The Effects of Wide Edge Lines on Lateral Placement and Speed on Two-Lane Rural Roads

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ABSTRACT

The results of an evaluation of effect of edge lines 4 in. and 8 in. wide on the lateral placement and speeds of vehicles on two-lane rural roads are presented. Data were collected at 12 locations on sections of roadway covering 55.2 mi. It was concluded from analyses of variance of lateral placement, lateral placement variance, encroachments by automobiles and trucks, mean speed, and speed variance that, overall, there were no statistically significant differences between the 4-in. and 8-in. wide edge lines. The mean lateral placement was significantly lower for the 8-in. line. However, changes in lateral placement and speed were not significant from a practical viewpoint.

There are a high number of run-off-the-road (ROR), drunken driving, and night accidents in rural areas. In 1980 there were 18,792 ROR accidents in rural areas in Virginia (1). Of this total, 269, or 1.4 percent, were fatal accidents; 8,367, or 44.6 percent, injury accidents; and 10,417, or 54.0 percent, property-damage accidents. ROR accidents accounted for 31.9 percent of all rural accidents, 38.5 percent of the fatalities in rural accidents (the largest percentage for any type of accident), and 35.1 percent of the persons injured in rural accidents. Drinking drivers--persons driving under the influence of alcohol (DUI)--were involved in 12,025, or 20.4 percent, of all rural accidents. Accidents involving DUI accounted for 31.7 percent of fatal accidents, 27.1 percent of personal injury accidents, and 16.3 percent of property-damage accidents in rural areas. There were 25,621 accidents during nighttime, which constituted 43.5 percent of all accidents in rural areas.

To provide guidance to motorists on two-lane rural roads, edge lines are used to delineate the right edge of the roadway. The edge line is one element in a pavement marking system that provides warning and guidance information to the driver without diverting his attention from the roadway (2). Reflectorized pavement markings are the most common form of delineation at night when the reduced visibility creates a greater need for guidance information.

Two research studies conducted on controlled test sections have concluded that 6-in. and 8-in. wide edge lines have an impact on the lateral placement of vehicles, especially those driven by alcohol-affected persons (3,4). Edge lines 8 in. wide have the potential to reduce the probability that a driver will run off the road and increase the probability that he will position his vehicle close to the center line. However, because wide edge lines have the potential to influence the lateral position of the vehicle in this manner, the probability of center-line encroachment may increase. No information was available on the impact of wide edge lines on lateral placement and speed under road conditions.

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OBJECTIVE AND SCOPE

The objective of this research was to evaluate the effect of edge lines on the lateral placement and speed of vehicles.

The scope was limited to two-lane rural roads. Primary routes were selected because accident data are more detailed and more readily available for them than for secondary routes.

The second phase of this research will address accidents.

STUDY DESIGN

The experimental plan for evaluating wide edge lines was a before-and-after study. Field data were collected for a before period with standard-width (4-in.) edge lines and for an after period following the installation of 8-in. wide edge lines. It was assumed that any differences in the measures of performance, lateral placement, and speed between the before and the after periods would be attributable to the wide edge lines. The primary measure of performance was lateral placement. The before-and-after data were collected during the fall of 1983 and 1984, respectively, for 8 of the 12 sites. The before-and-after data were collected during the spring and fall of 1984, respectively, for the remaining four sites. However, the traffic volumes at the sites are not dependent on the season. Data on lateral placement and speed were collected for a 24-hr period at the study sites by using a Leupold and Stevens traffic data recorder (TDR), described as follows.

Use of TDR

The configuration for collecting lateral placement and speed data with the Leupold and Stevens TDR is shown in Figure 1. The speed detector consisted of two sensor cables placed perpendicular to the edge line and 6 ft apart (Channel A). The position detector consisted of two sensor cables placed 6 ft apart at the edge of the pavement, but the trailing cable was laid at an angle other than 90 degrees to the edge of the pavement. A typical angle for the trailing detector was 45 degrees (Channel B). Vinyl tape was used to secure the sensor cables to the pavement.

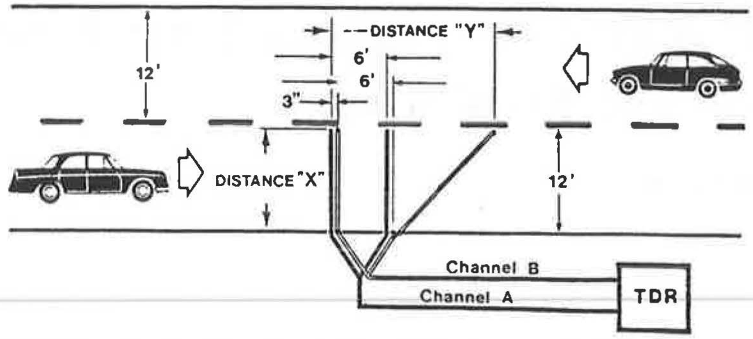

FIGURE 1 Configuration for collection of lateral placement data.

Traffic data were recorded on a magnetic cassette tape that was brought in from the field, read, and filed on a computer. The raw data were printed and screened for recording errors. Summary data on lateral placement and speed such as the mean, standard deviation, and frequency distribution were printed by using TDR report generator programs and programs developed at the Virginia Highway and Transportation Research Council.

Study Sections

Two sections of roadway, 36.3 mi and 18.9 mi long, were selected for the study. In the selection of those sections, the accident data on 11 road sections with high accident experiences were reviewed and these 2 were ranked first and second for the percentage of ROR accidents and alcohol- or drug-related accidents.

Study Sites for Field Data Collection

A sampling method based on the following criteria was developed to select sites for field data collection along the study sections.

1. Ideally, study sites should be located at 5-mi intervals along the study section (intervals of 3 to 7 mi were acceptable).
2. The direction of travel of the traffic volume to be studied should alternate (e.g., northbound, southbound, northbound).
3. The posted speed limit should be 55 mph.
4. The sites should be representative of the overall geometrics of the roadway (e.g., for a road section with many horizontal curves, the sites should be at curves).
5. Interference from intersections and driveways should be avoided.
6. The total sample should include left and right horizontal curves and tangent sections.
7. For curves the study site should be located midway between the beginning and middle of the curve.
8. A convenient parking area should be available for the vehicle transporting the data collection equipment.

With these criteria, 12 study sites were selected. Descriptive data on these sites are shown in Table 1. It is noted that some of the edge lines intended to be 8 in. wide were not.

ANALYSIS OF LATERAL PLACEMENT AND SPEED

The analysis of the lateral placement and speed data was performed for individual sites and for all sites. The objective was to determine whether there were any significant differences in lateral placement or speed for the 4-in. line as compared with the 8-in. line. The measures of performance and statistical tests are discussed in the following paragraphs.

Comparison of the Variances of Lateral Placement

For each site, the variances of the lateral placement of 4- and 8-in. wide edge lines were compared by using an F-test under the hypothesis that the variances are equal (6). The underlying populations were

TABLE 1 Data on the Study Sites

Location and Site No.	Direction of Travel	Geometrics	Lane Width[a] (ft)	24-Hr Traffic Count	Width of Edge Line (in.)
Route 20, Albemarle County					
1	Southbound	Left curve 6 degrees	10.92	2,307	7.0
2	Northbound	Left curve 11 degrees	9.58	1,982	7.5
3	Southbound	Straight	11.00	1,420	8.0
4	Northbound	Left curve 10 degrees	8.92	1,379	7.0
Route 20, Buckingham County					
5	Southbound	Right curve 5 degrees	9.00	911	7.0
6	Northbound	Straight	8.71	631	8.0
7	Southbound	Straight	8.79	534	7.8
8	Northbound	Straight	9.00	1,028	7.5
Route 501, Bedford County					
9	Southbound	Left curve 10 degrees	9.75	688	10.0
10	Northbound	Straight	8.46	559	10.0
11	Southbound	Right curve 7 degrees	8.17	390	10.0
Route 501, Rockbridge County					
12	Northbound	Left curve 3 degrees	9.83	1,482	7.0

[a]Inside lane markings.

assumed to be normally distributed. The alternative hypothesis is that the variance of the 8-in. wide edge line is either greater or less than the variance of the 4-in. line. A significance level of 0.05 was used.

Research by Stimpson et al. concluded that longitudinal change in lateral placement variance is one of the two most sensitive indicators of hazard (7), and Taylor et al. noted a strong correlation between the lateral placement variance and accident experience (8). In other words, the higher the variance in the lateral placement, the higher the hazard potential and number of accidents. Consequently, it was concluded that the lower the variance in lateral placement, the better the edge line performs.

The results of the F-test are shown in Table 2. For the day and night periods, 7 (58.3 percent) and 9 (75.0 percent), respectively, of the 12 sites showed no significant difference in the lateral placement variance.

TABLE 2 Comparison of Lateral Placement Variances

	Preferred Lateral Placement					
	Day			Night		
Site No.	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
1			X	X		
2	X			X		
3	X					X
4	X					X
5			X			X
6		X				X
7			X	X		
8			X			X
9	X					X
10			X			X
11			X			X
12			X			X
Total	4	1	7	3	0	9
Percent	33.3	8.3	58.4	25.0	0	75.0

The Wilcoxon matched-pairs signed rank test was employed to determine whether the variance in lateral placement variance was significantly different for the 4- and 8-in. wide edge lines for all 12 sites combined. This is a two-sample, nonparametric test (no assumptions are made on the distribution of the variances) for comparing two populations (4- and 8-in. wide lines) on the basis of a paired sample (4- and 8-in. lines lateral placement variance measure at a site) (6). For the two time periods, it was concluded that there was no significant difference in the variance of the lateral placement for 4- and 8-in. lines at a 0.05 level of significance.

Comparison of Means of Lateral Placement

The means of the lateral placement for each site were compared with a t-test under the hypothesis that the mean lateral placements of the two edge lines are equal. A significance level of 0.05 was used.

It is noted that good or preferred lateral placement is controversial. Research by Johnson, as well as others, has concluded that a corner-cutting strategy is used on curves (4). Other researchers have recommended driving in the center of the lane (3,7,8).

In a telephone conversation, one of the three driver education supervisors for the Commonwealth of Virginia Department of Motor Vehicles stated that the Department's policy on driver position in the lane is as follows:

1. The center of the lane is the predominantly recommended driver position in Virginia;
2. On left curves, drivers should stay to the left when there is no opposing traffic, to avoid gravel near the shoulder, which may cause skidding; otherwise, they should drive in the center of the lane; and
3. On right curves, they should always drive in the center of the lane.

Gravel near the shoulder did not appear to be a problem at the study sites. Therefore, in general, good lateral placement was considered to be synonymous with driving in the center of the lane. The preferred edge-line width is the one that results in a mean lateral placement closest to the center of the lane. For all sites, the mean lateral placements of both edge-line widths indicate that motorists tend to drive to the left of the center of the lane. In other words, the mean lateral placement was greater than the preferred placement. Consequently, the lower mean lateral placement was preferred.

As can be seen in Table 3, for 11 (91.7 percent) and 7 (58.4 percent) of the 12 sites, the mean lateral placement for the 8-in. wide edge line was significantly less than the mean for the 4-in. line for the day and night periods, respectively.

Similarly, a one-tailed, paired t-test of the 12 sites revealed that the mean lateral placement for the 4-in. wide edge line was significantly greater at a level of significance of 0.005 for the day period and of 0.05 for the night period. Therefore, from a statistical standpoint, the 8-in. wide line results in significantly better lateral placement than does the 4-in. line.

TABLE 3 Comparison of the Mean Lateral Placements

	Preferred Mean Lateral Placement					
	Day			Night		
Site No.	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
1		X			X	
2		X			X	
3		X			X	
4		X				X
5		X				X
6		X				X
7		X			X	
8		X				X
9	X					X
10		X			X	
11		X			X	
12		X			X	
Total	1	11	0	0	7	5
Percent	8.3	91.7	0	0	58.4	41.6

Encroachments on Opposing Lane

Encroachments on the opposing lane were compared by using a chi-square test under the hypothesis of independence of edge-line width and encroachments. A significance level of 0.05 was used. The alternative hypothesis is that the edge-line width causing the lower percentage of encroachments is preferred.

Encroachments were measured by using a lateral placement zone system consisting of 10 zones, in which each zone was 10 in. wide. The zones of encroachment are the zone in which the average vehicle would be crossing the center line and all zones to

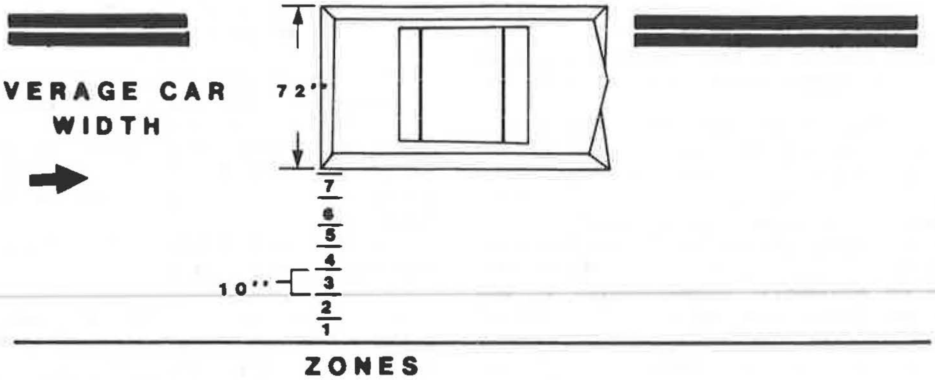

FIGURE 2 Zones of encroachment.

the left of this zone, as shown in Figure 2. The average widths of 6 and 8 ft were used for automobiles and trucks, respectively. Data from Consumer Reports show that the widths of 1984 model automobiles range from a 63.8-in. mean for small automobiles to a mean of 78.6 for large automobiles (9). The mean for medium automobiles is 70.8 in. Because data were not available on the distribution of automobile ownership by automobile size, the medium automobile was selected as the average vehicle and the average vehicle width of 72 in. was used. The American Association of State Highway and Transportation Officials design lengths for automobiles and trucks are 7.0 and 8.5 ft, respectively (10). An average truck length of 8 ft was selected, because the design vehicles are larger than the actual vehicles.

The zones of encroachment were determined as follows: (a) the average vehicle width was subtracted from the lane width to determine the minimum lateral placement for encroachment; (b) the associated zone was identified; and (c) if this position was in the half of the zone closest to the edge line, this zone and all higher zones represented the zones of encroachment; otherwise, all higher zones represented the zone of encroachment.

The encroachment results are shown in Table 4. For both time periods and for both automobiles and trucks, neither edge line appeared to perform consistently better than the other. This is supported by the Wilcoxon matched-pairs signed rank tests, which concluded that there were no significant differences in the encroachments for the two edge-line widths for both time periods between automobiles and trucks, with one exception. For trucks at night, the encroachments were significantly greater for 4-in. wide edge lines.

Distribution of the Lateral Placement of Vehicles by Zones

An example of the distribution of the lateral placement of automobiles by zones is shown in Figure 3 for Site 1 for the total period. In general, there were no noticeable changes in the position or range of lateral placements. These data are consistent with the earlier findings on the means and variance of lateral placement.

Comparison of the Variances in Speed

The variances in speed for the 4- and 8-in. wide edge lines were compared by using an F-test under the hypothesis that the variances are equal. The underlying populations were assumed normally distributed and a level of significance of 0.05 was used. The preferred speed variance was the lower one, because uniform driving tends to promote safety (4,9). In Table 5, for the day and night periods, the data show that the variance in speed showed no significant difference for 5 (41.7 percent) and 9 (75.0 percent) of the 12 sites, respectively.

TABLE 4 Comparison of Encroachments on Opposing Lane

	Preferred Encroachment											
	Day						Night					
	Automobiles			Trucks			Automobiles			Trucks		
Site No.	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
1		X		X					X			X
2		X			X				X			X
3		X				X		X				X
4	X					X	X					X
5	X				X		X					X
6		X				X			X			X
7		X				X			X			X
8	X					X			X			X
9	X				X				X		X	
10		X		X					X			X
11	X					X	X					X
12	X				X		X				X	
Total	6	6	0	2	4	6	4	1	7	0	2	10
Percent	50.0	50.0	0	16.7	33.3	50.0	33.3	8.3	58.4	0	16.7	83.5

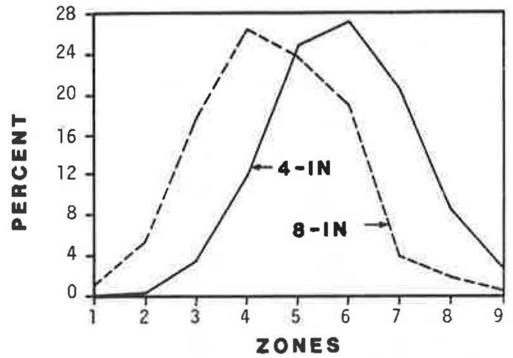

FIGURE 3 Lateral placement of cars by zones for the total period.

TABLE 5 Comparison of the Variances of Speed

	Statistically Lower Speed Variance					
	Day			Night		
Site No.	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
1		X		X		
2	X					X
3			X			X
4		X				X
5	X					X
6	X					X
7			X			X
8		X		X		
9	X					X
10			X			X
11			X			X
12			X	X		
Total	4	3	5	3	0	9
Percent	33.3	25.0	41.7	25.0	0.0	75.0

Use of the Wilcoxon matched-pairs signed rank test showed that there was no significant difference for the day and night periods.

Comparison of the Mean Speeds

The mean speeds were compared at each site by using the t-test under the hypothesis that the mean speeds are equal at a 0.05 significance level. The preferred speed was the lower one.

As shown in Table 6, for the day and night periods, 8 (66.7 percent) and 11 (91.7 percent), respectively, of the 12 sites showed no significant differences.

Similarly, the paired t-tests for all 12 sites combined concluded that at a 0.05 level of significance, the mean speeds of the 4- and 8-in. wide edge lines were not significantly different for either time period.

Summary of the Statistical Analyses

A summary of the findings from all the statistical tests is shown in Table 7. The lateral placement mean indicates a statistically better performance by the 8-in. wide edge line for both time periods. The superior performance in the Wilcoxon matched-pairs signed rank test for truck encroachments at night results from large differences between the 4- and 8-in. lines for two sites for this measure. In the Wilcoxon matched-pairs signed rank tests, large differences between the matched pairs are ranked higher,

TABLE 6 Comparison of the Mean Speeds

	Statistically Lower Mean Speed					
	Day			Night		
Site No.	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
1			X			X
2		X				X
3		X				X
4			X			X
5			X			X
6		X				X
7		X				X
8			X		X	
9			X			X
10			X			X
11			X			X
12			X			X
Total	0	4	8	0	1	11
Percent	0.0	33.3	66.7	0.0	8.3	91.7

and consequently one or two sites with large differences between the matched pairs may result in statistically significant differences whereas the remaining sites exhibit little or no difference. These 2 sites, when compared with the other 10 sites, are exceptions that favor the 8-in. wide edge line. The variance in lateral placement, automobile encroachments, and mean speed are not statistically different for 4- and 8-in. lines for either time period.

Therefore, the lateral placement mean is the only measure of performance that shows a statistically significant difference between the 4- and 8-in. wide lines. The difference suggests that 8-in. wide edge lines are preferred.

The study sites were grouped by road geometrics and lane width to examine performance trends related to these factors. However, no significant relationships were observed.

Practical Significance of Differences Between Edge Lines

The statistical significance of differences between performance measures for the 4- and 8-in. wide edge lines must be examined for practical significance, because statistical significance does not necessarily reflect a practical significance. In other words, given that there is a statistically measurable effect, is the change effective in improving traffic safety and operations? This question will be thoroughly addressed in the accident analysis in the second phase of this research project. Because only the mean lateral placement consistently showed a statistically significant difference, the practical significance of lateral placement differences based on engineering judgment is discussed in the following paragraphs.

In Table 8, mean lateral placement data are given for the 12 sites. A lateral placement shift of 6 in. is practical. With a tire width of about 6 in., the tire path will not overlap with a lateral placement shift of 6 in. or more. Also, it is believed that a shift is visibly noticeable at 6 in. On the basis of this information, only Site 3 displayed a practically significant lateral placement shift. This is probably because Site 3 had the widest travel lane and a greater variation in lateral placement was therefore possible. Consequently, it was concluded that, overall, there was no practically significant shift in lateral placement.

No other measure was closely examined for practi-

TABLE 7 Summary of Analysis for All Sites

	Preferred Line Width					
	Day			Night		
Measure of Performance	4 in.	8 in.	No Difference	4 in.	8 in.	No Difference
Lateral placement variance	4(33.3)	1(8.3)	7(58.4)[a]	3(25.0)	0.(0.0)	9(75.0)[a]
Lateral placement mean	1(8.3)	11(91.7)[b]	0(0.0)	0(0.0)	7(58.4)[a]	5(41.6)
Encroachment						
Automobiles	6(50.0)	6(50.0)	0(0.0)[a]	4(33.3)	1(8.3)	7(58.4)[a]
Trucks	2(16.7)	4(33.3)	6(50.0)[a]	0(0.0)	2(16.7)[a]	10(83.3)
Speed variance	4(33.3)	3(25.0)	5(41.7)[a]	3(25.0)	0(0.0)	9(75.0)[a]
Mean speed	0(0.0)	4(33.3)	8(66.7)[b]	0(0.0)	1(8.3)	11(91.7)[a]

Note: Percentages are shown in parentheses.

[a]Results of the Wilcoxon matched-pairs signed rank test.
[b]Results of the paired t-test.

TABLE 8 Mean Lateral Placement Data

	Day[a]			Night[b]		
	Mean (ft)			Mean (ft)		
Site No.	4 in.	8 in.	Difference (ft)[c]	4 in.	8 in.	Difference (ft)[c]
1	4.29	3.94	0.35	4.93	4.65	0.28
2	3.33	2.84	0.49	4.06	4.02	0.04
3	3.54	2.93	0.61	4.31	3.66	0.65
4	2.74	2.66	0.08	3.44	3.47	-0.03
5	2.17	2.04	0.13	2.94	2.98	-0.04
6	2.17	2.03	0.14	2.33	2.49	-0.16
7	2.76	2.32	0.44	3.60	3.22	0.42
8	2.05	1.92	0.13	2.26	2.26	0.00
9	2.80	3.02	-0.22	3.52	3.75	-0.23
10	2.16	1.81	0.35	2.86	2.57	0.29
11	2.21	1.99	0.22	2.93	2.58	0.35
12	2.85	2.34	0.51	3.47	3.04	0.43

[a]Mean difference = 0.27, standard deviation = 0.23, range of difference = 0.08-0.61.
[b]Mean difference = 0.17, standard deviation = 0.27, range of difference = 0.0-0.65.
[c]Difference: 4-in. values minus 8-in. values.

cal significance, because there were no overall statistically significant differences.

CONCLUSIONS

The following conclusions were drawn from the data presented in this paper:

1. Overall, there were no statistically significant differences between the 4- and 8-in. wide edge lines from the analysis of variance of lateral placement, lateral placement variance, encroachments by automobiles and trucks, mean speed, and speed variance.
2. The mean lateral placement was significantly lower for the 8-in. wide edge line. However, the difference was of a small magnitude and of no practical significance.
3. Lateral placement and speed were not practically affected by a change from a 4-in. to an 8-in. wide edge line.

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