study believed that the edge stripe helped them in driving. The 1957 research reported by Thomas and Taylor (7), on different highway sections tended to verify the placement results of the 1956 research and served as a basis for the adoption of edge striping on all 24-ft two-way highways and limited use on 4-lane divided highways.

Other studies have used accident analyses to show the benefit of delineation. Virginia studies reported by Mills (8) in 1958 showed the accident rate was reduced 57 percent on one route and 67 percent on another after special 6- × 48-in. delineators were installed. A paper by Musick (9) concerns accident studies made in Ohio on nine pairs of highway sections, 6 miles long on the average, throughout the state. One half of each pair was edge striped, and the other half was not edge striped. The main results were significant reductions of fatalities and injuries, night accidents, and accidents at intersections, alleys, and driveways.

The most recent delineator research was reported by the Arizona Highway Department (10). On seven representative 2-lane, two-way highway sections, 13 to 53 miles long, installation and maintenance costs were obtained for each delineation treatment (nondelineated vs steel post-mounted delineator plates, 2 × 6 in. placed 8 in. off the pavement edge and spaced 400 ft apart vs 4-in. white continuous shoulder stripe), traffic accident experience, vehicle speeds, and lateral placement of vehicles in a driving lane. The following results were obtained:

> 1. Night speeds increased when roadway delineation was installed. Increase of night speed was greater with shoulder stripe than with post delineators (5.9 mph vs 3.4 mph faster than the expected night speeds based on statewide trends).
> 2. Vehicle placement measured in feet from the centerline decreased under all shoulder conditions after dark. There is no significant difference between shoulder stripe and post-delineators with respect to vehicle placement day or night.
> 3. Neither shoulder striping nor post-mounted delineators had any deterrent effect on accident occurrence under the conditions of this study.

4. Installation and maintenance costs of the two systems are as follows:

System	Installation Cost/ Route Mile ($)	Annual Maintenance Cost/Route Mile ($)
Post-mounted delineators	146.11	18.55
Shoulder striping	117.97	124.40

On the basis of these cost data they concluded:

1. The annual maintenance cost of shoulder striping makes it too expensive to use except for short sections where special driver guidance is needed.
2. The use of post-mounted delineator plates is considered to be the most practical method of roadway delineation since it provides a satisfactory definition of the pavement edge at a reasonable maintenance cost.

SCOPE

The purpose of this research was to evaluate the effectiveness of roadside delineators on Interstate highways. Inasmuch as it was felt that the primary purpose of any type of roadside delineation was to enable drivers better to follow a road at night or under other adverse visibility conditions, it was hypothesized that the effectiveness of any such delineation would be reflected in improved traffic operation characteristics over those of nondelineated roadways. The two most sensitive characteristics that could be measured were considered to be vehicle speed and placement within a traffic lane, both of which are usually measured at a single "point" within a designated test section.

Based on the results of others' research, previously cited, it was anticipated that point studies might produce insignificant results. It was therefore further hypothesized that the effectiveness of a delineation treatment might be reflected in a smoother path of travel through a delineated section than one not delineated. To measure this characteristic a test vehicle equipped with time-lapse photography equipment was used on a limited study under all conditions of delineation.

Since most engineers agree that relatively sharp curves and interchange areas should be delineated, this research was limited to the study of tangent and relatively flat curve sections. A single 2-mile section of I-10 near Crowley, La., provided four test sections, two curves, two tangents, for the purpose of this research.

In addition to the standard Interstate post-mounted delineator, measurements were made under nondelineated and edge-striped conditions in all test sections. (See Fig. 1b.) Data were collected for both daylight and nighttime conditions.

The complete documentation of this research is contained in a recent report (12) of the Louisiana State University Division of Engineering Research.

EXPERIMENTAL PROCEDURES

Test Section Selection

Construction of I-10 through southern Louisiana is incomplete except for a few sections. One of these sections runs for 14.7 miles between Jennings and Crowley (Fig. 2). This section was opened to traffic in April 1963 two months prior to the start of this research. Average daily traffic measured on the eastern end of this section was 2,337 in May 1963 and 2,727 in May 1964. Though this relatively low volume would require longer periods of time to collect sufficient data for analysis, it was felt that a high percentage of the vehicles on the facility would be independent

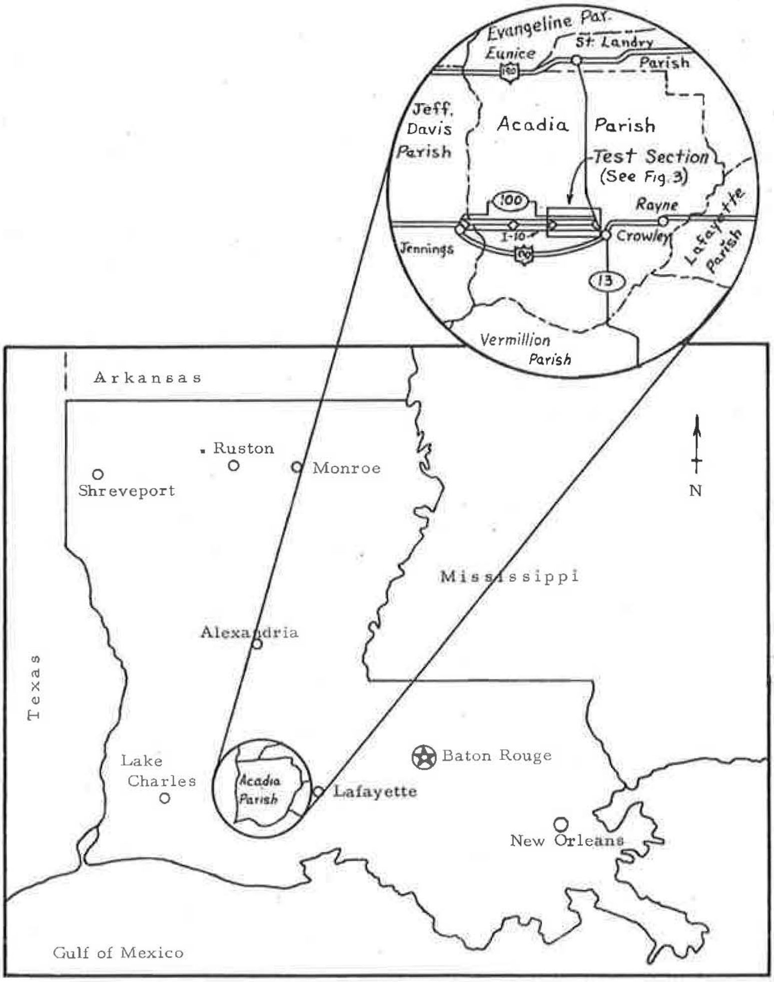

Figure 2. Location of project test sections.

of each other, and therefore their speed and placement characteristics should reflect the effect of roadway characteristics or delineation treatment.

The eastern end of this section of I-10 was used for this research because it had the longest tangent roadways, separated by a median at least 120 ft wide, and also contained a relatively flat curve at one end of this tangent (Fig. 3). It was felt that the wide median would minimize the effect of opposing headlights on vehicle speeds and placement. Another advantage of this location was the availability of continuous service roads on either side of I-10 providing a less conspicuous location for study personnel and equipment.

Speed and Placement Studies

Experimental Variables. —In setting up an experiment to measure speed and placement values, the following variables were considered important.

1. Delineation treatment—standard lane lines (Section 2B-5, 1) present for all 3 of the following treatments: (a) nondelineation (of roadside or edge of pavement), (b) post delineators, and (c) edge-stripe delineation.
2. Roadway alignment: (a) tangent, and (b) curve.

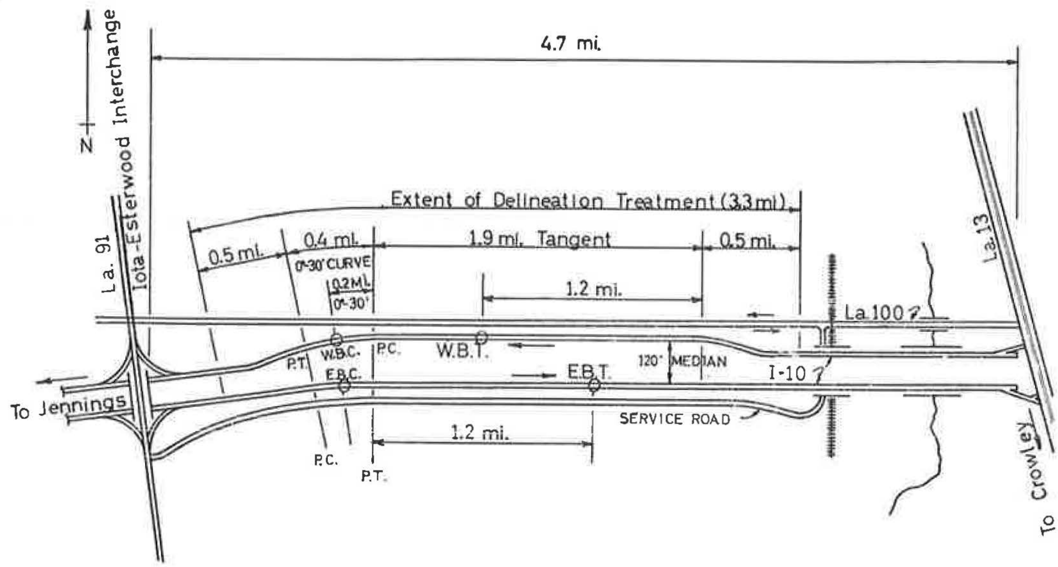

Figure 3. Experimental design: location of test sections in east end of I-10 between Crowley and Jennings.

3. Light condition: (a) daylight, (b) twilight, and (c) night.

4. Vehicle type: (a) passenger vehicles, pickup trucks, (b) single-unit trucks, and (c) heavy trucks (tractor with semitrailer, etc.).

5. Travel direction, length of travel on I-10 before test section: (a) eastbound—11 to 12 miles, and (b) westbound—2 to 3 miles.

Experimental Design

To evaluate these variables, a field design was used as shown in Figure 3. The 4.7-mile Crowley end of the I-10 section selected for these studies provided a 0.4-mile long (0° -30') curve and a 1.9-mile long tangent, back-to-back, both separated by a 120-ft wide median. Four study points were then selected: WBC, WBT, EBT and EBC (Fig. 3).

By studying both sections in both directions variables 2 and 5 were covered. On any given day measurements were made at one point for all vehicles that passed from about 1:30 p.m. to 11:30 p.m.; this covers variables 3 and 4. Variable 1 was covered by first studying traffic operation under nondelineated conditions; then post delineators were placed every 200 ft over approximately 3 miles extending 0.5 mile beyond each end of the test sections and studies repeated, and finally post delineators were removed and the same length of roadway was edge striped with solid white lines on both sides of each roadway. The order of conducting these studies (i.e., by section and 1st vs 2nd day of measurements) under each delineation condition was chosen by random selection. Field studies began on June 27 and were completed on August 29, 1963.

Analysis of traffic volumes from placement charts for nondelineated conditions in the first two weeks of July 1963 showed the average hourly volumes in one direction over 3-hr day periods and 3-hr night periods (Table 1). Because of a relatively low traffic volume on I-10, it was necessary to conduct studies under a given set of conditions at least one day and two nights to collect a usable sample of at least 100 (preferably 150) for each light condition.

TABLE 1
AVERAGE HOURLY VOLUMES

Condition	Shoulder Lane			Median Lane		
	Autos	Trucks	Total	Autos	Trucks	Total
Day (2-5 p.m.)	78	8	86	10	0	10
Night (8-11 p.m.)	28	2	30	2	0	2

Measurement Procedures

The speed of every vehicle passing through the test sections was measured with a radar speed meter with a range of 500 ft and accuracy of ±2 mph. Each vehicle's placement within the roadway was measured through use of a Bureau of Public Roads placement tape connected to a 20-pen recorder providing placement accuracy of ±0.3 ft. The use of this combination of equipment required only one tape across the road thereby reducing the suspicion of a speed trap; Louisiana State Police use the two-tube speed-clock system in measuring speeds.

At each of the four stations where measurements were made, an Interstate route marker was erected opposite a transverse joint in the roadway. This served a dual purpose in that it marked the study point for succeeding studies at that location and provided a mount for the radar speed meter.

The radar speed meter antenna was mounted behind a special route marker which had the zero in 10 changed to a circular shape with a 6-in. inside diameter. The inside of the numeral was cut out and a piece of plexiglass that had been painted with transparent Interstate blue paint placed over the hole. The radar antenna was therefore not evident to the passing motorist.

The vehicle detector for placement measurements was placed across the 24-ft pavement directly over the transverse joint and held in place by special clamps nailed into the joint. This detector was placed each day at noon and removed by midnight.

Special extension cables permitted recording equipment for both placement and speed measurement to be located on adjoining service roads. La. 100 runs parallel to and north of I-10 in this section with its south pavement edge located 78 ft off to the north pavement edge of the westbound I-10 roadway in the 1.9-mile tangent section. A service road runs parallel to and south of I-10 in this section with its north pavement edge located 49 ft off of the south pavement edge of the eastbound I-10 roadway in the 1.9-mile tangent section. It was felt that with recorders, personnel, and vehicles located on these frontage roads, drivers would be less likely distracted by the study operation.

One man could operate the recording station keeping watch on recorder operation and periodically placing time checks onto the chart. He also coded vehicle type and out-of-state marks onto the placement chart for later analysis purposes. A typical setup is shown in Figure 4.

Supplementary Studies

In order to obtain a check on the validity of the primary point studies and to obtain additional information of interest to this project, a number of supplementary studies were conducted.

Speed Studies. —In an attempt to see if the presence of a vehicle detector across the road and/or personnel off the roadside were affecting vehicle speed at the point of measurement, speed measurements were made simultaneously upstream and downstream from the test station on one day during each set of studies.

A man was stationed some 1,500 ft upstream from the station with a stop watch timing vehicle speed over 2 pavement slabs (117 ft). The downstream check was made with a second radar speed meter located 2,000 ft beyond the test station, the extra distance accounting for the fact that the radar meter detects speeds some 500 ft upstream from the meter's location. At all three points, each vehicle was identified as to make and color for later correlation. Analysis of the data provided a study of individual vehicle speed patterns and speed distributions at each point.

Placement Studies. —A second placement tape and recorder were located at the downstream speed measuring point generally on the same days that speeds were being checked there. The purpose of these studies was to ascertain if a different detector location would result in a different average placement and placement distribution. All

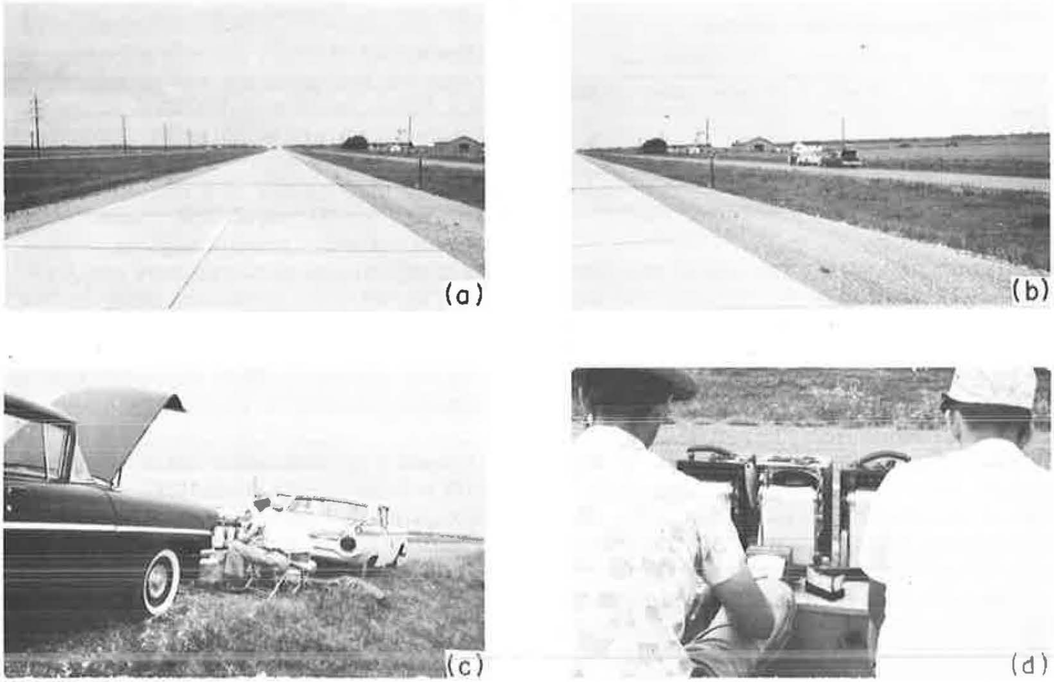

Figure 4. Typical equipment setup for speed and placement measurements: (a) drivers' eye view, (b) observers' vehicle location, (c) observers' location, and (d) measurement recorders.

of these studies were conducted on days when the main station was located on the eastbound tangent (EBT).

Interview Studies. —In an attempt to learn more about the composition of traffic using I-10 and to assess driver opinion of delineation treatments, two interview studies were conducted. The first was conducted on the last night of post delineation (August 12). The second was conducted on the last night (August 29) of point studies under edge-striped conditions.

The interview station in both cases was set up at the Crowley terminal of the eastbound roadway on the single-lane off-ramp. Two interviewers handled the station and a State policeman was on hand to direct traffic just ahead of the station.

Test-Vehicle Studies. —It was contended that the point studies might not provide the most sensitive measure of delineator effectiveness; therefore, it was felt necessary to conduct preliminary investigations to determine the feasibility of two test-vehicle techniques to provide such a measurement. It was hypothesized that the path followed by a vehicle through a test section would be a more sensitive or dynamic measure of delineator effectiveness than measurements at a single point within the section.

A university vehicle was equipped with a tach-generator unit driven off the vehicle's transmission. This unit is connected to a milliammeter recorder which provides a continuous profile of the vehicle's speed. In addition, a control box contains several switches which enable the operator to code in the location of the check points and other events that may affect the results.

One technique, "test driver," utilizes this vehicle when fitted out with a 16-mm magazine-load motion-picture camera mounted on the left rear door of the vehicle. A test driver is used with this technique, and the path followed by the vehicle over 2 or 3 miles of roadway is recorded by the camera. Individual frames are exposed at about 100-ft (of distance traveled) intervals through a solenoid actuated by the tach-generator unit. A distance indicator mounted on the vehicle's front bumper extends into the camera's field of view and appears near the top of each picture. The distance of the vehicle's left front tire from the roadway centerline can then be determined and a continuous placement profile obtained. Figure 5 shows the equipment setup for this procedure.

Although a very accurate placement measurement can thus be obtained, the technique has one inherent disadvantage. The driver, however unfamiliar or familiar he may be with the project, is in a somewhat artificial situation. He realizes that something unusual is going on, and his normal driving pattern may be greatly affected. It may be difficult to separate the delineation effect from the driving pattern.

A second technique, "car following," eliminated the above disadvantage. In this procedure the door-mounted camera is replaced by another 16-mm camera equipped with an 85-mm zoom lens and mounted on a tripod set up on the back seat of the test vehicle. Vehicles actually using I-10 were selected at random and followed at a constant distance of approximately 250 ft for at least two miles of roadway. Individual frames are again exposed at about 100-ft intervals of travel distance. One possible disadvantage of this technique may be that some drivers may become aware of the vehicle following them and think it is a police vehicle.

Measurement of the sample vehicle's speed was obtained by recording the camera vehicle's speed. This measurement depended on maintaining the camera vehicle at a constant distance and adjusting its speed whenever the sample vehicle changed speed.

One difficulty that was experienced with the car-following technique was night photography. A special fast (ASA320) negative type film was used with limited success with many samples lost due to underexposure. By illuminating the indicator at night, very satisfactory pictures were obtained with the test-driver procedure.

With both techniques, a number of frames on each film were referenced to known points along the roadway so that curve and tangent data could be separated.

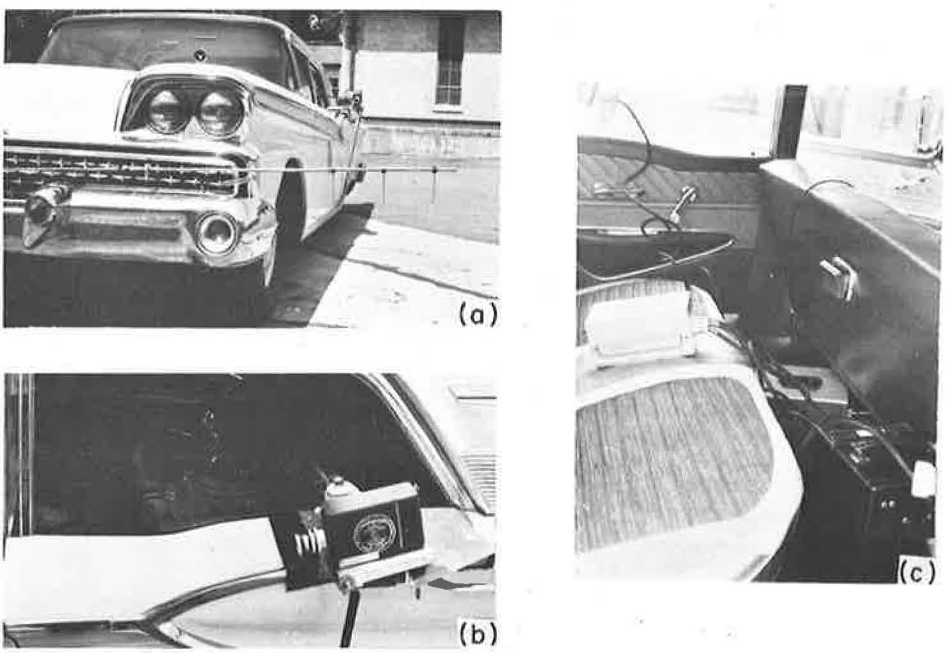

Figure 5. Equipment setup for the "test-driver" procedure: (a) camera-indicator relationship, (b) side-mounted camera, (c) control box, tach-generator and speed recorder in back seat of test vehicle.

Data Analysis

As soon as field data were received, procedures were initiated to process data into a form suitable for analysis.

Point Studies. —The first step in the process was to decode 20-pen chart indications into placement readings utilizing Bureau of Public Roads special tables. At the same time, the vehicle-speed values were read from the speed meter record. Then utilizing periodic time checks, data on both charts were matched to obtain a speed value and a placement value for each vehicle.

These values for independent vehicles were then transferred to data summary sheets. Vehicles were considered independent if they were not preceded by another vehicle closer than 6 seconds in time in either lane. Since volumes of median lane vehicles were very low, less than 10 percent of total at night, only data for shoulder lane vehicles were completely processed (see Table 1).

The data on the summary sheets were keypunched into cards and verified thus permitting any computer analyses deemed necessary. All data processing steps were completely checked before keypunching.

The initial analyses determined average values and standard deviations of the data. In addition, analyses of variance (F-test) and analyses of differences in means were performed.

Supplementary Point Studies. —Supplementary speed and placement data were similarly reduced for analysis purposes, and tabulations of speeds for the three special eastbound tangent studies were made for comparison with main station data.

Test-Vehicle Studies. —The films obtained in the test-vehicle studies were analyzed with a special time-and-motion projector with built-in frame counter. For test-driver runs, pictures were projected on a special white sheet of paper that was ruled off to fix the location of the vehicle-mounted indicator and mark the intersection of the indicator points with the ground. The projector operator then advanced the film frame by frame, lined up the picture as necessary and took the placement reading off the sheet (Fig. 6a).

With the car-following studies, the pictures were projected on a different white paper sheet on which a variable scale was drawn. The projector operator positioned each picture so that a 12-increment scale just fitted between the edge of pavement and roadway centerline and passed through the rear wheels of the vehicle in the picture. The distance in feet (and fraction thereof) between the left rear wheel and the roadway centerline could then be measured (Fig. 6b).

With both procedures, the projectionist obtained a tabulation of film frame numbers and corresponding vehicle-placement values. Vehicle speed and roadway check points were also referenced to frame numbers to complete the data. The placement data were then plotted frame by frame to provide a placement profile for analysis purposes. It was hypothesized that if delineation was effective, it would be reflected in a smoother placement profile than one where no delineation existed.

RESULTS

Point Studies

Median lane vehicles and trucks in the shoulder lane constitute small percentages of total volume on the test section. Data for median lanes were not processed, and trucks in the shoulder lane were excluded from the main analyses.

It is commonly accepted that a speed sample of 100 vehicles is satisfactory for analysis purposes, although one of 150 or more would be desirable. Because of low night volumes in the test sections, it was necessary to collect data on two nights to obtain a sufficient sample. Almost all of the results presented represent combined data for two days or two nights.

The principal results of these studies are summarized in Tables 2 and 3 presenting average values and standard deviations. The average values are also shown in Figure 7. Typical speed and placement distributions are shown in the Appendix.

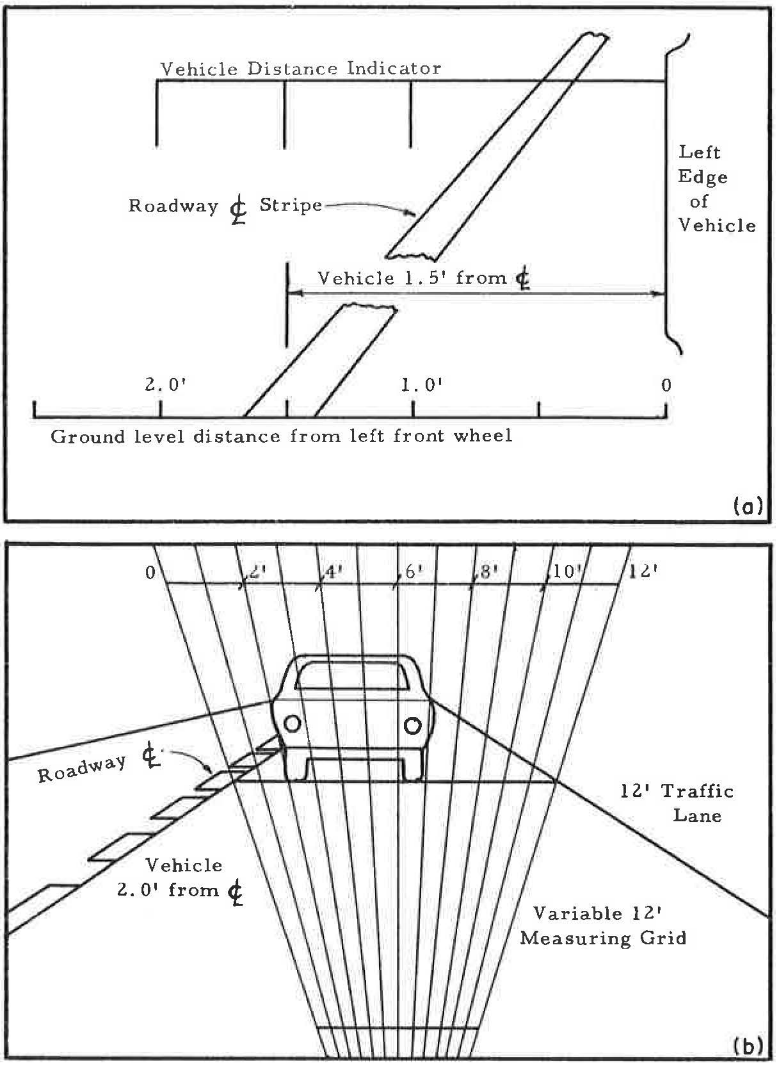

Figure 6. Film analysis techniques for test-vehicle placement-profile determinations: (a) test-driver technique, (b) car-following technique.

From the practical standpoint, it appears that the differences in speed or placement values are not significant. In general, speeds measured under post-delineated conditions are lower than those found under nondelineated conditions, a reversal of what was expected, but these differences are less than 2 mph which is the accuracy limit of the measurement. Also, vehicle placement at night was generally almost a foot closer to the centerline of the pavement than during the day, and there is no appreciable difference in placement, with one exception, under different delineation conditions.

To identify any significant differences in these measurements, an analysis of variance was performed on the averages in Tables 2 and 3. Tables 4 and 5 provide the following results:

1. Mean speeds measured under nondelineated conditions were significantly (at the 5% level) higher than those measured under either post-delineated or edge-striped conditions.

TABLE 2

VEHICLE SPEED VALUES—AVERAGES AND STANDARD DEVIATIONS*

Test Section	Light Condition	Nondelineated			Post Delineated			Edge Striped		
		Sample Size	Avg. Spd. (mph)	Std. Dev.	Sample Size	Avg. Spd. (mph)	Std. Dev.	Sample Size	Avg. Spd. (mph)	Std. Dev.
Eastbound tangent (EBT)	Day	501	58.8	7.6	415	57.3	8.2	503	58.8	7.1
	Night	225	59.3	8.7	235	57.4	9.0	239	59.7	8.2
Westbound tangent (WBT)	Day	416	59.2	8.1	361	57.3	7.6	500	56.8	8.4
	Night	176	59.6	9.7	158	57.8	8.5	176	56.9	7.9
Eastbound curve (EBC)	Day	163	60.9	8.1	410	60.6	8.1	526	58.1	8.6
	Night	168	59.1	9.2	170	59.0	7.6	153	58.3	8.3
Westbound curve (WBC)	Day	214	59.0	6.8	383	59.2	7.1	296	58.6	7.5
	Night	112	58.5	9.3	185	57.8	8.1	164	58.6	8.4

*Radar speed meter accuracy is ±2 mph.

TABLE 3

VEHICLE PLACEMENT VALUES—AVERAGES AND STANDARD DEVIATIONS*

Test Section	Light Condition	Nondelineated			Post Delineated			Edge Striped		
		Sample Size	Avg. Place-ment (ft)	Std. Dev.	Sample Size	Avg. Place-ment (ft)	Std. Dev.	Sample Size	Avg. Place-ment (ft)	Std. Dev.
Eastbound tangent (EBT)	Day	501	7.37	0.99	415	7.36	1.09	503	7.13	0.99
	Night	225	7.81	1.02	235	7.83	1.26	239	7.73	1.12
Westbound tangent (WBT)	Day	416	6.96	0.98	361	6.93	0.91	500	6.72	0.98
	Night	176	7.68	1.08	158	7.59	1.00	176	7.77	1.07
Eastbound curve (EBC)	Day	163	7.45	1.26	410	7.36	1.05	526	7.34	1.08
	Night	168	7.62	1.18	170	7.49	1.20	153	8.93	0.97
Westbound curve (WBC)	Day	214	7.33	1.17	383	7.47	1.28	296	7.67	1.28
	Night	112	8.38	1.70	185	8.13	1.35	164	8.50	1.23

*Vehicle placement is the measurement in feet between the center of vehicle to the edge of pavement; accuracy of this measurement is of the order of ±0.3 ft.

2. Mean placements measured at night were significantly (at the 1% level) closer to the roadway centerline than those measured during the day.

3. Mean placements of vehicles in the westbound curve section were significantly (at the 1% level) closer to the roadway centerline than those in the westbound tangent section.

4. There were no significant differences between mean speeds measured under daylight conditions and those measured at night.

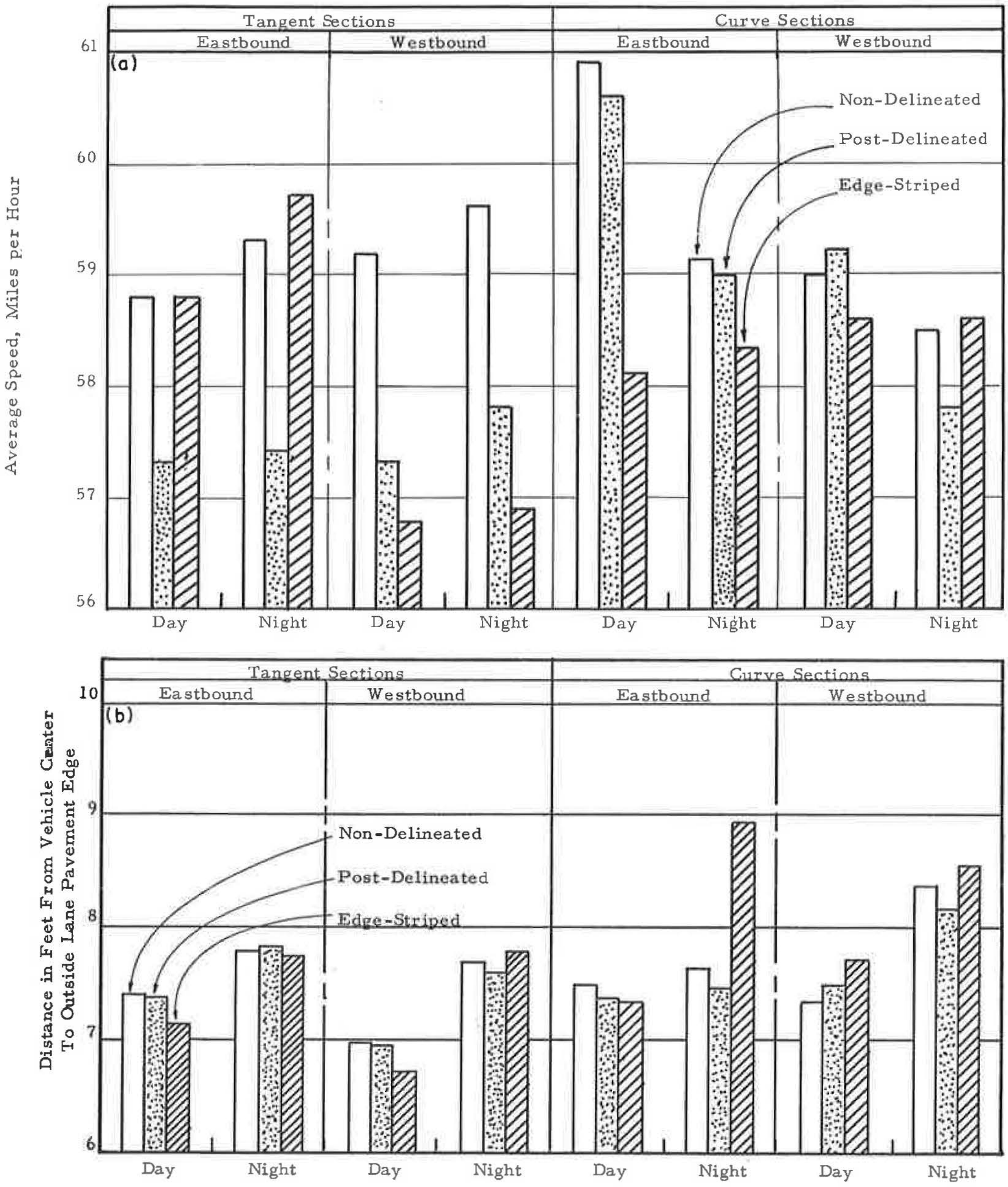

Figure 7. Comparison for all test sections: (a) average vehicle speeds, and (b) average vehicle placements.

5. There were no significant differences in mean speeds between any of the test sections.

6. There were no significant differences in mean placements between any of the delineation conditions.

7. There were no significant differences in mean placements between eastbound and westbound test sections.

TABLE 4

SUMMARY OF ANALYSIS OF VARIANCE OF AVERAGE VEHICLE SPEEDS

Source	Sum of Squares	D. F.	Mean Square	F
Light condition (day vs night)	0.28	1	0.28	0.34
Delineation condition (ND vs PD vs ES)	5.77	2	2.89	3.52
Sections (EBT, WBT, EBC, WBC)	5.91	3	1.97	2.41
Residual (error)	13.98	17	0.82	
Total	25.94	23		
Delineation breakdowns*:				
ND vs (PD+ES)	5.74	1	5.74	7.00**
PD vs ES	0.03	1	0.03	0.04
Subtotal	5.77	2		
PD vs (ND+ES)	1.14	1	1.14	1.39
ND vs ES	4.63	1	4.63	5.65**
Subtotal	5.77	2		
ES vs (ND+PD)	1.77	1	1.77	2.16
ND vs PD	4.00	1	4.00	4.88**
Subtotal	5.77	2		
Section breakdowns:				
Tangents vs curves	3.23	1	3.23	3.94
EBT vs WBT	1.14	1	1.14	1.39
EBC vs WBC	1.54	1	1.54	1.88
Subtotal	5.91	3		
Eastbound vs westbound	2.67	1	2.67	3.26
EBC vs EBT	1.84	1	1.84	2.24
WBC vs WBT	1.40	1	1.40	1.71
Subtotal	5.91	3		

*ND = Nondelineated, PD = post delineators, ES = edge striped.
**Significant at 5 percent level.

To see if there were certain groups of drivers that might provide a more sensitive measure of differences, the data cards were sorted in two different ways and means and standard deviations determined. The first sorting placed the cards into three groups according to the speed of the vehicle; the second, into two groups according to placement.

One of three speed groups consisted of all those vehicles traveling within the 10-mph pace groups of 55 to 64 mph as observed on the speed distribution curves (see Appendix). The other two groups were made up of all vehicles traveling slower than the pace group and all those traveling faster. Figure 8 summarizes the results of this analysis. One obvious characteristic is the faster a vehicle is traveling the closer it travels to the centerline of the roadway.

Since the pace group generally had a large enough sample size and was the most uniform group by speed, it was the only one for which the data were further analyzed. An analysis of variance on pace-group placement data is given in Table 6. The results show the same sources of variation to be significant as were shown in Table 5; however, the level of significance for the difference between the westbound curve and westbound tangent placements was only 5 percent as compared to 1 percent in the previous analysis.

The two-group placement sorting did not produce any results worth noting in this paper.

Table 7 gives the results of a statistical analysis commonly applied to "before and after" speed studies. Kennedy, Kell and Homburger (11) state that in this procedure:

TABLE 5

SUMMARY OF ANALYSIS OF VARIANCE OF AVERAGE VEHICLE PLACEMENTS

Source	Sum of Squares	D. F.	Mean Square	F
Light condition (day vs night)	2.92	1	2.92	34.76**
Delineation condition (ND vs PD vs ES)	0.18	2	0.09	1.07
Sections (EBT, WBT, EBC, WBC)	1.30	3	0.43	5.15*
Residual (error)	1.43	17	0.084	
Total	5.83	23		
Delineation breakdowns:				
ND vs (PD+ES)	0.00	1	0.00	0.00
PD vs ES	0.18	1	0.18	2.02
Subtotal	0.18	2		
PD vs (ND+ES)	0.09	1	0.09	1.07
ND vs ES	0.09	1	0.09	0.95
Subtotal	0.18	2		
ES vs (ND+PD)	0.18	1	0.18	2.02
ND vs PD	0.00	1	0.00	0.00
Subtotal	0.18	2		
Section breakdowns:				
Tangents vs curves	0.95	1	0.95	11.42**
EBT vs WBT	0.21	1	0.21	2.50
EBC vs WBC	0.14	1	0.14	1.67
Subtotal	1.30	3		
Eastbound vs westbound	0.00	1	0.00	0.00
EBC vs EBT	0.08	1	0.08	0.95
WBC vs WBT	1.22	1	1.22	14.53**
Subtotal	1.30	3		

*Significant at 5 percent level.
**Significant at 1 percent level.

...[I]t is necessary to estimate the standard deviation of the difference in means by use of the equation [σ has been substituted for s (11)]:

$$\hat{\sigma} = \sqrt{\sigma^2_{\overline{x}_b} + \sigma^2_{\overline{x}_a}}$$

where:

$\hat{\sigma}$ = standard deviation of the difference in means;

$\sigma^2_{\overline{x}_b}$ = mean variance ... of the "before" study; and

$\sigma^2_{\overline{x}_a}$ = mean variance ... of the "after" study.

If the difference in mean speeds is greater than twice the standard deviation of the difference in means, i.e.

$$(\overline{x}_b - \overline{x}_a) > 2\hat{\sigma}$$

where:

$\bar{x}_b$ = mean speed of the "before" study

$\bar{x}_a$ = mean speed of the "after" study

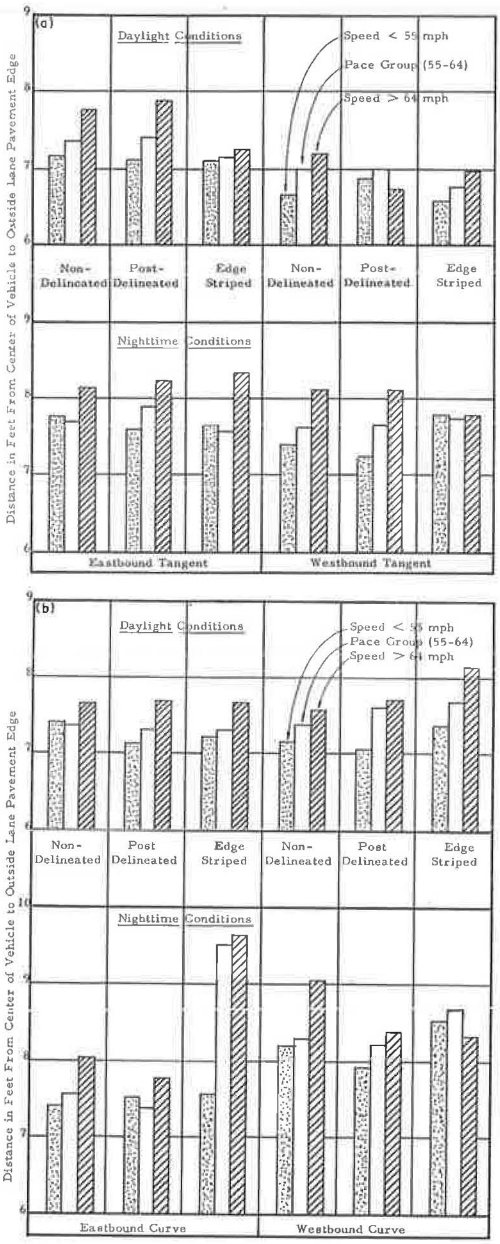

Figure 8. Comparison of average vehicle placements: (a) tangent sections, and (b) curve sections.

. . . it can be said with 95% confidence that the observed difference in mean speeds is significant (the change in conditions has significantly affected the mean speed).

This analysis was also applied to placement data as shown in Table 9. In all cases, the nondelineated daytime conditions serve as the control value being compared, it being hypothesized that this condition provides drivers with their best visibility.

There are several inconsistencies in results (Tables 7 and 8); however, the following results appear to be consistent.

1. Mean speeds in all test sections at nighttime under nondelineated conditions were not significantly different from daylight mean speeds under the same delineation condition.

2. Mean placement values in all test sections under post-delineated daylight conditions were not significantly different from mean placement values under nondelineated daylight conditions.

3. Mean placement values in all test sections under edge-striped nighttime conditions were significantly different from mean placement values under nondelineated daylight conditions.

4. Mean placement values in both tangent sections under both post-delineated and edge-striped nighttime conditions were significantly different from mean placement values under nondelineated daytime conditions.

In interpreting these results, it should be remembered that the accuracy of field measurements was of the order of ±2 mph for speeds and ±0.3 ft for placement values. This could negate the statistical significance of several of the above stated comparisons.

Additional before and after mean comparisons were made generally using the nondelineated nighttime condition as a control value, it being hypothesized that this condition provides drivers with the worst visibility. Tables 9 and 10 present these analyses with the following results.

TABLE 6

ANALYSIS OF VARIANCE FOR PLACEMENT OF PACE SPEED GROUP

Source	Sum of Squares	D. F.	Mean Square	F
Light condition (day vs night)	3.04	1	3.04	17.37**
Delineation condition (ND, PD, ES)	0.32	2	0.16	0.91
Sections (EBT, WBT, EBC, WBC)	1.43	3	0.48	2.74
Residual (error)	2.97	17	0.175	
Total	7.76	23		
Section breakdowns:				
Tangents vs curves	1.18	1	1.18	6.74*
EBT vs WBT	0.10	1	0.10	0.57
EBC vs WBC	0.15	1	0.15	0.86
Subtotal	1.43	3		
Eastbound vs westbound	0.00	1	0.00	0.00
EBC vs EBT	0.17	1	0.17	0.97
WBC vs WBT	1.26	1	1.26	7.20*
Subtotal	1.43	3		

*Significant at 5 percent level.
**Significant at 1 percent level.

TABLE 7

STATISTICAL ANALYSIS OF DIFFERENCES IN MEAN SPEEDS
DAYLIGHT "BEFORE" CONDITIONS

Test Section	Delineation and Light Conditions: Before	Delineation and Light Conditions: After	Difference in Means ($\bar{x}_b - \bar{x}_a$)	$2\hat{\sigma}$	Significant Difference in Means
Eastbound tangent	ND-DL*	PD-DL	+1.500	1.053	Yes
	ND-DL*	ES-DL	0.000	0.928	No
	ND-DL*	ND-NT	-0.500	1.344	No
	ND-DL*	PD-NT	+1.400	1.356	Yes
	ND-DL*	ES-NT	-0.900	1.260	No
Westbound tangent	ND-DL	PD-DL	+1.900	1.127	Yes
	ND-DL	ES-DL	+2.400	1.093	Yes
	ND-DL	ND-NT	-0.400	1.664	No
	ND-DL	PD-NT	+1.400	1.568	No
	ND-DL	ES-NT	+2.300	1.432	Yes
Eastbound curve (curve to right)	ND-DL	PD-DL	+0.300	1.500	No
	ND-DL	ES-DL	+2.800	1.474	Yes
	ND-DL	ND-NT	+1.800	1.904	No
	ND-DL	PD-NT	+1.900	1.723	Yes
	ND-DL	ES-NT	+2.600	1.847	Yes
Westbound curve (curve to left)	ND-DL	PD-DL	-0.200	1.179	No
	ND-DL	ES-DL	+0.400	1.275	No
	ND-DL	ND-NT	+0.500	1.988	No
	ND-DL	PD-NT	+1.200	1.511	No
	ND-DL	ES-NT	+0.400	1.608	No

*DL = daylight; NT = nighttime.

TABLE 8

STATISTICAL ANALYSIS OF DIFFERENCES IN MEAN PLACEMENTS
DAYLIGHT BEFORE CONDITIONS

Test Section	Delineation and Light Conditions: Before	Delineation and Light Conditions: After	Difference in Means ($\bar{x}_b - \bar{x}_a$)	$2\hat{\sigma}$	Significant Difference in Means
Eastbound tangent	ND-DL	PD-DL	+0.010	0.139	No
	ND-DL	ES-DL	+0.240	0.125	Yes
	ND-DL	ND-NT	-0.440	0.162	Yes
	ND-DL	PD-NT	-0.460	0.187	Yes
	ND-DL	ES-NT	-0.360	0.170	Yes
Westbound tangent	ND-DL	PD-DL	+0.030	0.136	No
	ND-DL	ES-DL	+0.170	0.131	Yes
	ND-DL	ND-NT	-0.720	0.189	Yes
	ND-DL	PD-NT	-0.630	0.186	Yes
	ND-DL	ES-NT	-0.810	0.188	Yes
Eastbound curve (curve to right)	ND-DL	PD-DL	+0.090	0.223	No
	ND-DL	ES-DL	+0.110	0.219	No
	ND-DL	ND-NT	-0.170	0.269	No
	ND-DL	PD-NT	-0.040	0.270	No
	ND-DL	ES-NT	-1.480	0.252	Yes
Westbound curve (curve to left)	ND-DL	PD-DL	-0.140	0.207	No
	ND-DL	ES-DL	-0.340	0.218	Yes
	ND-DL	ND-NT	-1.050	0.374	Yes
	ND-DL	PD-NT	-0.800	0.255	Yes
	ND-DL	ES-NT	-1.170	0.250	Yes

TABLE 9

STATISTICAL ANALYSIS OF DIFFERENCES IN MEAN SPEEDS
NIGHTTIME BEFORE CONDITIONS

Test Section	Delineation and Light Conditions: Before	Delineation and Light Conditions: After	Difference in Means ($\bar{x}_b - \bar{x}_a$)	$2\hat{\sigma}$	Significant Difference in Means
Eastbound tangent	ND-NT	PD-NT	+1.900	1.651	Yes
	ND-NT	ES-NT	-0.400	1.572	No
	PD-NT	ES-NT	-2.300	1.582	Yes
Westbound tangent	ND-NT	PD-NT	+1.800	1.992	No
	ND-NT	ES-NT	+2.800	1.886	Yes
	PD-NT	ES-NT	+1.000	1.802	No
Eastbound curve	ND-NT	PD-NT	+0.100	1.837	No
	ND-NT	ES-NT	+0.800	1.954	No
	PD-NT	ES-NT	+0.700	1.778	No
Westbound curve	ND-NT	PD-NT	+0.700	2.123	No
	ND-NT	ES-NT	-0.100	2.193	No
	PD-NT	ES-NT	-0.800	1.772	No

TABLE 10

STATISTICAL ANALYSIS OF DIFFERENCES IN MEAN PLACEMENTS NIGHTTIME BEFORE CONDITIONS

Test Section	Delineation and Light Conditions		Difference in Means	2σ	Significant Difference in Means
	Before	After	$(\bar{x}_b - \bar{x}_a)$		
Eastbound tangent	ND-NT	PD-NT	-0.020	0.213	No
	ND-NT	ES-NT	+0.080	0.199	No
	PD-NT	ES-NT	+0.100	0.219	No
Westbound tangent	ND-NT	PD-NT	+0.090	0.228	No
	ND-NT	ES-NT	-0.090	0.228	No
	PD-NT	ES-NT	-0.180	0.226	No
Eastbound curve	ND-NT	PD-NT	+0.130	0.259	No
	ND-NT	ES-NT	-1.310	0.240	Yes
	PD-NT	ES-NT	-1.440	0.242	Yes
Westbound curve	ND-NT	PD-NT	+0.250	0.392	No
	ND-NT	ES-NT	-0.120	0.388	No
	PD-NT	ES-NT	-0.370	0.275	Yes

1. There was no significant difference among mean speeds measured at night under any delineation condition on curve sections only.
2. The mean speed measured at night under post-delineated conditions was significantly lower than those measured under both nondelineated and edge-striped conditions for the eastbound tangent section only.
3. On the westbound tangent section only the mean speed measured at night under edge-striped conditions was significantly lower than the mean speed measured under nondelineated conditions.
4. There was no significant difference among mean placements measured at night under any delineation condition on tangent sections only.
5. The mean placement of vehicles measured at night in curve sections under edge-striped conditions was significantly closer to the centerline than that measured under post-delineated conditions.
6. In the eastbound curve section only the mean placement of vehicles measured at night under edge-striped conditions was significantly closer to the centerline than that measured under nondelineated conditions.

Supplementary Studies

Speed Studies. —As previously outlined, speed studies (upstream and downstream stations on EBT) were conducted on only one day under each of three delineation conditions. By matching vehicle descriptions it was possible to obtain the speed at all three stations for each of a total of 335 passenger cars on the three days. Again trucks were eliminated because of the small sample, but they generally maintained a relatively constant speed through all three stations, and speeds were relatively slow.

How well each sample at the main station represents the total sample collected at that station is shown in Figure 9 and given in Table 11.

The variation of speeds between the three stations was different on each of the 3 days, but there appears to be a general tendency of vehicles slowing down between the upstream station and the main station.

Downstream Placement Studies. —Supplementary placement data were obtained at a location downstream from the main station on the eastbound tangent one day only under each delineation condition. Because of manpower shortages, the first day's study was

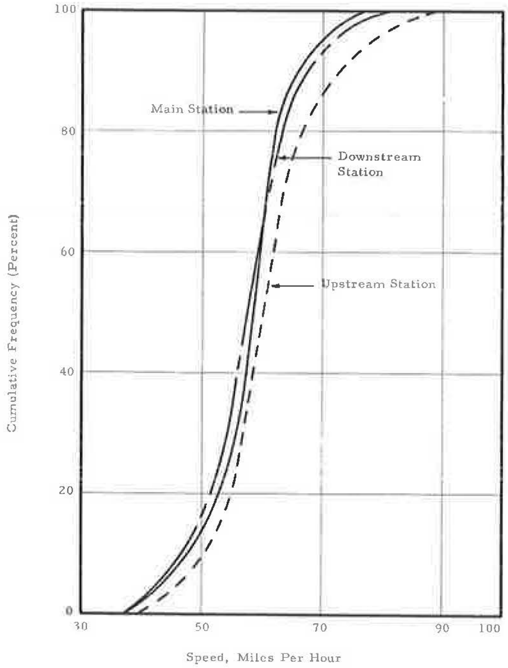

Figure 9. Cumulative frequency curves for 3-station spot-speed studies for combined data for all 3 conditions.

obtained with the second placement tape only 300-ft downstream so that the second 20-pen recorder could be manned by the main station operator. The other studies were conducted with the tape 2,000-ft downstream.

The results of these studies are shown in Table 12 and tend to show that the placement results would not vary significantly with location within a given test section. Again vehicles were identified at each station by brief descriptions, and only those downstream values which could be correlated to main station data were used. (Note how well the downstream sample seems to represent the main station total population.)

Interview Studies. —Interviews of eastbound drivers exiting I-10 at Crowley under both delineation conditions yielded the origin and destination data given in Table 13. Questions pertaining only to post delineators derived the following information.

1. Some 92.5 percent of the drivers said that they had seen the delineators although 25 percent of these had to be drawn out in questioning to be sure they had seen them.

TABLE 11

EASTBOUND TANGENT MAIN STATION MEAN SPEEDS
(Comparison of Sample Vehicles With Total Population)

Date	Delineation Condition	Main Station Total Population		Three Speed Sample	
		Number	Mean Speed	No.	Mean Speed at Station
7/17/63	Nondelineated	221	59.97	98	61.22
8/2/63	Post delineated	228	56.22	122	56.73
8/29/63	Edge striped	238	56.48	115	56.51

2. Of the 8 drivers who did not see the delineators, 5 were from out-of-state and 7 were driving this highway for the first time. Of those who saw the delineators: (a) 6 percent said they could get along without them; (b) 73.5 percent said they thought the delineators were helpful in driving or just that they liked them.

3. More enthusiastic in their support of the delineation were 20.5 percent with such comments as "best thing since the white line," "beautiful," and "wonderful, they're a big help."

Questions asked only to drivers passing through the test section under edge-striped conditions revealed:

1. A majority (59.5%) of these drivers said they had noticed the edge striping. Of this group, (a) 4.3 percent said they could get along without the striping; (b) 87.0 percent said that the striping was helpful; and (c) 8.7 percent were enthusiastic in their support of the striping.

TABLE 12

COMPARISON OF DOWNSTREAM PLACEMENTS WITH MAIN STATION PLACEMENTS

Date	Delineation Condition	Light Condition	Sample				
			Main Station			Downstream	
			No.	Mean Placement (ft)		No.	Mean Placement (ft)
				All Veh	Downstream Veh		
7/2/63	Nondelineated	Day	185	7.014	7.009	171	7.259
8/2/63	Post delineated	Day	228	7.715	7.154	153	7.327
		Night	157	7.767	7.802	139	7.927
8/29/63	Edge striped	Day	238	7.289	7.283	147	7.401
		Night	93	7.517	7.562	76	7.912

TABLE 13

O AND D DATA FOR EASTBOUND I-10 FOR TRAFFIC AT CROWLEY, LA.

O and D Characteristics	Test Section Delineation	
	Post Delineators	Edge Striping
1. Sample size		
a. Drivers of autos only	106	80
(1) Male	No breakdown	74
(2) Female	No breakdown	6
b. Interviews used	106	74
2. No. of passengers		
a. Driver alone	24.5%	41.9%
b. Only 1 passenger	30.2%	25.7%
c. 5 or more passengers	14.1%	12.1%
3. Vehicle registration		
a. Louisiana	82.1%	87.8%
b. Out-of-state	17.9%	12.2%
4. Trip origins		
a. Acadia Parish	12.3%	17.6%
b. Between Acadia Parish and Texas	55.6%	58.1%
c. Texas	29.2%	24.3%
5. Trip destinations		
a. Acadia Parish	47.2%	41.9%
b. Lafayette or Vermillion Parishes (east of Acadia Parish)	36.8%	43.2%
6. Trip ends at home	85.9%	81.0%
a. Origins	(34%)	(31.7%)
b. Destinations	(66%)	(68.3%)
7. Travel frequency on I-10 since delineated		
a. First time	39.6%	29.7%
b. More than once, but no more than once/week	33.1%	23.0%
c. Average one trip/day	11.3%	20.4%
8. Had driven entire 14.7-mi length of I-10 from Jennings before being interviewed	86.8%	83.8%

2. Two-thirds (67.6%) of the drivers said they had noticed the placement tape they crossed some 2 miles back from the interview station. Of these, (a) 38.2 percent did not know what it was; (b) 56.4 percent thought it was a traffic counter; (c) 5.4 percent thought it was a speed trap; and (d) 10.9 percent slowed down after passing it.

Test-Vehicle Studies

Because of the financial limitations of this project, it was not possible to conduct extensive test vehicle studies. Although the motion-picture film required is relatively inexpensive at $8.00 per 100-ft roll (processed), it costs several times that amount to obtain vehicle-placement data off the film through projection techniques.

Within these limitations, however, it was possible to obtain a total of about 60 test-driver runs through the test sections under all 3 delineation treatments and under both daylight and nighttime conditions. In addition, about 100 vehicles were followed under the same set of conditions, and distance-lapse photographs were obtained from the following test car; however, insufficient available light resulted in the loss of most of the night studies due to underexposure of even the fastest movie film available.

The completion of projected picture analysis in each type of test-vehicle study provided a frame-by-frame listing of vehicle placement with respect to the roadway centerline for either the test vehicle (where driven by a "test driver") or the vehicle "followed" by the test vehicle. A typical "placement profile," as obtained from either study, is shown in Figure 10.

Each placement profile was then analyzed over the lengths corresponding to the test sections passed through by the test vehicle. The two most important characteristics of each profile are the frequency of directional changes (D) by the vehicle and the average amplitude ($\bar{A}$) of the profile. These characteristics were used as the two main variables in an expression of the Placement Profile Smoothness Index (PPSI) as follows:

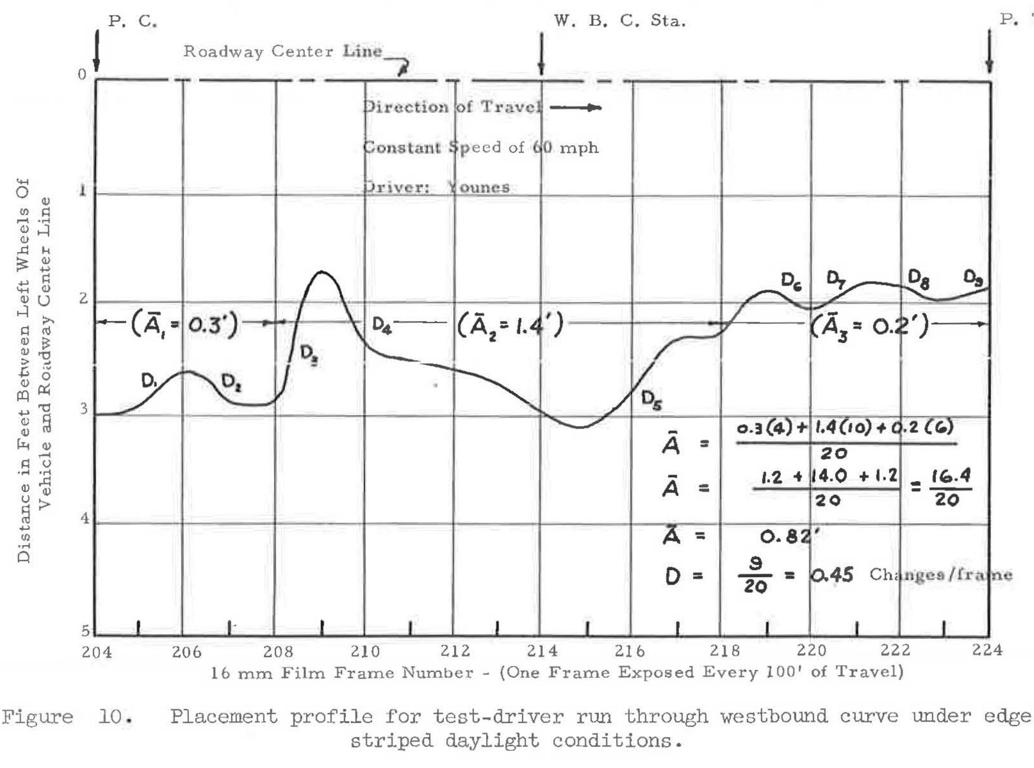

Figure 10. Placement profile for test-driver run through westbound curve under edge-striped daylight conditions.

$$PPSI = \frac{60}{\overline{V}} \frac{\overline{P}'}{D\,\overline{A}}$$

where

$\overline{V}$ = Average speed of test-vehicle through a test section, in mph;

$\frac{60}{\overline{V}}$ = speed ratio, unitless;

$\overline{P}'$ = adjustment factor based on the average placement ($\overline{P}$) of left wheels of vehicle in outside lane during run through a test section (see Table 14);

D = frequency of directional changes per picture frame in total run through a test section; and

$\overline{A}$ = average amplitude of placement profile through a test section, in feet.

The determination of the PPSI relationship was based on the following considerations.

1. As the frequency of directional changes and the average amplitude of the profile increase, the PPSI decreases, and the profile is considered rougher.
2. The approximate average operating speed through the test sections has been shown as 60 mph and it was felt that drivers of slower vehicles had more control over their vehicle than those going faster than 60 mph, hence the factor ($60/\overline{V}$).
3. Vehicles whose left wheels were 3.00 ft from the roadway center line were approximately centered in the outside lane of the test section, and it was felt that any vehicle generally operating off-center was in a relatively less desirable lane position. Vehicles near the outside edge of the pavement were in danger of leaving the pavement, and those near the roadway centerline (lane line) would possibly come in conflict with inside lane vehicles. The former condition was considered twice as detrimental as the latter.
4. A perfectly smooth placement profile would be a straight line 3.00 ft off the roadway centerline where $\overline{A}$ and D both equal zero and PPSI = ∞.

Based on this relationship, a total of 79 test-driver section runs under all experimental conditions and 44 daytime car-following section profiles were evaluated. The resulting profile characteristics were used to calculate PPSI values which were then averaged by section and experimental condition (Table 15).

Since the PPSI is a totally new characteristic, the reader has no way of knowing what significance the values in Table 15 have. As an aid to their interpretation, Figure 11 was prepared for an assumed average speed of 60 mph and average placement of 3.00 ft. Several "iso-PPSI lines" were drawn arbitrarily dividing the chart into eight profile type areas.

The results shown in Table 15, therefore would appear to substantiate the hypothesis that placement profiles obtained under daylight or delineated nighttime conditions were smoother than those obtained under nondelineated nighttime conditions. Placement profiles for test drivers under daylight conditions tended to be smoother than those obtained for vehicles followed by the test vehicle.

TABLE 14

PLACEMENT ADJUSTMENT FACTORS

$\overline{P}$	$\overline{P}'$	$\overline{P}$	$\overline{P}'$	$\overline{P}$	$\overline{P}'$
0.00′	0.75	2.00′	0.92	4.00′	0.83
0.25	0.77	2.25	0.94	4.25	0.79
0.50	0.79	2.50	0.96	4.50	0.75
0.75	0.81	2.75	0.98	4.75	0.71
1.00	0.83	3.00	1.00	5.00	0.67
1.25	0.85	3.25	0.96	5.25	0.63
1.50	0.875	3.50	0.92	5.50	0.58
1.75	0.90	3.75	0.88	5.75	0.54
2.00	0.92	4.00	0.83	6.00	0.50

Adverse Weather Observations

Although it was hoped that detailed studies could have been made under adverse weather conditions (i.e., rain and/or

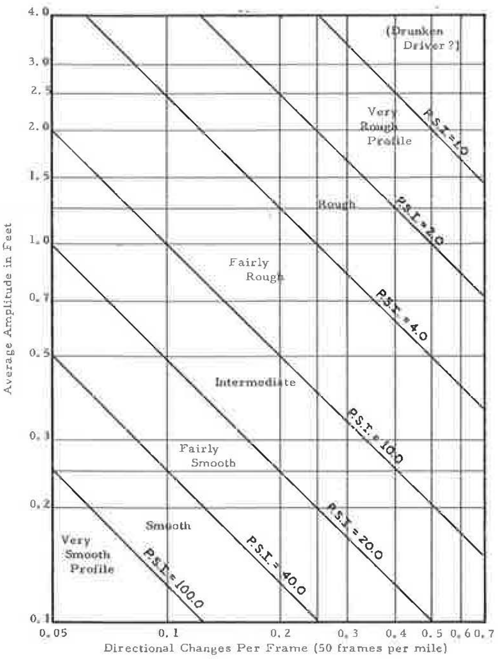

Figure 11. PPSI variation for average speed = 60 mph and average placement = 3.00 ft.

fog) it was impossible to do so for the following reasons:

1. The speed and placement equipment used for the primary studies of this investigation were inoperable under such conditions.
2. Such conditions were infrequent throughout the period during which field data was collected.
3. Test-car photography would be ineffective.

The researchers were, however, able to drive through the test sections, with post delineators in place, during a very heavy rainstorm and made the following observations:

1. The painted centerline (lane line) stripe was "washed out" by the rain and was ineffective as delineation.
2. The post delineators were definitely visible and gave a certain degree of confidence in following the road, which was not felt when driving along nondelineated portions of I-10 adjacent to the test sections.

TABLE 15

COMPARISON OF AVERAGE PLACEMENT PROFILE SMOOTHNESS INDICES

Experimental Conditions	WBT Only	EBT Only	Combined Tangents	WBC Curve L	EBC Curve R
Car-following, daylight	3.18* (11)**	3.50 (12)	3.35 (23)	3.59 (10)	3.01 (11)
Test driver:					
1. Daylight-combined Delineation conditions	6.78 (10)	4.88 (9)	5.88 (19)	4.97 (7)	7.65 (6)
2. Nighttime					
Nondelineated	3.69 (6)	5.05 (5)	4.31 (11)	3.55 (4)	3.77 (5)
Post delineators	6.82 (4)	4.47 (3)	5.81 (7)	7.29 (3)	5.77 (3)
Edge striped	5.33 (3)	4.29 (4)	4.74 (7)	4.33 (3)	4.00 (4)

*PPSI value.
**Number of values determining average.

GENERAL OBSERVATIONS

Speed and Placement Point Studies

Although a number of the speed and placement variations determined by this research were shown to be statistically significant, these results do not appear to be too important.

The significant differences in mean speeds generally are of the order of ±2 mph which is the accuracy limit of the radar speedmeter. In addition, most of the significant differences in speeds were decreases which tend to refute the hypothesis that delineation would increase night speeds. Had night speeds under delineated conditions been about 5 mph greater than night speeds under nondelineated conditions, however, it could have been said that the delineation was effective.

It was expected that nighttime placements would be closer to the roadway centerline than daylight placements based on the results of others previously cited (6, 7, 10). The amount of the significant placement difference ranges from 0.3 to over 1 ft which should not greatly affect vehicle operation on the roadway although vehicles that are closer to the centerline may have some influence on vehicles passing them in the inside lane. The significant difference in placement on the westbound curve as compared to the westbound tangent may be due to the direction of curvature being to the left.

The type of measurements obtained in this research as well as the subsequent data reduction procedures were subject to equipment and human errors. However, it is felt that adequate precautions were maintained to minimize the occurrence of such errors and that the results thereby obtained accurately reflect the speed and placement of most vehicles using the test sections of I-10.

The supplementary downstream placement studies tended to show that the same relative placement results would have been obtained regardless of placement tape position, and therefore the selected study points within each section were satisfactory. Although the supplementary speed studies showed many vehicles' speed at the main station to be lower than their upstream or downstream speeds, the main station speeds are considered representative. More than likely this effect was due to the drivers noticing the upstream observers coupled with visibility of vehicles parked near the main station. During regular operations, the first indication of observers was at the main station and the radar speedmeter picked up the vehicle speeds before drivers were aware of the observers.

The location of the placement tape on the pavement joint was effective in disguising its presence, particularly at night. Very few drivers thought that it was a speed trap since only one tape was used. The Louisiana State Police use two tapes at speed traps utilizing the electric speed clocks.

Some local residents that used the I-10 test sections almost daily were continually aware of the observers presence, and no doubt some knew what was being measured; a few such drivers were observed to vary their speed when passing by the main station. However, these drivers were in a minority as shown by the O-D data given in Table 13.

It might be considered that a major limitation of this research might be the fact that all studies were conducted on the four sections of the single segment of I-10 near Crowley, but project budget limitations precluded additional research at other sites. The site selected was considered most favorable due to its location relative to Baton Rouge and the relatively low traffic volumes providing predominantly independent vehicles.

Interview Studies

About two-thirds of the interviews conducted under edge-striped conditions were obtained by relatively inexperienced interviewers, which probably accounts for the fact that only 56 percent of the drivers were recorded as having seen the edge striping. As generally indicated on the interview forms, the question posed was "Did you notice the roadside delineation in the past two miles of your trip?" The term delineation was not one that many drivers understood, and unless the interviewer followed this question with one mentioning the specific type of delineation, it was not definitely known if they had missed seeing the delineation. Such questioning in the first study revealed that 92 percent of the drivers had seen the post delineators.

Test-Vehicle Studies

The results obtained from the test-vehicle studies should only be considered as supplementary to the primary studies of speed and placement. Since these studies involved previously untried procedures, they were too limited in scope to produce very significant results.

The test-driver technique had too few replications for each driver to determine adequately the effect of driver variability and to separate this effect of driver from the effect due to delineation conditions. The test drivers were in an artificial situation, and because of this, there is some question as to how well their placement profiles represent the driving population. This was borne out by the results given in Table 15 which showed that on the average test-driver placement profiles were smoother than placement profiles for vehicles that were followed.

The car-following technique met with partial failure in that high-speed motion-picture films were incapable of recording sufficient detail at night. It is possible that a faster lens or infrared technique might have produced satisfactory results, but such method development was not included as a part of this project. The car-following technique is considered better than the test-driver technique because the driver is not in an artificial situation; however, the test vehicle cannot follow the sample vehicle too closely or the driver may become aware of being followed and alter his normal driving pattern.

The PPSI determination was arbitrarily set up based on the basic characteristics of the placement profile, although some traffic researchers may recognize a similarity to Greenshields' "Quality Index" which was studied prior to development of this procedure (13). A more thorough analysis of more extensive studies would be required before a final equation and adjustment factors could be established. (Moreover, measures of stability for complex wave forms should be applied.) It is felt, however, that the relationship used in this study was satisfactory to show the nature of the results obtained.

CONCLUSIONS

Based on the results of the investigations conducted during this research and in view of the limitations of these investigations, the following conclusions appear to be in order.

1. Neither roadside post-mounted reflective delineators nor edge-stripe delineation have any significant effect on the speed or placement of passenger-car vehicles passing through the outside lane of delineated sections of an Interstate highway under fair weather conditions.
   a. Although speeds measured under nondelineated conditions were significantly (statistically) higher than those measured under either post-delineated or edge-striped conditions, these differences are not considered significant from a practical standpoint.
   b. Although some "before and after" comparisons of vehicle placements showed statistically significant differences, the general analysis of variance showed no statistically significant differences due to delineation treatment.
2. In general, passenger-car vehicles in the outside lane travel some 6 to 12 in. closer to the roadway centerline when their speeds exceed 64 mph than when their speeds are less than 55 mph.
3. In general, passenger-car vehicles in the outside lane travel some 3 to 9 in. closer to the roadway centerline at night than during the day.
4. Drivers of passenger vehicles at night are almost unanimous in their feeling that roadside delineation is helpful to their driving on the Interstate Highway.
5. Although test-vehicle results gave some indication of delineator effectiveness, the significance of this indication is unknown since the methods used have not been sufficiently tested for sensitivity to the variables involved.

RECOMMENDATIONS FOR FURTHER STUDY

Inasmuch as measurements of traffic operational characteristics of speed and placement during this research were not sensitive enough to illustrate any delineation effectiveness, which drivers apparently believe to exist, the following recommendations are suggested for further investigation of this problem.

1. Development of the test-vehicle technique should be carried to the point of being able to analyze placement profiles for the effects due to roadway geometrics, delineation, etc. This would require extensive studies with a large sample of both test drivers (with several replications each) and cars followed. The latter sample would depend on the successful development of the night photography technique.

2. Use of the galvanic skin response (GSR) technique on a sample of test drivers should be tried in an attempt to identify any comforting effect that delineation may provide. This may be a particularly effective means for obtaining data under adverse weather conditions. It is felt that such conditions would form a much better base for showing delineator effectiveness than fair weather conditions.

3. Once a more effective measurement is developed, studies should be conducted at more than one Interstate location. Also, treatment variations such as delineator type, location and spacing could be effectively evaluated.

4. In the research just completed, delineation treatments were varied on the same test section locations with only one treatment being evaluated at a time. An alternate approach would provide a site where several treatments could be randomly ordered simultaneously along an Interstate highway thereby providing an opportunity to evaluate the differences in operation of the same population of drivers under all delineation treatment conditions.

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Appendix

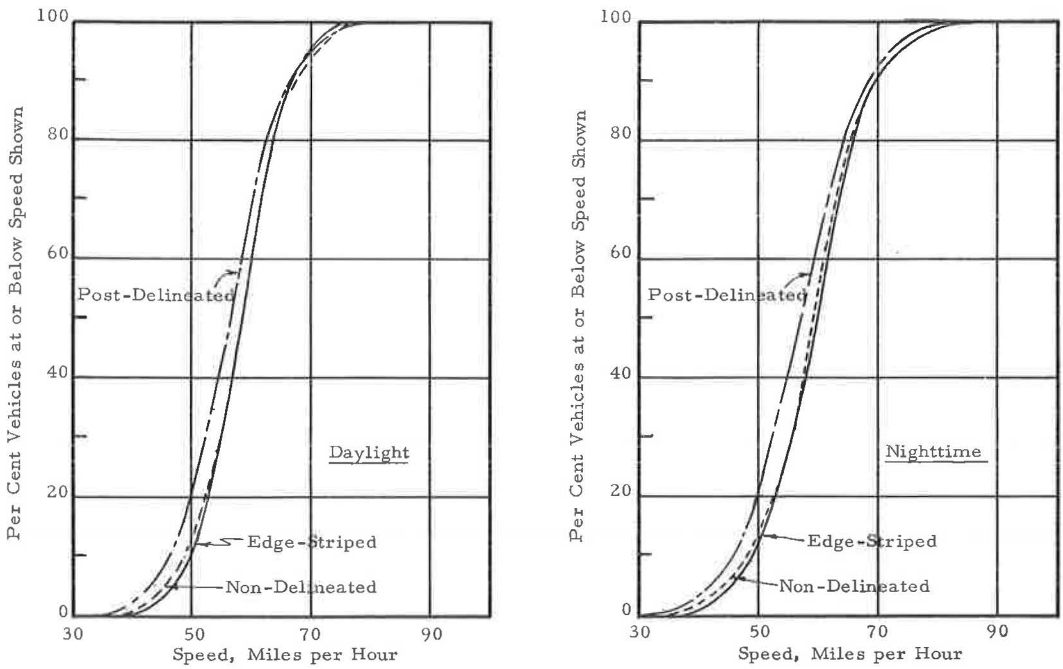

Figure A-1. Cumulative frequency curves for spot speeds at eastbound tangent station.

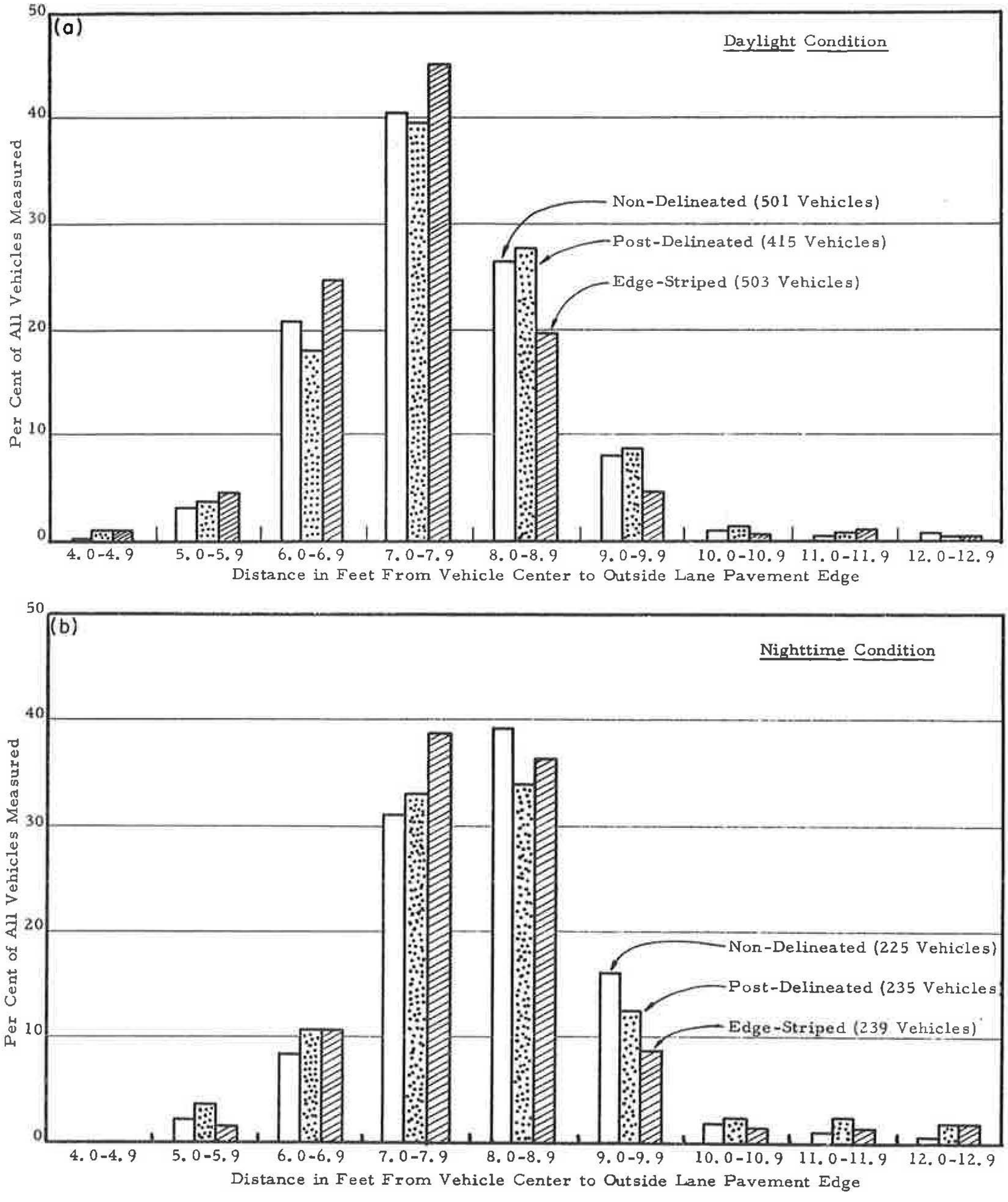

Figure A-2. Frequency distributions of vehicle placements at eastbound tangent station: (a) daylight, and (b) nighttime.