dents. Because the intersections remained unaltered, these increases are a result of chance, or, to use the technical term, regression-to-the-mean. [For further discussion of this phenomenon see the work by Hauer and Persaud (9).]

The 172 intersections examined by Ligon et al. recorded, on average, 0.51 accident in the before period and 0.84 accident in the after period. If some Philadelphia intersections that averaged 0.51 accident in 1973 were converted, then by interpolation from Table 9 these intersections would have recorded, on average, 1.32 accidents in 1974 if the conversions left safety unaffected. In other words, the average number of accidents recorded after conversion would have had to be higher than 1.32 to support a conclusion that removal of multiway stop control leads to a degradation in safety.

Although one might reasonably question whether the Philadelphia intersections are representative of the intersections studied by Ligon et al., this should not detract from the main point of the discussion--that it is misleading to draw conclusions about the safety effect of traffic control measures by simply comparing before-and-after accident records. By deemphasizing the apparent increase in accidents observed in this study, the authors have avoided this pitfall. It is hoped that, after this discussion, others will be persuaded to do likewise.

Authors' Closure

Persaud presents an interesting discussion concerning the safety aspects of the removal of unwarranted stop signs. It was thought that 3 years of accident data before and 3 years after conversion, as well as using control (nonconverted) sites (3 years before and 3 years after) would result in a meaningful experiment, statistically, because of the small number of accidents. Unfortunately, the agencies cooperating in the FHWA study could not provide the 3-year before data base and the study had to be completed in about 1 year. Persaud's Philadelphia example as well as his discussion of accounting for accident change due to chance agree with the authors' intuition and strengthens the recommendation for removal of unwarranted stop signs.

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Evaluation of Curve Delineation Signs

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ABSTRACT

The three post-mounted delineator systems currently used in Virginia were tested at five sites for their effectiveness in controlling run-off-the-road accidents. The changes in speed and lateral placement noted with the systems in place were taken as driver responses to the systems. The study indicated that drivers react most favorably to chevron signs on sharp curves greater than or equal to 7 degrees and to standard delineators on curves less than 7 degrees. It is suggested that statewide use of delineators based on these findings will improve the safety and uniformity in delineation on the rural highway system.

Travel on rural roadways is noticeably different from travel on urban streets. On the former, vehicular speeds are generally higher, the road surface usually is narrower and not as well marked, and the severity of accidents is greater than for urban highways (1).

Several studies have pointed out that a high proportion of the accidents that occur on rural curves happen at night and usually involve a single vehicle that runs off the road (1,2). For a majority of the rural roadways, those with average daily traffic (ADT) of less than 2,100 vehicles, single-vehicle run-off-the-road (ROTR) accidents have been reported to account for more than 40 percent of all accidents, with nearly one-half of these involving a personal injury or fatality (1,2).

Post-mounted delineators (PMDs) of various shapes, colors, and types have been used throughout the United States in an attempt to reduce the number of ROTR accidents. These markers have proved to be effective, especially at night or during adverse weather conditions when roadway markings may be covered (3).

The PMD has been demonstrated to be capable of influencing a driver's judgment of the sharpness of a road curve. This influence can be used to modify the pattern a driver follows through a curve, and thus to promote safety on rural highways (1).

CURRENT PRACTICE

The three basic types of delineation or alignment signs used on rural roadways in Virginia are

1. The 3 x 8-in. reflector on a wooden post (ED-1),
2. The 6 x 48-in. special striped delineator, and
3. The chevron alignment sign (WI-8).

Figure 1 shows these sign types (4).

Two general approaches are used in selecting delineators for a site. The Manual on Uniform Traffic Control Devices (MUTCD) (5) is an often-quoted source for delineation selection for freeways and major roadways. This manual recommends spacing, location, and height for the delineators without recommending the type of delineator to be used. The MUTCD states that "delineation is intended to be a guide to the vehicle operator as to the alignment of the highway; whatever is needed to provide that guidance in a clear and simple way should be installed" (5).

The second method of selection is local practice. A survey of each of the nine operating districts of the Virginia Department of Highways and Public Transportation found wide variations in the use of PMDs, and a review of delineation practices in other states revealed many of the same problems and practices that exist in Virginia. Several states are involved in studies to determine the safest delineation systems for rural roadways. Although the results from the states have not yet been finalized, the following conclusions can be drawn from their data:

1. Large chevrons are not effective and have little effect on speed, braking, or lateral placement within the curve (1).
2. Standard delineators in an MUTCD configuration positively affect speed, braking, and lateral placement and are particularly effective on sharp rural curves (1).
3. Rural curves with PMDs have a much lower nighttime ROTR accident rate than curves of similar characteristics without vertical delineation. Tests have shown the reduction rate to be 50 percent or more (6).
4. Long-term effects of PMDs are much less than the initial effect during the first few weeks. This suggests adaptation by local drivers. Because accidents on rural roads often involve drivers unfamiliar with the roadway geometry, this result does not negate the safety benefits of vertical delineators (1).

During the late 1970s and early 1980s FHWA initiated projects with eight state highway agencies to evaluate the effectiveness of different types of PMDs. The study noted that "it is not possible to state that the installation of post delineators under all conditions will result in a reduction in the number of run-off-the-road type accidents. The data that were collected indicate a trend toward reducing run-off-the-road accidents with the installation of post delineators" (6).

OBJECTIVE AND SCOPE

The purpose of this study was to determine in what areas current practice in the placement of the available types of delineator signs could be improved by providing uniformity. The only focus was the effects of different PMDs on driver behavior. Standard 4-in. pavement markings were in place at all test sites. Selected delineation strategies were evaluated and recommendations were developed for selecting the type of sign best suited for given roadway and environmental conditions, after the decision has been made to use vertical delineation at a site.

RESEARCH METHOD

Performance Measures

Studies on driver reactions to delineation systems placed on roadways generally rely on changes in vehicle movement as indicators of the reactions. The two most obvious changes in movement are vehicle speed and placement. The path a driver takes through a curve is dependent on his perception of the curve and of how best to traverse it. Because this positioning changes as the vehicle moves through the curve, it is desirable to record the placement and speed of the vehicle at several locations during the maneuver (1,7).

Vehicle speed is an indication of the apparent severity of the curvature of the roadway. Slow speeds entering the curve indicate that the driver is aware that the curve exists. Fast speeds at the start of the curve with slower speeds near the middle indicate braking by the driver, probably because the curve is sharper than he perceived it to be. Acceleration in the curve would indicate that the driver perceived the curve to be sharper than it actually is.

The path of the vehicle through the curve is also a good indication of the perceived sharpness. Movement across the centerline may indicate that the curve is not as sharp as it looks. This centerline encroachment may also be caused by objects along the shoulder of the road that the driver perceives to be a threat.

Vehicles traveling close to the right-hand edge of the road may indicate that the curve is sharper than it appears. This occurrence may also be an indication of high ADT, which causes drivers to feel unsafe driving near the centerline (1,7).

Although there are numerous exceptions to these hypotheses, in general it can be stated that a satisfactory delineation system is one that will pro-

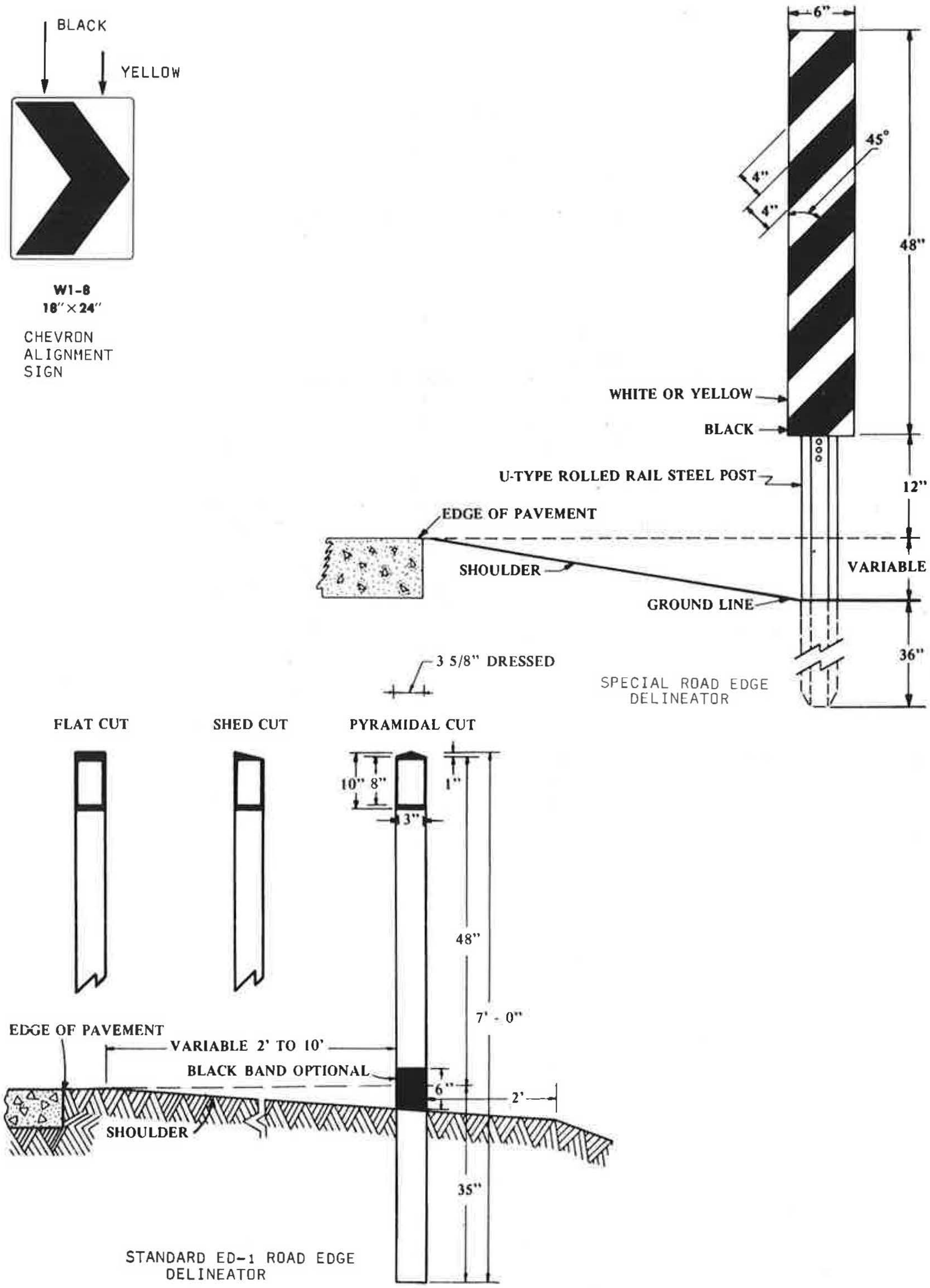

FIGURE 1 Alignment signs tested *(4)*.

duce uniform speeds and placement of a vehicle as it moves through the curve. The system will negate the need for excessive braking in the curve, and the absence of a change in speed when a vehicle is within the curve is a prime indication that the driver of the vehicle has correctly perceived the curvature of the road. Also, it will minimize encroachments on the centerline and edge line, thereby leaving most of the vehicles driving in the center of the lane (1).

On some roads vehicle type could be an important third item that should be recorded. For example, sites should be noted where exceptionally large numbers of heavy trucks are present or where continuous grades reduce the speeds of these trucks but not those of other vehicles. Because large trucks constitute a small percentage of the normal traffic on most rural roads, data for trucks were not studied separately.

Statistical Method

The effectiveness of different delineation treatments was measured by using the chi-square goodness-of-fit test. Here performance data for the marked roadway were compared with those obtained while the curve was unmarked.

The purpose of this analysis was to determine the value of statistical similarity for the delineation treatments of the marked roadway compared with those of the roadway without markers. The larger the value of α that was obtained, the more similar were the data for the two tests. A small value of α indicated that the delineation treatment had significantly altered the driver's path or speed or both through the curve. For example, an α value of 0.10 means a 10 percent level of significance, which in turn indicates a significant change in driver performance in the curve.

The results of this statistical evaluation indicated that there was no significant change in speeds after the delineators were installed. Most values were in the 0.90 range. However, there were significant changes in the lateral placement of vehicles. For this reason, the lateral placement changes were taken as the critical elements in the study; the changes in speed were noted for additional information.

Delineation System and Technique Selection

Delineation systems vary from exotics such as ascending and descending patterns, in-and-out patterns, and sign mix patterns to the more traditional systems currently used in Virginia (1). Because this investigation was intended mainly to test the systems used in Virginia, only three conventional systems were investigated (see Figure 1). The only variation made was that the wooden posts used with the standard road edge delineators were not painted. The decision to use treated but unpainted posts was supported by a study that involved the possible use of untreated posts, which found little difference between visibilities for the two types of posts (1). The MUTCD-recommended spacing and placement for standard delineators was used, as is often done in Virginia.

The most effective placement pattern for chevrons has not yet been determined. Most districts in Virginia use their own judgment to determine the placement and spacing of the chevron signs. The placement varies from a pattern in which one sign is always visible to a pattern in which at least three signs are visible. It was decided that because most of the districts recommend that three chevron signs be in sight such a pattern would be used. In examining MUTCD placement patterns, it was noted that the recommended spacing for standard delineators generally provided that four to six delineators would be in the drivers' view (2). By using this information, it was decided to space chevrons at a distance twice that recommended by the MUTCD for traditional delineators. This spacing proved adequate for this study.

Field Data Collection

To record the speed and lateral placement of the vehicles moving through the curve, a Leupold and Stevens traffic data recorder (TDR) was used. Eight tape switches were used to record data at the beginning and near the midpoint of the curve. The switches were temporarily placed from the edge of the centerline to the shoulders of the road. The leads from the switches were connected to the TDR, which was concealed off the roadway.

The switches were placed on the roadway in a predetermined pattern (Figure 2). The use of 6-ft spacing between matching channels (switches) allowed a variation in placement of 0.75 in. with less than a 1 percent change in speed or lateral placement--an important factor in field installations. As an automobile's tires crossed the first and second switches, their circuits were opened. The third switch closed the first circuit to generate the time from switch 1 to switch 3 and the vehicle's velocity. The fourth switch, which was laid at a 45-degree angle to facilitate field measuring and placement, closed the second circuit to generate the time from switch 2 to switch 4. The placement of the vehicle was then calculated by using the following formula:

$$\text{Lateral placement} = 6 * \tan(\theta)\,[(S_1/S_2) - 1] \quad (1)$$

where

- 6 = distance (ft) separating the speed detector switches,
- θ = angle of the lateral placement switch = 45 degrees,
- S_1 = speed of the vehicle measured by the speed switch, and
- S_2 = speed of the vehicle measured by the lateral placement switch.

Input from the tape switches was recorded on cassette tapes, and the data were processed on a computer. The output included volume, velocity, and

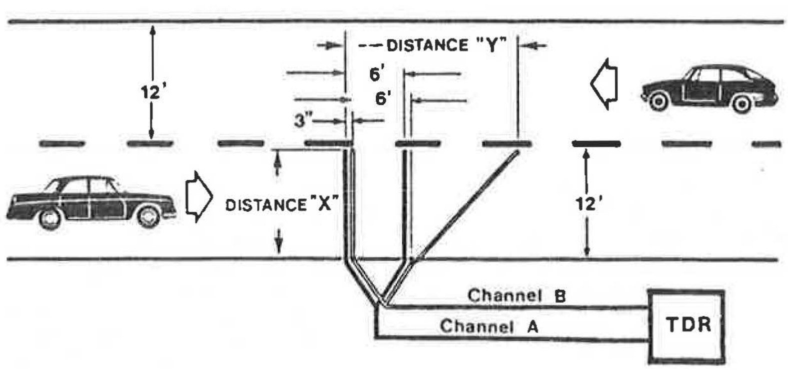

FIGURE 2 Configuration for data collection using two TDR channels per lane.

vehicle type information for the 10 zones into which each lane was divided for lateral placement measures.

Zones 1 through 9 were of equal width, whereas zone 10 represented vehicles that encroached more than 1 ft across the centerline. At the sites tested, zones 1 through 9 were each 8 in. wide (Figure 3).

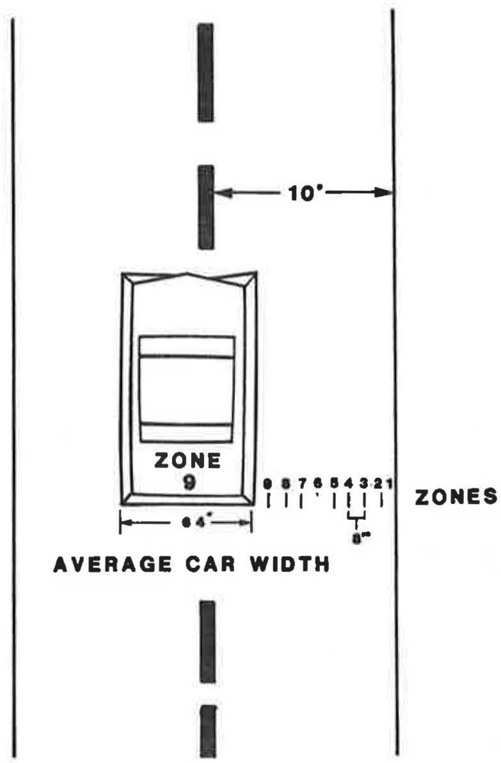

FIGURE 3 Illustration of lane zones.

By using this zonal width, it could be concluded that vehicles in zone 10 represented possible head-on collisions, whereas zones 8 and 9 represented possible sideswipe accidents. Zones 8 through 10 (zones 7 through 10 at the narrowest sites) were considered to be the centerline encroachment zones. Any vehicles in these zones were considered to be candidates for multivehicle collisions.

The data by lane-zone allowed trace data to be determined for average vehicles. This vehicle trace, combined with the velocity averages, was used to determine the effectiveness of the delineation treatments. That the use of average trace data tends to overshadow individual vehicle performance, especially at the two extremes, is of some concern for high velocity areas but is of no concern for low velocity areas (1).

Site Selection

Two groups of roadway sites were used. Sites in the first group were already marked with PMD devices and were used to study the data-collection system as well as to obtain base data (pretest program); those in the second group were initially free of any vertical delineation and were used in the actual testing program. Data were collected once at each pretest site and seven times at each test site. The first collection was taken while the test site was still without markers. Then the site was studied with each vertical delineation device in place to determine short-term effects and it was studied again several weeks later to determine long-term effects.

The following criteria were used to select the sites:

1. Proper signing using current spacing and erection techniques (pretest);
2. No delineation devices (test);
3. No obstacles (driveways, and so forth) on shoulder,
4. Accident history,
5. ADT of 1,000 to 3,000,
6. Location within 1-hr drive of Charlottesville,
7. Rural location,
8. All curves in same construction district to expedite the project,
9. Roadways carry at least some out-of-state traffic, and
10. Standard pavement markings at centerline and edge of pavements.

By using these criteria, a listing of candidate roads and locations was accumulated through interviews with highway officials. Each road or site was then evaluated to determine its suitability for testing.

Technical data for each curve were obtained from the headquarters of the district in which it was located; these were used to group the sites by length of curve, degree of curvature, and degree of grade. The pretest program indicated that vehicle placement was not significantly different in curves with different grades, so grade was not initially considered as a major influence on vehicle placement.

In the field evaluation of a test site, a vehicle was driven through the curve several times, the site was examined for signs of heavy braking or ROTR incidents, and a series of photographs was made. The data in Table 1 identify the sites chosen for the pretest and test phases of the study.

SITE EVALUATIONS

Preliminary Observations

The sites designated 1 through 8 in Table 1 were used for the pretest phase of this study, which was conducted to test the TDR equipment and to determine if the data obtained would allow meeting the study objectives. The data revealed some similarities in driver response characteristics for the different delineation treatments.

As an example, the data in Table 2 give the percentages of vehicle travel and average speeds in each zone across the lane for special pretests at sites 8 and 2. The data are statistically similar for both placement and speed; $\alpha = 0.250$ and 0.950, respectively, which indicates that two sites with different physical characteristics may induce similar driver responses for the same type of delineation signing.

There were also similarities between two of the chevron-marked sites. Here the zonal vehicle placements were not as significantly alike ($\alpha = 0.025$), but the average speed, placement, and centerline encroachment of sites 5 and 7 resembled each other.

Even though these data do not conclusively demonstrate that vehicle paths at sites with the same delineation systems are similar, they do indicate that the patterns are similar at some sites.

In studying the data and site characteristics, it is not the similarity that is worth noting but rather the general trends revealed in the vehicle

TABLE 1 Description of Study Sites

Site No.	Route	County	Curve location	Horizontal Curvature	Radius of Curvature (ft)	Length of Curve (ft)	Lane Width	Grade (%)	1982 ADT	Treatment
Pretest Sites										
1	20	Albemarle	0.6 mile south of I-64	10° 16'	558	237	12 ft 11 in.		3,440	Without markers
2	231	Albemarle	5.0 miles north of VA-22	8°	716	311	9 ft 2 in.	-4	2,600	Existing; special
3	20	Albemarle	7.6 miles south of I-64	8°	716	225	11 ft 0 in.		3,400	Existing; special
4	20	Orange	South of VA-616	4° 30'	1,273	240	9 ft 1 in.		3,990	Existing; special
5	20	Albemarle	Albemarle/Orange county line	12°	447	200	9 ft 0 in.	-5	2,180	Existing; chevron
6	33	Greene	9.6 miles west of US-29	11°	521	323	9 ft 0 in.	-6	2,860	Existing; chevron
7	33	Greene	9.7 miles west of US-29	7°	819	387	9 ft 0 in.	+5	2,860	Existing; chevron
8	231	Albemarle	6.9 miles north of VA-22	4°	1,433	470	8 ft 10 in.	-2	2,600	Existing; special
Test Sites										
9	20	Albemarle	6.8 miles south of I-64	12°	478	215	10 ft 4 in.	+2	3,440	All
10	33	Orange	At VA-652 and VA-664	5°	1,146	824	9 ft 4 in.		3,005	All
11	231	Albemarle	5.5 miles north of VA-22	5°	1,146	748	9 ft 8 in.	+4	2,600	All
12	22	Albemarle	East of VA-783	8°[a]	700[a]	300	9 ft 7 in.	-2	1,530	All
13	208	Louisa	South of VA-642	4°	1,433	583	10 ft 3 in.	-4	2,740	All

[a]Estimated.

TABLE 2 Example of Data Similarities for Sites 8 and 2—Day

Zone	Distribution by Zone in Lane (%) Site 8	Site 2	Avg Zonal Speed (mph) Site 8	Site 2
Beginning of Curve				
1	1.6	2.4	51.7	49.2
2	13.8	14.2	53.3	52.3
3	26.9	26.4	52.4	51.6
4	29.4	31.9	54.2	53.5
5	17.7	18.4	53.4	52.6
6	5.8	3.9	52.5	54.4
7	3.6	2.1	54.4	54.8
8	0.7	0.3	54.4[a]	54.3
9	0.1	0.3	65.0[a]	57.0
10	0.5	0.3	44.6[a]	53.0
Middle of Curve				
1	0.3	0.6	47.0	48.1
2	3.0	2.7	48.6	48.2
3	6.9	8.5	48.1	49.5
4	22.0	16.0	52.3	52.2
5	24.8	24.5	53.1	52.6
6	19.7	20.4	53.9	53.8
7	16.7	18.8	53.9	54.1
8	4.5	4.5	55.1	55.0
9	1.2	2.6	54.2	57.4
10	0.9	1.5	58.6	57.6

[a]Small number of data points accounts for wide variation in speeds.

data. The consistency in average lateral placement and speed alterations indicates that drivers react in a predictable manner to the different delineation techniques.

The data in Table 3, which give the results of seven tests at the beginning of the curve on site 10 during daylight (6:00 a.m. to 8:00 p.m.), demonstrate how the data can reveal trends in driver reaction. The data are broken down into the 10 zones for each test and include an additional total for possible centerline encroachments. Depending on lane width, the possible encroachments would occur in one of the last three or four zones. At this site, vehicles in zones 7 through 10 experienced encroachments. Centerline encroachments increased during all of the tests.

The percentages given in Table 4 reveal the general trend that vehicles travel away from the edge of the road when delineation signing is in place. The averages and variances in Table 4 more clearly reveal the change. Again, all of the tests of the delineation systems show similar movements, in this case, a strong movement away from the edge line. Also, there was a slight increase in the placement variance, which is used to determine how well defined the new path through the curve is.

The data in Table 5 reveal how vehicle speeds were affected by the new delineator signs. As can be seen, all of the systems induced an increase in speed during the day. The increase in speed with the chevrons was much less; this might indicate that the drivers perceived the chevron signs as obstructions close to the traveled way more than they perceived the other delineators as obstructions. Also, the speed variance increased greatly for the chevron signs whereas speed decreased when other delineators were used. This again points to the possibility that drivers were apparently not as comfortable with the chevrons as they were with the other delineator systems.

Main Tests

Sharp Curves

Two of the five curves studied in depth, sites 9 and 12, are considered to be sharp (curvature greater than 7 degrees). The data from both indicate that the chevron sign is the most favorable form of delineation at these sites. The data for site 9 indicate that of the three delineation systems, the chevrons produced the lowest probable centerline encroachment and, on average, the traveled paths of vehicles on roads with chevrons were closest to being centered in the lane. The placement variability was also lower than that of vehicles driving on roads that have other delineator systems.

The speeds at site 9 also indicated that chevrons performed best on that curve. The average speeds were slightly higher than those of the other systems--a maximum of 2 percent--but the speed variances were among the lowest found.

The data taken at site 12 revealed much the same trends. The centerline encroachment was lower for the roads with chevrons, and the average vehicle path was the most desirable, especially at the middle of the curve where it was about 0.5 ft farther away from the centerline. The placement variance was about average for the three systems studied.

TABLE 3 Example of Vehicle Placement by Percentages, Beginning of Curve (site 10, day)

	Curve Treatment						
		Standard		Special		Chevron	
	Without Markers	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Zone							
1	0.1	0.1	0.1	0.1	0.1	2.0	0.1
2	3.4	1.4	0.6	0.8	1.3	2.4	2.6
3	13.7	9.5	5.7	7.1	6.1	7.1	7.9
4	31.6	23.0	22.4	24.5	24.2	21.6	21.8
5	28.5	30.3	29.0	29.1	31.8	28.3	30.7
6	14.9	19.6	24.4	22.5	18.8	20.5	19.9
7	5.8	11.3	13.3	12.0	12.5	13.0	13.2
8	0.9	3.2	3.1	2.5	3.4	3.2	2.7
9	0.8	1.2	0.7	0.6	1.0	1.3	0.8
10	0.3	0.5	0.6	0.9	0.8	0.7	0.4
Possible centerline encroachment	7.8	16.2	17.7	16.0	17.7	18.2	17.1
Total volume for test period	924	862	975	932	912	709	978
Chi-square	–	0.05	0	0	0	0	0.005

TABLE 4 Example of Lateral Placement and Variability Data—Site 10 (ft)

	Beginning of Curve			
	Day		Night	
Curve Treatment	Lateral Placement	Variability	Lateral Placement	Variability
Without markers	2.75	0.75	3.21	0.87
Standard				
Short term	3.08	0.86	3.50	0.86
Long term	3.19	0.80	3.69	1.10
Special				
Short term	3.12	0.82	3.78	1.24
Long term	3.14	0.87	3.79	1.12
Chevron				
Short term	3.08	1.15	3.75	1.23
Long term	3.08	0.86	3.72	1.13

TABLE 5 Example of Vehicle Speed and Variability Data—Site 10 (mph)

	Beginning of Curve			
	Day		Night	
Curve Treatment	Speed	Variability	Speed	Variability
Without markers	51.8	46.2	53.3	41.0
Standard				
Short term	53.0	44.9	52.8	43.6
Long term	53.6	43.6	53.4	46.2
Special				
Short term	53.0	44.9	51.6	47.6
Long term	52.9	42.3	52.6	33.6
Chevron				
Short term	52.1	77.4	51.0	57.8
Long term	51.9	56.3	52.4	54.8

The chevrons at site 12 were not as successful in dealing with speed as they were at site 9. The speeds averaged about 50 mph, which were greater than the 35- and 40-mph speeds recommended by two signs in the area. For the chevrons, daytime speeds were slightly lower than for the other systems, whereas nighttime speeds were greater by as much as 2 mph. The speed variances for the chevrons were also slightly greater during the day, but at night they were about the same as for the other two systems.

Gentle Curves

At sites 10, 11, and 13 the standard and special delineators provided the best delineation; usually the standard delineators were preferred.

At site 10 the standard delineators produced the lowest levels of centerline encroachment and an average lateral placement that was slightly better than those of the special delineators or the chevrons. During the day the chevron produced the best lateral placement. However, at night the lateral placement for the standard delineators, which had a much smaller variance, was the best of the three systems tested.

The speed data for site 10 revealed the special delineator treatment to be superior; the vehicle speeds were greater than average and the speed variance was lower than that of the other two systems. The standard delineator proved to be the second most effective system in terms of speeds and speed variances.

The testing at site 11 indicated that the chevron signs produced some of the lower centerline encroachment figures, especially at the middle of the curve. There was little difference between the standard and special delineator treatments.

In average vehicle placements, no one system appeared to have a major advantage over the others. The special delineators caused the average vehicle path to be slightly closer to the center of the lane than did the other systems. The variance in vehicle placement for the special delineators was also the lowest, which indicated that the delineators were more uniformly accepted at this site.

The speeds recorded at this site changed little from one delineation system to another. The chevron sign produced the slowest speeds, but the speeds were variable. The standard and special delineators produced nearly the same speeds and variances; however, the changes over time for the two system were opposite--the speeds increased for the standard delineators and decreased for the special delineators. For both types of delineators, the speed variances decreased; the special delineators produced the largest decrease.

Site 13 was the most difficult of the test sites to analyze because of the loss of the data for the special delineator short-term test and the repaving of the roadway before the chevron long-term test.

Vehicle placement and speed data, however, do reveal that the standard delineators produced the lowest levels of centerline encroachment. Use of standard delineators also resulted in low levels of vehicle placement variance and produced a vehicle path near the center of the traveled lane through the curve. The placement variance results for the special delineators indicated that they are more effective in producing uniform traffic movements at night than the standard delineators, but the average lateral placement of vehicles traveling on roads with special delineators was much closer to the centerline. The chevron signs produced the highest variances in placement, but lateral placement was similar to that of the standard delineators.

The chevrons did a much better job, judging from the average speeds. They induced the lowest variance of speed of all of the systems at site 13. The standard delineators revealed good variances during the day but had the largest ones during the night; they also produced the lowest speeds during the day and the highest at night.

The results for the special delineators were always satisfactory, but never the best. This may indicate that, if only one type of delineation treatment is to be used in the state, special delineators would be the most appropriate because they produce no extreme changes in vehicle paths while still providing suitable guidance through the curve.

This general trend revealed by the data (preference for standard or special delineators for these less sharp curves) follows the guidelines that most of the districts in the state use. Therefore, it would appear that the use of these two signs is correct for those sites with a curvature of less than 7 degrees.

Discussion of Findings

All of the Virginia highway districts follow the MUTCD spacing guide for standard and special delineators, so the only problem found in the state related to spacing was with the chevron signs. This project used the system practiced in West Virginia; that is, the regular MUTCD spacing was doubled for the chevron signs (6). In the tests conducted this spacing proved to be successful in providing guidance without using an excessive number of signs.

By using the data and associated inferences obtained from the field tests along with information obtained in the survey of state delineation practices, a simplified delineation policy can be developed. For moderate curves (less than 7 degrees), where delineation is deemed to be necessary, the use of standard delineators spaced as recommended by the MUTCD appears to be the most satisfactory choice. This choice does present some problems to the state, the most significant of which is that the Salem, Suffolk, and Northern Virginia districts reported no current use of these delineators. Another problem is that many such curves are marked in other ways. However, this should be of little concern because the use of delineators already varies from site to site. The use of only standard delineators will eventually result in a more uniformly delineated highway system.

Previous studies tended to question the acceptability of chevron signs. They generally have reported that the signs induce an excessively large number of centerline encroachments along with little, if any, change in vehicle speeds (6). This was not found to be true at all of the five sites studied in this project. Chevrons produced less centerline encroachment than the standard or special delineators while still providing smaller vehicle placement variances at the sharper curves. Likewise, speeds were also decreased in these curves.

These data are supported by recent studies on the use of chevron signs. A possible explanation for this change in driver reaction is that when the first tests were performed chevron signs were a new delineation technique. Many drivers had never seen the signs before and were confused as to their meaning. With chevrons gaining wide acceptance, drivers are more familiar with the signs and are now capable of interpreting their meaning.

A second factor, and possibly a more important one, is chevron sign spacing. When first used, chevrons were used much as a normal delineator would be. This close spacing and large sign size combined to form a wall-like effect alongside the roadway. Drivers tended to move away from this effect and over the centerline. Spacing the chevrons at twice the normal distance tends to eliminate the wall effect while still providing guidance through the curve.

RECOMMENDED GUIDELINES

Many of Virginia's highway districts have been moving toward the use of different delineator systems for sharp and gentle curves, and this policy is supported by the findings of this study.

It has been determined in this study that drivers do react to vertical delineation along the roadway and that this reaction is related to the layout of the curve. Delineation systems used in curves should be matched to the expected driver responses based on such factors as the curvature of the road and sight distance. To ease this decision-making process, the following recommended guidelines are offered for curves deemed to require delineation because of the degree of curvature and not because of other factors such as the presence of intersections or hazards on the roadway shoulder.

For curves less than or equal to 7 degrees, the use of standard edge delineators (ED-1) is recommended. The spacing should conform to that given in Table 6 (4). The height of the delineator post should be 4 ft above the right edge of the pavement and the post should be located 6 to 8 ft from the edge of the pavement (5).

For curves greater than 7 degrees, the use of chevron alignment signs (WI-8) is recommended. These signs should be erected 6 to 8 ft from the edge of the road at a top-of-the-sign height of 4 ft above

TABLE 6 Suggested Spacing for Highway Delineators on Horizontal Curves *(4)*

Radius of Curve (ft)	Spacing on Curve for Standard Delineators, S (ft)	Spacing on Curve for Chevron Signs, C (ft)
50	20	40
150	30	60
200	35	70
300	50	100
400	55	110
500	65	130
600	70	140
700	75	150
800	80	160
900	85	170
1,000	90	180

Note: The distance is in feet rounded to the nearest 5 ft. Spacing for specific radii not given may be interpolated from the table. The minimum spacing should be 20 ft. The spacing on curves should not exceed 300 ft. In advance of or beyond a curve, and proceeding away from the end of the curve, the spacing of the first delineator is 2S, the second is 3S, and the third 6S but not to exceed 300 ft. S refers to the delineator spacing for specific radii computed from the formula $S = 3 \times (R-50)^{1/2}$. The spacing of chevron signs should be twice that used for standard highway delineators. C refers to the chevron spacing for specific radii computed from the formula $C = 7\ (R-50)^{1/2}$.

the right edge of the pavement. The chevrons should be spaced twice the distance of the standard delineators, as noted in Table 6.

The purpose of this study was to compare the existing PMD systems with one another. However, now that it has been revealed that delineation signing can alter a driver's path through a curve, the most effective pattern should be developed. Testing in this area has already been carried out, but the results of these studies have been mixed, with some spacing and height changes showing improvements (7,8).

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