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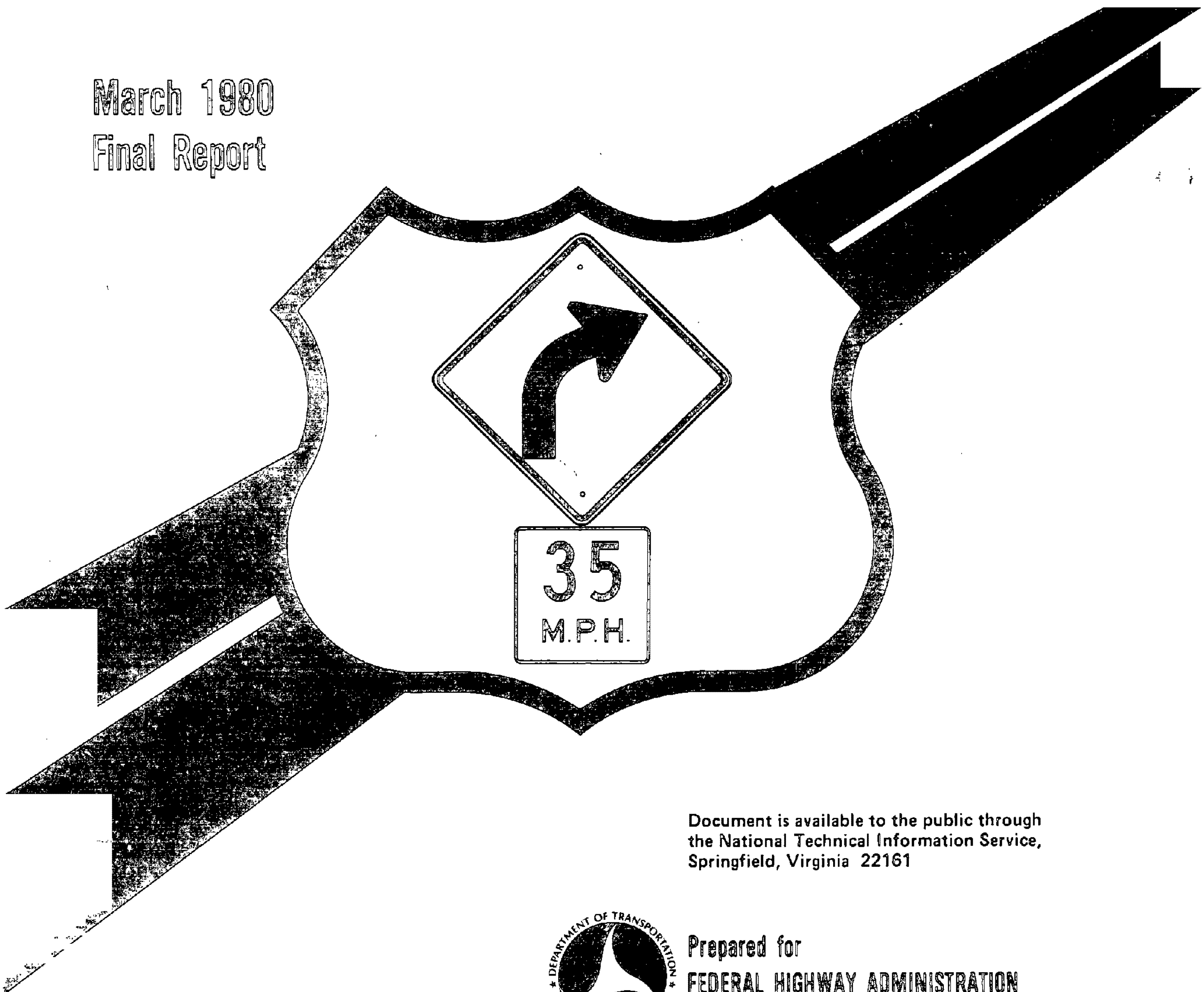
AN EVALUATION OF WARNING AND REGULATORY SIGNS FOR CURVES ON RURAL ROADS

March 1980
Final Report



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FOREWORD

This report discusses an experiment that was undertaken at two sites in Central Maine. The general purpose of the experiment was to evaluate several warning and regulatory signs that could be used for warning motorists on a rural two-lane road of a hazardous horizontal curve ahead. An executive summary of this report is now being prepared and will be distributed later to safety personnel and engineers who are responsible for the safe operation of rural two-lane highways.

Signs that were examined in the reported research ranged from the standard curve warning arrow to a regulatory speed zone sign in conjunction with the curve warning sign. Overall, five different signing conditions were examined. Data that were collected during the experiment included automatic monitoring of vehicle speeds as drivers approached the test sites and subsequently traversed each test site horizontal curve. Vehicle classification, center and edgeline crossing, and vehicle registration information were also collected manually. Both the automatic and manual data were collected within a multi-factor experiment design. Factors controlled for included: (1) motorist familiarity with the road, (2) presence or absence of opposing traffic, (3) drivers' speed as they approached each horizontal curve test site, (4) type of vehicle being driven by drivers whose performance was being monitored and (5) weather and ambient light conditions.

The experiment was jointly run by the Maine Department of Transportation and the University of Maine, Orono, as part of the FHWA research program at the Maine Facility

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Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

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Mr. J. H. Wyman of the Maine Department of Transportation was responsible for the actual running of the experiment. The FHWA contract manager was S. R. Byington.

16. Abstract

This report reviews an experiment undertaken to examine the effectiveness of five sign treatments for controlling driver speeds in the vicinity of hazardous horizontal curves on rural two-lane highways. Signs examined ranged from the standard curve warning arrow to a regulatory speed zone sign in conjunction with a curve warning sign. Data collected during the experiment included both the following electronic and manual data: speeds of motorists as they approached and negotiated two horizontal curves, vehicle classification and registration information, and whether vehicles crossed over center and edge line markings. Data were collected under both day and night conditions and under adverse weather conditions.

The principle findings were that no sign, or group of signs, were consistently more effective than another relative to decreasing the potential hazard at horizontal curves in rural two-lane situations. Because the report clearly shows that the experiment was well conceived, the reasons for the above results are not immediately clear. It may well be, however, that the proliferation of curve warning signs has lessened the average motorist's respect for the message they convey.

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Horizontal curves, rural two-lane roads, warning and regulatory signs, speed control.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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1.0 INTRODUCTION

One of the more common roadside warning signs seen by motorists is the curve warning sign. Placement of this sign, according to the Manual on Uniform Traffic Control Devices (MUTCD), is "...where engineering investigations of roadway, geometric, and operating conditions show the recommended speed on the curve to be in the range between 30 and 60 miles per hour and equal to or less than the speed limit established by law or by regulation for that section of highway" (FHWA, 1978). In many instances, however, it appears that use of the sign is merely to inform motorists of an alignment change where a speed change is not necessary. The MUTCD suggests that an advisory speed plate may also be used where "additional protection" is desired. Such speed plates often seem overused with the indicated speed being quite conservative. The net result may be that such signs are often ignored by motorists. The judgemental standards for placing such signs may also differ by jurisdiction with some setting stringent standards based on safety (speed reduction is necessary) while others use the signs in a purely informational manner (speed reduction is not necessary). In addition, King, et. al. (1978) note that interpretations of whether or not such warning signs carry with them the force of law vary, with many enforcement officials treating, for example, advisory speed limits as if they were enforceable (i.e., regulatory limits).

Several interesting questions thus arise. Do motorists respond at all to the curve warning signs; are reactions affected by the addition of advisory speed plates; and how effective are regulatory signs relative to warning signs? The answers to these questions are especially relevant in rural situations where drivers are typically traveling at somewhat higher speeds and are presumeably more dependent on information conveyed by signs than in urban situations. In order to address these questions, an experiment was designed to evaluate the effectiveness of several alternative sign configurations for informing and/or warning motorists of a horizontal curve on the road ahead in rural two-lane situations. The experiment was based on an original design by KLD and Associates, Inc., (King, et. al., 1978), and undertaken during the summer of 1978 as part of the rural road research program conducted at the Federal Highway Administration's (FHWA) Maine Facility.

King, et. al., also provided extensive background on the previous research findings relative to warning signs. Several examples, which have pertinence to this experiment, were: speed on the curve was not necessarily influenced by posted advisory speeds, but that approach speeds were often correlated with them; speed zone signs were among those with the best recall by drivers; overuse of advisory signs may lead to contempt for all signs (especially if posted advisory speeds are overly conservative); and that drivers may not differentiate between different types (e.g., one is standard, one had adjectives such as maximum or safe) of advisory speed plates.

The experiment was undertaken at two sites in Central Maine (one east of Waterville and the other just north of Dexter). The signs that were examined ranged from the standard curve warning arrow to a regulatory speed zone in conjunction with the curve warning. Data that were collected during the experiment included automatic monitoring of vehicle speeds as they approached the test sites and subsequently traversed the curve, and manual collection of vehicle classification, center and edgeline crossing, and vehicle registration information.

2.0 EXPERIMENT IMPLEMENTATION

2.1 EXPERIMENT CONTEXT

As noted in the previous section, the experiment that was undertaken was based on a modified version of an original design by KLD Associates, Inc. (King, et. al., 1978). In general, two horizontal curves were selected and instrumented so that data could be collected on motorists' behavior as they approached and negotiated the curve. Selected sign configurations were used at different times with comparisons being made of the differing reactions to them. The basic data on motorists' behavior were collected by using a series of sensors (Traffic Data Corporation coaxial road sensors) placed on the road surface at 60 m (200 feet) intervals on the approach to and through the curve. The sensors blended quite well with asphalt pavement and typically went unnoticed by drivers. (This assertion was borne out by driver interviews during another experiment, and numerous comments by visitors to the experiment sites.) The sensors were linked to a recording unit in a mobile traffic data collection vehicle (van) where the data were recorded on magnetic tape for later processing. The van was parked off the road and typically could not be seen by motorists traveling through the site. The capabilities of the data collection system were described elsewhere (Wyman and Lyles, 1979). The manually collected data were also recorded on the magnetic tape.

Two sites were used for this experiment, primarily to provide a means to assure that effects of various signs were not unique to a specific site. Several site candidates were identified by Maine DOT District Traffic Engineers as being hazardous locations and judged against the following criteria:

1. A horizontal curve where the approaching motorist could not see the end of the curve, and where there was a "need" to slow down in order to safely negotiate the curve.

2. Good pavement condition and shoulders (e.g., no potholes or drop-offs, respectively).

3. Minimal existing warning signs (e.g., none or a standard warning curve arrow).

4. Rural character of adjacent land uses (e.g., the curve should not be in a built-up area).

5. Reasonable volumes (i.e., greater than 2000 vehicles per day) with an expectation of 25-50% non-local traffic.

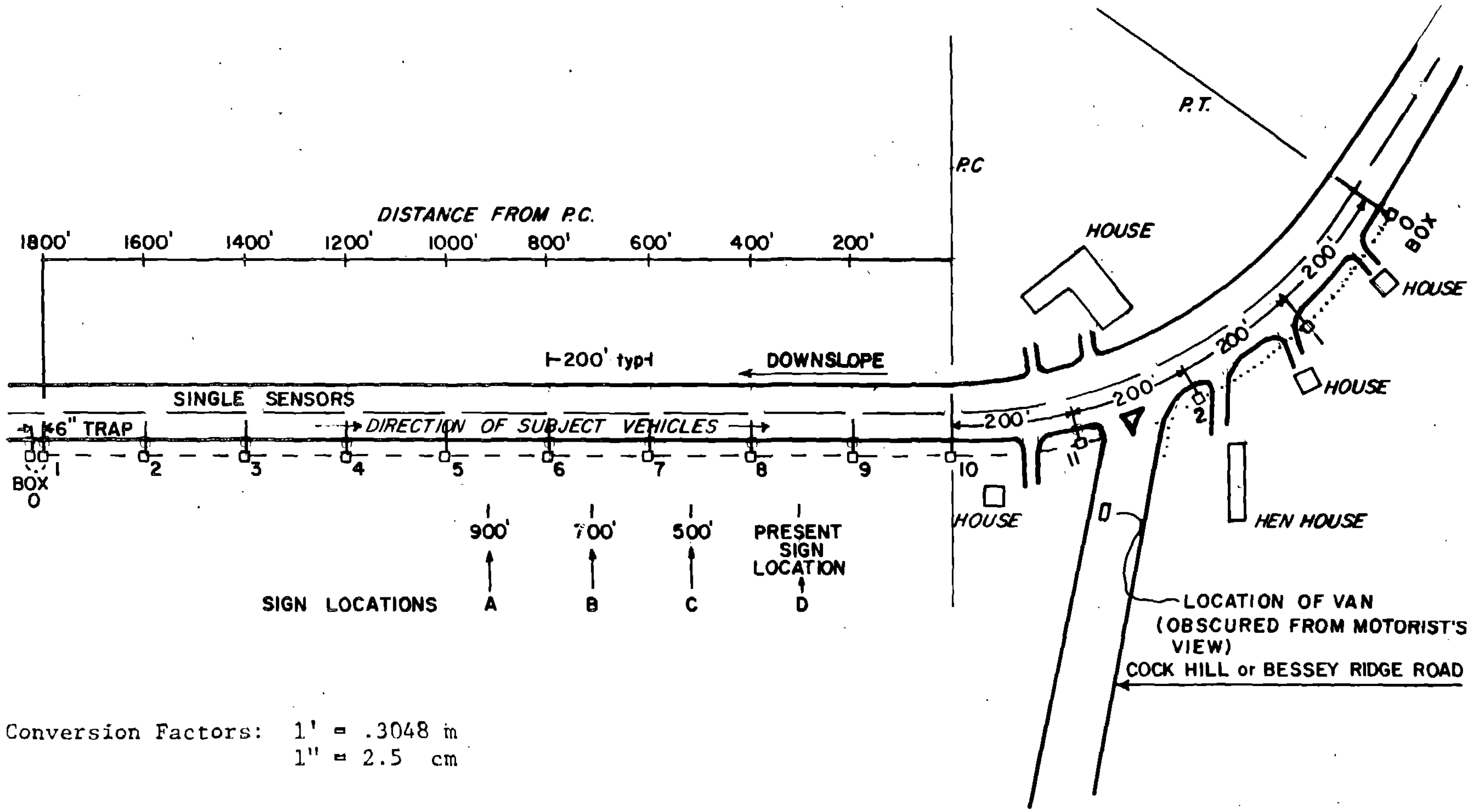
The "need" to slow down was defined somewhat arbitrarily but included 1) the inability to drive through the curve at 8 km/h (5 mph) faster than the posted speed limit without going over either the edgeline or centerline of the road and 2) the necessity for the majority of drivers to apply their brakes to negotiate the curve. As an illustration of the proliferation of curve signs, it should be noted that in the search for suitable curves for the experiment, none was located within a 48 km (30 mile) radius of the Facility that was not signed in some manner.

The two sites were about 72 km (45 miles) apart. Site 1 was located on State Route (S.R.) 23 about one mile north of Dexter. Data were taken on southbound motorists who had been traveling over hilly terrain. The site itself had an uphill approach to a crest vertical curve before going downhill through the horizontal curve (to the drivers' right). A minor dirt road went essentially straight ahead at the point of curvature (the minor road was a short cut into town used by local drivers). There were several farm houses in the area of the curve although they were set well back from the road. There was considerable evidence of cars crossing both the center and edge lines (badly worn center stripe and worn shoulder, respectively). This portion of S.R. 23 had an ADT of about 1000 although in the summer there was a fairly heavy flow to and from the Moosehead Lake tourist region to the north.

The second site was eastbound on S.R. 9 and U.S. 202 near Albion. The approach to this site was level for motorists who had been traveling over rolling terrain. The last couple of hundred meters before the curve were uphill with the horizontal curve then to the left. There were also a few farm houses in the vicinity of this site. Again the roadway showed signs of motorists crossing both the center and edgelines (especially the former). The volume at Site 2 was somewhat lighter - an ADT of about 700.

Both sites had a posted speed limit of 45 mph (72 km/h) for some distance prior to the curve. Both sites also had a standard curve warning arrow placed at about 91 m (300 feet) from the point of curvature. In addition Site 1 had a large directional arrow (red and white) in the curve itself. At both sites, new centerline markings had been painted prior to the experiment, and both had relatively good pavement (some cracking was evident at Site 1) and shoulders (although narrow).

For illustration purposes, Site 2 is shown in Figure 1 with the deployment of data collection system and the positioning of the signs. The layout shown is typical of both sites.



Conversion Factors: 1' = .3048 m
1" = 2.5 cm

FIGURE 1 HORIZONTAL CURVE SITE AND DATA COLLECTION ARRAY

2.2 DATA COLLECTION

As indicated above, data collection included tracking motorists as they drove through the experiment area. In addition to the electronic data collection, observers in the mobile system vehicle (van), which was on the side road at Site 2 (see figure) and in behind a stand of trees in a field at Site 1, collected manual data on vehicle classification, (automobile or recreational vehicle), Maine or non-Maine license plate classification, and the number of center and edgeline crossings. These data were observed and recorded for every "lead vehicle" (see the discussion of independent variables for a definition) and input to the magnetic tape record (with the electronic data). The observers also monitored system operation (e.g., were all sensors functioning).

Data collection alternated between the two curve sites and two others (another experiment) such that data collection was not continuous at one site for the entire summer. In general, all data were collected between June and October, 1978.

3.0 VARIABLES AND MEASURES

3.1 INDEPENDENT VARIABLES

The principal objective of the experiment was to assess the effectiveness of various types of warning signs as well as the gain in effectiveness, if any, by using regulatory signs in horizontal curve situations. The different sign configurations were tested under a variety of conditions to assure the consistency of reported results. The configurations tested and those conditions comprised the set of independent variables for this experiment and are discussed below.

3.1.1 Treatment Conditions

There were five different configurations that were examined. They are illustrated in Figure 2 and discussed below:

Condition 1 - Existing conditions. The standard curve warning sign (arrow) was placed closer to the curve than recommended by the MUTCD 91 m (300 feet). (See FHWA, 1978 for standards.)

Condition 2 - Standard curve warning sign at approximately the recommended distance from the curve - 213 m (700 feet).

Condition 3 - Standard curve warning sign supplemented with a non-standard warning sign that indicated a "MAXIMUM SAFE SPEED" of 35 mph (56 km/h).

Condition 4 - Standard curve warning sign in conjunction with a regulatory speed zone of 35 mph (56 km/h).

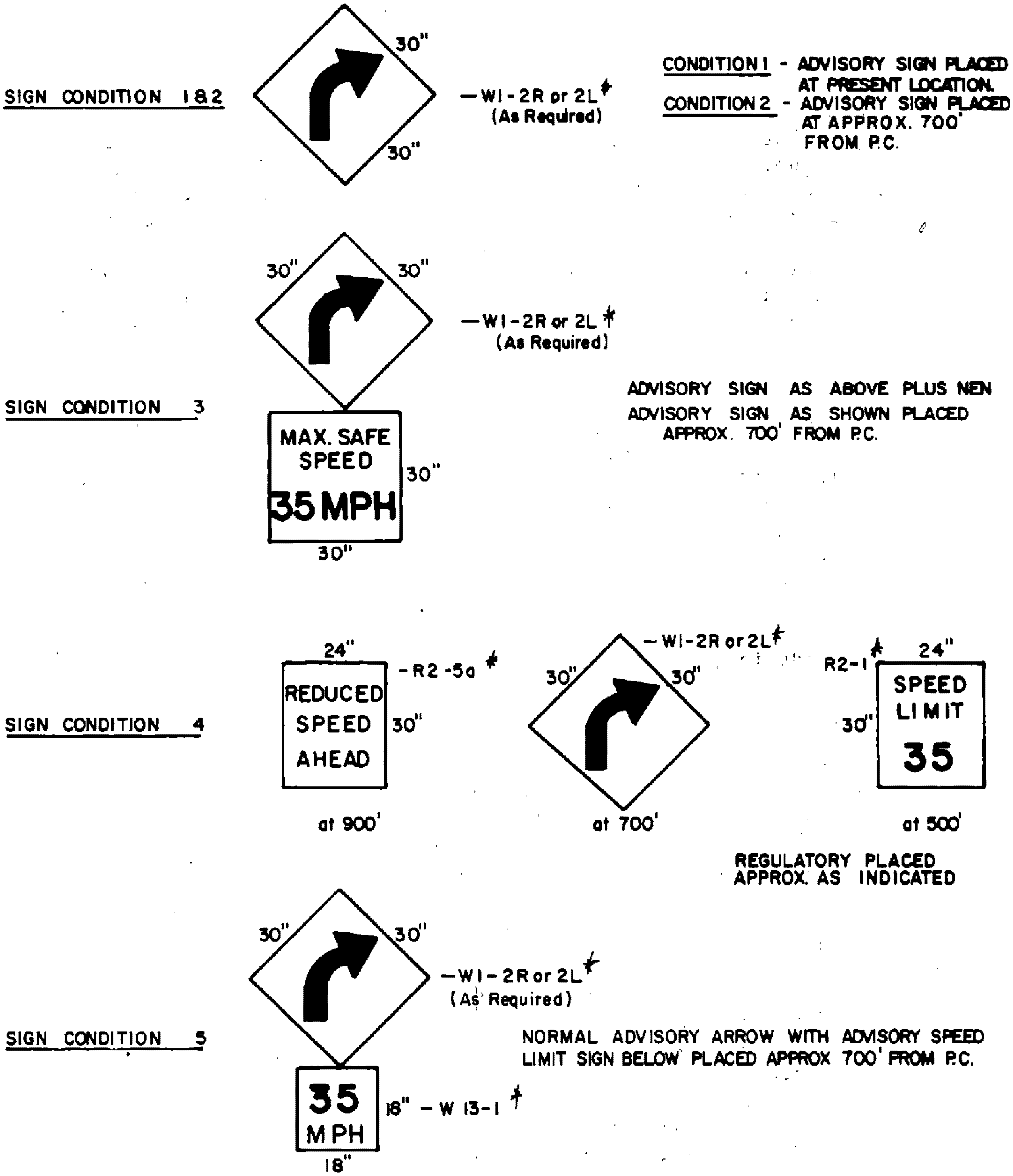
Condition 5 - Standard curve warning sign with a standard advisory speed plate indicating a speed of 35 mph (56 km/h).

The conditions that were used allowed the following questions to be examined:

1. Does the distance from the hazard to the warning sign make a difference in motorist reaction?

2. Does the addition of the advisory speed plate to the curve warning sign have any positive impact?

3. Does the more emphatic advisory speed plate (Condition 3) have any incremental effect?



* SEE THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVISES FOR STANDARDS
CONVERSION: 1 FT. = .3048 M

FIGURE 2 SIGN CONDITIONS FOR HORIZONTAL CURVE EXPERIMENT

4. Is motorist reaction to the regulatory signing different from the reaction to the warning conditions?

The order in which the treatment conditions were deployed at each site was randomized (with the exception of Condition 1 - Existing Conditions which was first in both instances) so that there would be no increasing or decreasing trend in the emphasis of the signs observed by repeat users of the road. The signs were switched to the next condition shortly (one-three days) after data collection ceased on any given condition. Hence, the next sign condition was typically in place for one and one-half to two and one-half weeks prior to data collection.

3.1.2 Sites

As described in detail above, two different sites were utilized. Reiterating, the primary reason for using two sites was to provide some verification that any sign effects were not unique to one site. While geometric characteristics were quite similar at both sites (e.g., lane and shoulder width), and the base speed limit, 72 km/h (45 mph), was the same, the gradient of the approach did differ. In addition, one curve was to the right and the other to the left relative to the direction that subject vehicles were going. Thus, while some comparisons between the absolute effects at the two sites might be misleading, the general trends in effectiveness should be similar.

3.1.3 Ambient Light

Data were collected continuously during both the day and night, (until about 11:00 PM) although twilight data were discarded. The day-night stratification provided a reasonable basis to determine if no (or low) light conditons caused any change in sign effectiveness. Note that at night the manual data on center and edge line crossing and the state of vehicle registration were not collected.

3.1.4 Opposing Traffic Present (Opposition)

Although the driver of a subject vehicle could not see around the curve (to see if other vehicles were approaching), the data collection configuration allowed a determination to be made as to whether a driver encountered opposition on the last part of the approach to the curve or on the curve itself. Such drivers were separated from drivers who encountered no opposition since the behavior of the two groups would presumeably differ (e.g., a driver encountering opposition on the curve was presumeably more likely to slow down and not cross the centerline).

3.1.5 Motorist Familiarity

Another issue of interest was the impact of motorist familiarity (with the road) on sign effectiveness. For example, it could be argued that everyday users of the road would be more aware of the changing signs and the activity at the intersection, and respond differently to the signs than would a one-time user.

In order to gain some insight into the potentially differential behavior of these two groups of motorists, manual data were taken by the observers so that all motorists could be classified according to whether or not their vehicle was registered in Maine, a crude proxy for motorist familiarity. Note that it was possible to make the registration determination only during the day.

3.1.6 Entry Speed

It was reasonable to assume that the magnitudes of motorists' reactions to signs and the intersection itself varied according to how fast they generally drove (i.e., their mean free speed). For example, if a sign condition was particularly effective in causing motorists to slow down for the intersection, it was likely that faster drivers slowed down more than slower drivers did (the latter were already driving at speeds closer to the "safe" speed). Assuming that this was the case, there were several options that were available for accounting for it. However, given that the analysis to be performed was based on an analysis of variance (ANOVA) model, the most straightforward method was to use some expression of the mean free speed as a covariate. Thus, the effects of the vagaries of motorists' driving habits (as far as speed was concerned) was accounted for explicitly. The best available estimate of motorists' mean free speed was that speed recorded as they entered the instrumented area - i.e., the entry speed, or speed recorded by the initial 1.8 m (6 foot) trap.

3.1.7 Weather Conditions

While a full sample of weather condtiions was not possible, data were collected on rainy days. Thus, at least partial analysis was done for "good" versus "bad" weather conditions.

3.1.8 Type of Vehicle

In the past, axle counts had been used to proxy the type of vehicle passing through a site. For this experiment, the observers were able to classify vehicles as either automobiles or recreational vehicles. The former class included automobiles and pick-up trucks (with or without low caps). The latter included large motorized mobile homes, pick-ups with large (over cab) caps, larger vans, and cars or pick-ups with trailers.

Large trucks and commercial vehicles were excluded primarily due to the lack of adequate numbers of such vehicles using the road.

3.1.9 Other Variables as Restraints

There were several other factors that could be considered as independent variables and provide further levels of stratification. In order to keep the analysis (and data collection) manageable, the more important of these were used as either restraints in the experiment or as conditions to eliminate some data.

1. Day of the Week - in order to provide as much homogeneity in the traffic mix as possible, data collection was typically limited to weekdays only.

2. Turning vehicles that entered the system but then turned off at the side road, (minor side roads were present at both sites) or those that entered there, were discarded.

3. Queue Vehicles - because drivers of vehicles in a queue (less than six (6) seconds headway to the preceding vehicle) tended to react more to the vehicle immediately in front of them rather than to other conditions (e.g., the signs), they were eliminated from consideration. Hence, only the first, or lead, vehicles were considered.

4. Slow Vehicles - vehicles which had an entry speed of less than 56 km/h (35 mph) were discarded as being anomalous.

The experiment design is summarized in Table 1.

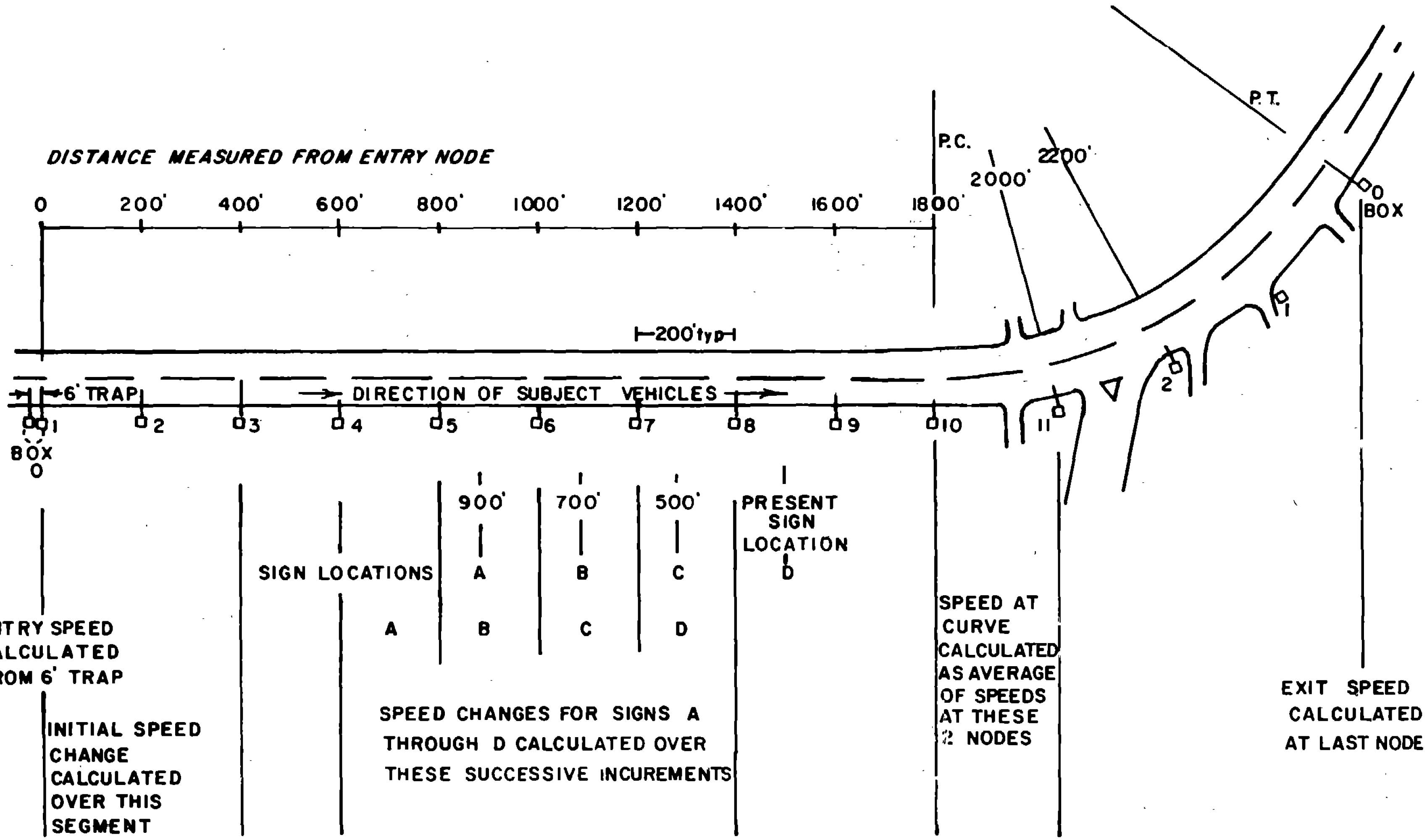
3.2 DEPENDENT VARIABLES/MEASURES OF EFFECTIVENESS

A set of twelve variables was measured for each vehicle as it passed through the experiment area. The raw data took the form of time intercepts of the sensors on the road surface or the time that the manual data (e.g., edgeline crossings) were recorded. These data were later processed so that a vehicle was "tracked" through the area. Ten of the twelve variables were then speed or speed-related characteristics of the vehicle's passage. The remaining two variables were concerned with time spent in violation of the limits of the travel lane. Each of these variables was selected so that the interpretation was directly related to the effectiveness of the particular sign treatment and, thus, the minimization of the hazard condition at the curve. All speeds were measured over 61 m (200 feet) links (except the entry speed which was calculated over a 1.8 m (6 feet) trap). Figure 3 illustrates where each variable was measured.

Table 1. Summary of Experiment Design

Independent Variable	Levels
Treatment Condition (see also Figure 2)	1. Curve Warning Arrow (Existing position) 2. Curve Warning Arrow (Standard MUTCD position) 3. Curve Arrow + Max. Safe Speed 35 mph Plate 4. Curve Arrow + Regulatory Speed Zone (35 mph) 5. Curve Arrow + Standard Advisory Speed Plate (35 mph)
Sites	1. Route 23 (S.B.) Dexter 2. Route 9 (E.B.) Albion
Ambient Light	1. Day 2. Night
Opposition Traffic	1. Yes 2. No
Motorist Familiarity	1. Maine 2. Non-Maine
Entry Speed	Included as a covariate in analysis
Weather Conditions	1. Good visibility; dry 2. Rain; wet pavement
Type of Vehicle	1. Auto 2. Recreational Vehicle

Conversion Factors: 1 mph = 1.609 km/h



OTHER VARIABLES:

—DISTANCE TO MINIMUM SPEED-MEASURED TO NODE FROM ENTRY POINT

—MAXIMUM SPEED CHANGE-MAXIMUM OF SPEED CHANGE OVER 2 SUCCESSIVE NODES

NOTE: ALL NODE SPEEDS (EXCEPT ENTRY SPEED) ARE AVERAGE SPEEDS OVER THE PRIOR 200' SEGMENT

CONVERSION: 1' = .3048 M

FIGURE 3 CALCULATION OF DEPENDENT VARIABLES

3.2.1 Entry Speed

As indicated, the entry speed of vehicles was used as a covariate to account for the impact of individual entry speeds on the values of other variables. The average entry speed was also used to establish the degree of similarity among the various samples of drivers that passed through the experiment site. That is, the average entry speeds of various groups were compared to insure that, overall, given samples of motorists were behaving similarly to each other prior to seeing the signs. For example, given other independent variables as constant (e.g., day, dry pavement), the average speed of the group of motorists later seeing Sign 1 was compared to the groups of motorists later seeing Signs 2 through 6. If the mean entry speeds of these six groups were not significantly different, that implied that, overall, the six groups had been behaving similarly prior to entering the instrumented area.

3.2.2 Initial Speed Change

Soon after each vehicle entered an experiment area, the treatment condition was visible (although not legible). The first variable that reflected any possible reaction to the treatment was the initial speed change, measured over the first 122 m (400 feet) of the instrumented area.

3.2.3 Speed Changes at Signs

Four other speed changes were also measured. These changes were in the vicinity of the four test sign locations shown in Figure 1 (A, B, C and D). Each of the speed changes was measured as the difference between the speeds calculated over the links ending 91 m (300 feet) and 30 m (100 feet) prior to the sign location. Measuring the speeds at these points illustrated any speed change due to the reaction of the motorist having read the sign. Measurement of these speed changes also allowed for a general overview of when speed changes occurred on the approach to the intersection.

3.2.4 Speed at the Hazard

One of the more important, and least ambiguous, measures of the effectiveness of a particular treatment condition was the average speed attained at the hazard itself (in this instance, the curve). A lower speed indicated a safer situation.

3.2.5 Distance to Point of Minimum Speed

Good driving technique was demonstrated when a driver slowed down before entering the curve and accelerated slightly while on the curve. Thus, the location of the minimum speed varied according to the overall driving technique used in negotiating the curve. The distance was measured relative to the entry point of the instrumented section.

3.2.6 Maximum Speed Change

The maximum speed change (between any sequential pair of link speeds) was indicative of the abruptness of motorists' reactions to either the signs or the curve itself. Assuming that the speeds at the intersection were within acceptable limits, the more desireable treatments resulted in more uniform speed reduction.

3.2.7 Exit Speed

The last variable calculated was the motorists' speeds at the end of the instrumented area (at the "exit"). Comparison of this variable to the speed at the curve provided an indication of how rapidly the motorists resumed their normal speed. While the motorists were not yet on the tangent after the curve, they could see the road ahead and had, in fact, exited the most hazardous area.

3.2.8 Lane Placement

The last two variables that were calculated were concerned with lane placement, and derived from the manual data on edge and centerline crossings. The variables take the form of total time spent over the centerline (i.e., encroaching on the opposing lane) and total time spent over the edgeline (i.e., encroaching on the shoulder area). They were calculated as the time between sequential indications (manual) that the center or edgeline had been crossed.

4.0 DATA ANALYSIS AND TECHNIQUES

4.1 GENERAL DESCRIPTION OF DATA

Data were collected at each site between June and October, 1978. Typically, data were collected for several days for each of the combinations shown in Table 2 (except for rain data which were collected whenever possible). Once all data for a given cell of Table 2 were identified, each vehicle record was examined for completeness of the record (i.e., were all or most of the dependent variables calculated), whether or not the vehicle in question was a lead vehicle, and whether or not the vehicle had an entry speed of at least 56 km/h (35). Once these requirements had been met, fifty (50) observations were selected at random from the remaining data for that cell subject to the additional conditions that up to twenty-five of vehicles could be opposed, out-of-state, rec. vehicles, or combinations of these factors (e.g., out-of-state rec. vehicles). However, most of the cells had a disproportionate number of unopposed and in-state autos. This was due to the lower volumes of both total and Maine registered vehicles than had been expected at both sites. There was an overall shortfall of night data collected at Site 2 due to low volumes at night and scheduling problems for data collection. These problems notwithstanding, most of the analyses that had been planned were, in fact, undertaken. Significance testing was carried out at the ninety-five percent (95%) level throughout.

4.2 ANALYSIS APPROACH AND TECHNIQUES

The principal purposes of the analysis were to ascertain whether a particular sign (or set) was superior to others in lessening the hazard at horizontal curves in rural two lane situations, and whether that superiority was consistent over all conditions (e.g., was Sign Condition 4 more effective than the others and was that the case both during the day and night, etc.).

The basic method was to use an analysis of variance (ANOVA) approach first with a multiple-factor model (e.g., consider signs, sites and ambient light at once) and then in a one-way model with accompanying comparisons (contrasts) of the explicit effects of each sign condition with other factors (e.g., ambient light, site) held constant. The ANOVAs were undertaken on each dependent variable separately. The statistical program that was used was the Statistical Package for the Social Sciences (SPSS, Nie, et. al., 1975).

4.3 ANALYSIS AND DISCUSSION OF INDEPENDENT VARIABLES

A set of eight independent variables (see Table 1) were considered in the experiment. The basis for discussion of the effects of each of these factors was a series of multiple-factor ANOVAs. The

Table 2. Sample Sizes

	SITE 1		SITE 2	
	Day	Night	Day	Night
Sign 1	50 50*	42	50	12
Sign 2	50 34*	50	50	Missing
Sign 3	50 50*	50	50	27
Sign 4	50	50	50	7
Sign 5	50	50	50	50

* Numbers indicated with an asterisk indicate rain data

most important effect, that of the treatment conditions, is also addressed more explicitly in later sections of this report. There was an explicit limitation of the number of factors that could be considered simultaneously (5) imposed by the SPSS routines (see Nie, et. al., 1975). In the initial analysis data were segregated by site and weather conditions leaving five factors to be considered.

4.3.1 Sites

As noted there were two sites utilized in the experiment. In general, all sign conditions were deployed at both sites although, as a practical matter, there was an inadequate number of data collected at Site 2 at night for a completely rigorous analysis. In the initial five-factor ANOVAs that were undertaken, all data were separated by site - that is, all analyses that were undertaken considered each site separately. That there were differences (in the values of the dependent variables) according to site, was essentially taken as a given due to the considerations, first, that there were physical (geometric) differences between the two sites, and, second, that previous research (e.g., Lyles, 1979) in similar situations had shown strong site effects. That is not to say, however, that the trend of effectiveness of different sign treatments varied by site (in fact, the trends - e.g., sign x was better than sign y - were the same) but that the absolute effects did. Hence, not only did the multiple-way ANOVAs consider sites separately, but so did all subsequent analysis (i.e., the one-ways concerend only with treatment (sign) effects).

4.3.2 Weather Condition

The only weather data available for analysis were collected at Site 1 and then only for three sign conditions during the day (see Table 2). Thus, weather effects were considered separately - that is, two factor analyses (weather and sign conditions) were undertaken for each dependent variable. No main effects or interactions were found that indicated that weather (dry pavement and good visibility vs. rain and wet pavement) was significant. Note that the weather conditions were never really poor (e.g., downpours that effectively limited visibility), and that all rain data were acquired during the day. So, while the results indicated that weather was insignificant, caution should be used in interpreting this result.

4.3.3 Ambient Light

Ambient light condition was one of the five factors considered simultaneously in the multiple factor ANOVAs. The results of these ANOVAs are summarized in Table 3 for Site 2. Site 2 was considered to be illustrative for the purposes of presentation, and in fact, was more interesting than Site 1. (Fewer significant results were noted for Site 1.) Note, however, that the table is limited to a

Table 3. Summary of Significant Maine and 2-Way Interaction Effects
(Site 2 - Good Weather Only)

Dependent Variable	Significant Main Effects No Covariate*	Significant Two-Way Interactions No Covariate*	Significant Main Effects With Covariate*	Significant Two-Way Interaction With Covariate*
Entry Speed	None	None	----	----
Initial Speed Change	None	Signs/Opposition	Familiarity	Signs/Opposition Signs/Familiarity
Speed Change-Sign A	Signs, Veh. Type, Opposition	Light/Veh. Type	Signs, Veh. Type, Opposition	Light/Veh. Type
Speed Change-Sign B	Signs	None	Signs	None
Speed Change-Sign C	Signs, Veh. Type, Opposition	None	Signs, Opposition	None
Speed Change-Sign D	Signs	Light/Veh. Type	Signs	Signs/Light Light/Veh. Type
Speed at Curve	Signs, Light	None	Signs, Light	None
Distance to Minimum Speed	None	None	Veh. Type	None
Maximum Speed Change	None	None	None	None
Time Over C.L.	Familiarity	Signs/Veh. Type	Familiarity	None
Time Over E.L.	None	Opposition/Veh. Type Signs/Veh. Type	None	Signs/Veh. Type
Exit Speed	Signs, Light	Signs/Opposition Signs/Light Signs/Familiarity	Signs, Light	Signs/Opposition

* Covariate was Entry Speed

consideration of daytime data and results. The factors considered (simultaneously) in the ANOVA were signs, ambient light, presence or absence of opposing vehicles (opposition), vehicle type, and driver familiarity with the site (familiarity). Entry speed (see Section 4.4) was considered as a covariate.

The ambient light level (day or night) was found to be significant as a main effect on the speed at the hazard itself (curve) and on the exit speed. There were also several instances where ambient light level had an interaction effect in combination with one of the other variables (i.e., with signs on exit speed, vehicle type on two of the speed changes). (Note that only main effects and two-way interactions were considered; higher order interactions were disregarded.) Although this evidence does not seem particularly strong, day and night data were, nonetheless, considered separately when the one-way analyses were undertaken. Specific magnitudes of any day/night differences are discussed in later sections.

An additional set of two-way ANOVAS was undertaken that considered only the effects of signs and ambient light. The results of these analyses were not substantially different from the multi-factor results (i.e., significance occurred for the same dependent variables) although the other independent variables were held constant.

4.3.4 Opposing Vehicles

It had been anticipated that whether or not a motorist encountered a vehicle going the opposing direction would affect his/her behavior. Hence, this effect should be accounted for when assessing the effectiveness of the signs. In the multiple-factor ANOVA it was found, however, that the effect of an opposing vehicle being present was typically insignificant. In the few instances when this factor was significant, the effect was present on the dependent variables measured early in the subject motorist's reactions (i.e., relative to the speed changes near the signs) rather than at the curve itself, although there was a significant interaction with signs on the exit speed.

Based on the a priori assumption that opposition vehicles would have an impact and the findings summarized above (although not of overwhelming significance), the one-way analyses undertaken later also allowed for separate consideration of opposed and unopposed motorists. Again, the magnitudes of the effects are discussed in later sections.

4.3.5 Familiarity of Drivers

As with other experiments of this genré (see Lyles, 1979), the impact of motorist familiarity with the sites was largely unknown. Whether or not drivers were familiar with the site was approximated with vehicle registration - i.e., Maine and non-Maine. This indication was available only for daytime users of the roads. A review of Table 3 (and similar results for Site 1) revealed that familiarity was generally not a significant factor. Thus, no further allowance was made for familiarity in the ensuing analyses.

4.3.6 Vehicle Type

Vehicle type was found to be significant in a few instances (two of the speed change variables) for Site 2 (Table 3). However, vehicle type was never significant as a main effect at Site 1. It should further be noted that there were few (relative to the number of auto/pick-ups) recreatiional (rec) vehicles accounted for in the analysis - 38 of 362 at Site 1 and 27 of 328 at Site 2. Due to the small numbers of rec vehicles in the sample and the observed insignificance of their effect overall, no further allowance was made for vehicle type.

4.3.7 Treatment Conditions (Signs)

By far the most prevalent effect in the multiple way ANOVAs was that due to the signs. The signs had a significant effect for most of the speed change variables and speed at the curve. In addition to the main effects there were also several instances of significant interactive effects. Table 3 illustrates the pattern of sign significance that emerged. It should be noted that although the effect of signs was still clearly the most pervasive at Site 1 as well, significance was not noted on quite so many of the variables. The effects of the signs are addressed more explicitly in a later section of this report.

4.4 THE EFFECTS OF ENTRY SPEED

Table 3 shows results for the multiple-factor ANOVAs both with and without entry speed considered as a covariate. Entry speed was used as a covariate to account for the effect that varying entry speeds would have on values of other dependent variables for given motorists. It can be noted that although the covariate was often significant, the pattern of significant effects (e.g., main effects for signs) was typically similar whether or not the covariate was included.

It can also be noted in Table 3 that when entry speed was examined as a dependent variable there were no significant main or interaction effects for any of the independent variables. This result attested to the similarity among the various samples of motorists as they entered the test (instrumented) area.

The basic conclusion drawn from the above results was that there was no basic cause for concern over varying entry speeds possibly adversely affecting the other variables.

4.5 ANALYSIS AND DISCUSSION OF DEPENDENT VARIABLES

In order to explicitly examine the effectiveness of the various signs, several sets of one-way ANOVAs were undertaken on the dependent variables. The most pertinent of these are summarized in Table 4. For each one-way ANOVA several of the independent variables were held constant - these are shown at the top of the table (e.g., Site = 1, Opposition = Yes, Weather = Good, Light = Day). The entries in each column indicate whether or not the effects due to the signs were significant, in general, for each dependent variable. In each instance, a set of comparisons (contrasts) was also undertaken to establish which signs were, in fact, the most effective. The following paragraphs are addressed, in turn, to the explicit sign effects in a variable by variable fashion. Note, however, that, in general, the sign effects appeared to be more consistent at Site 2 than at Site 1 - that is, the instances where there was significance were more numerous at Site 2.

4.5.1 Initial Speed Change

While the summary for the multi-factor ANOVAs (Table 3) showed no significant main effects on Initial Speed Change at Site 2 (although there were at Site 1), the evidence from the one-ways was mixed (Table 4). The appropriate question was which sign was most effective in the instances when there were significant differences among the signs.

Table 5 shows more detail of the findings for the initial speed change and most of the other dependent variables. Table 5 shows the effectiveness rankings of the signs (by mean value) for each of the ANOVAs summarized in Table 4. For the initial speed change, Table 5 illustrates some confusing outcomes - while for Site 1 the order of effectiveness was relatively similar, the order for Site 2 contradicts the result for Site 1. That is, the trends in effectiveness were dissimilar. (This finding was not limited to the Initial Speed Change.) It should be noted that at Site 1 the motorists were traveling on an upgrade in the area where this variable was measured, whereas at Site 2 the grade was level. While this fact may play some part in the explanation, the trends (in which signs were most effective) still should have been the same.

4.5.2 Speed Change - Sign A

At Site 1 relatively large speed changes occurred both in the initial speed change segment and just before the Sign A position. In general, these changes ranged from 4 km/h (2.4 mph) to 11 km/h (6.7 mph) for the various signs (see Table 5). The differences at Site 2 were not nearly so dramatic with some sign conditions actually resulting in slight .3 km/h (.2 mph) increases. Similarly there were no consistencies noted in the trends of effectiveness of signs at the two sites, or between day and night data. That is to say that

Table 4. Summary of One-Way ANOVAs For Sign Effects

Independent Variables							
Site	1	1	1	2	2	2	2
Opposition	Yes	--*1	--*1	--*1	Yes	No	--*1
Weather	Good	Good	Good	Good	Good	Good	Good
Light	Day	Day	Night	Day	Day	Day	Night
Dependent Variables							
Initial Speed Change	Yes	Yes	Yes	No	No	Yes	No
Speed Change-Sign A	Yes	No	No	Yes	No	Yea	No
Speed Change-Sign B	No	No	No	Yes	No	Yes	No
Speed Change-Sign C	Yes	No	No	Yes	Yes	No	No
Speed Change-Sign D	No	No	No	Yes	Yes	Yes	No
Speed at Curve	--	--	--	Yes	No	Yes	Yes
Distance to Min.Speed	No	No	No	No	No	No	No
Maximum Speed Change	No	Yes	No	No	No	No	No
Time Over Centerline*2	No	No	No	No	No	No	No
Time Over Edgeline*2	No	Yes	Yes	No	No	No	No
Exit Speed	Yes	Yes	No	No	No	No	Yes

In the table a "Yes" indicates that the overall Sign Effects were statistically significant (.95) while a "No" indicates that they were not statisticlly significant. At Site 1 there was a large number of missing data as well as a data reduction problem causing the calculation of the speed at the curve to be impossible.

*1 No distinction made as to whether individual motorists were opposed or not, although at night unopposed predominates

*2 These variables may provide erroneous results - see text

Table 5. Ranking of Sign Effectiveness for Each Variable Based on Mean Values

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Site	1	1	1	2	2	2	2
Opposition	Yes	--*1	--*1	--*1	Yes	No	--*1
Weather	Good	Good	Good	Good	Good	Good	Good
Light	Day	Day	Night	Day	Day	Day	Night
1. Initial Speed Change	3(0.4) 2(1.7) 1(2.4) 5(3.0) 4(4.2)	3(0.6) 2(1.8) 1(2.5) 4(2.8) 5(3.1)	3(0.0) 1(1.6) 2(2.0) 4(2.1) 5(3.1)	4(-0.2) 1(-0.1) 5(1.0) 2(1.1) 3(1.5)	4(0.0) 2(0.1) 1(0.5) 5(1.1) 3(2.0)	1(-0.5) 4(-0.5) 5(0.9) 3(0.9) 2(3.3)*[4]	3(0.4) 5(0.5) 1(0.7) 4(0.8)*[3] 2-MSG.*[2]
2. Speed Change Sign A	3(2.4) 4(4.4) 1(5.2) 2(6.1) 5(6.2)	3(3.9) 4(4.9) 1(6.0) 5(6.1) 2(6.7)	2(4.2) 5(4.4) 4(4.5) 1(5.3) 3(6.3)	1(-0.2) 5(-0.1) 3(0.8) 4(0.8) 2(1.0)	1(-0.1) 5(0.5) 4(0.7) 3(1.2) 2(1.5)*[3]	5(-0.7) 1(-0.2) 2(0.0)*[3] 3(0.3) 4(1.0)	1(-0.2) 3(0.1) 5(0.4) 4(0.8) 2-MSG.*[2]
3. Speed Change Sign B	1(0.1) 4(0.4) 3(0.7) 2(0.7) 5-MSG.*[2]	4(0.3) 1(0.4) 2(0.9) 3(0.9) 5-MSG.*[2]	4(0.0) 2(0.3) 3(0.4) 1(0.5) 5-MSG.*[2]	4(-0.8) 2(-0.6)*[3] 1(-0.1) 5(0.1) 3(0.5)	4(-1.1) 1(-0.4) 5(-0.5) 1(0.2) 3(0.4)	4(-.4) 1(0.4) 2(-0.2)*[3] 3(0.6) 5(0.8)	4(-0.9*[3] 5(1.0) 3(3.6) 2-MSG.*[2]
4. Speed Change Sign C	4(0.3) 1(1.3) 3(1.6) 2(1.7) 5-MSG.*[2]	4(1.0) 2(1.3) 3(1.4) 1(1.5) 5-MSG.*[2]	2(0.9) 1(1.17) 4(1.2) 3(1.3) 5-MSG.*[2]	3(-0.9) 2(-0.4) 1(-0.1) 5(0.1) 4(0.6)	3(-1.1) 2(-0.4) 1(0.2) 5(0.4) 4(0.8)	3(-0.7) 1(-0.4) 2(0.2) 5(-0.2) 4(0.4)	1(-0.7) 5(-0.1) 3(0.0) 4(0.3*[3] 2-MSG.*[2]

Table 5. Ranking of Sign Effectiveness for Each Variable Based on Mean Values (Continued)

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Site	1	1	1	2	2	2	2
Opposition	Yes	--*1	--*1	--*1	Yes	No	--*1
Weather	Good	Good	Good	Good	Good	Good	Good
Light	Day	Day	Night	Day	Day	Day	Night
5. Speed Change Sign D	2(0.8) 1(1.1) 3(1.5) 4(1.5) 5(1.6)	1(0.9) 2(1.1) 4(1.2) 3(1.5) 5(1.7)	3(0.1) 2(0.3) 1(0.5) 5(0.6) 4(0.8)	2(1.0) 4(1.4) 1(1.6) 3(1.8) 5(2.3)	5(-0.4) 1(0.1) 4(0.4) 2(0.8) 3(1.6)	4(-0.2) 5(0.2) 1(0.4) 2(0.6) 3(1.2)	1(-0.1) 4(0.0)*[3] 5(0.4) 3(0.9) 2-MSG.*[2]
6. Speed at Curve	Missing*[2]	Missing*[2]	Missing*[2]	2(40.9) 1(40.7) 4(39.8) 5(38.8) 3(38.2)	2(41.1) 4(40.1) 1(39.7) 5(39.3) 3(39.0)	1(41.5) 2(40.4) 4(39.6) 5(38.4) 3(37.3)	1(44.9) 3(41.4) 4(40.5)*[3] 5(39.0) 2-MSG.*[2]
7. Distance To Min. Speed	1(1971) 2(1834) 5(1816) 3(1741) 4(1720)	2(1917) 1(1914) 5(1891) 4(1787) 3(1752)	3(1897) 2(1800) 1(1735) 5(1665) 4(1652)	1(2081) 4(2081) 5(2076) 2(2073) 3(2044)	4(2083) 5(2080) 2(2070) 1(2052) 3(2032)	1(2107) 5(2076) 4(2080) 5(2072) 3(2058)	4(2142)*[3] 3(2074) 1(2050) 2-MSG.*[2]
8. Exit Speed	2(36.7) 3(36.7) 5(36.0) 1(31.6) 4-MSG.*[2]	3(37.6) 5(37.0) 2(36.3) 1(32.1) 4-MSG.*[2]	3(38.6) 5(38.0) 2(37.3) 1(35.8) 4-MSG.*[2]	1(38.6) 2(38.5) 4(38.2) 5(37.5) 3(37.4)	2(39.2) 4(38.6) 5(38.5) 3(38.1) 1(37.4)	1(39.6) 4(37.9) 2(37.1) 3(36.6) 5(36.5)	1(43.5) 3(41.1) 4*38.5)*[3] 5(37.5) 2-MSG.*[2]

Table 5. Ranking of Sign Effectiveness for Each Variable Based on Mean Values (Continued)

Numbers outside parentheses indicate sign conditions. Numbers inside parenthesis indicate mean values. Units for variables 1-6 and 8 are mph, and for variable 7, feet.

For the explanation and discussion of the rankings shown - see text.

Notes:
- *1 Opposed and unopposed observations combined
- *2 Data missing due to mechanical failure in field (e.g., sensor broke), inability to track vehicle, or small overall sample size.
- *3 Based on less than 10 observations
- *4 Based on 11 observations including an "outrider"

Conversion Factors: 1' = .3048 m; 1 mph = 1.609 km/h there was no conclusive evidence of the superiority of one sign over another.

In the instance where there was an overall statistically significant difference among the means in Table 4, in Table 5 it was found that these differences were either operationally quite small (e.g., in column 4 the total difference between the highest and lowest is only 2.7 km/h (1.7 mph), or inconsistent with one another (e.g., compare the order of effectiveness between columns 1 and 6).

4.5.3 Speed Changes - Signs B, C and D

At Site 1 after the large initial change in speed and the similarly large change in the vicinity of Sign A, the magnitude of remaining speed changes dropped off considerably. The effectiveness rankings for both sites shifted quite a bit from one column to another with no evidence of any pattern. In addition, the magnitudes of the speed changes were generally quite small (with one exception, all were less than 3.3 km/h (2 mph). The sole exception to this (Col. 7, Table 5) was a 5.8 km/h (3.6 mph) speed reduction near Sign B for Site 2 when the sign condition was the curve arrow with the "maximum safe speed" advisory plate. No obvious explanation was found for this apparent anomaly.

4.5.4 Speed at the Curve

Unfortunately, due to electronic and data reduction problems, the determination of the speed at the curve could not be made at Site 1. Examining the results from Site 2, however, it can be seen that the curve arrow with the advisory speed plate held some advantage over the other configurations although during the day the operational advantage was not great - the difference between the "best" sign (3) and the worst (2) was only 4.3 km/h (2.7 mph). At night, however, this maximum difference rose to 9.5 km/h (5.9 mph). Thus, there was some evidence that the advisory speed plates had more effect in slowing the motorist down for the hazard (curve) than did other signs.

4.5.5 Distance to Minimum Speed

The distance to the occurrence of the minimum speed was measured from the beginning of the instrumented area. For Site 2 the results indicated that the motorists were going slowest some distance after they had passed the actual point of curvature (i.e., they were into the curve before they had slowed down completely). Similar, although not as striking, results were noted for Site 1. The similarity among the values for the various signs should also be noted.

4.5.6 Exit Speed

The final variable calculated for each motorist was the speed over the last 61 m (200 feet). The most interesting result was that in every case the exit speed (on the average) was slower than the speed at the hazard. This result, coupled with that for the location of minimum speed, clearly means that the motorists were generally still slowing down as they entered the curve. This, in turn, implies that the motorists did not think they were going the proper speed when they initially entered the curve. Hence, they continued to slow down and were going slower as they left the curve than when they entered it, in spite of the fact that at both sites the road ahead was visible and relatively straight over the last link.

4.5.7 Other Variables

Two other dependent variables were also calculated for each motorist, although results were not shown in Table 5. Lane placement was to have been indirectly explored through the use of the center and edgeline violation times. However, the results obtained essentially showed nothing and were unreliable as well. The following were the reasons that no results on these variables were presented:

1. There were few instances when any overall statistical differences were detected.

2. The average values obtained were quite small (on the order of 1/2 - 1 second) which, given the sample size used, was too small to depend on since the data were based on manual entry and subject to reaction time error.

3. Edgelines were inadvertently repainted (they had almost been non-existent) by maintenance crews after part of the data had already been obtained.

4.5.8 Impacts Due to Other Independent Variables

In earlier sections the effects due to some of the independent variables were discussed and dismissed (e.g., the effects due to motorist familiarity with the road). The actual effects of whether or not opposition traffic was encountered and of light conditions (day and night) can now be addressed based on the results presented in Table 5.

Relative to the potential light effects, it was noted that the sign effectiveness at night was not consistent between the two sites (i.e., the ordering of signs by effectiveness was different). Nor was there any consistent trend between day and night results at the same site. Thus, there is little that can be said about the effects of light conditions other than that no overall pattern of increased (or decreased) effectiveness was discerned.

The other effects were those due to the presence of opposition traffic. Any possible differences were highlighted by a direct comparison of columns 1 and 2 in Table 5. The general trend appeared to be one of similarity - that is, in most instances whether or not motorists were opposed seemed to be of little consequence relative to which sign(s) was (were) more or less effective.

5.0 CONCLUSIONS AND DISCUSSIONS

5.1 CONCLUSIONS BASED ON EXPERIMENT RESULTS

The results reported in previous sections were negative relative to whether one sign or group of signs was more effective than another. Any discernible trend in effectiveness at one site, or under one set of independent conditions, was contradicted by results at the other site, or under another set of conditions. That is, no sign, or group of signs, was consistently found to be more effective than another relative to decreasing the potential hazard at horizontal curves in rural two-lane situations.

In order to better appreciate the overall findings it is instructive to review them with reference to a scenario for a "good" driver traversing a horizontal curve when an effective sign was present. Such a scenario had the following elements: the driver entered the instrumented area traveling at about the speed limit; he/she saw the sign(s) ahead and became alert for the possible need for corrective (defensive) action to be taken ahead; as the sign became legible the driver read it and began to take the corrective action (i.e., slowed down for the curve); the driver, having slowed, entered the curve at, or close to, the appropriate (e.g., posted speed); and, finally, having seen the road ahead and realizing that the hazard had been safely negotiated, accelerated slightly as the curve was left behind.

The random drivers that were studied in the experiment behaved somewhat differently than the idealized scenario indicated. Typically, drivers at Site 1 were traveling at approximately the speed limit (72 km/h (45 mph)) while most motorists at Site 2 were exceeding it by 3.2 - 4.8 km/h (2 - 3 mph), although the latter violation should have had no impact on the overall results. While motorists at Site 1 slowed considerably initially and near sign position A, their counterparts at Site 2 actually increased their speed slightly in several instances. In addition, signs that were effective (relative to these initial variables) at Site 1 were not effective at Site 2.

Subsequent speed changes at Site 1 were operationally quite small (most averages were less than 2.4 km/h (1.5 mph)), while at Site 2 slight increases were still being recorded in many instances. Unfortunately, data on the speeds at the curve were unavailable for Site 1. However, Site 2 data showed that although considerable decreases in speeds had occurred from the last sign position, any trend in sign effectiveness was still not apparent (signs effective during the day were not at night and/or the ordering in effectiveness of signs at the curve was not consistent with the order observed earlier on the approach).

In addition, at Site 2 in every case, the average exit speed was lower than the average speed at the curve. This, and the earlier reported fact that the minimum speed had occurred beyond the point of curvature, proved conclusively that drivers were still slowing down as they entered the curve - which was counter to the "good" driver scenario.

In general then, it was seen that the drivers' behavior differed substantially from what was desireable and, furthermore, that any trends in effectiveness that were apparent were largely contradictory with one another. The basic result was that no sign, or group of signs, can be concluded to be more effective than others.

5.2 DISCUSSION OF CONCLUSIONS

In spite of the lack of clear evidence of one sign being superior to another, it was clear that there were reasonable speed changes in most instances. There was the question, however, as to whether the presence of any sign was responsible for the speed change or whether the motorist slowed down merely because of his/her own ability to see (or not, as the case may be) and react to the physical conditions present ahead.

Based on the data that were available and the results of the analyses, it is impossible to say that the signs had no effect as advance warnings of the condition ahead. It is possible, and appropriate, however, to say that no sign(s) was (were) found to be indisputably superior to the others.

Relative to the overall reactions to the situation, it should be noted that the result was always in less than desired behavior in the curve - motorists all entered the curve faster than desired and continued to slow as they traversed at least the first section. The important point being that they all attained their minimum speed at approximately the same point, regardless of which sign had been deployed.

Thus, although there was considerable evidence that the physical characteristics of the sites as well as the motorists' perceptions of the hazard ahead (apart from what the sign conveyed) had some impact on their reactions, it cannot be stated that these factors were the only, or even the major, things affecting motorists' behavior. It is impossible, however, in the context of the experiment that was undertaken, to allocate the decreases in speed, between the signs and the reactions to physical characteristics.

Given that the results of this experiment were less than expected relative to being able to recommend one sign over another, the question arises - was the experiment itself appropriate for discerning the effectiveness of the various signs in the context that they (the signs) were being examined. This question is best responded to by examining the experiment relative to others designed to examine similar phenomena.

The basic procedure of tracking random motorists through a road segment after they have seen one of a series of test signs had been used several times in the past with success at the Facility (see e.g., Koziol, et. al., 1978, Lanman, et. al., 1979). The mobile equipment used in this experiment (which is similar in data collection concept to the fixed base system in the earlier experiments noted above) had also been used successfully (Lyles, 1979). The term success, as used above, refers to the fact that captured data were realistic and that trends in sign effectiveness were readily discerned (and not, per se, to the fact that one type of sign was superior to another). Similarly, the basic independent and dependent variables that were defined for this experiment have been used successfully in other experiments.

It seems clear then, that based on previous experience, the experiment was well conceived relative to data gathering techniques and the formulation of independent and dependent variables. In light of this it appears that the results of the experiment were valid - that is, there was little discernible difference in effectiveness among the sign configuration tested for reducing the degree of hazard at horizontal curves in rural two-lane situations. Note that this result is not meant to imply that no warning device should be deployed in such situations, only that there was little difference among those tested.

The reasons for the above result are not immediately clear. It may well be, however, that the proliferation of curve warning signs with and without advisory speed plates has lessened the average motorist's respect for the message they convey. An implied result is that when a really serious curve exists that advisory speed plates (even a more emphatic one as tested) and/or regulatory signs will be ineffective remedies.

In light of the above, additional research on the most effective device in more serious curve situations may be indicated, possibly including investigation of motorists stated (via a survey) perceptions of the seriousness of situations when they are confronted with various signs. Other areas of inquiry might include a more definitive review of the criteria used by state and local traffic engineers for deploying curve warning signs of various types. The results of such research could be revised standards/guidelines for sign deployment.

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