Methods for Field Evaluation of Roadway-Delineation Treatments

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The objective of this study was to establish the relationships between various traffic-performance measures and accident probability on two-lane rural roads. This information would enable researchers to evaluate new roadway-delineation treatments without having to collect before-and-after accident data over a period of many years. Accident data and speed and lateral-placement measures were collected for typical roadway sections of both tangent and curvilinear alignment. Multiple linear regression analysis was then used to develop an accident-probability model. Important influencing variables were centrality of vehicle placement within the traveled lane, difference in lateral placement along the roadway section, skewness of the speed distribution, pavement width, and shoulder width. Procedures for the field evaluation of delineation-treatment effectiveness were then specified.

Roadway-delineation practices have developed over the years primarily as a result of field experience and limited subjective evaluation by engineering and maintenance personnel. Relatively few in-depth studies have been conducted, and most have dealt with limited aspects of specific delineation treatments. For instance, new devices such as raised pavement markers have undergone intensive material and maintenance testing, but their best use as part of an overall system for roadway delineation has received insufficient attention. Some before-and-after accident studies have been made, but they have required lengthy time periods to conduct; also, these studies have addressed either isolated spot-location problems or extensive distances of diverse highway features that make proving true cause-and-effect relationships difficult. Limited diagnostic field tests have been run by using teams of engineers, police, and lay drivers, but the results have been difficult to reconcile with serious questions of cost-effectiveness. Also difficult to interpret, especially for the policy maker, are the findings of studies that have used traffic-performance measures as basis for evaluation. A valid issue arises over whether certain statistically significant changes in speed and lateral-placement data are of any practical consequence.

In an effort to address these problems, the Federal Highway Administration (FHWA) recently initiated a two-phase delineation research project (1). The objective of the first phase was to establish the relationship between various traffic-performance measures and accident probability on two-lane rural roads. This information would permit traffic engineers to evaluate new delineation treatments without having to collect before-and-after accident data over a period of many years. The objective of the second phase was to apply the methodology to the field evaluation of potentially more cost-effective delineation treatments. This paper summarizes the results of the first phase of this research.

EXPERIMENTAL DESIGN

The scope of the research study was confined to application of delineation treatments for three general types of roadway characterized by type of alignment described below. In each case, the roadway was to have two lanes, have an average daily traffic (ADT) volume of fewer than 500 vehicles, and be located in a rural environment.

Type of Alignment	Description
Tangent	Predominantly straight, horizontal curves of 3° or less, more than 5 km (3 miles) long and desirably 16 km (10 miles) long
Winding	Predominantly curved, curves greater than 3° and tangents less than 457 m (1500 ft) between curves, more than 5 km (3 miles) long and desirably 16 km (10 miles) long
Isolated horizontal curve	More tangent than winding, curve greater than 3° and desirably isolated from other curves by 0.8 km (0.5 mile) or more

Given the delineation situations to be modeled, we had to develop appropriate traffic-performance measures. Although vehicular speed and lateral placement were expected to be among the primary raw measures, the proper formulation of these and other possibilities warranted a systematic investigation. The first step in this investigation was a review of published literature for known accident relationships.

Previous research had shown that type of delineation can influence speed and lateral placement; however, establishing a statistically significant relationship with accident experience had been difficult (2, 3, 4, 5, 6). Studies clearly showed that complex interactions occur among highway geometrics, delineation treatments, environmental conditions, traffic-performance measures, and accident experience. For example, horizontal alignment, lane width, and delineation might relate directly to the number of excursions from the proper lane, but the expected accident rate would also be affected by the lateral distance available for recovery described, in large part, by the width of the shoulder or the opposing lane.

In the context of this study, a traffic-performance measure was defined as any measurable parameter that describes the flow of traffic at a point or over a section of two-lane highway. These measures can take the form of various statistics such as mean, variance, skewness, or percentile. The objective of this study was to develop models that relate accident rate to traffic-performance measures for three general geometric situations. Critical to the model development was the collection of data for those traffic-performance measures most likely to be related to accidents and at the most appropriate locations along the test section. To supplement engineering judgment, a selection methodology using the information-decision-action (IDA) sequence file and an accident-prior-movement (APM) analysis was applied (2).

For a specific geometric situation, the IDA analysis defines the desired driver action, determines the decision necessary to effect these actions, and then specifies the information needed by the driver to make the required decision. The most useful elements of the IDA analysis for its application to this study were the actions required by the driver to properly negotiate a particular situation. These actions could be translated into traffic-performance measures.

The APM approach to identifying appropriate traffic-performance measures for a given situation was to define the possible accident types that can occur and determine possible vehicle movements that could have preceded each type of accident. Traffic-performance measures could then be chosen to describe or quantify those prior movements.

Traffic-Performance Measures for Tangent Roadways

A tangent section can be categorized as a steady-state situation. A steady-state situation means that a driver's task requirements are limited to maintaining continuous adjustive control, both lateral and longitudinal. Except for transitional situations that arise, such as at intersections or during passing maneuvers, an IDA model for the rural-tangent section is characterized by a lack of change. Only three control actions are required of the driver on a tangent. Speed should be maintained, position in lane should be maintained, and a reasonable distance from the vehicle in front should be maintained. The traffic-performance measures that numerically describe these actions are speed-profile statistics, lateral placement (including the frequency of shoulder and centerline encroachments), and headway.

For the purposes of the APM analysis, four basic accident types are likely to occur on a two-lane tangent section without any intersections or other situations that would require a change in the driving task. These types include head-on and side-swipe accidents for opposite-direction vehicles and rear-end and run-off-road accidents for same-direction vehicles. Possible prior movements for these accident types include high speed, rapid deceleration, shoulder encroachment, centerline encroachment, and short headway. The appropriate traffic-performance measures are the same as those identified through the IDA analysis.

Traffic-Performance Measures for Curvilinear Roadways

The driving task is much more demanding for winding-roadway sections and isolated horizontal curves than for tangent sections. Adjustments to the steady-state control behavior associated with tangent roadways are required to safely negotiate the curvature. Guidance for these adjustments must be provided at certain key locations to inform the driver of the necessary actions.

For two-lane curved alignments, the IDA and APM analyses also identified speed and lateral placement as the primary indicators of driving behavior. However, four specific locations were suggested for measurement points:

1. Advance of curve,
2. Point of curvature,
3. Curve midpoint, and
4. Point of tangency.

Because the task of driving through a curved section usually results in adjustments to both speed and lateral placement, the relative extent to which these parameters change between consecutive measurement points should reflect the degree of driving difficulty and therefore degree of hazard.

Site Selection

Several criteria were established for selecting a variety of sites at which data on accident experience and traffic performance would be collected. Initially, a large number of 4.8 to 8.1-km (3 to 5-mile) sections of two-lane highways in six eastern states were identified on the basis of the site-selection matrix given in Table 1. Resource constraints dictated that field experiments could only be conducted for a maximum of approximately 36 sites. Therefore, the search process was directed toward locating one acceptable site for each cell of the site-selection matrix. For purposes of analysis, all boundaries were established to provide a broad range of delineation-treatment, roadway-situation combinations. The actual frequency with which each combination might be found in the field was of secondary importance. In addition, any site that had not experienced an accident over a 5-year period, regardless of type of delineation present, was deleted from consideration (only five potential sites were rejected by this criterion).

Potential sites were then field inspected and evaluated for acceptability. Each site was required to have one or more subsections with a reasonably small gradient and a horizontal alignment that would have the following characteristics:

1. A pure tangent section that is at least 1.1 km (0.68 mile) long and ends in horizontal curves no sharper than 3°;
2. An S section that has two consecutive, reversed curves that are separated by a tangent no longer than 152 m (500 ft), are approximately equivalent, and are 5° or sharper to be clearly distinguishable from the tangent section; and
3. An isolated horizontal curve that is isolated from other curves by 0.5 to 0.8 km (0.3 to 0.5 mile) and is on a highway that is more tangent than winding.

Accessible, safe, and reasonably inconspicuous parking places were required for the vehicle housing the data-collection equipment. Potentially significant roadside features that might uniquely affect vehicle tracking or accident occurrence were avoided. The pavement had to be reasonably free of cracks and sound to allow attachment of electronic tape switches. Shoulders that afforded a significant visual contrast to the pavement were avoided especially at sites without edge lines. In all cases, the existing delineation could be neither badly worn nor newly installed.

Data Collection

The site-selection process resulted in the identification of 32 field sites. Two sites each in the tangent-roadway and horizontal-curve sections could not be found. On the basis of the potential traffic-performance measures identified by the IDA and APM analyses, we decided to concentrate on two observable parameters, speed and lateral placement. Measurement was accomplished by using pairs of resistance-based electronic tape switches. The location of each pair of switches, or trap, was determined on the basis of the IDA analysis. Typical tape-switch deployment configurations are illustrated in Figures 1 through 3. For tangent situations, traps were placed about 183 m (600 ft) apart.

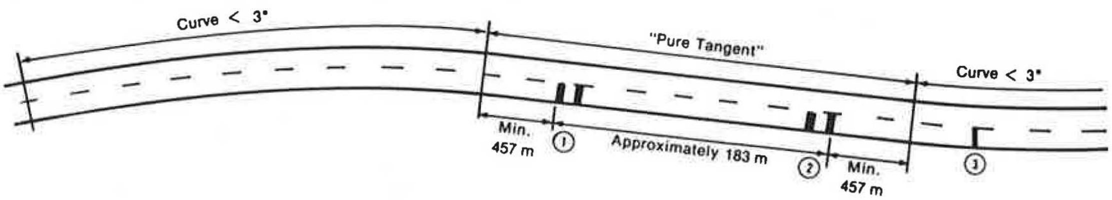
The tape switches were connected to a vehicle placement and event monitor (VPEM). The VPEM contained D'Arsonval meters for lateral-placement measurement and high-precision digital clocks to collect data for speed calculations. A pneumatic tube counter was also installed well downstream of the monitored area to obtain an hourly volume profile. As a vehicle crossed successive tape switches, the 50-mark lateral-placement meters and digital clocks would stop at the measured values until they were manually reset. This prevented confusion of readings when vehicle platooning occurred,

Table 1. Site-selection matrix.

Roadway Section Type	Degree of Curvature	Roadway Width (m)	Volume[a]	Shoulder Width (m)	Painted Centerline Only	Painted Centerline and Edge Lines	Painted Centerline and Edge Lines Plus Post-Mounted Delineators
Tangent		4.9 to 5.5	500 to 2000	≥1.2	x	x	—
		5.8 to 6.4	500 to 2000	<1.2	x	x	—
		5.8 to 6.4	500 to 2000	≥1.2	x	x	—
		5.8 to 6.4	2000 to 5000	<1.2	x	x	—
		5.8 to 6.4	2000 to 5000	≥1.2	x	x	—
		6.7 to 7.3	500 to 2000	<1.2	0	x	—
		6.7 to 7.3	2000 to 5000	≥1.2	0	x	—
Winding		4.9 to 5.5	500 to 2000	<1.2	x	x	—
		5.8 to 6.4	500 to 2000	<1.2	x	x	—
		5.8 to 6.4	500 to 2000	≥1.2	x	x	—
		5.8 to 6.4	2000 to 5000	<1.2	x	x	—
		5.8 to 6.4	2000 to 5000	≥1.2	x	x	—
Isolated horizontal curve	3 to 6	4.9 to 5.5	500 to 2000	<1.2	x	x	—
	3 to 6	5.8 to 6.4	2000 to 5000	≥1.2	x	—	x
	3 to 6	6.7 to 7.3	2000 to 5000	≥1.2	—	x	x
	>6	4.9 to 5.5	500 to 2000	<1.2	x	0	—
	>6	5.8 to 6.4	500 to 2000	≥1.2	—	x	x
	>6	5.8 to 6.4	2000 to 5000	≥1.2	0	—	x

Notes: 1 m = 3.3 ft.
x = site found; 0 = desirable site could not be found; — = no site was sought.
[a] Based on 1975 average daily traffic.

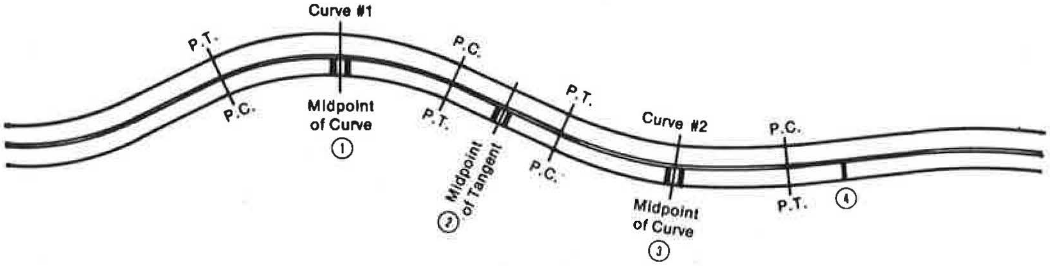
Figure 1. Configuration of measurement apparatus for tangent roadway section.



Station	Location	Measurement
① & ②	Points on tangent section no closer than 457 m (1,500 ft.) from nearest curve	Speed Lateral Placement*
③	Any point beyond Station ②	Volume

*Includes centerline and shoulder encroachments.

Figure 2. Configuration of measurement apparatus for winding roadway section.



Station	Location	Measurement
①	Midpoint Curve #1	Speed Lateral Placement*
②	Midpoint of Tangent	Speed Lateral Placement*
③	Midpoint Curve #2	Speed Lateral Placement*
④	Any point beyond Station ③	Volume

*Includes centerline and shoulder encroachments.

and allowed accurate recording of values before subsequent free-flowing vehicles arrived.

Reading of the lateral-placement meters was generally to the nearest half or whole mark, or to within 1 to 2 percent of the calibrated length of the tape switch. Possible additional measurement errors consisted of 0.2 percent within the VPEM (determined under laboratory conditions) and 1 to 2 percent related to the tape-switch calibration process. In total, the error in the determination of true lateral placement for an individual activation was expected to be 2 to 4 percent of the calibrated switch length, or 7.6 to 15.2 cm (0.25 to 0.50 ft). Because there was no reason to suspect a significant systematic bias in this error, the individual deviations from true lateral placement were of little consequence when averaged over a large sample.

The error of the speed measurement was a function of the clock resolution (±0.01 s), the trap length, the amount of error in the physical layout of the trap, and the magnitude of the vehicle speed. In general, for a trap length of 6.71 ± 0.06 m (22 ± 0.2 ft) and a speed of 80.5 km/h (50 mph), the speed estimate would be ±3.2 km/h (2 mph) of the true value. This result is comparable to the accuracy expected from a radar speed meter.

The choice of the sample size to be used in the conduct of the data-collection effort was one of the more important decisions to be made in the planning phase of the project. An assumption of normally distributed speed and lateral-placement observations plus previous estimates of typical population variances were used in a standard statistical formula to determine the required sample size for estimating the true population mean. For a significance level of 95 percent and a confidence interval of ±3.2 km/h (2 mph) to estimate mean speed, a minimum sample size of 100 observations would be required. With this number of observations the typical confidence interval for lateral placement estimation is about ±6.4 cm (2.5 in), which is an acceptable value slightly less than the measurement error of the tape-switch system.

The sample size required to accurately estimate the variance was determined by expressing the confidence interval in terms of sample variance, points in the chi-square distribution, and alternative values for degrees of freedom (d.f.), i.e., sample size minus 1. We found that a larger sample size is required to obtain the same degree of accuracy found above in the estimation of the mean. The results of this analysis indicated that, to maintain an error of no more than ±10 percent in the estimate of standard deviation for lateral-placement observations, a sample of 150 observations would be desirable. A sample of 100 was considered the practical minimum and yields a confidence interval of ±14 percent at the 95 percent significance level.

On the basis of the sample-size analysis and the relatively high person-hour costs associated with sampling under low-volume conditions, the basic speed and lateral-placement data were collected for a minimum of 100 observed vehicles during both day and night conditions respectively. Although delineation is most critical under adverse weather conditions, particularly at night, the infrequent and unpredictable nature of rainfall precluded the possibility of collecting sufficient wet-weather data for accident modeling purposes.

In all cases, lateral-placement measurements were referenced to the outside edge of the traveled lane, which was defined as the physical edge of pavement for roadways without edge lines and the midpoint of the edge line for roadways with edge lines. In the latter case, any pavement or stabilized material outside the edge lines was considered to be part of the shoulder width. Other data recorded for each site included the average daily traffic volume, width of traveled way, speed limit, length and degree of curve (if any), and type of delineation.

STATISTICAL ANALYSIS

To provide insight into driver performance as related to safety and to help guide the modeling effort, a distributional analysis of the speed and lateral-placement data among the three general roadway types was undertaken. The analysis revealed that the mean and variance of speed did not vary significantly between traps within a given site or between day and night visibility conditions. However, when lateral-placement data were compared, readily observable differences appeared for winding and horizontal curve sites (Figures 4 and 5).

In cases where there was a travel path from an inside curve to an outside curve on sections of winding roadway, the lateral-placement profile showed an increasing displacement from the shoulder. This straightening of the roadway was most pronounced under night conditions. In cases of isolated horizontal curves, there was little variation in lateral placement between the advance point and the point of curvature; however, between the point of curvature and the curve midpoint, motorists tended to move closer to the shoulder for the inside curve and closer to the centerline for the outside curve. Again, the night displacements were more pronounced. As the magnitude and frequency of these displacements increase, the accident potential of the roadway also seems to increase.

In addition to the basic speed and lateral-placement data discussed above, a number of other traffic-performance measures were derived for the accident-modeling effort. These were generally arithmetic functions of speed or lateral-placement statistics normalized by ADT volume, shoulder width, or width of the traveled lane.

Accident Data

Accident data were obtained for each study site for a minimum of 2 years during which the existing delineation was present. The data base encompassed a period from as early as 1969 through 1975. Data were always based on multiples of 12-month periods to avoid introducing possible seasonal biases. In determining accident rates for a tangent or winding section, we included accidents that occurred anywhere on the entire section length (4.8 to 8.1 km or 3 to 5 miles).

In determining accident rates for an isolated horizontal curve, we included accidents that occurred within a subjectively established zone of influence extending 229 m (750 ft) beyond the points of curvature. However, because isolated horizontal curves represented spot locations rather than extended sections of roadway typical of tangent and winding situations, the observed number of accidents was extremely low. Therefore, to provide a larger data base on which to compute accident rates, additional horizontal curve sites were selected wherever possible for each of the 10 cells of the site selection matrix.

The objective of the accident modeling was to relate accident histories to the traffic-performance measures collected at the sites; therefore, we hypothesized that certain subsets of the accident data would be more highly correlated than the entire set of accidents. For example, we assumed that traffic-performance measures collected during nighttime conditions would be more closely related to night accidents alone than to all accidents. Therefore, the accidents were grouped into the following subsets.

1. Total accidents were considered to be all accidents except those occurring during snowy- or icy-pavement conditions or during fog conditions. Snow- and ice-related accidents were deleted to eliminate the unfavorable bias for northern states as opposed to southern states. Also, when snowy, icy, or foggy conditions occur, traffic-performance measures are likely to be quite different from those observed during field data collection.

2. Non-intersection-related accidents were considered to be the portion of the total accidents that did not occur in or near any intersection within the study section.

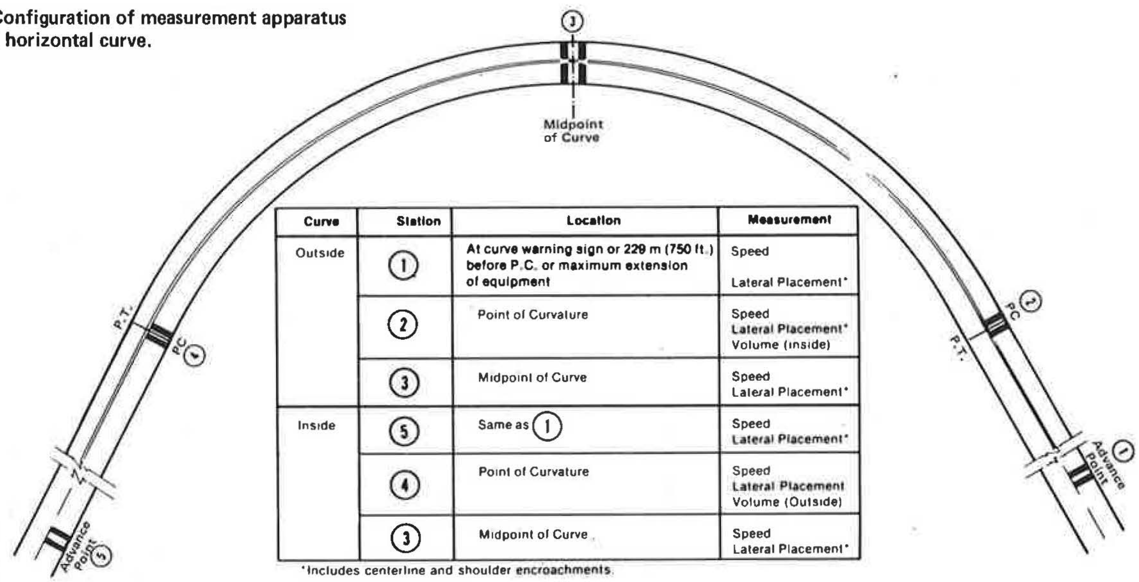
3. Light-condition accidents were considered to be the total accidents that occurred, grouped into daytime and nighttime subsets, to correspond with the traffic-performance measures observed within day versus night hours.

4. Pavement-condition accidents were considered to be the total accidents that occurred, grouped into wet- and dry-pavement condition subsets.

5. Delineation-related accidents were considered to be the portion of the total accidents that were identified as being possibly related to the presence or absence of delineation. An accident that involved any one or more of the characteristics given in the table below was classified as not related to delineation.

Accident Type	Characteristic
Collision	Train
	Animal
	Fixed object within travel lanes

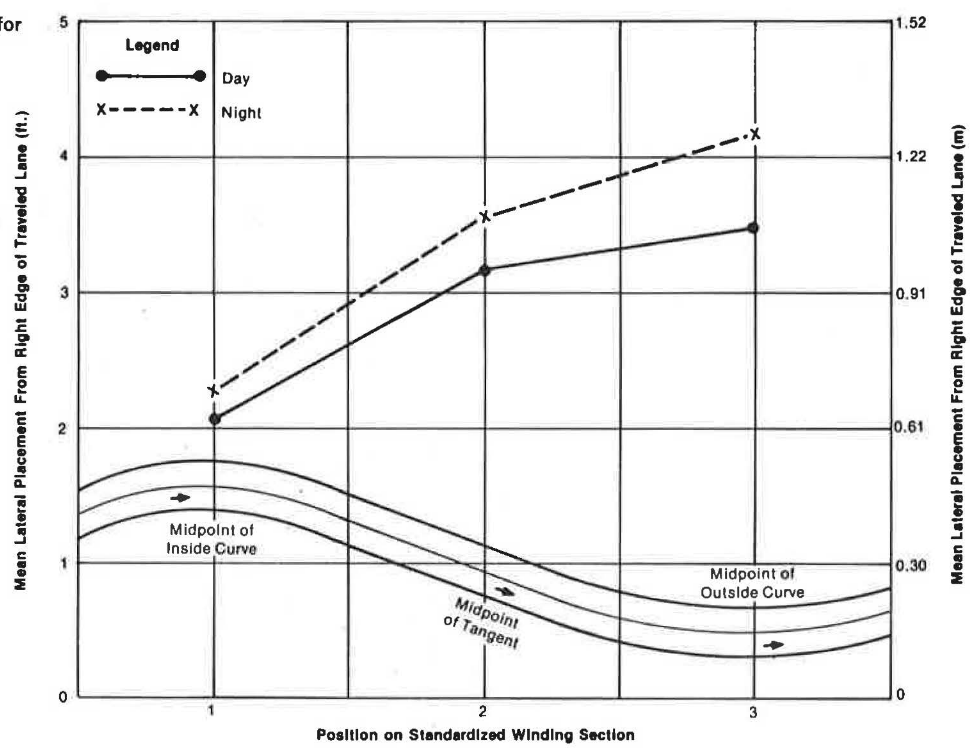
Figure 3. Configuration of measurement apparatus for isolated horizontal curve.



Curve	Station	Location	Measurement
Outside	(1)	At curve warning sign or 229 m (750 ft.) before P.C. or maximum extension of equipment	Speed Lateral Placement*
	(2)	Point of Curvature	Speed Lateral Placement* Volume (inside)
	(3)	Midpoint of Curve	Speed Lateral Placement*
Inside	(5)	Same as (1)	Speed Lateral Placement*
	(4)	Point of Curvature	Speed Lateral Placement Volume (Outside)
	(3)	Midpoint of Curve	Speed Lateral Placement*

*Includes centerline and shoulder encroachments.

Figure 4. Lateral-placement profile for winding roadway section.



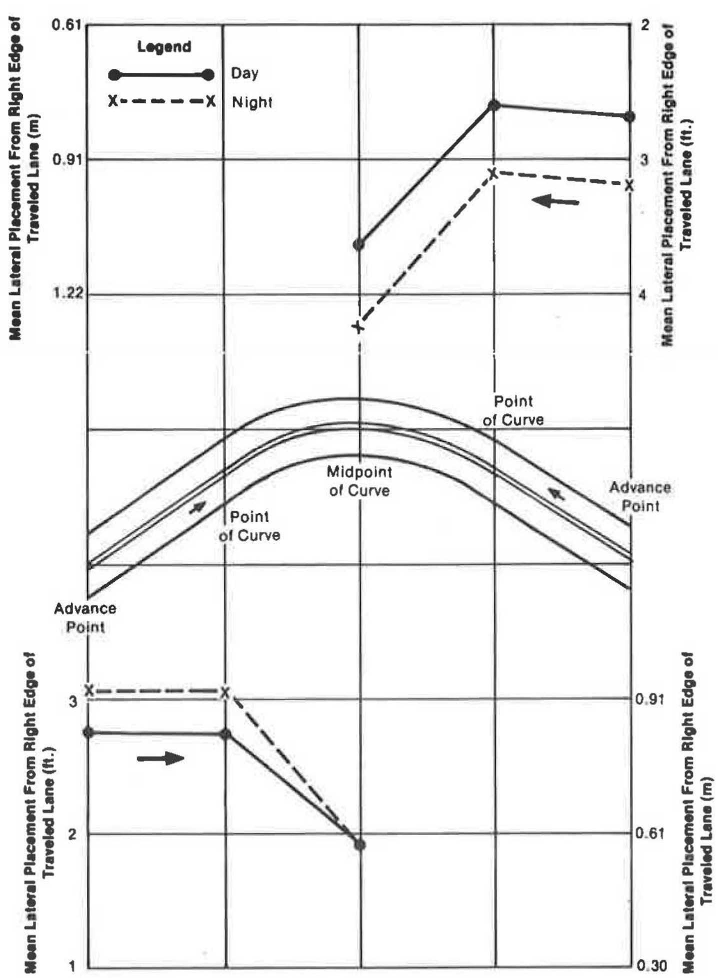
Accident Type	Characteristic
Maneuver	U-turn Starting Improper turning Parking Backing
Traffic control	Police officer Railroad crossing
Major factor	
Driver-related	Improper turn Backing onto roadway Stopped on roadway Avoiding animal or object
Vehicle-related	Defective equipment Struck by object
Roadway-related	Road defect
Vehicle	Farm truck Emergency vehicle

Table 2. Number of sites and accidents by roadway section type.

Roadway Section Type	Number of Sites	All Reported Accidents	Total Accidents[a]	Other Accidents[b] Day	Night	Total
Tangent	12	490	449	105	90	195
Winding	10	410	360	92	83	175
Horizontal curve	20	78	71	16	19	35
Total	42	978	880	213	192	405

[a] Excludes snow-, ice-, and fog-related accidents.
[b] Delineation-related, nonintersection, dry-pavement accidents.

Figure 5. Lateral-placement profile for horizontally curved roadway section.



Selected characteristics of the accident data are shown in Tables 2 and 3. Single-vehicle, run-off-the-road accidents were the most prevalent on all three roadway types especially during the hours of darkness, when only about 20 percent of the ADT occurred. Also apparent is the very low number of accidents that occurred at the sampled horizontal-curve sites. An analysis of severity data indicated that, overall, 3 percent of all accidents resulted in a fatality and 43 percent resulted in personal injury (these percentages are slightly higher for the isolated horizontal-curve situation).

Accident Modeling

Using traffic-volume data supplied by each state, we calculated accident rates for the selected field sites for both daytime and nighttime periods. For tangent and winding sections, accident rates were expressed in units of accidents per million vehicle-kilometers traveled and were calculated by using the following equation:

$$\text{Accident rate} = [(10^6)(N)]/[(L)(\Sigma_j ADT_j)(P_f)(L_f)] \quad (1)$$

where

N = number of accidents occurring during a given time period and under a specifically defined set of roadway, surface, and lighting conditions;
L = section length in kilometers (1 km = 0.6 mile);
ADT_j = ADT during time period j, either a portion of a year or a year;

Table 3. Percentage distribution of accidents by selected characteristics.

Accident Type	Tangent: Total Accidents[a]	Tangent: Other Accidents[b] Day	Tangent: Other Accidents[b] Night	Winding: Total Accidents[a]	Winding: Other Accidents[b] Day	Winding: Other Accidents[b] Night	Horizontal Curve: Total Accidents[a]	Horizontal Curve: Other Accidents[b] Day	Horizontal Curve: Other Accidents[b] Night
Single vehicle									
Run-off-road	36	35	63	64	62	73	52	69	74
Fixed-object	16	4	2	7	5	5	13	13	0
Other	1	2	1	1	2	0	1	0	0
Multiple vehicle									
Head-on	3	3	3	2	3	1	4	0	0
Sideswipe (same direction)	9	17	7	5	4	4	4	13	5
Sideswipe (opposite direction)	5	8	8	8	11	13	8	6	5
Rear-end	11	17	7	4	3	1	9	0	0
Angle	17	11	4	6	4	0	5	0	5
Other	2	3	4	3	4	4	4	0	11

[a] Excludes snow-, ice-, and fog-related accidents.
[b] Delineation-related, nonintersection, dry-pavement accidents.

P_f = factor to account for the average percentage of the time period during which the weather conditions at the time N can be expected; and
L_f = factor to account for the average percentage of ADT occurring under the ambient light conditions present at the time of N.

Because the isolated curve was being considered as a point location, L was omitted from the above equation leaving the accident rate expressed in accidents per million vehicles. Many different accident rates (reflecting permutations of the above parameters) were calculated and later analyzed. However, the accident rate ultimately used for the tangent and winding situations considered only those delineation-related accidents occurring at night on dry pavement and away from the influence of intersections.

The accident modeling was initiated by assuming that values of certain traffic performance measures (as suggested by the IDA and APM analyses) plus geometric variables could be used to independently predict potential accident hazard. The traffic-performance measures would indicate the manner in which drivers traverse a given section of roadway; the geometric variables would in effect define the available factor of safety inherent in the roadway design. Extreme values of traffic-performance measures in combination with a limited factor of safety would be expected to result in an above-average accident rate.

After preliminary analysis of the speed and lateral-placement data, we combined the tangent and winding roadway situations to form a single general roadway data set. Isolated horizontal curves were retained as a separate situation because of the difference in the accident-exposure measure. A number of traffic-performance measures for both daytime and nighttime dry-pavement conditions were then developed from the speed and lateral-placement data. Generally, these derived variables expressed the change in the average vehicle trajectory between two specifically defined stations, normalized by a geometric element to represent an available margin for driver error.

Alternative accident-probability models were then formulated and tested by using multiple linear regression analysis. A statistically significant regression model could only be developed for delineation-related, nonintersection accidents that occurred on extended sections of two-lane roadway during nighttime, dry-pavement conditions. The model shown below explained almost 81 percent of the accident-rate variance within the sample at the 95 percent significance level. The standard error of estimate was 1.33.

$$AR = 5.01 + 0.610CI + 58.2DPV + 2.03SI - 0.886RW - 0.501SW \quad (2)$$

where

AR = number of nighttime, delineation-related, nonintersection accidents per million vehicle kilometers (dry-pavement condition only);
CI = centrality index;
DPV = difference in lateral-placement variance;
SI = skewness index;
RW = roadway width measured between outside edges of the two traveled lanes (meters); and
SW = shoulder width (meters).

The centrality index is expressed as

$$CI = (\overline{LP_e} - \overline{LP_c})/0.1LW \quad (3)$$

where

$\overline{LP_e}$ = mean lateral placement of the right vehicle tire with respect to the right edge of the traveled way (meters),
$\overline{LP_c}$ = mean lateral placement of the left side of the vehicle with respect to the centerline of the roadway (meters), and
LW = width of traveled lane (meters).

As the value of the centrality index approaches zero, lateral clearance on each side of the average vehicle is maximized. For the winding-roadway situation, the centrality index was computed for the midpoint of the inside curve, shown as station 1 in Figure 2. The difference in lateral-placement variance is expressed as

$$DPV = (LP^2_{s1} - LP^2_{s2})/LW \quad (4)$$

where LP^2_{si} = variance of lateral placement with respect to the right edge of the traveled way, measured at station i (square meters).

In the case of tangent roadways, the locations of stations 1 and 2 are illustrated in Figure 1. As shown in Figure 2, for winding-roadway situations, stations 1 and 2 represent the midpoint of the inside curve and the midpoint of the intervening tangent respectively. The distance between the two measurement points was approximately 152 m (500 ft).

The skewness index (SI) describes the skewness of the distribution of vehicle speeds. As this statistic becomes increasingly positive, a higher percentage of the traffic stream is traveling at a rate exceeding the mean speed. For the winding roadway the skewness index was computed for the midpoint of the inside curve, shown as station 1 in Figure 2.

In each case, the sign of the regression coefficient corresponds to the expected relationship between the variable and accident potential. Increasing values of the three traffic-performance measures indicate greater deviations in vehicle trajectories and, therefore, greater potential hazard. Increasing values of roadway and shoulder width, on the other hand, indicate greater margins for error in vehicle guidance and, therefore, reduced potential hazard. A sensitivity analysis revealed that the relative influence of the traffic-performance variables on potential accident rate ranges from two to three times that of the roadway- and shoulder-width variables.

CONCLUSIONS

In considering the application of the model to the evaluation of new delineation treatments, we must emphasize certain limitations. First, the model was developed from data collected at a limited number of field sites. Validation of the significant variables and their relationship to accident potential is a need that remains to be fulfilled. Second, the model can only be used to compute the expected rate of delineation-related, nonintersection accidents that occur during hours of darkness and on dry pavements. Thus, the equation developed should not be considered capable of accurately predicting the overall accident rate for any particular section of rural highway.

The potential benefits of delineation under other conditions, including the isolated horizontal-curve roadway section, must be evaluated by different methods. One approach would be to experimentally evaluate traffic-performance measures derived from speed and lateral-placement data. If statistically significant changes occur when type of delineation is varied, these changes could then be interpreted in terms of their potential effect on hazard. This type of evaluation procedure will, in fact, be applied in the second phase of this research study. It is anticipated that the additional experience with the model and the traffic-performance measures will permit a more definitive assessment of their appropriate role in traffic-safety studies.

ACKNOWLEDGMENTS

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Critique of the Traffic-Conflict Technique

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This examination of the utility of the traffic-conflict technique includes an evaluation of previous studies and a discussion of recent results of a Federal Highway Administration (FHWA) study. The FHWA study attempts to develop a rigorous experimental design by using traffic conflicts as the basic response variable to measure the effectiveness of implementing various access-control techniques. Although some of the studies conclude that the traffic-conflict technique is a reliable tool for predicting accident potential, these conclusions are not well supported. The concept of conflict analysis should not be abandoned, however, but a more rigorous data base should be acquired before the reliability and utility of conflict analysis can be assured.

Traffic accidents are the ultimate measure of safety for a highway location. Because attempts to estimate the relative safety of a highway location are usually fraught with the problems associated with the unreliability of accident records and the time required to wait for adequate sample sizes, the traffic-conflict technique (TCT) was developed as a substitute measure. Originally developed by the General Motors Research Laboratories (GMR) in 1967 (2), TCT was conceived as a method of measuring accident potential at intersections. Conflicts were defined as evasive vehicular actions and characterized by