Report No. FHWA/RD-85/

DRIVER NEEDS ON TWO-LANE RURAL HIGHWAYS

Volume IV - Literature Review

April 1985

Final Report

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research and Development
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/RD-85/100		

4. Title and Subtitle	
Driver Needs on Two-Lane Rural Highways Volume IV-Literature Review	5. Report Date April 1985 6. Performing Organization Code
7. Author(s) R.S. Hostetter, K.W. Crowley, H.W. McGee, Sr., and W.E. Hughes	8. Performing Organization Report No.
9. Performing Organization Name and Address INSTITUTE FOR RESEARCH 257 South Pugh Street State College, PA 16801	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-81-C-00096
12. Sponsoring Agency Name and Address Offices of Research and Development Federal Highway Administration Washington, DC 20590	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code T-0634

15. Supplementary Notes FHWA Contract Monitor: Dr. Truman M. Mast (HSR-10)
Subcontractor: Bellomo-McGee, Inc.
410 Pine Street, S.E., Vienna, VA 22150

16. Abstract This study identified driver information needs on rural two-lane roads along with potential types of problems that could be alleviated through informational treatments. A simple, inexpensive procedure was developed that could be used by state and local jurisdictions to identify information deficiencies on two-lane rural roads. As part of the study, a 5000-mile, 15-state sample of roadway and informational characteristics was acquired using a microcomputer-based instrumented vehicle. The data base, supplemented by a detailed task analysis effort, provided a means of determining the nature of informational problems and of estimating the magnitude of information deficiencies on the nation's rural two-lane road system.

This volume presents the abstracts and a critique of all studies reviewed. Also included is an index showing the pages and author codes for groups of studies involving common geometries, e.g., narrow bridge, horizontal curve, and/or common measures, e.g., accidents.

This is volume 4 of a four volume set. The volume titles are:

Volume	FHWA#	Short Title
I	-	Technical Report
II	-	SLIDE - A Procedure
III	-	Appendices
IV	-	Literature Review

17. Key Words	18. Distribution Statement
Rural Highways, Two-lane Roads, Driver Needs, Roadway Characteristics, Information Deficiencies	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	320	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

* U. S. GOVERNMENT PRINTING OFFICE : 1973 725-504/328

Report No. FHWA/RD-85/

DRIVER NEEDS ON TWO-LANE RURAL HIGHWAYS

Volume IV - Literature Review

April 1985

Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research and Development
Washington, D.C. 20590

NOTICE

LITERATURE REVIEW

Introduction

This volume includes the references reviewed and critically evaluated for purposes of planning and implementing the study. Each reference includes a notation of the appropriate literature descriptors (indicated by an x on the chart), a summary or abstract, and a study-specific critical analysis which provides some indication of the applicability of the reference to the present study. While the references are listed in alphabetical order according to the first author, a series of indices are provided on pages 307 to 317 to aid the user in identifying by page number, all studies having certain common features. In addition each reference contains an author code. While these codes were originally assigned as working codes for project personnel they have been maintained in this document in the event that the user is seeking a reference by a specific author. In this case, the letter in the code, which coincides with the last name of the first author, can be used to more readily locate the reference.

The first index is the most general, indicating the references relevant to each of the literature descriptors used. Another index indicates the type of measure used, i.e., driver behavior, accident, or analytical. This information is provided for each alignment, cross section, and situation category. The final index relates the alignment, cross section, and situation categories to the information media categories.

For all indices the studies are listed by page number. It should be noted that in the interest of space, descriptor pairs for which there are no references were omitted from the index.

A/10.0

REFERENCE: Agent, K. R., "Relationships between Roadway Geometrics and Accidents," Highway Research Record 541, 1975.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade X Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway X Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Analysis of Accident Statistics.

SUMMARY/ABSTRACT:

Statewide average and critical rates of accidents were determined from 1970, 1971, and 1972 Kentucky accident records for each type of rural highway. Accident data, obtained from state police computer tapes, were summarized to give the number of accidents on each highway type as well as information on accident severity, road surface conditions, light conditions, road character, and type of traffic control. Four-lane undivided highways had the highest average accident rate, and parkways (toll roads) had the lowest rate. The severity of accidents was related to types of accidents, highways, and traffic control and to safety belt use. Accidents involving pedestrians were the most severe, and single-vehicle accidents ranked next highest in severity. Excluding accidents at railroad crossings, accidents that occurred on curves had the highest severity index. The use of safety belts was associated with reduced severity.

CRITICAL ANALYSIS:

This study presented tables and figures intended to establish rural, statewide averages that could be used for comparison against specific road sections to detect problem areas. "If the accident rate for a particular section of highway exceeds the critical rate for that highway type, the section may be considered hazardous." The critical accident rate on two-lane rural roads was based on a mean AADT of 1036. Accident types - head-on, rear-end, angle, pedestrian, etc. - were not related to geometrics, only to road type - two-lane, four-lane undivided, etc. Various accident types were related to traffic control -stop sign, signal, curve sign, yield, etc. - across all road types. The study has no direct implications for the "Driver Needs" study in that it is restricted to a single state.

A/1.0

REFERENCE: Agent, K. R., "Transverse Pavement Markings for Speed Control and Accident Reduction (Abridgment)," TRR 733, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent Horizont. X Curve Vertical ___ Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass X Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: Speed Selection

SUMMARY/ABSTRACT:

Transverse pavement markings were placed ahead of a sharp curve that had a history of high accident rates. Before-and-after studies of speed and accidents were conducted. The markings were placed so that drivers who failed to slow when approaching the curve would see the transverse lines on the pavement at an increasing rate. The spacing of lines was intended to create an illusion of acceleration that would cause the driver to slow. The results indicated that pavement markings can be an effective speed-control measure and reduce accidents. At the single site studied, the obedience of drivers to this type of hazard warning was more effective than signing alone. Further use of this type of marking may be warranted at locations at which excessive speed contributes to accidents. The length of roadway marked in this trial was 247 m (810 ft). Although the striping tape performed satisfactorily, painted lines could be used as an alternative.

CRITICAL ANALYSIS:

Only one site was tested. Consequently, the application of these pavement markers should not be generalized to include all areas. Further testing should be completed before that can be done. One major drawback was that after a year, a significant amount of wear had taken place in the wheel paths.

Pertinent findings include the following:

Average speed reduction, measured from the beginning to the end of the striping, was:

	BEFORE	6 MONTHS AFTER	IMPROVEMENT (Significant at = .005)
DAY	8.5 mph	12.3 mph	3.8 mph*
NIGHT	2.4 mph	6.8 mph	4.4 mph

Average speed, measured at the end of the striping (which was the beginning of the curve), was:

	BEFORE	6 MONTHS AFTER	IMPROVEMENT (= .005)
DAY	41.3 mph	34.8 mph	6.5 mph*
NIGHT	40.5 mph	39.1 mph	1.4 mph

Percent less than 35 mph (advisory speed) at the beginning of the curve was:

	BEFORE	6 MONTHS AFTER	IMPROVEMENT
DAY	10	60*	
NIGHT	19	32	13

* not specified if one week after installation or 6 months after.

AA/1.0

REFERENCE: Allen, R. W., et al, "Driver's Visibility Requirements for Roadway Delineation," Volume I. Effects of Contrast and configuration on Driver Performance and Behavior. US DOT, FHWA, Report No. FHWA-RD-77-165. November, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
X Tangent	___ Pavement	___ Intersection	X LanePlacemt/ Rd Following	___ Design
___ Horizont.	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
X Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	X Performance
___ Vertical Curve	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Grade	___ Other	___ L.W.Transit.		
___ Other		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The overall purpose of this multiphased research study was to establish visibility requirements for roadway delineation that can be used to help establish the cost-effectiveness of a variety of delineation treatments. Given the visibility requirements developed here and subsequent cost/benefit analysis, a rational approach can be taken for the development, design, and maintenance of roadway delineation.

Two basic contract objectives were addressed in this research study: 1) experimentally determine the optimum and minimum visual roadway delineation treatments; and 2) establish the lower saturation limit of yellow/white paint mixture that can still be distinguished from white. These two objectives are somewhat independent and were pursued in two different research efforts which are documented in separate volumes of this report.

Two issues are addressed in this first volume: 1) the human factors requirements for adequate delineation visibility under adverse visual conditions of night, rain, and fog; and 2) the development of functional specifications for a methodology to assess highway marking contrast. The research on the above issues will provide guidance for delineation design and maintenance and quantification of driver performance and can be used in subsequent cost benefit analysis studies.

A combined theoretical experimental approach was taken in this research. A theory for delineation visibility and driver perceptual requirements was developed and tested in a laboratory simulation. Further validation tests were then conducted in an instrumented vehicle on the open highway. The simulation and field test results were compared and connected analytically through the use of the previously developed visibility theory, and a model was developed to quantify steering performance in terms of delineation contrast and configuration (i.e., line segment and gap lengths).

It was found that the quality of delineation under adverse visibility conditions depends on a combination of contrast and configuration. Conclusions are drawn about delineation contrast and configuration requirements, and suggestions are made on practical field techniques for measuring delineation contrast.

CRITICAL ANALYSIS:

The results relate primarily to the driver's ability to laterally control his vehicle along a delineated pathway (i.e., steering control for lane placement). In the simulator tests, lane position variability, preferred speed, and driver rating were all found to be similarly sensitive to delineation configuration and visual range. In the field tests, lateral lane position variability was found to be sensitive to delineation contrast. It was found in the simulation tests that reduced visibility and intermittent dashed or dotted lines tended to induce longer time delay for steering corrections and impair driver perception of road curvature more than other combinations of visibility and delineation configuration.

Steering performance was found to degrade as the segment-to-gap ratio was reduced and the cycle (segment plus gap) length was increased. The addition of a solid right edge line produced dramatic improvement in performance during adverse visibility conditions.

One important finding that is applicabale to the current study is that optimum delineation, while improving steering performance, might induce vehicle speeds (and associated stopping distances) which are in excess of typical obstacle detection ranges during reduced visibility. Thus on rural roadways where volumes are sufficientl, low that traffic does not produce speed constraints, the trade-off between tracking accuracy and speed must be considered.

A/2.0

REFERENCE: Allington, R. W., "Criteria for the Longitudinal Placement of Warning Signs," Traffic Engineering, August, 1970, pp. 54-56.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design X Placement ___ Performance ___ Other

OTHER DESCRIPTORS: General

SUMMARY/ABSTRACT:

In some locales, warning signs are much too far in advance and the driver "forgets" the warning prior to reaching the condition of concern and tends to over-drive the roadway conditions. This paper suggests criteria for the logical definitive placement of warning signs and the minimum visibility of stop indicators without advance warning signs based upon recognized physical and physiological data.

CRITICAL ANALYSIS:

His mathematical derivation of the actual numbers (Table III) does not agree with his verbal description. However, he presents an acceptable methodology to specify placement distances in terms of approach speed, speed at the condition of concern, and comfortable braking deceleration rates. In mathematical terms, the recommended distances to locate advance warning signs can be expressed as follows:

A/2.1

$$S_t = 1.47[(V_{approach})(tg) - \frac{(A_{in\text{-}gear})(tg)}{2} +$$

$$(V_{approach} - (A_{in\text{-}gear})(tg)) \frac{(V_{approach} - (A_{in\text{-}gear})(tg) - V_{HA}}{A_{Brake}} -$$

$$\frac{(V_{approach} - (A_{in\text{-}gear})(tg) - V_{haz})^2]}{2A_{Brake}}$$

where:

$V_{approach}$ = 85th percentile speed, mph

t_g = time from when the driver takes his foot off the accelerator to when he begins his braking, sec (he uses 3 seconds).

$A_{in\text{-}gear}$ = deceleration rate of the vehicle "in-gear" with no foot on the brake or accelerator, mph/sec, which is a function of the approach speed. (He uses 1 mph/sec for 30 mph, 1.33 mph/sec for 40 mph, 1.67 mph/sec for 50 mph, 5.2 mph/sec for 60 mph, etc.).

A_{Brake} = comfortable deceleration rate of the vehicle with the braking system engaged, mph/sec, which is a function of the approach speed. (He uses 1 mph/sec for 30 mph, 1.33 mph/sec for 40 mph, 1.67 mph/sec for 50 mph, 2 mph/sec for 60 mph, etc.)

V_{haz} = desirable speed at the condition of concern.

Only recently, a request for a change to the MUTCD was proposed for placement distances of warning signs. The request is currently in the rule-making process. These values are shown on an attached sheet.

A/2.2

Posted Speed Limit or 85th Percentile Speed, Whichever Is Greater. (mph)	Recommended Placement Distance (ft)						
	Condition A	Condition B	Condition C Posted Advisory Speed or Desired Speed at Hazard (mph)				
			10	20	30	40	50
20	175	100	100	-			
25	250	100	100				
30	325	100	150	100	-		
35	400	150	200	175	100		
40	475	225	275	250	175	-	
45	550	300	350	325	250	150	
50	625	375	425	400	325	225	-
55	700	450	500	475	400	300	225
60	775	550	575	550	500	400	300
65	850	650	650	625	575	500	375
70	900	750	750	700	650	575	450

where:

Condition A requires high driver judgement and is applicable to complex driving situations where the driver needs extra time to make and execute a decision (e.g. a lane change on a high volume, high speed roadway).

Condition B requires a stop and is applicable to situations which require the driver to come to an immediate stop (e.g. a STOP sign).

Condition C requires a deceleration and is applicable to situations in which the driver will likely be required to decrease his speed (e.g. a dip).

A/3.0

REFERENCE: Andrew, C., "An Interview Survey of Motorway Driver Information Requirements and Signal Understanding," Transport and Road Research Laboratory, Laboratory Report 742, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

A home interview survey of drivers using M4 or A4 between Slough and London was carried out during 1972 to obtain information on various aspects of motorway use. The County of Berkshire (including the County Borough of Reading) was chosen as being a suitable catchment area and the drivers were selected at random from driving license records. Interviews with 523 respondents were successfully completed. The results from these were weighted according to each respondent's frequency of travel on these stretches of road, so as to give data representative of all the drivers living in Berkshire who used these roads. In the first part of the interview the drivers were questioned about their use of M4 and A4, and about factors they thought were important concerning their choice of route, bad weather, delays and hazards. Questions were also asked about their requirements for traffic information and about methods of providing it. In the second part of the interview the drivers were shown diagrams of standard, and non-standard, motorway matrix-signals to test their understanding of them. One finding was that the red "STOP" lights were poorly understood and often treated only as hazard warnings.

CRITICAL ANALYSIS:

This study has no direct application, but may serve as relevant background information for planning data collection with subject drivers.

BB/20.0

REFERENCE: Bali, S., Potts, R., Fee, J. A., Taylor, J. I., and Glennon, J., "Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments for Rural Two-Lane Highways," Volume I, Executive Summary. US DOT, FHWA, Report No. FHWA-RD-78-50, April, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
X Tangent __ Horizont. Curve X __ Vertical Curve __ Grade __ Other	__ Pavement __ Lane Width __ Shoulder __ OffRoadway __ Other	__ Intersection __ Driveway __ Tunnel __ Bridge __ L.W.Transit. __ Schl. Zone __ Speed Zone __ No Pass.Zone __ RR Crossing __ Other Cross. __ Other	__ LanePlacemt/ Rd Following __ CarFollowing __ O.T. & Pass __ Other	__ Design __ Placement X Performance X Other

OTHER DESCRIPTORS: Application

SUMMARY/ABSTRACT:

Under this research study, the effect of various delineation treatments on accident rates was assessed by analyzing accident data from more than 500 roadway sites in 10 States for tangent, winding and isolated horizontal curve sections on two-lane rural highways. Cost-benefit and cost models for evaluating specific delineation treatments were developed and guidelines formulated by executing the cost-benefit models for selected delineation treatments.

This Volume briefly presents an overview of the conduct of the study and results of the final report.

CRITICAL ANALYSIS:

Where the Task F recommendations from the current study involve delineation systems, the cost data from this study can be used to specify the volume level cutoffs where various systems are not likely to be cost effective. Further, the results of the accident data analysis can be used as an input to the development of information system recommendations for curve sites and winding road sections.

BB/21.0

REFERENCE: Bali, S. G., McGee, H. W., and Taylor, J. I., "State-of-the-Art on Roadway Delineation Systems," US DOT, FHWA, Report No. FHWA-RD-76-73, May, 1976.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
X Tangent	___ Pavement	X Intersection	___ LanePlacemt/ Rd Following	X Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
X Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	X Other
___ Other	___ Other	X L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: Application

SUMMARY/ABSTRACT:

Roadway delineation treatments and systems are those devices and techniques which individually or in combination provide guidance, regulatory, or warning information to drivers under various highway situations. This state-of-the-art report on roadway delineation systems constitute an update to the National Cooperative Highway Research Program Report 130. In the first part of the report, studies documented since the publication of NCHRP Report 130 are reviewed. This review is organized under two headings; Delineation Situations and Delineation Treatments. Under the former heading, studies relative to the application of different delineation treatments and systems for various highway situations are evaluated. The latter heading contains reviews of the studies from the standpoint of materials, cost, maintenance, durability and environmental effects. Recommendations subject to on-going research on delineation applications under different highway situations are given in the second part. A partially annotated bibliography is also included.

CRITICAL ANALYSIS:

The updated guidelines recommended in this report should be considered in developing our recommended information systems. A brief summary of those pertinent guidelines is given on the next page.

1) Pavement Markings

- Gap and mark lengths should be 34 ft and 6 ft, respectively.

- Continuous edge lines should be placed on all roads over 22 ft in width, where traffic volumes justify the expenditure. They are particularly important where shoulders are bad.

- A 4-inch width should be used on centerlines and edgelines.

- Eight-inch broken lines, with a gap of 13 feet and a mark of 7 ft, could be used for special applications where crossing is permitted (i.e., climbing lanes).

- When centerlines are used, edgelines and/or delineators should be used.

2) Post Delineators

- Post delineators should be installed along the right side of 2-lane rural roads at a spacing of 400 ft. Three delineators should be visible at all times.

- Crystal (white) delineators should be used on the right side.

- Amber retroflective delineators should be removed from culvert markers when crystal delineators are used. They should not be removed if crystal delineators are not used.

- Guardrails need not be marked in a special manner if crystal delineators are used.

3) Raised Pavement Markers

- When raised pavement markers are used for daytime conditions, standard pavement paint lines should be simulated (spacing of RPMs = 3 or 4 ft).

- When RPMs are used for nighttime conditions, a spacing of 80 ft for reflectorized RPMs is sufficient for lane lines and broken lines; a spacing of 24 ft for high-intensity markers and a spacing of 6 ft for low-intensity markers is sufficient for solid lines.

4) Horizontal Curve Pavement Markings

- Supplemental treatments with longer visibility distances are required to supply anticipatory information.

- Centerlines and edgelines (if pavement width is sufficient) or some other delineation treatment are desirable.

5) Horizontal Curve Post Delineators

- Amber delineators are recommended for right curves (placed on LEFT side of roadway) and crystal delineators are recommended for left curves (placed on RIGHT side of roadway).

- When post delineators are used on both sides, a two-color system should be used.

- Spacing is recommended in the MUTCD.

- Post delineators should be used at all curves over 5° of curvature having a central angle exceeding 20°.

6) Horizontal Curve Raised Pavement Markers

- RPMs can be very effective at horizontal curves especially if they are not used on tangents.

7) Pavement Width Transitions - Pavement Markings

- Edgelines should be continued or added if non-existent on the approach.

- Painted arrows should indicate the lane being dropped.

8) Pavement Width Transitions - Post Delineators

- Spacing of post delineators may be shortened to emphasize a feeling of constriction.

- Use of post-mounted delineators on both sides are recommended.

9) Stop Approaches - Pavement Markings

- Edgelines should be added where none exist on the approach roadway.

- Transverse stripes, although not recommended, may be used.

10) Stop Approaches - Post Delineators

- Progressively shorter spacing (from 200 ft to 10 ft) of post delineators can be used on approach to STOP signs.

- Crystal delineators are recommended.

- Post delineators, at progressively shorter spacings, may be added to the left side of the roadway.

11) Stop Approaches - Raised Pavement Markers

- When used, a progressively shorter spacing of RPMs is recommended on approaches to STOP signs.

- Crystal, rather than red, RPMs should be used.

- RPMs may be added to edgelines.

BB/1.0

REFERENCE: Bandyopadhyay, A. K., "Evaluation of Traffic Control Devices at Intersections of Low Volume Roads and Streets," Interim Report, Purdue University, Lafayette, Indiana, December, 1976.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The purpose of this study was to evaluate the performance of two-way STOP, YIELD and no control intersections at low volume roads in Indiana. The evaluation parameters included travel time through intersection, number of stops and conflict conditions as well as occurrence of accidents at intersections. In addition, operating costs of vehicles for travelling through different types of controls were also estimated.

A total of 53 intersections from different low volume roads were studied. Four cross street volume ranges were considered: 0-25, 26-50, 51-100 and above 100 vehicles per hour.

It was observed that the mean travel time through STOP controlled intersections was signifcantly higher than that through YIELD controlled intersections. In the volume range of 0-25 vph, mean travel time through unsigned intersections was significantly less than that through YIELD controlled intersections. It was further observed that on an average 32.4 percent of vehicles failed to stop at STOP controlled intersections. The operating cost through STOP controlled intersections was considerably higher than that through YIELD controlled intersections. However, the difference in operating costs between YIELD and uncontrolled intersections was not significant. On the basis of accident records for the last three years, it was determined that there was no significant difference in the occurrence of accidents in the STOP, YIELD and no control intersections.

BB/1.1

CRITICAL ANALYSIS:

The author failed to specify whether the stop sign violations were observed at intersections with the lower volumes and adequate sight distance triangles. Nor was there mention made as to whether any of the violations created near-conflicts with crossing vehicles. Other than the safety problems associated with the high rate of violations, the data on travel time, operating costs, etc., are not relevant to the current project.

B/10.0

REFERENCE: Benham, J., Laguros, J. G., "Accidents and Roadway Geometrics at Bridge Approaches." Public Works, Vol. 104, No. 4, April 1973, pp. 67-70.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel _X_Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The study attempts to develop relationships between the number of accidents and the geometric elements of a roadway at bridges, and to demonstrate how to use the relationships in highway engineering.

CRITICAL ANALYSIS:

Bridges considered were those more than 20 feet long. To obtain valid geometric data, it was determined that 500 feet on either side of the bridge was adequate. The geometrics of the roadway were recorded within these limits, except for sight distances. Eleven independent variables were used to analyze the data based on previous studies indicating that the variables contributed to or were related to accidents at bridge approaches: (1) ADT, (2) width of bridge, (3) width of approach pavement, (4) critical stopping sight distance, (5) critical approach grade (percent), (6) horizontal curvature (degree), (7) height of bridge guardrail, (8) length of bridge, (9) speed, (10) number of driveways and intersections, and (11) index of sufficiency rating. The data were classifed by: (a) two-lane or four-lane rural highways (two-lane were state and U.S. routes), (b) day versus night, (c) dry versus wet pavement, (d) surface type (bituminous or concrete), (e) bridge width, and (f) volume. Investigation of several models followed, with the results below. Some of the results of relevance to the current project are as follows:

(1) The predictor models indicated that ADT was one of the most significant variables.

(2) Sight distance available at night is important on two-lane roadways.

(3) Degree of curvature is a critical element in accidents during daylight on two-lane roadways.

(4) Wet pavement accidents are precipitated by roadway elements to a higher degree than are dry pavement accidents (two-lane roads).

(5) Sight distance and degree of curvature become significant variables in wet pavement conditions, but they are not significant enough to be included for dry-pavement conditions (two-lane).

(6) For two-lane roadways, the difference in multiple correlation coefficients is small between single and multiple car accidents.

(7) Concrete and bituminous pavements contribute about equally to accidents on two-lane roadways.

The variables noted above will be taken into consideration in classifying bridge problems and recommending warning information systems.

B/1.0

REFERENCE: Berg, W. D., "Experimental Design for Evaluating the Safety Benefits of Railroad Advance Warning Signs," US DOT, FHWA, Report No. FHWA-RD-79-78, April, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone _X_ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement _X_ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report presents the findings and conclusions of a study to develop an experimental design and analysis plan for field testing and evaluation of the accident reduction potential of a proposed new railroad grade crossing advance warning sign. Several alternative sampling frameworks were initially developed to determine which might offer the most efficient design in terms of required sample size. Because of the very large sample sizes associated with the alternative sampling frameworks, an analysis was undertaken to determine the minimum relative reduction in accident rate which would economically justify deployment of the new advance warning sign. The cost of undertaking the field studies and analyses was then evaluated so that it could be compared to the expected value or utility of the information to be derived from the study. The results indicated that the proposed accident study would be both experimentally and economically impractical. It was therefore recommended that an accident study not be undertaken. Several policy options were then examined.

CRITICAL ANALYSIS:

Berg reported that the red and yellow advance warning sign was not recommended by the National Advisory Committee because: 1) this sign did not reduce vehicle speed, 2) significance of a 5 percent increase in head movement was not sufficient justification to base a change, 3) there were no indications of potential safety benefits, and 4) economic impact of replacing the existing sign has not been determined. This has implications to the current study (e.g.. a new design for an existing sign may be met with stiff opposition).

The number of crossings and the average annual accident rates for crossings controlled only by crossbucks are shown below.

The policy recommendations made were: 1) undertake further study of the potential safety effectiveness of the new sign using alternative measures of effectiveness (e.g. head movement), or 2) if the new sign is believed to have the potential for offering a marginal safety improvement, approve its use on an 'as needed' basis.

Table 2. Characteristics of grade crossings with and without advance warning signs.

		Warning Sign	
Location		Yes	No
Rural	Arterial	1,337 0.060	324 0.070
	Collector	8,822 0.050	3,689 0.037
	Local	19,050 0.029	41,232 0.019
	Total	29,209 0.037	45,245 0.021

Cell values: number of crossings average annual accident rate

B/2.0

REFERENCE: Bezkorovany, G. and Ku, C. C. "The Influence of Horizontal Curve Advisory Speed Limits on Spot Speeds." Traffic Engineering, Volume 36, No. 12, September, 1966, pp. 24-28.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. X Curve ___Vertical ___Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ ___Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Two advisory speed plaques were analyzed. The first sign was a standard advisory speed plaque, the second plaque contained the words "Slow To" in addition to a numerical value. The study concluded that drivers did not differentiate between the two types of signs. Further, their speed at the center of the curve was not significantly influenced by the posted advisory speed. Investigations of approach speeds to curves, however, showed a correlation with posted advisory speeds. Fast moving vehicles approached a curve with a lower speed when a 30-mph advisory speed sign had been installed.

CRITICAL ANALYSIS:

Experiment was conducted when posted speed limit was 65 mph, spot speeds were obtained only at the center of the curve for all 12 situations. However, one conclusion might still hold:

The geometric design characteristics of a curve had a significant effect on spot-speeds measured at the center of the curve. When signs showing the same numerical speed limit were posted on curves of different characteristics, the highest mean speed resulted on the flattest curve and the lowest mean speed on the sharpest curve.

This would imply that motorists "drive" the curve according to how severe it appears to them.

B/5.0

REFERENCE: Bhise, V. D., and Rockwell, T. H., "Toward the Development of a Methodology for Evaluating Highway Signs Based on Driver Information Acquisition," HRR 440, 1973, pp. 38-56.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This paper presents the findings of a research study conducted to develop a methodology for evaluating road signs by the use of an eye-marker camera as a primary research tool. The methodology attempts to evaluate a road sign by determining the degree of match between the sign-reading behavior of drivers and the characteristics of the signs, the highway, and the traffic situations. Data were collected on the eye movements of drivers under actual driving situations involving more than 400 different Interstate highway signs. The data were analyzed by specially developed computer programs that also computed sign evaluation measures describing sign-reading behavior of the drivers. Further analyses showed that the sign evaluation measures were related to many factors associated with the characteristics of the signing, the driver, the highways, and the traffic situations. Understanding how various factors influence sign-reading behavior provides a basis for the implementation of the methodology for both the evaluation and the design of highway signing.

CRITICAL ANALYSIS:

The specific results are not applicable because only Interstate Highway signs were evaluated. However, the method used has applicability in research on unsigned two-lane rural low volume roadways in that a determination could be made as to which available "natural" were used for anticipation of curvature, etc.

C/10.0

REFERENCE: Campbell, R. E. & King, L. E., "Rural Intersection Investigation for the Purpose of Evaluating the General Motors Traffic Conflicts Technique," HRB Special Report 107, 1970, 60-69.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade X Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Intersection Data Collection Methodology

SUMMARY/ABSTRACT:

A traffic conflict is any potential accident situation. The traffic-conflicts technique developed by General Motors Research Laboratories is a means for analyzing the accident potential of roadway intersections through observation and tabulation of 5 conflict categories: left-turn, weave, cross-traffic, rear-end, and violation. These conflicts occur when evasive action, such as braking or weaving, is necessary to avoid an accident. To date, this technique has been applied mainly to urban intersections. The purpose of this study was to investigate the application of the traffic-conflicts technique to rural roadway intersections.

The technique was found to be flexible enough to be applied to both rural and urban intersections, and it is the authors' opinion that the traffic-conflicts technique does detect accident potential and that it appears to be a good systematic method for studying and evaluating the accident potential of an intersection prior to development of an accident history. However, more research and experience with the technique will be necessary to establish this as a fact.

CRITICAL ANALYSIS:

The traffic conflicts technique was applied to two rural intersections: the ADTs at the first intersection were 4,600 and 7,000; and the ADTs at the second intersection were 4,400 and 7,500. Daytime data were collected for 11 hours on each of two days at both sites; and nighttime data were collected for 5 hours on each of two nights only at one site.

Correlations of conflicts with accident data were in the predicted direction but not significant. The authors felt that more conflict and accident data may have resulted in significance. It would appear that the use of "conflicts" data is largely inappropriate for the current study unless two different information systems were being compared on a higher volume intersection. Otherwise the use of the technique would not be cost effective.

C/1.0

REFERENCE: Carstens, R. L., and Woo, R. Y-H., "Liability and Traffic Control Considerations for Low Water Stream Crossings," Iowa State University, Engineering Research Institute, Report No. HR-218, April, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing X Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design X Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Low water crossing.

SUMMARY/ABSTRACT:

A low water stream crossing (LWSC) is a ford, vented ford (one having some number of culvert pipes), low water bridge, or other structure that is designed so that its hydraulic capacity will be insufficient one or more times during a year of normal rainfall. A significant potential for accidents and liability claims could result from the use of LWSC's. It was concluded from this research the liability could be reduced to within acceptable limits if adequate warning of the presence of the LWSC were afforded to road users or if vehicular passage over an LWSC were precluded during periods when the road is flooded. It was recommended that LWSC's be used only on unpaved roads and that they not be used in locations where flooding of an LWSC would deprive dwelling places of emergency ground access. From surveys of 71 students and 128 county engineers, the signs shown on attached sheet were recommended to be installed at LWSC's. A 700-ft supplemental distance advisory plate may be used in conjunction with the FLOOD AREA AHEAD warning sign if the LWSC is not apparent from a point 1000 ft in advance of the crossing. An advisory speed plate may be used if the maximum recommended speed at the LWSC is less than speed limit.

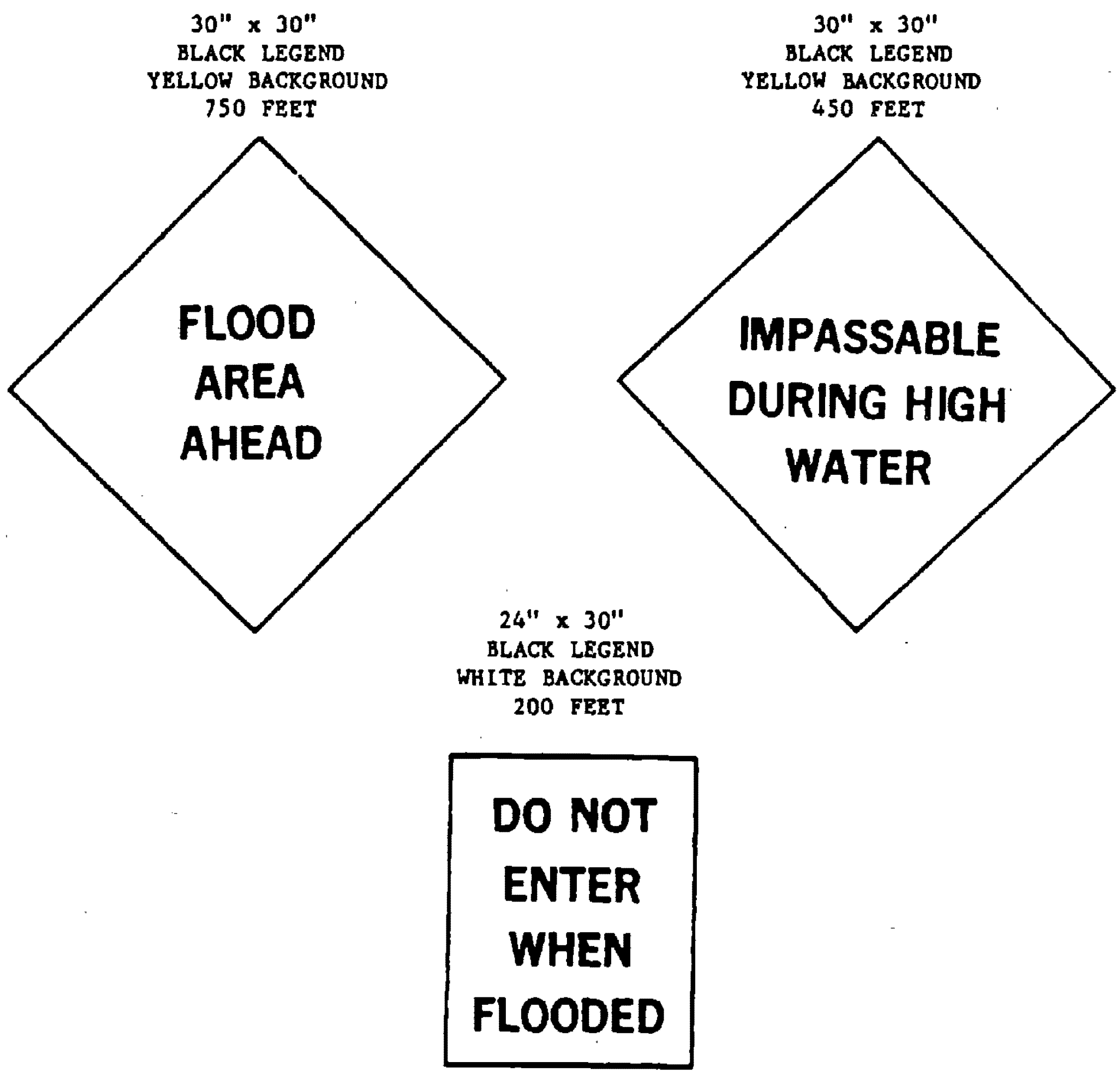
CRITICAL ANALYSIS:

These signs have been proposed as changes to the MUTCD. Notice will soon be released in Federal Register under "Announced Proposed Rule Changes."

C/1.1

A survey of current practice revealed that out of 154 respondents in 23 states, 70% reported the use of LWSC's. 81% reported the use of one or more warning signs, 30% used hazard markers, 29% used delineators, 19% used regulatory signs, and 14% used other devices.

Figure 1. Signs recommended for installation at low water stream crossing.



C/2.0

REFERENCE: Christian, M. R., Barnack, J. J., and Karoly, A. E., "Evaluation of Limited Sight Distance Warning Signs," Traffic and Safety Division, NY DOT, February, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent	___Pavement	___Intersection	___LanePlacemt/	___Design
Horizont.	___Lane Width	___Driveway	Rd Following	___Placement
X Curve	___Shoulder	___Tunnel	___CarFollowing	X Performance
Vertical	___OffRoadway	___Bridge	___O.T. & Pass	___Other
___ Curve	___Other	___L.W.Transit.	___Other	
___Grade		___Schl. Zone		
___Other		___Speed Zone		
		___No Pass.Zone		
		___RR Crossing		
		___Other Cross.		
		X Other		

OTHER DESCRIPTORS: Limited sight distance.

SUMMARY/ABSTRACT:

National attention has been drawn to current use of the Limited Sight Distance (LSD) warning sign. Its use has proliferated under current policies to allow many substandard vertical curves to remain, when a highway is reconditioned. This study is a quantitative look at the effectivenss of those signs. Analysis of spot speed data shows that vehicle operating speeds are essentially the same or significantly higher when LSD signs are present. Results of the motorist sign survey indicate that drivers interpret the LSD sign less correctly than five other standard traffic signs. A review of traffic signs on a sample of recently completed reconditioning and preservation (R & P) projects determined that the LSD signs are second in number only to the horizontal curve warning sign. The study recommends a modification of the current policy on the use of the sign and more detailed study by FHWA at a national level.

C/2.1

CRITICAL ANALYSIS:

- NYDOT's guideline for use of sign is where resurfacing or minor road improvements are likely to increase speeds significantly above design values for the vertical alignment. This has led to proliferation of signs on resurfacing projects.

- Radar spot speeds were found to be the same or even higher with the sign.

- Speeds are a function of speed limit, not sign.

- Driver understanding of sign is very low.

- Sign is not effective as presently designed and used.

The conditions under which the sign is used may be obtained from the "section" catalogs collected on the current project.

C/3.0

REFERENCE: Coleman, J., Koziol, J. S., and Mengert, P. H., "Railroad Grade Crossing Passive Signing Study," Transportation Engineering, Volume 47, No. 11 (November, 1977), pp. 15-18.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone X RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Most railroad grade crossings in the United States have passive warning signs only. A study is now underway to develop improved signing for use at grade crossings. This study is jointly funded by 25 States, the Federal Railroad Administration and the Federal Highway Administration. This article, a condensation of a report, describes the seven signing systems (combination of an at-crossing sign and advance warning signs) tested in two states during Phase 1 of the study, the types of data collected, the results of Phase 1, and the final three signing systems to be tested nationwide in Phase 2 of the study.

CRITICAL ANALYSIS:

Phase I results are annotated in Koziol, J. S., and Mengert, P. H., "Railroad Grade Crossing Passive Signing Study," Interim Report, US DOT, FHWA, Report No. DOT-TSC-FHWA-76-1, January, 1977.

Phase II results are annotated in Koziol, J. S., and Mengert, P. H., "Railroad Grade Crossing Passive Signing Study," Final Report, US DOT, FHWA, Report No. FHWA-RD-78-34, August, 1978.

C/4.0

REFERENCE: Comeau, C. M., "National Functional System Mileage and Travel Summary -- From the 1976 National Highway Inventory and Performance Study," US DOT, FHWA, June, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The purpose of this report is to present nationwide functional classification mileage and travel data from the 1976 National Highway Inventory and Performance Study (NHIPS). The tables were compiled from data furnished by the 50 states, the District of Columbia, and Puerto Rico.

Mileage and travel data for the functionally classified systems for 1975 and 1980 and projected travel for 1990 are included. In general, tabulations are by state for rural, small urban, and urbanized area types. Certain tables contain data by small urban area population group and by individual urbanized area. Mileage and travel density characteristics are tabulated for 1975, while mileage by jurisdictions and connecting link data are reported only for the 1980 systems.

CRITICAL ANALYSIS:

National totals are presented for each functional class for rural area types. However, no differentation is made between two-lane and multi-lane highways. As such the data are only marginally useful for project purposes.

C/5.0

REFERENCE: Comeau, C. M., "National Highway Inventory and Performance Summary -- From the 1976 National Highway Inventory and Performance Study," US Department of Transportation, Federal Highway Administration, Report No. FHWA-PL-78-006, December, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The purpose of this document is to make available significant national and state inventory and performance data which has not been published elsewhere in this level of detail. The data were collected on a sample basis and furnished by 46 state highway agencies for the 1976 National Highway Inventory and Performance Study (NHIPS). This report primarily contains 1975 data on the physical aspects of the highway plant and its operating and performance characteristics. It includes data for rural and urban arterial and collector systems; local road and street systems are not included in the tables.

These data were furnished by the states for the purpose of the NHIPS and are not to be considered as substitutes for official estimates or statistics, or as replacement for more comprehensive data available at the state or local level.

The report includes tables or figures on type of facility and functional class; volume/capacity ratio; peak hour operating speed and vehicle miles of travel; average overall travel speed and vehicle hours of travel; K, D, and truck factors; pavement type and condition; right-of-way width and land area; and rural horizontal and vertical alignment.

C/5.1

CRITICAL ANALYSIS:

For this report, the author grouped 2- and 3-lane rural highways together. Consequently, the contents will not provide us with any <u>accurate</u> estimates of 2-lane rural highway characteristics.

C/6.0

REFERENCE: Cribbins, P. D., and Walton, C. M., "Traffic Signals and Overhead Flashers at Rural Intersections: Their Effectiveness in Reducing Accidents," HRR 325, 1970, pp. 1-14.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Two specific types of operational improvements -- overhead flashers and traffic signals installed at low-volume, high-speed rural intersections -- were selected for investigation in this study. The effectiveness of the devices in reducing traffic accidents was earmarked as the primary objective of the analysis. Initially, all flashers and signal devices installed in North Carolina since 1965 were considered, but subsequent investigation and a more restrictive definition of a test site reduced the original inventory from 72 flashers and 153 signals to 14 flashers and 19 signals. A before-and-after study was made encompassing minimum time frames of 1 year prior to and immediately after installation of the device. Accident exposure during the two periods was compared on the basis of exposure rates, severity indexes, and equivalent property damage only (EPDO) accidents and rates. It was determined that the equivalent property damage only rate, rather than the normally used accident rate, was the most reliable and significant indicator of accident consequences. If all other factors were constant, any significant change in rate after installation of the control device could be attributed to the presence of the device. The relationship between the installation of signals and equivalent property damage only rate reduction was not statistically significant except for undivided highway intersections. The relationship between the installation of a flashing beacon and rate reduction was found to be statistically significant at the 1 percent confidence level.

C/6.1

CRITICAL ANALYSIS:

The following results are pertinent for high-speed ($\geq$ 45 mph) rural intersections:

- The effect of signal installations on accident experience cannot be significantly predetermined.

- On the average, installation of a signal at undivided highway intersections will reduce EPDO rates (α = 0.025).

- On the average, installation of a flashing beacon at any type of rural intersection will reduce EPDO rates (α = 0.01).

Thus, safety benefits, in terms of EPDO rates, can be gained from installing beacons at rural intersections. This suggests that the use of flashing beacons should be considered for inclusion in the "section" catalogs for the current project.

D/10.0

REFERENCE: Dart, O. K. & Mann, L., "Relationship of Rural Highway Geometry to Accident Rates in Louisiana." Highway Research Record 312, 1970, 1-16.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade X Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Accident Rates and Geometric Features

SUMMARY/ABSTRACT:

The purpose of this project was (a) to determine which geometric variables contribute most to accidents, and (b) to predict the accident potential of a certain section of Louisiana highways. This study involved approximately 1,000 miles of rural highways distributed evenly throughout Louisiana. The accident records investigated cover a 5-year period from 1962 to 1966. The variables studied in order to find their relation to accidents were: percentage of trucks, traffic volume ratio, lane width, shoulder width, pavement cross slope, horizontal alignment, vertical alignment, percentage of continuous obstructions, marginal obstructions per mile, and traffic access points per mile. These 10 variables, their squares, and their first order interactions were used in a regression analysis to construct mathematical models to determine the contribution of the variables to total accidents, accidents on wet roads, accidents on dry roads, accidents during the day, accidents during the night, total injuries, and total fatalities. One mathematical model shows that a total of approximately 46 percent of all accidents are explained by the 10 variables included in this study. The variables not investigated - involving the driver, the vehicle, and other geometrics -account for the remainder of the variation in total accidents. Based on their interaction with traffic volume, the two geometric variables having the most important affect on accident rates are pavement cross slope and traffic conficts. The remaining geometric variables studied in order of decreasing effect on accident rates are lane width, horizontal alignment, and shoulder width.

D/10.1

CRITICAL ANALYSIS:

The authors caution that attempts to generalize the study's results outside of the state of Louisiana are dubious because the causative accident factors may vary with geography.

Among the specific results of potential relevance to the current study are the following:

(1) Accident rate (accidents per million vehicle miles) increases as traffic volume ratio increases (i.e. peak hour volume to service volume at level B).

(2) Accident rate increases as lane width decreases from 12 through 9 feet; the accident rate increases precipitously as lane width decreases from 10 to 9 feet.

(3) Accident rate increases as the number of traffic conflicts per mile increases (i.e. the number of minor intersections and driveways).

(4) Roadways with relatively flat cross-slopes are more accident prone than those with better slopes.

(5) An analysis of 246 sections with respect to total accidents yielded the following hierarchy of importance of variables (all first order interactions):

A. traffic volume and pavement cross slope
B. traffic conflicts and traffic volume
C. lane width and traffic conflicts
D. traffic volume and horizontal alignment
E. shoulder width and horizontal alignment
F. traffic volume and trucks

(6) The authors suspect that the relative importance of cross slopes may be attributable to hydroplaning effects in the high rainfall areas of Louisiana.

(7) The one variable that contributed the most to accident rates was traffic volume ratio: this indicates that the more nearly that a roadway carries traffic volumes approaching or greater than its design service volume, the more likely it will experience a greater accident rate.

(8) Horizontal alignment is relatively more influential than vertical alignment in accident rates.

These data, along with data from other studies, will be used to determine which geometric variables will be coded for the "sectional" catalogs of the current study.

D/1.0

REFERENCE: Deacon, J. A., Zeeger, C. V., and Deen, R. C., "Identification of Hazardous Rural Highway Locations," TRR 543, 1975, pp. 16-33.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

An effective procedure was developed for identifying hazardous rural highway locations based on accident statistics. Indicators of accident experience that are necessary include the number of fatal accidents, total number of accidents, number of equivalent-property-damage-only accidents, and the nature of the local safety improvement program., local traffic and roadway conditions, and prevailing attitudes toward highway safety. Specific recommendations are given for use of the procedure in Kentucky. Critical accident rates are established by using quality control procedures. In identification of hazardous highway locations, distinction is made between short highway segments (spots) and large segments (sections), and spots are further classified as intersection and nonintersection locations. Intersection spots should include a distance of 0.15 mile (0.24 km) along all approaches; nonintersection spots should be 0.3-mile (0.48-km) floating segments; and sections should be 3-mile (4.8-km) floating segments. Both spots and sections should be classified by highway type and location. The use of 1- and 2-year intervals for accumulating and evaluating accident statistics was found to be desirable.

D/1.1

CRITICAL ANALYSIS:

The entire method is geared to identify hazardous spots (0.3 miles in length) and sections (between 2 and 5 miles in length) on the basis of accident data. For those states with adequate accident record systems, it may be possible, by using this method, to determine the general relationship between information deficiencies and accidents. This suggests that sampling preference should be given to states known to have good accident record systems so that data from the current study can be used in conjunction with accident data. While such analyses are not within the scope of the current study, the potential utility of the data base can be increased by designing the sampling plan in the manner suggested above.

D/11.0

REFERENCE: Denton, G. G., "A Subjective Scale of Speed when Driving a Motor Vehicle." Ergonomics, 9, 1966, pp. 203-210.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass _X_ Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Speed Control

SUMMARY/ABSTRACT:

An experiment is described which attempts to establish a subjective scale of speed, or more precisely of passive locomotion, such as that experienced by the driver of a motor vehicle. By a method in which the subject is required to produce a speed which in his opinion bears a given proportional relation to the standard speed presented, speed expressed as a sensation and real speed S are tested for a possible power law relation of the form $\psi = KS^n$.

It is found that n is not a constant, but has a definite correlation with speed. The time taken by subjects to change from one speed to another is also positively correlated with speed. The implictions of these facts are discussed.

A more suitable mathematical model is derived from the transformed data from which it is possible to predict performance for sensation ratios other than those tested.

Some possible applications of the findings to the study of driver behavior, and their relevance to speeding offences and accident rate at the ends of motorways, are given.

CRITICAL ANALYSIS:

In this study, four men and four women each made 90 runs over a 1 1/2 mile test track that was straight and flat. The vehicle driven had no speedometer available to the driver. For Part I, the subjects accelerated to either 20, 30, 40, 50, or 60 mph and were then asked to halve their speed. For Part II, the subjects accelerated to either 10, 15, 20, 25, or 30 mph and then were asked to double their speed.

The data indicated that drivers underestimated their speed (did not decelerate enough) when decelerating and overestimated their speed (did not accelerate enough) when accelerating. In particular, instead of halving their speed, drivers tended to reduce only by 30%; and in doubling their speed, as the initial speed increased, the drivers underestimated the doubled speed by progressively larger differences (initial speed = 10, doubled speed = 19.6; initial speed = 20, doubled speed = 33.4, initial speed = 30, doubled speed = 43.7).

"Continuous high speed has a marked effect on our subjective estimate of speed so that when we slow down to leave the motorway we will be going faster than our senses tell us, although after a time at the lower speed our subjective speed estimates gradually return to normal . . . "

"When drivers were asked to halve their speed they only reduced it by about 30%, e.g. they have been travelling 100 km per hour and are asked to halve it, i.e. to 50 km per hour, they will only come down to 70 km per hour."

These results have implications for curves which require a significant reduction from normal operating speed. That is, drivers who rely on speed estimation and do not utilize the speedometer may enter curves at a higher speed than realized. Since the driver workload on curves is higher than on tangent sections and the sampling pattern is known to be more complex, it is possible that drivers fail to monitor the speedometer as frequently under these conditions. It is possible that advisories can act as a reminder to monitor speed.

D/12.0

REFERENCE: Denton, G. G., "The Influence of Visual Pattern on Perceived Speed." Department of the Environment LR Report No. 409. Crowthorne: Transport and Road Research Laboratory.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone _X_ Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report is concerned with the instability of the relationship between real speed and the sensation of speed experienced by the driver relative to the physical speed at which he is moving. The various contributing factors are outlined. Speed adaptation is considered as a major factor responsible for errors in the driver's judgement of speed, and the hypothesis is made that by deliberately distorting the spatial geometry of the visual field it should be possible to counteract the effects of adaptation. The results of this experiment carried out on a simulator confirmed the possible value of such a technique. Proposals are made for future research into the control of behavior by the use of illusion, particularly in the driving situation.

CRITICAL ANALYSIS:

Using a moving road simulator, this author "found that a driver's sense of speed could be manipulated by introducing structured patterns on the road surface. The patterns consisted of white transverse bands whose spacing decreased exponentially. It was shown that these patterns had the effect of enabling drivers more accurately to halve their speed when asked to do so, but in some cases caused them to reduce their speed by more than the amount asked for . . . The effect clearly has use on roads where traffic tends to approach junctions too rapidly."

Two different transverse stripe patterns were tested via a moving road simulator.

The results indicated that when asked to halve their speed, drivers in the no-pattern control condition reduced by about 33%. Under the test conditions, subjects reduced at least 50% and sometimes more. Greater reductions ($p < .001$) were associated with the more rapidly decelerating pattern at nearly all speeds.

While such a treatment may not be feasible for widespread use, it does appear to have potential as a spot treatment for certain types of problem sites.

D/2.0

REFERENCE: Dewar, J. A., and Ells, J. G., "Comparison of Three Methods for Evaluating Traffic Signs," TRR 503, 1974, pp. 38-47.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent	___Pavement	___Intersection	___LanePlacemt/ Rd Following	___Design
___Horizont. Curve	___Lane Width	___Driveway	___CarFollowing	___Placement
___Vertical Curve	___Shoulder	___Tunnel	___O.T. & Pass	X Performance
___Grade	___OffRoadway	___Bridge	___Other	___Other
___Other	___Other	___L.W.Transit.		
		___Schl. Zone		
		___Speed Zone		
		___No Pass.Zone		
		___RR Crossing		
		___Other Cross.		
		___Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Three experiments were conducted to compare three methods of evaluating traffic sign perception. In the first experiment, subjects were required to classify signs according to type and to identify the meaning of the signs while driving toward them under normal highway traffic conditions at 30 mph (48 kph) and 50 mph (81 kph). The distances at which subjects were able to classify and to identify each sign were measured. Two classes of sign, regulatory and warning, were used, and half of each class had symbolic messages while the other half had verbal messages. The second experiment was a partial replication of the first, with certain modifications. The signs were one-third normal size and the subject drove the vehicle at 17 mph (27 kph). The third experiment was a laboratory study in which verbal reaction time required to classify and identify slides of traffic signs was measured. Signs used in the first two experiments were used as stimuli in the third experiment. The results indicated that the three measures of performance were closely related. Signs were classified at a greater distance than they were identified. Performance was better on symbolic than on verbal signs (except for the reaction time measure), and it was better on warning than on regulatory signs. In addition, performance on individual sign messages was highly correlated across the different measures.

D/2.1

CRITICAL ANALYSIS:

Experiment # 1 tested 16 subjects (min. of 5 years driving experience, average age = 25.8 years) to determine the distances at which traffic signs were classified (either regulatory or warning) and the distance at which they were identified while driving at a constant speed on a flat, straight stretch of 2-lane, paved, undivided highway with a wide shoulder. Signs were mounted so the bottom of the sign was 7 ft above the highway; they were placed 1 ft from right edge of paved shoulder and 10 ft from outside edge of driving lane. Each subject viewed each sign four times (2 times at 30 mph, 2 times at 50 mph).

It should be noted that drivers were in an alerted condition, actively searching for a sign which always appeared at the end at a 5,315 ft section. The only other tasks loaded on the driver were to maintain speed and, to a lesser degree, lane placement. Consequently, the distances at which drivers could classify and identify signs should be considered as <u>maximum</u> recognition distances. The distances are shown in Exhibit 1.

The purposes and results of experiments # 2 and # 3 are not applicable to the current study.

This reference provides data on the maximum recognition distances under "ideal" conditions for several pertinent regulatory and warning signs at speeds of 30 mph and 50 mph. Recognition distances recommended will be considered in the media application criteria (Task E-3) and information systems design (Task F-2).

Sign and Message Type	Message	Classification		Identification	
		30 mph	50 mph	30 mph	50 mph
Warning, symbolic	Winding Road	3,004.5	2,878.51	1,029.5	1,003.7
	Hill	2,696.8	2,621.3	1,068.2	1,126.1
	Bump	2,899.7	3,080.2	953.0	1,019.2
	Pavement Ends	3,578.0	2,927.2	946.0	864.9
Warning, verbal	Yield Ahead	3,234.6	3,022.0	596.8	521.3
	Pavement Narrows	2,927.7	3,234.5	410.7	416.2
	Soft Shoulder	3,280.8	3,130.6	581.5	555.2
	Fresh Oil	3,210.9	3,075.4	599.3	497.0
Regulatory, symbolic	No Right Turn	2,540.0	2,781.6	700.4	779.3
	No U Turn	2,726.3	2,597.5	726.5	764.8
	No Trucks	2,781.9	2,885.7	725.4	675.0
	Turn	2,909.1	2,579.2	721.9	672.7
Regulatory, verbal	No Left Turn	2,638.0	2,868.3	555.3	510.4
	No Parking	3,131.4	3,373.7	486.8	473.9
	Two Way Traffic	3,222.5	3,004.2	443.5	410.4
	Do Not Pass	2,482.3	2,761.3	530.4	521.8

Exhibit 1. Sign Classification and Identification Distances (in ft) from Dewar and Ellis Study

D/3.0

REFERENCE: Dewar, R. E., "Psychological Factors in the Perception of Traffic Signs," Canada Department of Transport, Road and Motor Vehicle Traffic Safety Branch, February, 1973.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	X Design X Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

A number of basic psychological processes are involved in the perception of traffic signs. These will be examined with a brief description of the process or variable, followed by a review of the research directly related to traffic signs. Each major psychological variable will be discussed in a separate section. Some sections are quite lengthy, because there has been a great deal of relevant research. Others are brief, either because there has been little or no research directly related to the perception of traffic signs, or because the topic overlaps with other variables and is dealt with in part elsewhere in the report. There is also considerable variability in the detail with which different studies are described. In general, more detailed accounts are given where the results were considered to be of major importance, or where the method was unique and/or of special interest.

CRITICAL ANALYSIS:

This report is essentially an in-depth review of literature pertinent to the perception of traffic signs in general. Subject areas related to driver characteristics include: static and dynamic visual acuity, peripheal vision, scoptic vision, dark adaptation, glare recovery, depth perception, perceptual organization, information processing, channel capacity, attention, short-term memory, stimulus response capability, fatigue and learning. Subject areas related to signs included: color, shape, lettering and spacing, symbols, sign placement, and legibility. A discussion of laboratory and field methodology to evaluate signs is also present.

Pertinent to the current study are the following:

- Field evaluation of new sign installation should consider novelty effects, controlled "before" and "after" conditions, adequate sample sizes, and control sites.

- As speed increases, the focal point of attention shifts further ahead of the vehicle. At 25 mph, the natural focusing point of the eye lies approximately 600 ft ahead of the car; at 45 mph, it lies 1200 ft ahead of the car (source where this was derived is not cited). This would imply that drivers tend to compensate for higher speed. If sight distance is inadequate, then this is a serious problem because drivers might not be able to stop to avoid a hazard.

- Criteria for signing is shown on the following page. These criteria may be useful as our application, design or placement criteria (Task E).

Studies that were discussed and are related to our study have been annotated directly.

CRITERIA FOR GOOD SIGNS

1. A sign should be easy to detect (attract the driver's attention) and the most important information should be emphasized by whatever means possible.

2. A sign should be legible, or easy to "read," under all conditions (e.g., day, night, bad weather), and when seen at a glance. Simple verbal messages and pictographs are more legible than complex ones.

3. The message should be easily understood, with no sources of misinterpretation and ambiguity, and should not depend on a high order of logical deduction for its comprehension.

4. The action to be taken by the driver should be clearly understood (this is often a function of education of the driver).

5. The design of the sign should be such that the information can be quickly rejected by those drivers not needing it.

6. Legend and location should conform to the driver's expectation based on pre-trip planning or previously obtained information, signs seen earlier, and subjective evaluation of the driving situation.

7. The meaning of a sign should be easily learned and remembered.

8. Each type of information should be ranked for its importance to the driver, and this hierarchy should be expressed in the choice of color, size, shape, and message form and in rules governing location.

9. The system should prepare the driver in advance for turning decisions and oncoming road and traffic conditions. Adequate time should be available to act on the information.

10. Information requiring different types of action by the driver should be conveyed differently.

11. Signs should be installed only where the information is needed. Overuse of signs breeds disrespect.

12. The use of all codes and forms of message content should be uniform throughout the system. Ideally, uniform signs should be used throughout the world.

D/4.0

REFERENCE: Dietrich, C. W., and Markowitz, J., "Investigation of New Traffic Signs, Markings, and Signals," Volume I, Laboratory Experiments and Road Tests, Bolt, Beranek, and Newman, Inc., Cambridge, Mass., Report No. 1762, December, 1972.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	X Intersection	___ LanePlacemt/ Rd Following	X Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
X Grade	___ OffRoadway	___ Bridge	___ Other	X Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		X Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		X Other Cross.		
		X Other		

OTHER DESCRIPTORS: Situation: low clearance, divided highway, slippery roadway.
Information media: recognizability.

SUMMARY/ABSTRACT:

120 Laboratory stimuli (six versions of 20 different signs) were presented tachistocopically for a controlled exposure time and observers were asked which of a set of possible signs had, in fact, been presented on a given trial. The observer's confidence in his judgments was recorded on a four-point numerical scale. A measure of recognizability was then computed. Two groups of observers were used in the laboratory tests: Pre-college students (Group A) and assembly workers from a nearby electronics factory (Group B). For Group A subjects, the proposed pictographs (KEEP RIGHT, NO LEFT TURN, LOW CLEARANCE, SIGNAL AHEAD, CATTLE CROSSING, SLIPPERY WHEN WET, DIVIDED HIGHWAY BEGINS, and DIVIDED HIGHWAY ENDS) performed better than the standard MUTCD (1968) signs. For Group B subjects, the standard signs were more recognizable than their proposed pictographic replacement. A separate analysis of seven regulatory signs with supplementary legends found that the legends helped Group B observers but hindered Group A observers before training. After training, the pictograph and legend became much more complementary.

Seven regulatory signs were evaluated using a visual interruption apparatus on a closed road course. For the group of "average" drivers:

D/4.1

DO NOT ENTER, KEEP RIGHT, and NO RIGHT TURN were found always superior in their experimental form. YIELD and NO TRUCKS were found superior in their experimental forms with legends. NO U-TURN and NO LEFT TURN were found superior in their standard form. For the "experienced" group of subjects, KEEP RIGHT, NO TRUCKS, NO LEFT TURN, and NO RIGHT TURN were found superior in their experimental form without legend. YIELD and NO U-TURN were found superior in their standard forms.

CRITICAL ANALYSIS:

While the results of the study could be applicable in that phase of the current project which involves sign design alternatives for various types of information, the results do not apply to the data collection phases of the project.

E/10.0

REFERENCE: Eck, R. W. and Lechok, S. A., "Truck Drivers' Perceptions of Mountain Driving Problems." Transportation Research Record 753, 1980, pp. 14-21.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve X Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway X Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	X LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Escape Ramps

SUMMARY/ABSTRACT:

A questionnaire was used to determine truck drivers' perceptions of mountain driving problems and truck escape ramps. A postage-paid self-mailer form was used in a variety of situations. Some questionnaires were mailed to drivers, some were distributed at truck terminals in West Virginia, and others were distributed at truck stops along Interstate highways. Difficulties encountered in obtaining a reasonable response rate are described. The questionnaire, which was completed by 180 drivers, sought information on driver age and experience and on the nature of trucking operations. Other questions dealt with mountain driving problems such as gear selection, signing, brake inspection, and use of brake-check areas. The final section of the form examined driver attitudes toward truck escape ramps. It was found difficult to obtain information from truck drivers by using standard survey techniques; a personal-contact approach was necessary. Questionnaire results indicated that load carried and weather conditions were important factors in gear selection on downgrades. Speed-limit signs on problem downgrades had little effect on gear selection by drivers. Drivers strongly supported the use of brake-check areas at summits of grades; however, a siginifcant number indicated that they do not inspect their brakes regularly. Equipment failure and inexperience in mountain driving were the most frequently cited reasons for runaway-truck accidents. More than 90 percent of the drivers said that they would use an escape ramp if they were out of control on a downgrade. Some drivers fear that ramps will cause either personal injury or property damage or both.

E/10.1

CRITICAL ANALYSIS:

Drivers were asked whether improved signing before a grade would enable them to make a better choice of gear selection. If drivers responded positively, they were asked what information should be indicated on the sign. Overall, 146 of the 177 responding drivers (82%) felt that improved signing would help them. Those drivers who responded affirmatively indicated that information on length and steepness of grade and on sharp horizontal curvature would be helpful. Several drivers recommended that a diagram of the hill be shown.

The final question dealing with mountain driving was whether maps of the downgrade posted at brake-check areas would be helpful, 83% of the drivers responded affirmatively. These results are consistent with the hypothesis that the more familiar a driver is with a grade and the more information that is made available, the better the decision on gear selection is.

Another question was whether signs for existing escape ramps were adequate; 71% of the drivers felt that they were. Several drivers included recommendations for improved signing: the need for more signs, more descriptive signs, the location of signs within the reach of headlights; the use of lighted signs and ramps and the location of signs further in advance of the ramp to allow for greater reaction time.

The authors concluded by noting that signing can play an important role on downgrades, especially on routes that serve as major interregional corridors for freight and passenger movement, since the percentage of drivers unfamiliar with mountain driving is probably greater on these roads.

These findings will be considered in that phase of the current study which deals with truck driver information needs.

EE/1.0

REFERENCE: Ellis, N. C., "Driver Expectancy: Definition for Design," Texas Transportation Institute, Report No. RF-0606-5, June, 1972.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Driver Expectancy

SUMMARY/ABSTRACT:

The present paper addresses a single aspect of the driver sub-system, namely driver expectancy. The objectives were to: (1) define driver expectancy operationally; (2) delineate factors which influence driver expectancy; and (3) propose a design philosophy accompanied by an analytical technique for implementing driver expectancy criteria.

Study results led to the development of the following operational definition:

> Driver expectancy relates to the observable, measurable features of the driving environment which: (1) increase a driver's readiness to perform a driving task in a particular manner, and (2) cause the driver to continue in the task until it is completed or interrupted.

This definition suggests that driver expectancy can be defined in terms of the conditions it causes rather than the conditions that cause it. Although the factors that influence driver expectancy are primarily those same factors which the highway engineer now uses in roadway design, the approach suggested will require the designer to examine these factors from a slightly different perspective. It seemed that the most useful thing one could propose at this stage in development of the driver expectancy concept would be a general design philosophy. Such a philosophy is proposed coupled with a flow analysis and checklist for general use in implementing driver expectancy in roadway design. //AUTHOR//

EE/1.1

CRITICAL ANALYSIS:

This paper presents a general discussion of driver expectancy as a tool for design. Although it includes the DRIVER EXPECTANCY CHECKLIST (AASHO, 1972), it contains very little pertinent information that has not already identified.

E/1.0

REFERENCE: Ells, J. G., Dewar, R. D., and Milloy, D. G., "An Evaluation of Six Configurations of the Railway Crossbuck Sign," Ergonomics, Volume 23, No. 4, 1980, pp. 359-367.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	___ LanePlacemt/ Rd Following	X Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		X RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Two experimental versions of the X-shaped railway crossbuck sign (white with red border, and yellow with black border) and the Canadian standard were compared in a series of four experiments. The angular separation between the blades of the sign was varied (45° and 90°), and all signs were tested against both a grass-green and a sky-blue background. Standard Canadian regulatory and warning signs were used as distractor stimuli in all experiments. Laboratory measures of classification time, glance legibility, and legibility distance indicated the experimental versions to be generally superior to the existing standard. Legibility distance was greater for signs with blades separated by 90° than for those with 45° angles. A final experiment revealed initial comprehension of the red and white crossbuck to be better than that for yellow and black version.

CRITICAL ANALYSIS:

The results warrant consideration for the sign design phase of the current project (Task E-2). However, the laboratory results were not verified in the field. Further, a "novelty" effect could have produced a portion of the improved performance for the experimental signs used. Thus the results of the study provide some sign design alternatives to be evaluated, but no direct recommendations.

GG/1.0

REFERENCE: Georgia Department of Transportation, "Chevron Marker Report," May, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The Georgia DOT conducted a review of existing methods and examined new methods of an effective traffic control device for horizontal alignment changes. The chevron alignment sign was chosen and applied at three test sites: an urban freeway and two rural roads. Based on the assumption that a series of chevrons improved communication of undefined hazards to the motorists, (especially during darkness) so that an inconspicuous change in alignment is specifically accentuated, the Georgia DOT concluded that the chevron marker can best meet the unfulfilled driver needs. They recommended expansion of its application to other locations within state.

CRITICAL ANALYSIS:

It should be noted that Georgia DOT did not conduct a formal "before-after" evaluation of the chevron markers, but relied on visual evaluation and engineering judgment as the basis for approval for use of the devices.

G/1.0

REFERENCE: Glennon, J. C., "Design and Traffic Control Guidelines for Low Volume Rural Roads," NCHRP Report 214, Transportation Research Board, October, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement X Lane Width X Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone X Speed Zone X No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Application

SUMMARY/ABSTRACT:

Low-volume rural roads, those carrying 400 vehicles per day or less, constitute two-thirds of the total U.S. highway system. Their key importance to the national transportation objective cannot be denied. Not only are they the largest single class of highway, but they are also the vital link of the nation's agricultural economy.

National guidelines for the design of low-volume rural roads are contained in the 1971 AASHTO publication "Geometric Design Guide for Local Roads and Streets." For traffic control devices, the basic guidelines are presented in the "Manual of Uniform Traffic Control Devices." But, because these national guidelines reflect the safety needs of primary highways, their application to the reconstruction of existing low-volume rural roads is continually being questioned in a time when local highway agencies must spend a majority of their limited funds for highway maintenance.

This research was undertaken to reevaluate the safety needs on low-volume rural roads. On the basis of a series of functional analyses relating safety performance to specific design and operational elements, a set of revised guidelines was developed. The revised guidelines apply to total roadway width, horizontal curvature, roadside design, speed signs, curve warning signs, centerline markings, and no-passing stripes. These guidelines are proposed to supplement the existing national policies, with each revised guidelines either replacing or clarifying the existing national guideline.

The widespread application of the revised guidelines should provide for more consistent design and traffic control of low volume rural roads consonant with a rational balance between highway investment, highway safety, and traffic service.

CRITICAL ANALYSIS:

Glennon found that current standards for speed limit signs, curve warning signs, centerline markings, no passing markings, roadway width and surface width are inadequate for low volume rural (LVR) roads. His recommendations include the following:

1) SPEED LIMIT SIGNS -- The design speed should be used as the posted speed limit. This would minimize drivers overdriving the geometrics.

2) CURVE WARNING SIGNS W/ADVISORIES -- Curve warning signs w/advisory speed plates showing the curve design speed should be displayed if the curve design speed is the following in relationship to the highway design speed:

HWY DESIGN SPEED (mph)	CURVE WARNING SIGN W/ADVISORY WARRANTED IF THE CURVE DESIGN SPEED IS LESS THAN
20	20
30	25
40	30
50	35

These values were derived based on an analysis of the maximum acceptable tracking corrections in curve negotiations..

3) CENTERLINE MARKINGS -- are warranted on paved LVR roads when the ADT $\geq$ 300 vpd. This was based on a cost/benefit analysis using an expected number of head-on meetings per day.

4) NO PASSING STRIPES -- are not warranted on paved LVR roads. This was based on a cost/benefit analysis using an expected number of passing conflicts per mile.

5) ROADWAY WIDTH -- The minimum roadway widths recommended are based upon design speed; percentage of trucks and busses; and frequency of use by farm machinery. The values are given in the report and are derived from an analysis of tracking error at various design speeds.

6) SHOULDER WIDTH -- LVR roads with design speeds above 45 mph require shoulders. However, minimum shoulder widths are not specifically recommended in this report.

These findings are pertinent to the current study and may be very helpful for the media application selection criteria and recommended information systems. If a human factors analysis reveals similar findings, then Glennon's analytical treatments can be used to support our recommendations. It should also be noted that his warrants for curve warning signs <u>could</u> also be applied to higher volume rural roads.

G/2.0

REFERENCE: Goldblatt, R. B., "Effect of Flashing Beacon on Intersection Performance." TRR 644, 1977, pp. 91-95.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	X Intersection	___ LanePlacemt/ Rd Following	___ Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	X Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This paper presents the results of a study on the operational effects of various types of continuously and vehicle-actuated flashing beacons. The study was performed at the Federal Highway Administration's Maine facility. Both electronic and manual data collection techniques were used. Five intersection and three advance warning device configurations were tested at the intersection of US-2 and Me-152. The use of continuously flashing intersection beacons along stopped approaches encourages speeds consistently lower than those achieved by STOP signs or vehicle-actuated intersection beacons. Certain vehicle-actuated advisory warning devices helped to reduce speed variance on major (nonstopped) approaches. A vehicle-actuated STOP AHEAD beacon caused drivers to begin braking sooner than they would without a beacon. Reduced speed variance was also noted when the advance warning beacon was used. These effects disappeared if there was a beacon at the downstream intersection.

CRITICAL ANALYSIS:

While some of the treatments evaluated appear to have excellent potential, the applicability of the more advanced treatments to much of the two-lane rural system is questionable due to cost. This is not to say that these treatments would not be recommended for known problem intersections; however, widespread use, particularly on lower volume intersections, would be cost prohibitive. The configurations evaluated in the study will be considered as candidates for intersections with sight-distance restrictions and carrying higher volumes or for certain types of problem intersections.

G/3.0

REFERENCE: Goldblatt, R. B., "Guidelines for Flashing Traffic Control Devices," US DOT, FHWA, Report No. FHWA-RD-76-190, July, 1976.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. X Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone X Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report details the development of guidelines for the installation of certain classes of flashing traffic control devices. The devices studied were, continuous flashing and vehicle-actuated two-way and four-way STOP intersection beacons, continuous and vehicle-actuated advanced warning (STOP AHEAD) beacons and vehicle actuated beacons for speed limit control on curves.

The guidelines are based upon the results of a state-of-the-art review, extensive field work, accident studies, and analytical investigations. They are presented in graphical form with a set of procedures for their use.

CRITICAL ANALYSIS:

Results of the field work performed at the Maine Facility are documented in Goldblatt, R. B., "Effect of Flashing Beacons on Intersection Performance," TRR 644, pp. 91-95.

Field work was also performed in New York, NY and Charlotte, NC. Although Charlotte is non-rural, the experimental results for two-lane test sites may be applicable to the rural environment.

G/3.1

The results and conclusions related to the various configuration are as follows:

1) Overhead intersection beacon

- The Traffic Conflicts Technique cannot be expected to yield useable results unless ADT's are high enough to assure sufficient exposure and the traffic split must remain such that a high degree of traffic interaction exists.

- Time headways on the non-stopped approach are a more suitable measure of effectiveness than gap acceptance for the stopped approach. Yet the data obtained provides information that could be obtained from speed profiles.

- The use of actuated intersection beacons over continuous beacons had no significant effect on the braking characteristics, as measured by brakelight applications, on the stopped approach.

- There was no significant difference in the coefficient of variation, a measure of speed dispersion, and the 85th percentile speed along the stopped approach between continuous and flashing beacons.

- Actuated intersection and "When Flashing - Vehicle Entering" warning sign w/beacons produced significantly smaller dispersons than only continuous flashing intersection beacons along the non-stopped approach.

2) "STOP AHEAD" advance warning sign actuated beacon

- Mean speeds and speed variances were significantly smaller after installation.

3) <u>"WHEN FLASHING - TOO FAST FOR CURVE" warning sign w/actuated beacon</u>

- No significant reductions were found in speed variance at three locations (30 ft upstream of the detector, at the sign, 275 ft downsteam of the detector) at two test sites.

- At one site, significant reductions in mean speed were observed at all measurement locations. At the other, no significant reduction in mean speed was found at the sign or downstream of the detector. This was attributed to the fact that the end of the curve was visible downstream of the detector.

4) <u>"SPEED VIOLATION - WHEN FLASHING" sign w/actuated beacon</u>

- No reduction in speed variance, but mean speed and 85th percentile speed were significantly reduced.

All the guidelines that Goldblatt proposes for the five flashing traffic control devices entail accident frequency warrants. These are of little value for the current project because we are primarily concerned with recommending devices in the absence of accident data.

G/10.0

REFERENCE: Gordon, D. A. "Perceptual Basis of Vehicular Guidance." Public Roads, 1966, 34, pp. 53-68.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade _X_Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: IDA Cues

SUMMARY/ABSTRACT:

Vehicular guidance is related to the driver's visual environment - described in basic terms of position and movement - in the four parts of this article: "Generalized Equations, the Driver's Moving Visual Environment"; "Static and Dynamic Visual Fields in Vehiclur Guidance"; "Motion Parallax and Perceptual Hypothesis Testing"; and "Perceptual Mechanisms in Vehicle Guidance." As the visual environment is an organized spatial entity, hence it may be considered a field having static and dynamic aspects. The positional field includes the angular coordinates of spatial points around the eye position. The velocity field includes the vectors of angular motion around the driver's eyes, as he moves on his path. These vectors vary with the speed and direction of the driver's motion. Inasmuch as the location of the vectors is determined by the positional field, this field might be called the positional-velocity field. The acceleration field is defined in terms of angular acceleration vectors rather than velocity. This field might be called the positional-acceleration field.

In Part I, equations are presented on the general organization of visual space around the eye of the moving driver. Derivations included on the effects of rectilinear motion, and horizontally and vertically curved motions, and combinations of these motions. In Part 2, the principles applying to the perception of the positional, velocity, and acceleration fields under rectilinear motion are discussed. In Part 3, the concept of motion parrallax, widely accepted as a cue to depth, is examined. It

was concluded that terrain movements on a circular path could not be interpreted in any consistent manner to show the distance of seen objects. A perceptual hypothesis principle is proposed to explain the major contributions of observer motion to space perception. In Part 4, the driver's perceptions are analyzed in the basic vehicular maneuvers of steering, perceptual anticipation, and car following.

CRITICAL ANALYSIS:

The perceptual problems in vehicular guidance were considered in the context of the positional, velocity, and acceleration fields around the moving vehicle. These are very general and persistent aspects of the driver's visual environment. The equations governing these fields, and the fields themselves, were considered for features and regularities that might explain human spatial perception. The following conclusions were made from the analyses.

Part 2:

- The interpretive scaling of visual angle is a key factor in interpreting perspective and in perceiving size, distance, and motion perception.

- Simple and obvious features of the visual environment, which have often been ignored in explanations of space perception, are believed to provide important aids for vehicluar guidance. The roadway ahead of the vehicle, for example, may be used to obtain the scale of the terrain and objects in it.

- The driver may see his vehicle, or some part of the environment as reference for motion. If the foreground is visually fixated, a curious illusion of motion is seen. The background seems to rotate forward and around the foreground. This velocity parallax curl is based upon the difference in velocity vectors between foreground and background.

- Roadway boundaries and lane markings are used in aligning the moving vehicle with the road. This conclusion challenges the often quoted statement that the focus of expansion is the cue for the direction of sensed locomotion.

- Angular acceleration increases as the square of vehicular speed. The consequences of this relation for the perception of vehicular speed are indicated.

- The pattern of the angular acceleration field does not resemble any familiar pattern of visual experience. It therefore seems that angular acceleration is not directly sensed. By extension, it is doubtful that higher derivatives of motion are seen as such.

Part 3:

Helmholtz's formulation of the motion parallax cue to distance fails when the observer follows a curved path. Angular velocity on the ground plan does not decrease systematically with distance; rather it shows an asymmetrical pattern, which would lead to an erroneous interpretation under the rules of linear motion parallax. It has been suggested that observer motion aids space perception by providing a test of prior perceptual interpretations or hypotheses under changed perspective.

Part 4:

- When the vehicle is aligned with a straight or regularly curved highway, the road assumes a steady state appearance. The borders and lane markers remain almost stationary in the driver's field of view. The driver's problem in lateral guidance, car following, and other maneuvers may be to maintain an acceptable steady state condition and to null deviations from the steady condition by utilizing visual feedback information.

- If the moving vehicle is misaligned laterally with the road, the entire field moves as a unit. No one part of the road borders or lane markers is essential for steering.

- The extent of lateral misalignment is indicated by the rate and extent of slewing and sideslipping of the road borders and lane markers. The driver's perceptual response is based upon an integration of these and other items of information.

- The driver's anticipation requirements must be considered in the design of road features such as curves, signal lights and signs. These requirements have not been extensively studied.

- The driver's ability to estimate the time required to reach an object ahead may be based upon his estimate of perceived distance.

- The visual stimulus to car following on a curvilinear path is discussed. It is concluded that need exists for expirical validation studies of car following theory.

- Guidance theories based upon characteristics of the velocity field, such as the motion parallax cue to depth, the center of expansion, and nul locus indicators of alignment, fail on curved roads. Features of the velocity field shift with the vehicle's curved path of motion.

Note that this is a strictly theoretical and analytical treatment of the rate of perception in vehicle guidance. It may be useful in creating the IDA task analyses in that perceptual cues relevant to steering, for example, are discussed. These cues are not always discrete, concrete items on the roadway but Gestalts that maintain a steady state appearance.

G/4.0

REFERENCE: Gordon, D. A., "Studies of the Road Marking Code," US DOT, FHWA, Report No. FHWA-RD-76-59, April, 1976.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	_X_ Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The studies described in this report are concerned with the driver's reactions to road markings. The first study investigated the driver's understanding of the various white and colored markings on the road and approval of different road marking applications. It was found that the driver favors markings which show the path of travel under adverse conditions, or which guide him in performing difficult maneuvers. Troublesome markings are those which attempt to communicate meanings which the driver may find difficult to interpret or which may be considered unnecessary. Respondents did not show a satisfactory understanding of the road marking code. More than a quarter of the explanations of the single solid white, single wide white, double broken yellow, single broken yellow and single broken white markings were wrong.

The second study concerned the development of an "ideal" coding system. Respondents chose "the most logical and understandable" marking to fit a variety of common highway situations. It was found that a broken line has a natural association (population stereotype) with permission to cross. Yellow markings are associated with hazard.

It was concluded that the driver requires instructions on poorly understood markings. It was also recommended that yellow markings not

be used to indicate counter-flow traffic. Yellow markings should be used where a real hazard exists, such as on railroad crossings, bus stops, left turn channelizations, dangerous curves and highway repair areas.

CRITICAL ANALYSIS:

The major conclusion was that most subjects were unaware that yellow markings are intended to indicate the opposite movement of traffic in the adjacent lane. For the purposes of the current study, the liklihood of driver understanding will be included as a media selection criteria.

G/11.0

REFERENCE: Gupta, R. C. and Jain, R. P. "Effect of Certain Roadway Characteristics on Accident Rates for Two-Lane, Two-Way Roads in Connecticut." Highway Research Record 541, 1975, pp. 50-54.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade _X_ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Predicting Accident Rates with Geometric Data

SUMMARY/ABSTRACT:

This study identified and defined which roadway elements are statistically correlated with accident occurrence and evaluated the relative merit of each element as an index of accident prediciton. Of the three principal factors associated with accidents, the vehicle, the driver, and the roadway, this paper considers contribution of the roadway. Four selected geometric elements: roadway width, horizontal curvature, vertical clearance, and restricted sight distance, were rated for adequacy, and these ratings were then correlated with accident rates. Multiple linear regression analyses were performed to examine these relationships. The resulting correlation coefficients were quite small. Of the four geometric characteristics considered, restricted sight distance and horizontal curvature appear to have some effect on accident rates and vertical clearance appears to have no effect.

CRITICAL ANALYSIS:

Accident rates were negatively correlated with sight distance adequacy ratings, and this association was the strongest of the four predictor - criterion combinations examined. The next best association was for horizontal curvature, indicating that the higher the degree of curvature, the

G/11.1

higher the accident rating. A predictive regression equation was generated on the basis of the data, but this equation explains only 5% of the variance in accident rates.

H/1.0

REFERENCE: Hanscom, F. R., "An Evaluation of Signing to Warn of Potentially Icy Bridges," TRR 531, 1975, pp. 18-35.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel _X_Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This field study examined driver responses to a potentially slippery bridge during periods of possible preferential icing. Study objectives were to examine motorists' general awareness of the hazard and to assess the relative effectiveness of various warning sign treatments. Measures of signing effectiveness were motorists' speeds at critical bridge approach locations and questionnaire responses regarding motorists' observations and interpretations of the signs. The speed data were obtained via the Traffic Evaluation System.

Two bridge approaches were signed using combinations of activated and nonactivated signs both at the bridge and 1,000 feet in advance of the bridge during periods of possible preferential icing. Significant speed reductions on the bridge and at the bridge entry point were elicited by activated signing. The most effective sign condition was advance and bridge-located activated signing used during hours of darkness. Activated signing used at the bridge was observed to have a greater impact than activated signing used at the advance location. Drivers were more responsive to the signs during periods when the hazard was greater. Bridge approach roadway geometry was seen to impact on motorists' observation and response to the signing. Improved results were obtained on a short sight-distance approach where the bridge did not compete visually for driver attention.

H/1.1

CRITICAL ANALYSIS:

The signs evaluated for this study are shown in Figure 1.

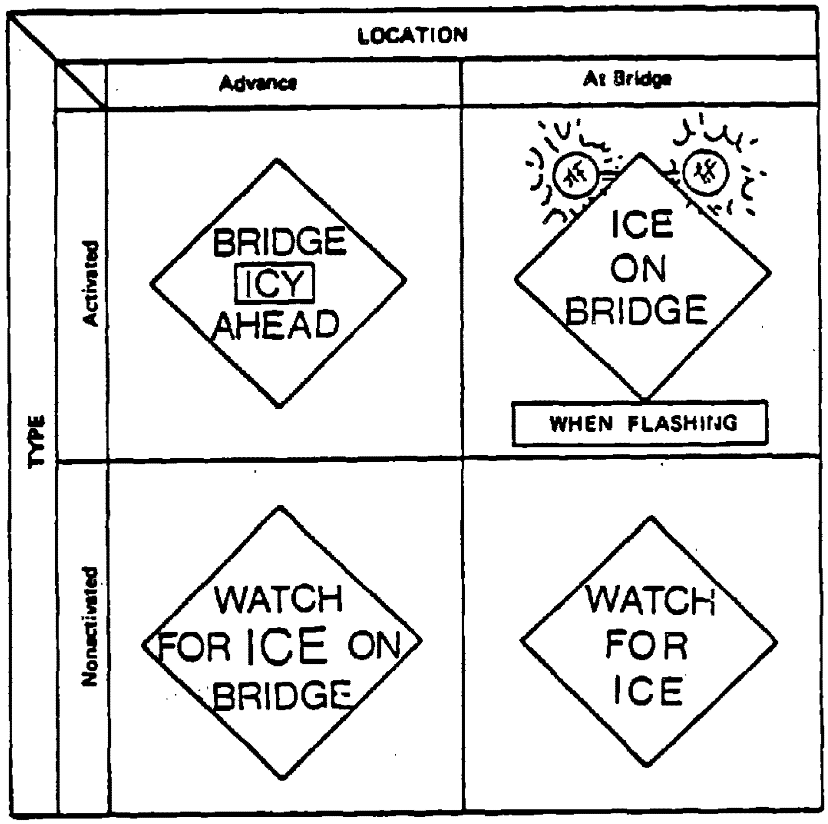


Figure 1. Icy bridge warning signs which were evaluated.

Bridge-located signs were positioned 100 ft from the entry point to the bridge and Advance Warning signs were located 1000 ft in advance of the sign. One of the bridge sites had long sight distance and the other had short sight distance.

While the results are generally applicable, it should be noted that only a limited sample was obtained for each sign condition, i.e., data were collected for one hour for each sign condition for each approach. Also, it should be noted that long term effectiveness of activated "icy bridge" signs systems is dependent on the reliability of the ice-detection system, thus the performance results presented here represent only the potential effectiveness of the system.

Pertinent findings from the interview portion of the study are as follows.

- Interviewed motorists who had observed the signing exhibited lower speeds on the bridge and its approach.

- Drivers acknowledged the possibility of bridge icing when at least one activated sign was displayed, regardless of the actual presence of frost.

- During periods of light frost, more motorists acknowledged the possibility of ice formation on the bridge. The motorists' cue of frost was predominently its accumulation on their windshields.

- Those drivers who indicated the possibility of bridge icing did exhibit lower speeds.

H/2.0

REFERENCE: Hanscom, F. R., "Driver Awareness of Highway Sites With High Skid Accident Potential," US DOT, FHWA, Report No. FHWA-RD-74-66, July, 1974.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel X Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: Wet Pavement

SUMMARY/ABSTRACT:

This field study examined driver responses to two types of potential highway skidding hazards: wet pavements subjected to high frictional driving demands, and bridges during periods of possible preferential icing. Study objectives were to examine motorists' general awareness of the hazards and to assess the relative effectiveness of various signing treatments which warn of the hazards. Measures of signing effectiveness were motorists' speeds at critical driving locations and questionnaire responses regarding motorists' observations and intepretations of the signs.

Three curved highway sections were treated with five experimental signing conditions. Variations on the "Slippery When Wet" symbolic sign ranged from its use by itself, through increasing levels of specificity and conspicuity, to its use with flashing lights and an advisory speed limit. Experimental signing conditions incorporating flashing lights were effective at reducing highest quartile mean speeds below the critical safe wet pavement speed based on roadway geometry and surface conditions. Questionnaire results indicated that 60 percent of the interviewed motorists saw and properly interpreted the more conspicuous warning signs. Motorists' cues of potential hazard were observed to be: roadway curvature and superelevation, behavior of other motorists, appearance of pavement surface, ambient conditions, known site accident history, and presence of the warning sign. About one percent of the interviewed motorists cited the warning sign as their cue of potential skidding hazard.

H/2.1

Two bridge approaches were signed using combinations of activated and nonactivated signs both at the bridge and in advance of the bridge during periods of possible preferential icing. Significant speed reductions on the bridge and at the bridge entry point were elicited by activated signing. Activated signing used at the bridge was observed to have a greater impact than activated signing used at the advance location. Drivers were more responsive to the signs during periods when the hazard was greater.

CRITICAL ANALYSIS:

The results of the activated/nonactivated signs evaluation are annotated in Hanscom, F. R., "An Evaluation of Signing to Warn of Potentially Icy Bridges," TRR 531, 1975.

Six sign configurations, shown on an attached sheet, were evaluated to determine the differential effects for varying combinations of driver maneuvers (decelerating, cornering and accelerating) and pavement condition (dry, wetting, and wet). Only 1 of the 3 sites evaluated was a two-lane rural road. Results for the two-lane rural site are pertinent for the current study. The Traffic Evaluator System (TES) was used to gather speed data and a questionnaire survey was conducted to determine motorist attitudes. Four tapewswitch locations were used (200 ft before the curve sign location, at the point of curvature, at the middle of the curve and at the point of tangency). The findings for the two-lane rural site included the following:

- Sign conditions with flashing beacons elicited greater mean reductions than all non-flashing signs at the curve entrance and all except the SLOW WHEN WET sign at the middle of the curve, although the magnitude of the mean speed reductions is quite small (i.e., less than 5 mph).

Further analysis on the highest quartile speeds revealed that:

- Warning signs which displayed flashing beacons or a SLOW WHEN WET panel were effective in reducing the highest quartile mean speeds below the critical wet weather speed.

- No significant effect on deceleration was observed as a function of the signing.

- Mean highest quartile speed differences obtained between the no-sign condition and each experimental sign condition reveal that the most effective sign configuraitons were those which included flashing beacons.

Survey results showed that:

- Motorists who saw signing slowed down.

- Drivers who could recall the sign message did not exhibit any greater speed reduction than drivers who could not recasll the message but who did recall seeing a sign.

- Experimental signing was more often seen by more familiar motorists at the rural site.

Hanscom concluded that little or no benefits could be obtained from the use of the symbolic "SLIPPERY WHEN WET" sign alone. He recommended a symbolic "SLIPPERY WHEN WET" sign in conjunction with an advisory speed plate and a rainfall-activated hazard identification beacon for use at slippery wet pavement sections.

IMPLICATIONS:

Drivers need information concerning pavement slipperiness. The symbolic sign with the supplemental plaque SLOW WHEN WET would be, according to this analysis, the most promising passive sign. However, it can be inferred that drivers drive according to how they perceive the surface condition. In which case, signing may only reduce liability.

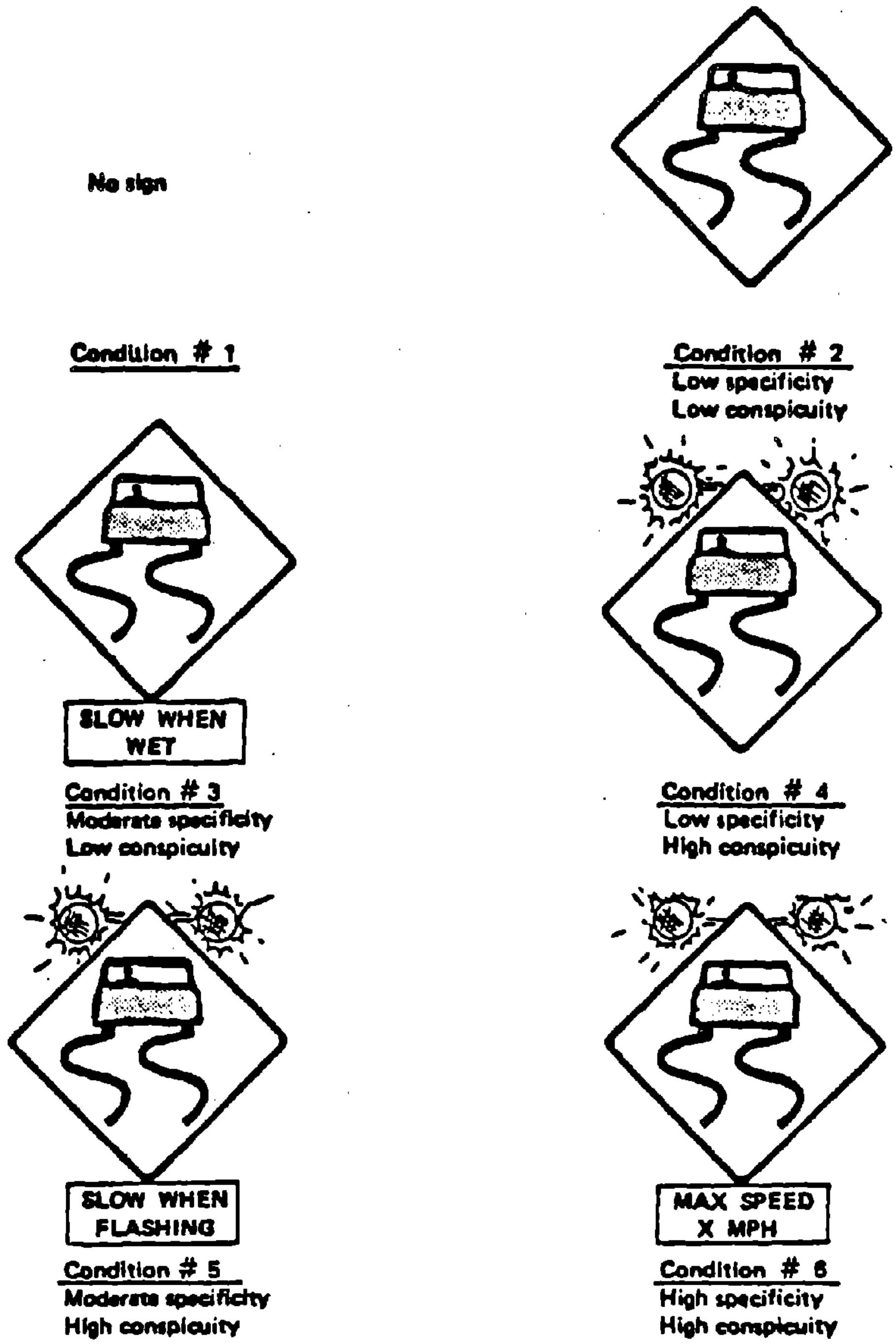


Figure 12. Wet pavement warning signs which were evaluated.

H/3.0

REFERENCE: Heathington, K. W., and Urbanik, T., "Driver Information Systems For Highway-Railway Grade Crossings," HRR 414, 1972, pp. 59-77.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone X RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	X Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The first objective of this research was to evaluate driver attitudes concerning hazards at highway-railway grade crossings. Respondents considered highway-railway grade crossings relatively more hazardous than other potential highway hazards but considered none of the potential hazards to be very serious. The second objective was to evaluate the economic priorities for improving railroad grade crossings relative to eight other highway improvements. Respondents considered safety at highway-railway grade crossings to be very important. The third objective was to evaluate driver preferences for information systems to be used at highway-railway grade crossings. An overhead changeable-message sign was the most preferred alternative method of warning. The fourth objective was to evaluate driver preferences for messages to be used in an information system for highway-railway grade crossings. The respondents preferred information even when no train was present and preferred full words rather than abbreviations.

CRITICAL ANALYSIS:

Data was collected through an attitudinal survey of 259 respondents to determine driver attitudes on a relative and an absolute scale. Of the objectives noted in the abstract, only the first objective is pertinent to the current study. The procedure related to this objective involves the use of photographs of various advance warning signs properly mounted along a two-lane state highway. The location was selected such that any hazard could exist beyond the crest of a small hill.

In comparison with a number of other situations, the railroad grade crossing was rated the most hazardous situation. This result was obtained using paired comparisons.

When respondents were asked to rate the hazardousness of each situation on an absolute scale, the crossroad, yield-controlled intersection, railroad crossing, and curve were considered only moderately hazardous. The respondents were indifferent about stop-controlled intersection and considered signalized intersections to be the least hazardous.

H/10.0

REFERENCE: Herrin, G. D. and Newhardt, J. B. "An Empirical Model for Automobile Driver Horizontal Curve Negotiation." Human Factors, 16, 1974, pp. 129-133.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent Horizont. X Curve Vertical ___ Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass X Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Speed Control

SUMMARY/ABSTRACT:

Continuous recordings of test drivers on rural horizontal curves indicated that test drivers exhibited a non-linear relation in velocity and lateral acceleration at the point of maximum acceleration. A model is proposed which includes a driver aspiration velocity, maximum lateral acceleration tolerance, and an expedience parameter related to the driver's willingness to trade velocity for lateral acceleration. The model provides a good fit to different types of data which include: (1) "relaxed" drive vs. "late for appointment" scenarios; and (2) familiarity of roadway. The empirical models indicate changes in the expedience parameter and aspiration velocity.

CRITICAL ANALYSIS:

These authors build upon the work of Ritchie (1972) by expanding on the observed inverse relationship between maximum lateral acceleration tolerated on a curve and the forward velocity of vehicle at that peak.

The authors theorize that if speed is assumed to be a manifestation of driver desire or utility for expediency, then lateral acceleration may be viewed as a comfort index or a safety criterion upon which the driver adjusts his velocity.

H/10.1

The study utilized two groups of drivers in an actual driving situation, operating under two different "instructional" sets. Group I (ten drivers) encountered 10 curves over a 9 mile course of two lane rural roads in driving the course 4 times each. Group II (ten drivers) made 2 runs over a 14 mile course with 15 curves. Drivers were instructed to drive either "as though you are late for an important appointment" or "as though you are on a leisurely Sunday afternoon drive." It was found that:

(1) Leisurely drivers (low expediency) tolerated significantly lower levels of lateral acceleration on curves.

(2) Highly familiar drivers (3rd and 4th run) tolerated slightly higher levels of lateral acceleration than unfamiliar drivers (1st or 2nd run).

(3) The data could be described by an equation that uses estimated parameters for aspiration velocity, acceleration tolerance, and driver expedience. The resulting model can be used to predict velocity - lateral accelerations on horizontal curves.

The authors point out that the results of the study indicate that both acceleration and velocity tolerances are reduced for the leisure drive with only slight changes as the driver becomes familiar with the roadway. A more subtle effect in level of expedience was observed with familiarity, in that drivers become more expedience oriented in subsequent runs on the same roadway. The results of this study for leisurely, unfamiliar drivers are consistent with earlier results reported by Ritchie et al (1968) and Taragin (1954).

This sort of result argues against using free field curve-speed performance for evaluating curve warning signing systems. That is, not only do familiar drivers have relatively less need for information, but they are also more tolerant of higher levels of acceleration. To interpret a performance result without knowledge of both familiarity and trip purpose, could lead to erroneous conclusions. The results of this study suggest that the use of subject drivers would be more appropriate and that a specific "instructional" set be provided for subjects.

H/4.0

REFERENCE: Hulbert, S. F., Beers, J., and Fowler, P., "Motorists' Understanding of Traffic Control Devices," AAA Foundation for Traffic Safety, Falls Church, VA, March, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	X Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

A multiple choice survey was administered to 3164 motorists from all areas of the country to assess driver understanding of 23 different scenes involving 16 traffic control signs, signals and markings. Participants were shown short movies of typical scenes depicting the approach and the control devices. Test results showed that driver understanding of traffic controls presented ranged from 18% on one control to a high of 97% on another. In general, participants understood symbol signs better than either signals or pavement markings. A summary is shown in Table A, attached.

CRITICAL ANALYSIS:

Pertinent to our study were the following findings:

- Many participants misunderstood the SCHOOL ZONE and SCHOOL CROSSING sign. They knew they were in school areas, but misunderstood the specific meanings of the two signs.

- 47% did not understand the significance of the orange background.

H/4.1

- 94% responded correctly on the first choice to the SIGNAL AHEAD symbol sign.

- Only 29% understood that on a two-way rural roadway you can cross the single, solid yellow line to safely pass another vehicle. 63% thought the line meant "NO PASSING PERMITTED." It should be noted that this marking is not recommended by the MUTCD but has been widely used.

While the results are of general interest, many of the signs, signals, and markings evaluated would not be encountered in the rural two-lane system.

TABLE A
MOTORIST UNDERSTANDING OF CERTAIN TRAFFIC CONTROL DRIVING SITUATIONS

	TCD Test Situations	% Drivers Answering Correctly on First Choice
Signs -		
4.1.1	School Zone Symbol Sign	18
4.1.2	School Crossing Symbol Sign	45
4.1.3	No Left Turn Symbol Sign	90
4.1.4	No Right Turn Symbol Sign	92
4.1.5	No U-Turn Symbol Sign	97
4.1.6	Lane Drop Symbol Sign	87
4.1.7	Signal Ahead Symbol Sign	94
4.1.8	Orange Color of Warning Signs	53
4.1.9	Two-Way Traffic Symbol Sign	93
Signals -		
4.2.1	Red X Symbol Signal	80
4.2.2	Green Arrow Symbol Signal (Left)	51
4.2.3	Red Arrow Symbol Signal (Left)	71
4.2.4	Yellow Arrow Symbol Signal (Left)	89
4.2.5	Green to Yellow to Red Signal Arrow Series	44
4.2.6	Red Arrow Symbol Signal (Right)	75

TABLE A (Continued)

Pavement Markings -

4.3.1	New Two-Way Left Turn Striping	24
4.3.2	New Two-Way Left Turn Lane	69
4.3.3	Old Two-Way Left Turn Lane (New Reverse Lane) Move Into	65
4.3.4	Old Two-Way Left Turn Lane (New Reverse Lane) Move Out Of	62
4.3.5	Old Two-Way Left Turn Lane (New Reverse Lane) Use	48
4.3.6	Single Solid Yellow Stripe (Mountain Road)	29
4.3.7	Single Solid Yellow Stripe (Urban)	34
4.3.8	Single Solid Yellow Stripe (Construction Area)	25

H/5.0

REFERENCE: Hulbert, S. F., and Fowler, P., "Motorists' Understanding of Traffic Control Devices, Test II," AAA Foundation for Traffic Safety, Falls Church, VA, December, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone X RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing X O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Recognition

SUMMARY/ABSTRACT:

Over 1700 licensed drivers from the United States and Canada participated in the second AAA Foundation for Traffic Safety Research test-film project designed to determine motorist understnading of driving situations involving 19 specific traffic control signs, signals, and pavement markings. An analysis of driver responses by region of the country (East, West and Central), age, and the sex of the driver showed these results: Only three traffic control situations were repeated from the first test series. The overall results of the second test program generally followed the same pattern as the first test in that: a) there is wide variance in motorist understanding of the meanings of traffic control devices which are installed along highways to communicate important information to drivers. Correct responses to the different traffic control situations ranged from only 7 percent to 97 percent; b) older drivers consistently scored lower in understanding and recognition of traffic control communication. Younger driver age group scored higher, in general; c) there was no significant difference in understanding by male and female drivers; d) new symbol signs for advance warning of STOP and YIELD signs appeared to be clearly understood by all drivers, (symbol signs, in general, were better understood than pavement markings and signals); e) the use of the single solid yellow line in terms of passing situations on rural highways is not well understood by drivers; f) while more drivers scored correctly on the meaning of the "orange" background signing used to identify construction areas, one out of every four drivers didn't understand this meaning; g) driver

H/5.1

Education and driver improvement programs need to give more attention to understanding the meanings of traffic control devices.

The highest recognition score by motorists was given to the familiar RAILROAD CROSSING sign. However, less than half of the drivers correctly understood the meaning of the commonly used YIELD sign. Responses to signals relating to exit, continuous lanes, merge lanes, etc., are also discussed.

CRITICAL ANALYSIS:

Methodology was similar to the one employed during the first study performed by AAA, (i.e., Hulbert, S. F., Beers, J. and Fowler, P., "Motorists' Understanding of Traffic Control Devices," AAA Foundation for Traffic Safety, March, 1979.) It is not applicable to our study.

A summary of the results are shown in Table A. Pertinent findings for rural scenes related to our study included the following:

- YIELD AHEAD sign was correctly identified by 86% of the respondents.
- STOP AHEAD sign was correctly identified by 84% of the respondents.
- RAILROAD ADVANCE sign was correctly identified by 97% of the respondents.
- The single solid yellow centerline on a two-lane rural road was not well understood. Only 39% knew it was legal to cross these stripes. 61% responded that it was illegal.

TABLE A

TCD TEST SITUATIONS	% of Drivers Answering Correctly On First Choice
Signs:	
Yield Sign	45
Stop Ahead Sign	84
Exit Only Sign on Freeway Overhead Sign	44
Railroad Crossing Sign	97
Continuous Lane, No Merge Required	7
Construction Area Signs	74
Optional Lane Arrow on Overhead Sign	58
Yield Ahead Sign	86
Chevron Road Alignment Sign	46
Keep Right Sign	35
Signals:	
Standard Traffic Control Signal	70
Exclusive Green Arrow (Left)	59
Offset Intersection	33
Pavement Markings:	
Yellow Stripes (Solid/Dash) Center Road	26
New Two-Way Left Turn Lane	79
Single Solid Yellow Line (Rural Road)	39
Diamond Lane; Buses and Right Turn Only - Car Continues Straight	76
Diamond Lane; Buses and Right Turn Ony - Truck Turns Right	84
Lane Ends Dashes	69

I/1.0

REFERENCE: ITE Technical Council Committee 4A-A, "Yield Sign Usage and Application," ITE Journal, October, 1978, pp. 37-43.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This paper presents a summary of a state-of-the-art report on the use of "YIELD" signs and on the effectiveness of the devices in controlling traffic at intesections and elsewhere. The paper also presents warrants for the use of "YIELD" signs at: 1) minor move at a major intersection with channelized turning lanes, 2) intersection of two minor streets, and at median crossings.

CRITICAL ANALYSIS:

Almost the entire paper is devoted to an analysis of YIELD signs in urban areas. It offers little pertinent information for the current study.

I/2.0

REFERENCE: ITE Technical Council Committee 4E-A, "Experimental Traffic Control Devices," ITE Journal, May, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. _X_Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	_X_Design _X_Placement _X_Performance ___Other

OTHER DESCRIPTORS: Situations are not specified.

SUMMARY/ABSTRACT:

Information relating to the installation of experimental traffic control devices was obtained by use of a questionnaire soliciting available data from various governmental agencies and research organizations. It was found that of the 163 devices 33% were signs, 23% were signals, 17% were markings, 12% were rumble strips, and 15% were other. Most of these were developed to reduce accidents (81%), improve driver information (65%), or improve traffic guidance (53%) in a suburban or urban area (77%). The devices were used at intersections (54%), mid blocks (23%) and continuously (23%). Of the devices evaluated, 63% conformed to the MUTCD; however, interpretation has been requested for 28% of the devices not conforming to the MUTCD. Committee 4E-A concluded from this study that each experimental device should be fully evaluated and documented with respect to its effectiveness in achieving its intended goals. The committee recommends that the devices be reported through ITE, including a description of the device. The general location where the device is applicable, the traffic characteristics pertinent to its use and the results obtained.

The paper also indicates the 12 evaluation methods used for experimental traffic control devices and shows the frequency of use and significance of each method. The methods, noted in order of frequency of use, are: subjective field review, before/after accident studies, maintenance evaluation, cost analysis, photographs, before/after volume studies, speed surveys, driver interview, travel time studies, photometric studies, video recordings and computer simulation.

I/2.1

CRITICAL ANALYSIS:

While the study provides no direct inputs to the current effort, it indicates that subjective field review is an acceptable means of evaluating information systems. A form of subjective field review will be used for the "site" evaluations at the early stages of the current project.

I/3.0

REFERENCE: ITE Technical Council Committee 4I-M, "Review of Usage and Effectiveness of Advisory Speeds," ITE Journal, Volume 48, No. 9 (September, 1978), pp. 43-46.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent Horizont. X Curve Vertical ___Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Committee 4I-M surveyed 40 states to determine the state-of-the-art regarding the use of advisory speeds and the effectiveness of the displays. The use of advisory plates on warning sign was found to vary widely among sign groups and among states. Only on the curve warning sign did average usage exceed 50 percent for the states surveyed. Only four other signs (Grade, Surface Conditions, Construction Ahead and Men Working) had accompanying usages greater than 10 percent. An extremely significant (99 percent) trend was observed between the increased usage of advisory plates on curve warning signs with increased miles of rural road roadway. In response to whether states were satisfied that advisory speed plates are effective in their present form, 41.2% replied "Yes," 41.2% replied "Yes, with reservations," and 17.6% replied "No." Reservations included: the devices are overused, the speeds are set too low, and the average motorist had little or no respect for them. Based on the survey results, it was suggested that uniform procedures to establish advisory speeds be created.

CRITICAL ANALYSIS:

Other pertinent survey results include:

- 85 percent of the respondents indicated that they did not feel the need for additional applications in the MUTCD.

- 95 percent utilize the ball bank indicator to determine the appropriate curve speed, with a total of 36.9% selecting that speed at which a 10 degree reading is obtained and 26.3% utilizing a look-up table after obtaining an experimental reading.

- 47.2 percent of the state respondents indicated that they do not collect data to evaluate the effectiveness of advisory speed plate; 24% use radar speed checks, 16.7% use accident studies and 11.1% use engineering field studies.

- California developed their own curve warning sign and, as of 1978, have applied it at 500 locations where the standard sign was found inadequate. This sign integrates the advisory speed infomraiton into the face of the sign rather than using a separate speed plate.

- Connecticut utilizes a speed reduction warning sign where the speed limit is reduced by increments of 15 mph or more.

- Illinois uses successive advisory speed signs (displaying a 5 to 10 mph reduction successively) to aid the motorist in slowing to a very low advisory speed (e.g., 20 mph).

- In terms of the current study, the various state practices may have to be taken into consideration for the critique of the "section" catalogs and for certain of the "site" evaluations.

I/4.0

REFERENCE: Ivey, D. L., et al, "Safety at Narrow Bridge Sites," NCHRP Report 203, June, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel X Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	X LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes methods (other than widening of a bridge) for reducing hazards associated with a narrow bridge. A major feature is the development of a bridge safety index (BSI) for determining priorities for improvement of bridges having restricted width.

In an attempt to define the narrow bridge problem, data on speed and lateral position of vehicles at 25 bridge sites of various geometric characteristics were collected and analyzed by the Texas Transporation Institute. From these data it was determined that there was little lateral movement of vehicles when approaching bridges more than 24 ft in width (the clear width of pavement measured at right angles to the center of the roadway). There was a movement of more than 2 ft toward the center of the roadway in bridges 15 ft or less in width. On bridges 17 to 18 ft wide, most drivers place the left edge of their vehicle on the centerline when unopposed by traffic. Some observations drawn from the data are as follows:

1. Any bridge less than 24 ft wide should be considered a restricted-width bridge, but not necessarily a hazardous bridge site.

2. Any bridge less than 18 ft in width should be considered a one-lane bridge.

3. Any bridge with a width of 15 ft or less should be considered a hazardous site.

On the basis of the data collected and the experience of the researchers, the BSI was developed as the sum of ten individual bridge site rating factors. The BSI approach is presented in the form of tables and figures readily usable by practicing engineers. It is considered suitable for trial implementation as a technique for making a reasonable estimate of the relative degree of hazard at various restricted-width bridge sites. By use of an example problem, the BSI is explicitly defined to permit its direct application in practice. As a result, corrective action can be taken at the more hazardous sites even if extensive accident records are not available.

The report identifies a number of corrective measures that can be applied to hazardous bridge sites when widening is not economically feasible. The recommended corrective measures are approaches that can be considered, along with engineering judgment, to reduce the possibility and severity of accidents at potentially hazardous sites.

"Before" and "after" evaluations of corrective measures at restricted-width bridge sites were obtained from a Texas improvement project. Accident data over a two-year period indicated that the fatal accident rate of a section of U.S. 90 near Gonzales, Texas was 56 percent higher than the statewide average. Many of the reported accidents were located in the vicinity of bridges. A comprehensive safety program was conducted, including extensive corrective measures of the bridge rails. The bridges were predominantly 24 and 26 ft wide. There were two types of railing. One railing was constructed of concrete posts with concrete beams; the other type was concrete posts with steel beams. The roadway had a 24-ft paved surface width with 8-ft paved shoulders and thus was substantially wider than the bridges. The corrective measures appear to have been effective in reducing the number of reported accidents. In the 22 months prior to application of corrective measures, 20 accidents involving the bridges were reported. During the 17 months following the applications, only 4 reportable accidents occurred. This verification, though limited, provides sufficient evidence to indicate good probability of success when the recommended corrective measures are implemented.

Data were also summarized from the questionnaire regarding measures to improve safety conditions on narrow bridges (such as warning signs, pavement markings). The following measures are either used or recommended by the states responding to the particular questions (5 and 6):

1. Delineators, reflective signs, raised pavement markers, edge stripes, and reflective paint on end posts.

2. Standard "narrow bridge" sign.

3. Standard "one-lane bridge" sign.

4. Eleven-inch edge line from 50 ft in advance of bridge with the inside edge of the stripe in line with the inside edge of the bridge abutment, or curb line if curbing exists. The stripe shall extend for 150 ft then taper to the edge of roadway. The length of taper, L, is equal to the speed limit, S, times the transition width, W, which is the right-angle distance from the edge of the roadway to the inside edge of the bridge abutment or curb line. The width of transition is measured 200 ft in advance of the bridge.

5. For one-lane bridges, the broken centerline will be as follows:

   a. Two-way roadway -- remove the centerline on each approach back to the beginning of the edge line stripe.

   b. One-way roadway -- remove the centerline on the approach end for a distance of 400 ft from the beginning of the edge line stripe, and on the exit end of the bridge remove the centerline beyond the bridge for a distance equal to the taper length (L) plus 200 ft. On two-way roadways where a one-lane bridge exists, a no-passing line is installed a minimum distance of 500 feet on each approach.

6. Use a team approach for diagnosing problem areas and recommending treatment.

7. All signing and marking done in accordance with the Manual on Uniform Traffic Control Devices (4).

8. Installation of traffic lights for assignment of right-of-way.

9. Use barrier rails to divert traffic away from parapets and wingwalls.

10. The abutment would be striped with reflective white and black stripe. A button-type delineator would also be placed at this location to accent the bridge end. In advance of the abutment, several treatments have been utilized. Where there is guardrail, delineators will be placed on this guardrail. In many cases, for several hundred feet in advance of the bridge the black and white striped panels are used to lead the driver into the proper bridge lanes. Narrow bridge signs would be utilized as an additional standard. Pavement delineators may also be used on the centerline and edge line to give additional warning to the driver and guide him across the bridge.

11. Use warning signs at preceeding cross roads.

12. Use rumble strips.

13. Use channelizing guardrail, reflectorized standard MUTCD signs and a triple 3-in. amber delineator at all four corners of the bridge. Also, use clearance markers at the corners.

14. Standard MUTCD treatment.

15. Standard MUTCD signs with placement corresponding to 85th percentile speed. Placement varies--from 250 ft for 35 mph and below to 750 ft for 56 mph and over.

16. Use no passing zones, including use of no passing signs and pennants along with standard MUTCD signs and delineators.

17. End walls marked with black and white striped panels (reflectorized).

18. Flared W-section guardrail with MUTCD hazard markers and signs.

19. Yellow and black hazard panels at end of bridge.

RECOMMENDED TREATMENTS FOR NARROW BRIDGES

Treatment No.	Treatment Description
1	Change approach grades
2	Realign roadway
3	Install smooth bridge rail
4	Install approach guardrail
5	Place edge lines
6	Remove centerline for one-way operation
7	Place pavement transition markings
8	Install narrow bridge sign
9	Install stop, yield, or signalization
10	Transition shoulders to bridges
11	Advisory speed signs
12	Re-route commercial vehicles
13	Environmental control
14	Approach bridge delineation

CRITICAL ANALYSIS:

Field studies were conducted at 25 selected two-way two-lane bridge sites in rural areas in the states of Arizona, Maine, Minnesota, Missouri, New Mexico, Texas, and Virginia to obtain measures of vehicle speed and lateral position. Roadway widths ranged from 22 ft to 46 ft. Bridge width ranged from 15 ft to 44 ft. Speed data on 200 vehicles were obtained using radar and/or a Vanguard Motion Analyzer. Vehicle placement data were collected at 1200 ft and 300 ft from the bridge end and at the bridge end, using visual observation and film techniques. Principal findings include the following:

- The distance from the left wheels of the vehicle to the centerline of highway was greater for vehicles facing oncoming traffic than for vehicles facing no traffic. (At 1200 ft, $D_{oncoming}$ = 3.8 ft, D_{none} = 2.6 ft).

- The distance from the left wheels of the vehicle to the centerline of the highway was greater at 1200 ft from the bridge than at the bridge end. (At bridge end, $D_{oncoming}$ = 2.5 ft, D_{none} = 1.4 ft).

- Vehicle speeds 1200 ft from the bridge were slightly higher than speeds at the bridge end. (At 1200 ft, $V_{oncoming} = V_{none}$ = 49 mph, at bridge end, $V_{oncoming} = V_{none}$ = 47 mph).

These findings show that a driver traveling toward the bridge unopposed maintains much more room between the right wheels of his vehicle and the bridge rail than he does between the left wheels and the centerline. If opposed, the driver maintains about as much room between the right wheels and the bridge rail as between the left wheel and the opposing vehicle. This implies that the centerline and oncoming vehicles are the primary cues for positioning his vehicle.

Corrective measures were applied to four bridges to evaluate their relative effectiveness. At one site at the Maine Facility, 3 treatments (edgelines, edgelines and non-standard warning sign, and edgelines, non-standard warning sign and guardail) were evaluated. Results showed that there was no significant change in average vehicle placement for unopposed vehicles. Studies at three Texas bridges evaluated edgelines and object markers and found no significant changes in vehicle placements of unopposed vehicles. NARROW BRIDGE warning signs, delineators, hazard paddle markers and guardrails were part of both "before" and "after" conditions.

I/4.5

It should be noted that much of the data related to the BSI concept will be considered for use in the current project. In order to use this index, data on the following is required:

1) Bridge width
2) Approach roadway width, 1200 ft from bridge
3) Approach lane width, 1200 ft from bridge
4) Approach shoulder width, 1200 ft from bridge
5) Bridge shoulder width
6) Approach sight distance
7) Approach traffic speed
8) Degree of horizontal curvature on approach
9) Length of tangent from horizontal curve to bridge
10) Approach and departing grade
11) Number of conflict points within 1200 ft
12) Traffic volume
13) Traffic mix
14) Structural evaluation of bridge

While the first nine data items listed will be used for the bridge site evaluations, it will not be possible to obtain data on the last five items. However, since each bridge site evaluated will be accurately located, the data base could be provided to others; e.g., state agencies who may be interested in obtaining the remaining data items for purposes of applying the full scale Bridge Safety Index.

J/1.0

REFERENCE: Jones, G., "Investigation of New Traffic Signs, Markings and Signals," Volume 2. Driver Questionnaire. Bolt, Beranek and Newman, Inc., Cambridge, MA, Report No. 1762, December, 1972.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge X L.W.Transit. ___ Schl. Zone ___ Speed Zone X No Pass.Zone ___ RR Crossing X Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Low clearance, slippery pavement, driver understanding.

SUMMARY/ABSTRACT:

Five sections of a questionnaire were designed to provide assessments of the meaning of traffic control devices as symbols, the implication of this meaning for action, and the preference of drivers for one control device over another. These sections were each mailed to 500 different drivers in Massachusetts (responses ranged from 59 to 75). Twenty-one separate signs, pavement markings on 2-, 3-, and 4-lane roads, and two-signal configurations were evaluated. In the areas of signs, some respondents were confused by existing signs with 5% to 10% not recognizing common warning signs. While respondents generally preferred lettered signs to unlettered signs, their strong preference was for signs that carry both symbols and letters. In the area of markings, most respondents correctly interpreted the intended meanings of the form (broken or solid, single or double) of road markings, although they dichotomized their judgments into permitted or prohibited. They interpreted colors (yellow or white) as precautionary rather than as indicators of the direction of traffic flow. In the area of signals, the use of steady yellow arrows were not understood as the cautionary equivalent of a steady yellow circular ball. 25% interpreted the steady red arrow, as a signal to stop and then turn.

J/1.1

CRITICAL ANALYSIS:

While the data are not relevant to the planning portions of the current study, some of the specific results obtained will be used as an input to the development and choice of information treatments for Tasks E and F.

J/10.0

REFERENCE: Joral, N. H. " Lateral Vehicle Placement as Affected by Shoulder Design on Rural Idaho Highways." HRB Proceedings 41, 1962, pp. 415-432.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width X Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	X LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance X Other

OTHER DESCRIPTORS: Edgelines

SUMMARY/ABSTRACT:

During 1957, 1958, and 1959, lateral placement observations were made by the Idaho Department of Highways on bituminous-paved 2- and 4-lane rural highways having different shoulder designs. Placement data were recorded for 7,777 free-moving passenger and commercial vehicles at eight locations throughout Idaho. The study was made to evaluate the influence of shoulder design on vehicle placement. Before-and-after data were recorded to measure the effect of shoulder striping and contrasting shoulders. Effects from other factors were kept to a minimum by rational selection of study locations. Lateral placement on the roadway was recorded from visual observations of the vehicle in relation to 1-foot reference markings on the pavement.

CRITICAL ANALYSIS:

Data were collected on free-moving vehicles at 8 different rural sites; 5 of these sites were two lane facilities, and the results extracted from the study in this review pertain only to the two-lane roadways. All of the sites were located on straight and level sections as far away as possible from intersections, bridges, and other lateral restrictions. The speed limit at all sites was 60 mph.

J/10.1

It was found that:

(1) In the absence of edgeline, the width of the shoulder influenced the lateral placement of the vehicles. Both passenger and commercial vehicles were closer to the centerline on sections with narrow shoulders than on sections with wide shoulders.

(2) Both passenger and commercial vehicles traveled closer to the centerline after the installation of a 2" white reflectorized edgeline. The greater shift was observed for commercial vehicles on sections with the widest shoulders. However, width of travel lanes defined by the stripe was confounded with shoulder width in this study. That is, wider lanes (17 feet) were defined when the shoulder was wide (8 feet) while narrower lanes (11.5 feet) were defined when the shoulder was narrow (3 feet).

(3) Passenger vehicles traveled with the center of the vehicle closer to the centerline than did commercial vehicles, both before and after installation of the shoulder stripes.

(4) On sections with shoulders having both surface texture and color contrast with the travel lanes, the average travel path was located closer to the centerline than on sections with no shoulder contrast; the average shift was 2 feet. This effect held for both passenger and commercial vehicles.

(5) More shoulder encroachments were observed from commercial than from passenger vehicles, and more encroachments were found on the sections with wide shoulders. The use of shoulder striping reduced the amount of encroachment. Less shoulder encroachment was observed on two lane sections with contrasting shoulders than on sections without shoulder contrast.

(6) The narrower the roadway, the greater was the tendency for drivers of passenger vehicles to travel in the same wheel tracks.

K/10.0

REFERENCE: Kelley, C. R. "The Measurement of Tracking Proficiency." Human Factors, 11, 1969, pp. 43-64.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	X LanePlacemt/ Rd Following	___ Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	X Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: Operational Measures

SUMMARY/ABSTRACT:

The problem of measuring tracking proficiency is reviewed and analyzed. The five classes of measurements discussed are:

(1) single-axis error amplitude scores;
(2) multi-axis error amplitude scores;
(3) simple frequency scores; control effort;
(4) special engineering measurement techniques;
(5) adaptive tracking measurements.

The most widely used score in psychological investigations, time on target, is shown not to be an interval measurement of tracking error amplitude and, in addition, is shown to be unreliable. Seventeen equations for the measurement of tracking skill are described. Adaptive tracking measurement techniques are shown to be more effective than are techniques employing fixed difficulty tasks.

CRITICAL ANALYSIS:

This article is a review of alternative measures of tracking proficiency, including the lateral control of an automobile. The discussion is abstract and often quantitative in orientation. While it was reviewed in relation to the potential for providing interpretative insights into driver performance measures of steering control for the current study, it appears that the data to be obtained from the proposed measurement system are not sufficiently "fine" or sufficiently controlled for application of the tracking measures identified in this document.

K/11.0

REFERENCE: Kermit, M. L. and Hein, T. C. "Effect of Rumble Strips on Traffic Control and Driver Behavior." HRB Proceedings 41, 1962, pp. 469-482.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass X Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Speed Control and Rumble Strips

SUMMARY/ABSTRACT:

Rumble strips were installed at four different locations in Contra Costa County, California. Accident rates were greatly reduced, stop sign violations were significantly reduced, and vehicle speeds and deceleration rates before a sharp curve were reduced. Before-and-after motion pictures of vehicle paths showed marked changes in driver behavior. The rumble strips consisted of a series of spaced overlays placed on the road surface using 3/4 inch stones and seal coat techniques. In three locations durability of the strips was increased by using synthetic resin formulations to hold the stones in place.

Explanations for reductions in accident rates and changes in driver behavior are based on the added visual, audible, and tactile stimuli produced by the rumble strips. The noise level in a vehicle with closed windows was raised from 92 decibels background to 102 decibels on the strips. These strong signals help alert the driver to changing road conditions. Driver reaction times are faster in response to audible and tactile stimuli than to visual stimuli. In addition, roads where drivers are preconditioned to expect high speeds and few hazards, or where driver boredom may result in visual hallucinations, are especially in need of the strong stimuli provided by the rumble strips to produce desired behavior. Economic justification for the strips is analyzed in terms of accident cost reduction. Other strip designs are shown for a variety of road conditions.

K/11.1

CRITICAL ANALYSIS:

This study presents data regarding the effect of rumble strips installed at four low-volume intersections in Contra Costa County, California. These strips consisted of a series of 25-foot-long areas of rough, textural aggregate placed on the appropriate lanes at 50- to 100-foot intervals. Motorists traversing these strips received strong audible, tactile and visual stimuli.

Site I was a stop-sign-controlled approach to a T intersection; Site II was an uncontrolled approach to a T intersection where the through movement required a right turn; Site III was a skewed approach to a stop sign controlled Y intersection; and Site IV was a four-way intersection.

The data indicated that, after 20 to 32 months at each intersection, the number of accidents was at the very least, cut in half, and accident severity was reduced; these reductions occurred during a period of time when accident rates on other county roads were increasing. In addition, a series of spot speed readings at each site taken a week before and two months after the strips were installed indicated that despite the fact that approach speeds to the rumble strips had increased from pre-to post-testing, significant reductions were obtained in average and 85th percentile speeds after the first three rumble strips had been crossed in the post-condition. Moreover, at Site II, the strips resulted in significantly better lane placement after drivers had negotiated the through-right turn. Finally, in another study cited in this article, a continuous 300 foot rumble area on the approach to a stop sign resulted in a greater percentage of drivers observing the stop sign.

The authors suggest that rumble strips could be used to warn drivers of reduced lane width on a narrow bridge by tapering the unstripped area of the road onto the bridge, and to warn drivers of unexpected horizontal curves. The authors also suggest that rumble strips could be used to differentiate the shoulder of the road from the traveled lanes.

K/11.2

A cost-benefit analysis by the authors suggests that rumble strips are a net savings at a given site even if only 1 accident per year is eliminated. The installation cost for rumble strips on both sides of a four-way intersection was estimated to be $1,000.00

K/1.0

REFERENCE: King, G. F., Abramson, P., Cohen, J. W., and Wilkinson, J. R., "Seven Experiment Designs Addressing Problems of Safety and Capacity on Two-Lane Rural Highways," Volume I: Introduction, Description of Experiments and Common Elements. US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-78-2-I. May, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This is, an introduction to the results of a research project, "Design and Development of Seven Rural Traffic Related Experiments for Future Implementation at the Maine Facility." The specific objectives of each experiment and features common to all seven are presented in this volume. In Volumes II-VIII, each experiment is individually considered. Contents of these volumes include a state-of-the-art survey, bibliography and experimental design.

CRITICAL ANALYSIS:

The primary value of the report for the current project is the listing of dependent measures recommended for various situations. These are listed on the following table.

SITUATION	DEPENDENT MEASURES				
	SPEED	PATH	ACTION	INTER-ACTION	REACTION
Narrow Bridge	X	X			X
Long Lane Closure	X		X	X	
Short Lane Closure	X		X	X	
Slow-Moving Vehicle	X		X	X	X
Horizontal Curve	X	X	X		
Steep Downgrade	X		X		
Bicycle	X	X			
No-Passing Zone			X		
Driveway	X	X			
Parked/Disabled Vehicle on Shoulder	X	X			
Combination of Driveway and PDV	X	X	X		
Intersection w/Adequate Sight Distance	X		X		
Intersection w/Inadequate Sight Distance	X		X		

These recommendations will be considered in the planning of the data collection involving subject drivers' performance.

K/3.0

REFERENCE: King, G. F., Abramson, P., Cohen, J. W., Wilkinson, M. R., "Seven Experiment Designs Addressing Problems of Safety and Capacity on Two-Lane Rural Highways," Volume IV: Experimental Design to Develop and Evaluate Remedial Aids to Warn Drivers of Slow-Moving Vehicles on a Grade, US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-78-2-IV. May, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following X CarFollowing X O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Accidents between vehicles traveling in the same direction represent a large proportion of all traffic accidents. Past studies have shown that as the speed differential between two vehicles traveling in the same direction increases, the accident rate soars. This speed differential is commonly found with a large vehicle ascending a grade being overtaken by a faster vehicle. In this volume, an experimental design was developed to evaluate a series of active and passive warning devices, including roadside and vehicle-mounted devices. A state-of-the-art survey and bibliography are included. A questionnaire, designed to appraise motorists' reactions to these devices, is appended.

CRITICAL ANALYSIS:

The Slow-Moving Vehicle Experiment was performed and the results are documented in Lanman, M. H. et al, Evaluation of Techniques for Warning of Slow Moving Vehicles Ahead, US DOT, FHWA, Report No. FHWA-RD-79-79. May, 1979.

K/4.0

REFERENCE: King, G. F., Abramson, P., Cohen, J. W., and Wilkinson, M. R., "Seven Experiment Designs Addressing Problems of Safety and Capacity on Two-Lane Rural Highways," Volume VI: Experimental Design for Comparative Evalution of Warning-Advisory and Regulatory Traffic Control Devices, US DOT, FHWA and TSC Report No. DOT-TSC-FHWA-78-2, VI, May, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
__ Tangent Horizont. X Curve Vertical __ Curve X Grade __ Other	__ Pavement __ Lane Width __ Shoulder __ OffRoadway __ Other	X Intersection __ Driveway __ Tunnel __ Bridge __ L.W.Transit. __ Schl. Zone __ Speed Zone X No Pass.Zone __ RR Crossing __ Other Cross. __ Other	__ LanePlacemt/ Rd Following __ CarFollowing __ O.T. & Pass __ Other	__ Design __ Placement X Performance __ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The overuse of regulatory type signing on highways has been found to cause motorists to ignore all signing. In this experimental design, advisory-warning signs, regulatory signs and a combination of the two types will be tested in four experiments. The first experiment will compare curve signing; the second, intersection signing; the third, no passing zone signing; and fourth, signs for steep downgrades. A state-of-the-art survey and bibliography are included.

CRITICAL ANALYSIS:

The dependent variables suggested in these experimental designs will be reviewed and used as an input to the design of the studies involving subject drivers' performance.

K/5.0

REFERENCE: King, G. F., Abramson, P., Cohen, J. W., and Wilkinson, M. R., "Seven Experiment Designs Addressing Problems of Safety and Capacity on Two-Lane Rural Highways," Volume VII: Experimental Design to Develop and Evaluate Measures for Reducing the Effects of Roadside Friction on Traffic Flow, US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-78-2, VII, May, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection X Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. X Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The objective of this experiment is to investigate the problems of roadside friction which interfere with the smooth flow of traffic that is caused by external forces. This report is designed to determine the effects of roadside friction on driver behavior and to study various countermeasures at problem locations.

CRITICAL ANALYSIS:

The dependent variables suggested in these experimental designs will be reviewed and used as an input to the design of the studies involving subject drivers' performance.

K/6.0

REFERENCE: King, G. F., Abramson, P., Cohen, J. W., and Wilkinson, M. R., "Seven Experiment Designs Addressing Problems of Safety and Capacity on Two-Lane Rural Highways," Volume VIII: Experimental Design to Develop and Evaluate Remedial Aids for Intersections with Inadequate Sight Distance, US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-78-2-VIII, May, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	X Intersection	___ LanePlacemt/ Rd Following	___ Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This experiment is planned for low-volume rural intersections on or near the Maine Facility. A number of remedial aids, both active and dynamic, will be tested. The devices are designed either to focus the motorist's attention on existing conditions or to display information about a possible conflict at the intersection.

CRITICAL ANALYSIS:

The slow-moving vehicle experiment was performed and the results are documented in Lyles, R. W., <u>An Evaluation of Signs for Sight Restricted Intersections</u>. US DOT, FHWA,. Report No. FHWA-RD-80-002, February, 1980.

KK/20.0

REFERENCE: King, G. F. and Lunenfeld, H., "Development of Information Requirements and Transmission Techniques for Highway Users," NCHRP Report 123, Highway Research Board, 1971.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance _X_Other

OTHER DESCRIPTORS: Evalaution Technique

SUMMARY/ABSTRACT:

A team of engineers and psychologists studied drivers' information needs and the means of satisfying them. Through the technique of task analysis, a body of information needs was identified, the satisfaction of which enables drivers to perform the driving task safely, conveniently, efficiently, and comfortably. Principal factors were defined that organize the needs into functional groups, delineate the interactions between them, and identify the criteria for selecting and transmitting needs to be satisfied.

Analysis of the driving task disclosed that the operations that a driver performs can be characterized in terms of a hierarchy. The basic tasks of tracking and speed control (called microperformance) are at one end of the hierarchy, driver responses to road and traffic situations are in the middle; and direction finding and trip planning (called macroperformance) are at the other end. Driver information needs were arranged in aaccordance with this hierarchy. A demanding priority (primacy) exists in satisfying information needs, with micro needs having priority over situational and macro needs. Satisfying this primacy of information needs is basic to the design of a highway information system.

KK/20.1

Another key factor in the performance of the driving task is expectancy. When a trip is planned, the driver forms expectations of the conditions to be encountered in transit. Expectations are also formed while driving, regarding roads, signs, services, etc. These expectations operate in such a manner as to provide the driver with a basis for planning his trip, and to provide him with information about what directional information he should expect in transit, when to expect it, and what it should look like.

On the basis of these principles, as applied to actual sections of Interstate and rural arterial highways, a procedure was developed to permit the systematic application of pertinent human factors principles to the review of information system designs. The procedure was formalized in "Notes for a Manual on Information System Review Procedures" (Appendix H). This manual, in addition to containing an iterative formal procedure that can be used for the review of proposed signing plans, contains a section in which human factors principles that are useful to the traffic engineer are abstracted and defined.

CRITICAL ANALYSIS:

This is one of the seminal efforts in the area of driver information needs. While too broad to be effectively abstracted here, the document served as one of the primary source documents for the current project. The commentary driving procedure used to obtain data is proposed as one of the data collection methods in the current study. Also, portions of the task analysis data will be used as input to the task analysis to be conducted for various rural two-lane situations. Finally, many of the concepts from this study were further developed and formalized as the FHWA "Positive Guidance Procedure"; a procedure which forms the general underpinnings of the approach to be used in the current study.

K/12.0

REFERENCE: King, L. Ellis; Plummer, Ralph W. "Lateral Vehicle Placement and Steering Wheel Reversals on a Simulated Bridge of Variable Width." Highway Research Record, No. 432, 1973, pp. 61-68.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width X Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel X Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	X LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Many states are engaged in large-scale programs of highway construction and improvement, which include construction of new bridges as well as widening of older ones. At the present time there are no proven guidelines on the optimum shoulder width for bridges. The research reported here utilized a Greenshields Drivometer and an 8-mm time-lapse movie camera to record steering reversals and lateral placement in the vicinity of a simulated bridge. Eight male and two female subjects were tested for eight shoulder width conditions. Each subject drove the instrumented test vehicle across the simulated 50-ft bridge for a total of 30 runs for each of the eight test conditions. Statistical and graphical analyses of the data showed considerable variation among the individual subjects. However, certain trends were shown for all subjects. Steering reversals, both minor and major, were relatively constant for shoulder widths greater than 4ft. The distance of vehicle from centerline of roadway also reached a maximum for a 4- to 6-ft shoulder width. The subjects tended to drive closer to the centerline for shoulder widths less than or greater than approximately 4 to 6 ft. These results indicate the need for a minimum shoulder width of 4 to 6 feet if traffic operations are not to be influenced.

K/12.1

CRITICAL ANALYSIS:

In addition to providing some relevant data on the effects of bridge-related geometrics on driver performance, this study indicates that steering wheel reversals may be a performance measure which is sensitive to narrower shoulder widths on bridges. While this measure would not be generally useful for the purposes of the current study, it could be of use in evaluating a treatment which involved the creation of a perceptual effect.

One problem with generalizing the actual performance effects observed is that the test subjects were instructed not to exceed 30 mph. Except for very low design rural roads or for bridges for which the approach involves severe curvature, most of the two lane bridges encountered on the two-lane system would be driven at a much higher speed.

K/7.0

REFERENCE: Koziol, J. S., "Maine Facility Research Summary," Results 1973-1976. US DOT, FHWA, Report No. FHWA-RD-77-54, May, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent	___Pavement	___Intersection	___LanePlacemt/ Rd Following	___Design
___Horizont. Curve	___Lane Width	___Driveway	___CarFollowing	___Placement
___Vertical Curve	___Shoulder	___Tunnel	___O.T. & Pass	X Performance
___Grade	___OffRoadway	X Bridge	___Other	___Other
___Other	___Other	___L.W.Transit.		
		X Schl. Zone		
		___Speed Zone		
		___No Pass.Zone		
		___RR Crossing		
		___Other Cross.		
		___Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

An overview of the Maine facility--a two-lane rural highway test site--is presented, and past experimentation conducted at the facility is summarized. Experiments briefly described include Speed Control in Rural School Zones, Evaluation of Speed Control Signs for Small Rural Towns, Narrow Bridge Warning Devices, Flashing Traffic Control Devices at Intersections, and Passive Signing at Railroad Crossings. /Author/

CRITICAL ANALYSIS:

These experiments have been annotated elsewhere.

- Rosenbaum, M. J., Young, P., Byníngton, S. R., and Basham, W., "Speed Control in Rural School Zone," TRR 541, 1975.
- Ivey, D. L., et al, Safety at Narrow Bridge Sites, NCHRP Report 203, 1979.
- Koziol, J. S. and Mengert, P. H., Evaluation of Speed and Control Signs for Small Rural Towns, US DOT, FHWA, Report No. DOT-TSC-FHWA-76-3, May, 1977.

- Goldblatt, R. B., "Effect of Flashing Beacons on Intersection Performance," TRR 644, 1977.

- Koziol, J. S. and Mengert, P. H., Railroad Grade Crossing Passive Signing Study. Interim Report. US DOT, FHWA, Report No. DOT-TSC-FHWA-76-1, January, 1976.

K/8.0

REFERENCE: Koziol, J. S., Fulchino, A. R., Mengert, P. H., and Stewart, G., "Effectiveness of Speed Control Signs in Rural School Zones and Small Communities," US DOT, FHWA, Report No. FHWA-RD-79-20, July, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. _X_ Schl. Zone _X_ Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_ Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Results are described of experiments conducted in Mississippi, California, and Oregon testing the effectiveness of speed control signs in rural school zones and small communities on high-speed, two-lane highways. Signs tested included existing signing, a reduced speed ahead sign, speed limit and reduced speed ahead signs coupled with hazard identification beacons, and a speed violation sign activated when a driver exceeded the speed limit in effect. Also, roadside interviews were conducted at the sites and a questionnaire booklet was administered to groups to assist in determining the ability of each of the signs to increase safety and improve driver awareness of potential hazards. The questionnaire booklet provided information on public reaction and understanding of the signs. Results indicated that the combination of signs and hazard identification beacons and the speed violation sign provided the most substantial improvement in reducing speeds and increasing awareness of roadside conditions for both small communities and school zones. A wide variability in response to the new signs persisted from site to site. The improvement ranged from 2 to 10 mph. The combination of signs was not always more effective compared to the individual signs with hazard identification beacons. The speed violation sign, when added to the signs with hazard identification beacons, resulted in no additional improvement at some sites. Signs without hazard identification beacons were inadequate for informing drivers of existing speed limits. Driver opinion indicated that, in order to obtain a high degree

of safety in rural school zones and small communities, effective speed control signs must be used in addition to the establishment of reasonable speed limits and strict enforcement.

CRITICAL ANALYSIS:

School Zones Study: Seven sign configurations were tested (notated as Figure 2-8 on attached sheet). A total of seven sites (3 in Oregon, 2 in Mississippi, 2 in California) were evaluated using electronic speed detection sensors. These sites had ADT's of 2,000-3,000 and approach speeds between 35 and 55 mph. Four measures of effectiveness, that may be applicable to the current study, were employed: average speed profile, mean speed, 85th percentile speed, and percent compliance.

Principal findings included the following:

- In terms of average speed profiles, configurations (see attached sheet - Figure 2-8) 6 showed a 2-7mph improvement respectively over the base configuration at all sites tested. The next most effective configuration was 3 which showed a 1-5 mph improvement at 2 of 3 sites tested and a slightly less improvement at the third site.

- In terms of mean speed, cpmfogiratopms 5 and 6 showed a 2-5 mph reduction of mean speed in the school zone over the base configuration.

- 85th percentile speed in the school zone and percent compliance provided little additional information over the average speed profile and mean speed measures.

- Drivers tend to incorrectly interpret the REDUCED SPEED AHEAD sign as a sign which identifies or establishes the beginning of a speed zone.

- School advance signs are not understood as well as school crosswalk or pedestrian crosswalk signs. The use of the word "SCHOOL" on the school advance sign is related to a greater awareness and response.

- Drivers view the school speed limit sign assembly with hazard identification beacons as the most effective for causing them to become cautious or to slow down.

The following conclusions are potentially useful for the current project:

1) Improvements in school zone speed control signs may result from more use of hazard identification beacons to draw attention to signs and to convey the message that the school speed limit is in effect at a particular time.

2) Improvements in driver recognition and response to reduced speed ahead may result from use of panels with words such as "SCHOOL ZONE AHEAD." Drivers seem to need sign features which help them distinguish between reduce speed ahead signs and speed limit signs.

3) Improved uses of school advance signs can result from use of panels with the word "SCHOOL" or the words "SCHOOL ZONE" to help clarify the intended use of these signs.

4) Uses of panels with the words "WHEN CHILDREN ARE PRESENT" are not consistent with individual beliefs about when school speed limits should be in effect.

Speed Zones Study: Four sign configurations (notated as Figure 3-3 on attached sheet) were tested. Two sites in Mississippi were evaluated using electronic speed detection sensors. These sites had ADT's between 2,000 and 3,000 and approach speeds of 55 mph. The four MOE's employed in the school experiment were used.

K/8.3

Principal findings included the following:

- In terms of average speed profiles, configuration 2 (see Figure 3-3 on attached sheet) resulted in significantly lower speeds by 3-7 mph compared to the base configuration at all 3 sites tested. Addition of the speed violation sign to configuration 2 did not result in any additional significant speed reductions. The Reduced Speed Ahead sign, when added to the base configuration did not seem to reduce speeds, especially in the regulated zone.

- In terms of mean speed, configuration 2 lowered the mean speed by 3-8 mph in the speed zone compared to the base configuration. The Speed Violation sign (configuration 3) when added to configuration 2 resulted in a statistically significant improvement of 1 mph.

- The 85th percentile speed in the speed zone and the percent compliance measures provided little additional information over the average speed profile and mean speed measures.

- Drivers have a tendency to view the reduced speed ahead sign as a speed limit sign, although actual speed profile data indicate that the drivers continue to reduce their speeds beyond the reduced speed ahead sign.

- Most drivers seem to understand hazard identification beacons on signs as a message of a requirement for an immediate speed reduction; however, a substantial number of drivers (37%) believe that a gradual speed reduction is adequate.

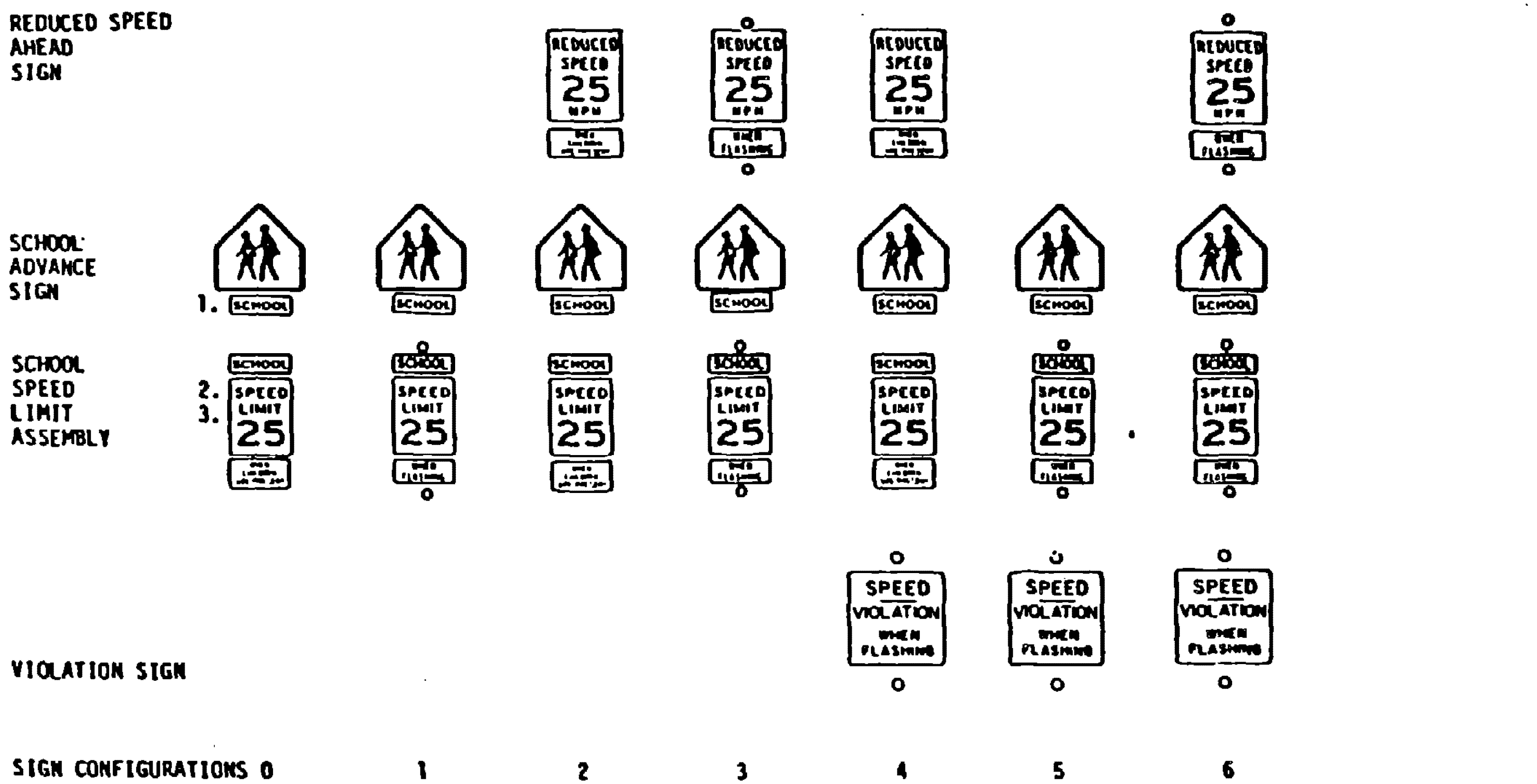
- Driver awareness of roadside signs with hazard identification beacons was greater than awareness of signs without hazard identification beacons. The highest level of awareness occurred for the Speed Violation sign.

K/8.4

The conclusions useful for the current project are:

1) Reduced speed ahead signs with hazard identification beacons have the srongest potential for obtaining speed reductions at the beginning of a small community speed zone.

2) speed limit signs with hazard identification beacons have good potential for obtaining speed reductions and to remind drivers to maintain a safe speed while driving through a small community.



1. The legend SCHOOL attached to the school advance sign applies only to the California test sites.
2. The speed limits vary from site to site. They are as follows: Potter, Lakeside, and Anguilla, 25 mph; Branson, 45 mph; Brown, Ladd Acres, and Barnes, 20 mph.
3. At the Oregon test sites, the word "limit" does not appear on the speed limit sign.

FIGURE 2-8. SCHOOL SIGN CONFIGURATIONS

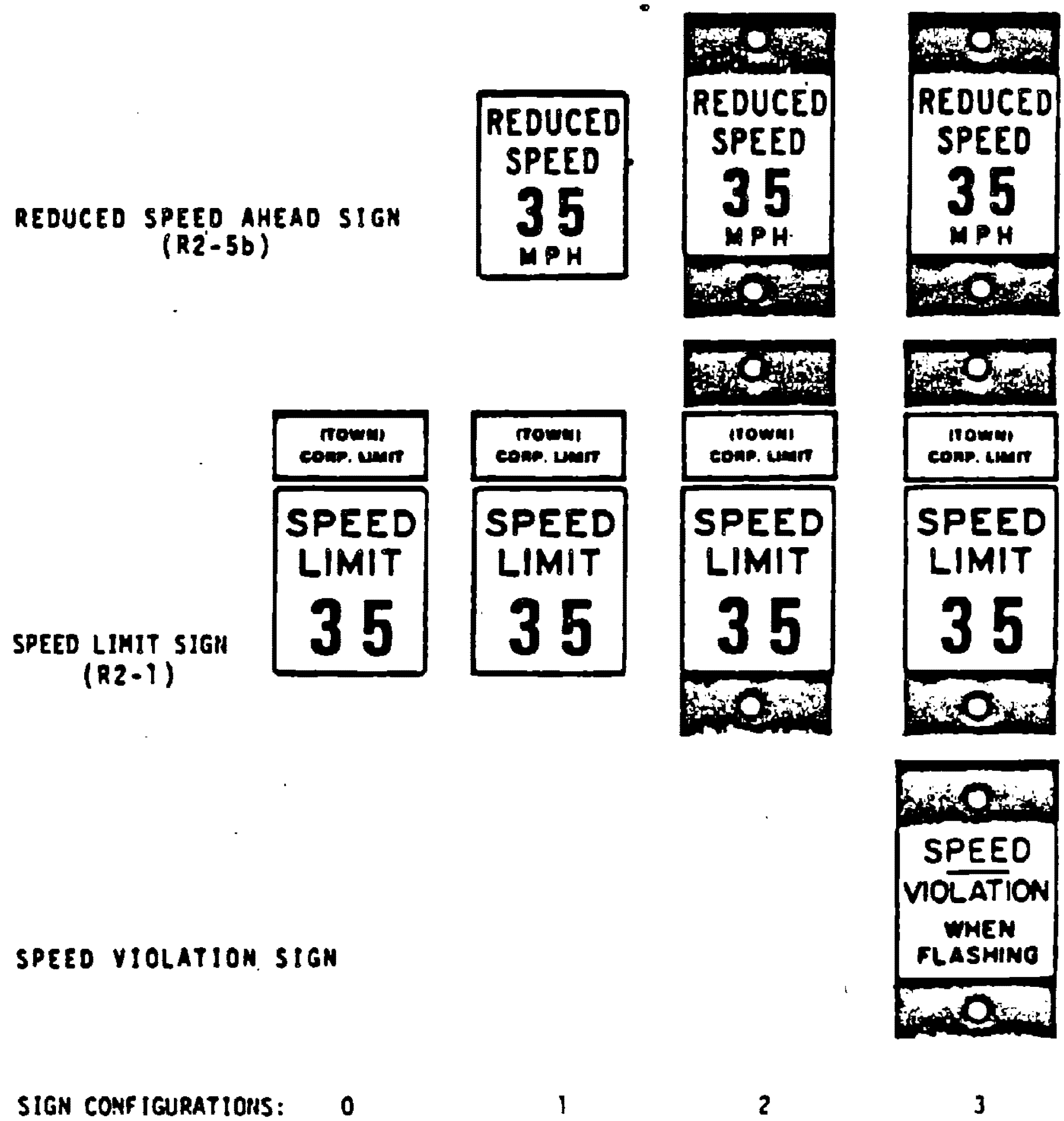


FIGURE 3-3. SMALL COMMUNITY EXPERIMENT: SIGN CONFIGURATIONS

K/9.0

REFERENCE: Koziol, J. S., and Mengert, P. H., "Evaluation of Dynamic Sign Systems for Narrow Bridges," US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-78-3, September, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel X Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes the results of a before-and-after study to evaluate the effectiveness of dynamic sign systems in alerting motorists to the presence of narrow bridges on two lane rural highways. Vehicle speed and lateral placement data were gathered for each of the dynamic sign systems tested as well as for the base (before) passive system as drivers approached and crossed the narrow bridge. These data were used as the primary measures of effectiveness for determining the ability of each of the sign systems to increase safety and improve driver awareness of potential hazards. A roadside survey was independently conducted by the State of Maine to determine the public reaction to the dynamic sign systems. The results of the survey were made available to the authors and are discussed in this report.

Four sign systems were examined under both day and night conditions. These included flashing beacons, strobe lights, and two neon message signs. Two additional sign systems involving bridge lights were examined at night only. The sign systems were dynamic in the sense that they were activated by traffic approaching the bridge. The experiment was conducted at the Federal Highway Administration Maine Facility located on US Route 2.

Results showed no substantial and consistent differences between the existing and dynamic sign systems in terms of the speed and lateral

placement measures. It may have been that these measures were not sensitive to or good indicators of the possible change in driver behavior to the new signs. The roadside survey provided additional driver awareness measures for determining the safety benefits of the new sign systems but also did not reveal any important improvements.

CRITICAL ANALYSIS:

Given that this study was apparently well designed and sample sizes were adequate, and given that the experimental sign systems were extremely conspicuous, it would appear that signs for narrow bridges with no sight distance restriction have little effect on driver behavior and cannot be evaluated via conventional measures of effectiveness.

K/20.0

REFERENCE: Koziol, J. S. and Mengert, P. H., "Evaluation of Speed Control Signs for Small Rural Towns," US DOT, FHWA and TSC, Report No. DOT-TSC-FHWA-76-3, May, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone _X_Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes the results of a comprehensive experiment dealing with speed control and driver behavior when approaching and driving through speed zones on a high speed, rural, two-lane highways. The basic objective of the experiment was to test the range of practical traffic control devices which alert drivers to the need for reducing speed when approaching concentrated areas of population and invoke voluntary compliance with the speed regulatory devices in a manner promoting increased safety in vehicle operation. Twelve different configurations of speed limit signs and warning devices were evaluated. All experiments were conducted at the Federal Highway Administration Maine Facility in the Town of Palmyra located along US Route 2. The speed regulation in effect for all sign configurations was 35 mph (56 km/h).

Traffic activated waring signs (i.e., signs with flashing beacons activated by vehicles violating the speed regulation) were the most effective for both day and night. During the day, flashing signs (i.e., signs with continuously flashing beacons) appeared to be second in effectiveness. At night, pavement marking and rumble strips appeared to be second in effectiveness to the traffic activated configuraiton and more effective than continuously flashing beacons.

K/20.1

CRITICAL ANALYSIS:

The 12 different sign/marking configurations evaluated over 9 time periods (2 weeks each) for each direction of travel, are shown on an attached sheet, notated as Figure 3-2.

Speed profiles were obtained from the Maine Facility's instrumentation. The three primary measures of effectiveness were speed reduction in the vicinity of the devices, average speed of vehicles not in compliance, and percent of vehicles in compliance with the 35 mph speed limit.

The details of the effects of the various signing configuraitons are as follows:

1) Dynamic warning signs achieved a maximum of 25 to 30 percent compliance with the 35 mph speed limit; reduced speeds in the vicinity of the traffic control devices by 3- to 4-mph and reduced the average speed of vehicles not in compliance by 2- to 3-mph over the passive signs tested.

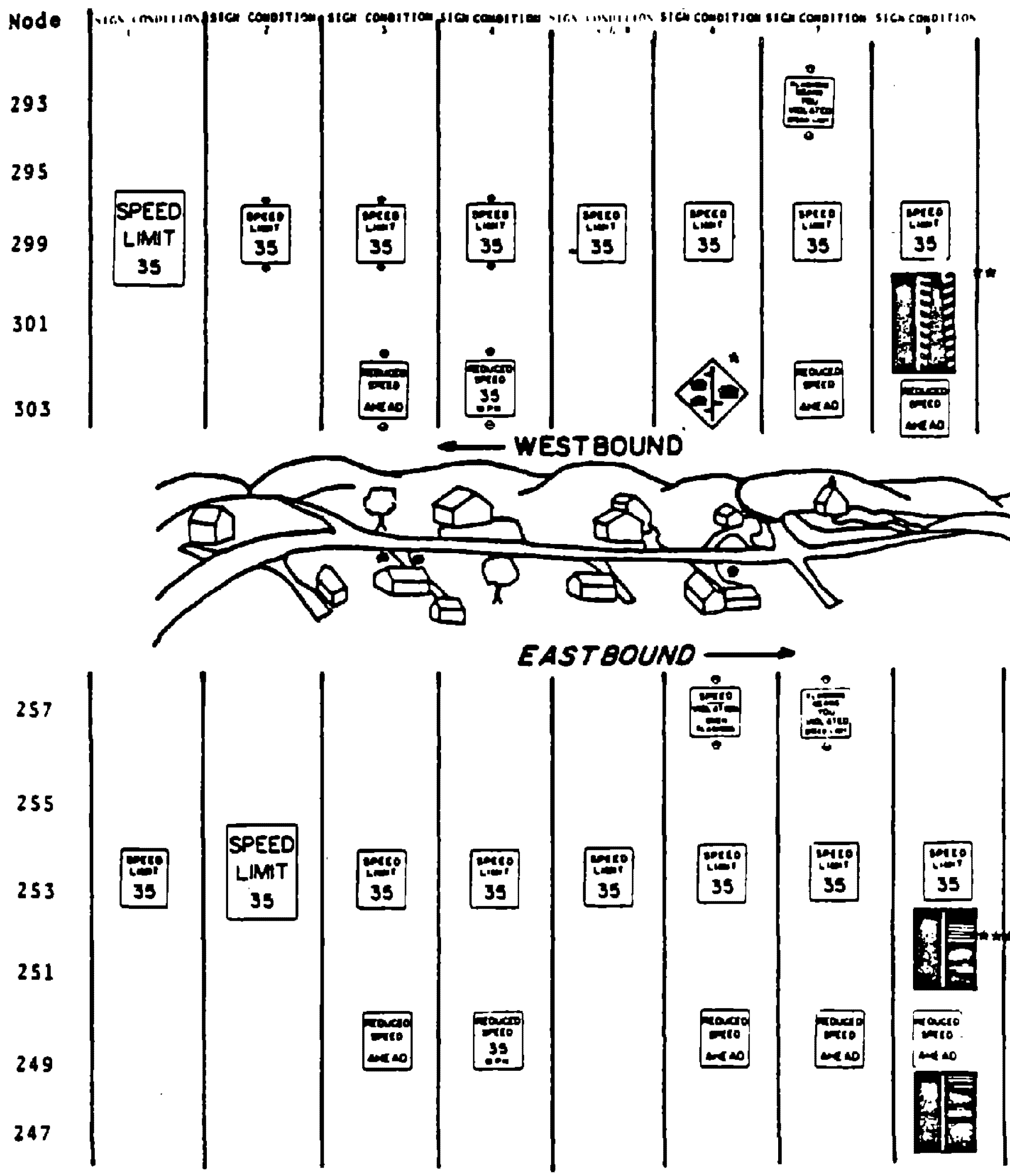
2) Warning signs with flashing beacons reduced speeds in the vicinity of the traffic control devices by only 1 mph and reduced the average speed of vehicles not in compliance by about 1 mph over the passive signs tested during the day.

3) Pavement markings and rumble strips did not reduce speeds in the vicinity but did reduce the average speed of the vehicles not in compliance by 1 to 2 mph over the passive signs tested during the night.

IMPLICATIONS:

Numerous measures of effectiveness were examined in this study including mean speed, 85th percentile speed and speed variance of vehicles passing through, average compliance to the 35 mph speed limit (averaged over all nodes in the reduced speed zone), speed reduction between entrance node and three nodes within the speed zone, and speed distributions at various nodes. Each measure showed basically the same general results. Consequently, the authors contend that selection of the most appropriate measures for discriminating speed signing effectiveness may not be a critical matter.

Given the relatively small speed reductions observed and given the high potential of a "novelty" effect for some of the configurations, the cost effectiveness of the traffic actuated system and even the flashing beacon is questionable.



* Symbol Sign
** Road Markings
*** Rumble Strips

FIGURE 3-2. SIGN CONFIGURATION SEQUENCE

K/21.0

REFERENCE: Koziol, J. S. and Mengert, P.H., "Railroad Grade Crossing Passive Signing Study," Interim Report, US DOT, FHWA, Report No. DOT-TSC-FHWA-76-1, Janaury, 1977. (Results also reported in Traffic Engineering (November, 1977) by Coleman, J., Koziol, J. S. and Mengert, P. H. under the same title).

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	_X_Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes the results of Phase I of a study to determine the effectiveness of new passive signing configurations in warning drivers of the potential hazards at railroad crossings. The first phase was begun in March, 1975 and evaluated seven sign configurations (notated as Figure 1 on an attached page) at five test sites in Ohio and one site in Maine. The purpose of Phase I was to determine, at a few crossings, whether any of the new signs showed promise of being more effective than the existing sign configuration and to evaluate a variety of experimental variables. The major finding of Phase I was that the new signs in Ohio averaged an increment of 19 percent more head movements (from 35.5 percent to 54.5 percent) than the base condition. However, there were no signifcant differences between the sign configurations, including the base configuration, in terms of the speed profiles. After-data was collected 3 to 6 weeks after the new signs were installed.

CRITICAL ANALYSIS:

Phase II results are reported in Koziol, J. S. and Mengert, P. H., Railroad Grade Crossing Passive Signing Study. Final Report. US DOT, FHWA.

K/21.1

Report No. FHWA-RD-78-34, August, 1978. See critique on this report for the implications of this study on driver information systems.

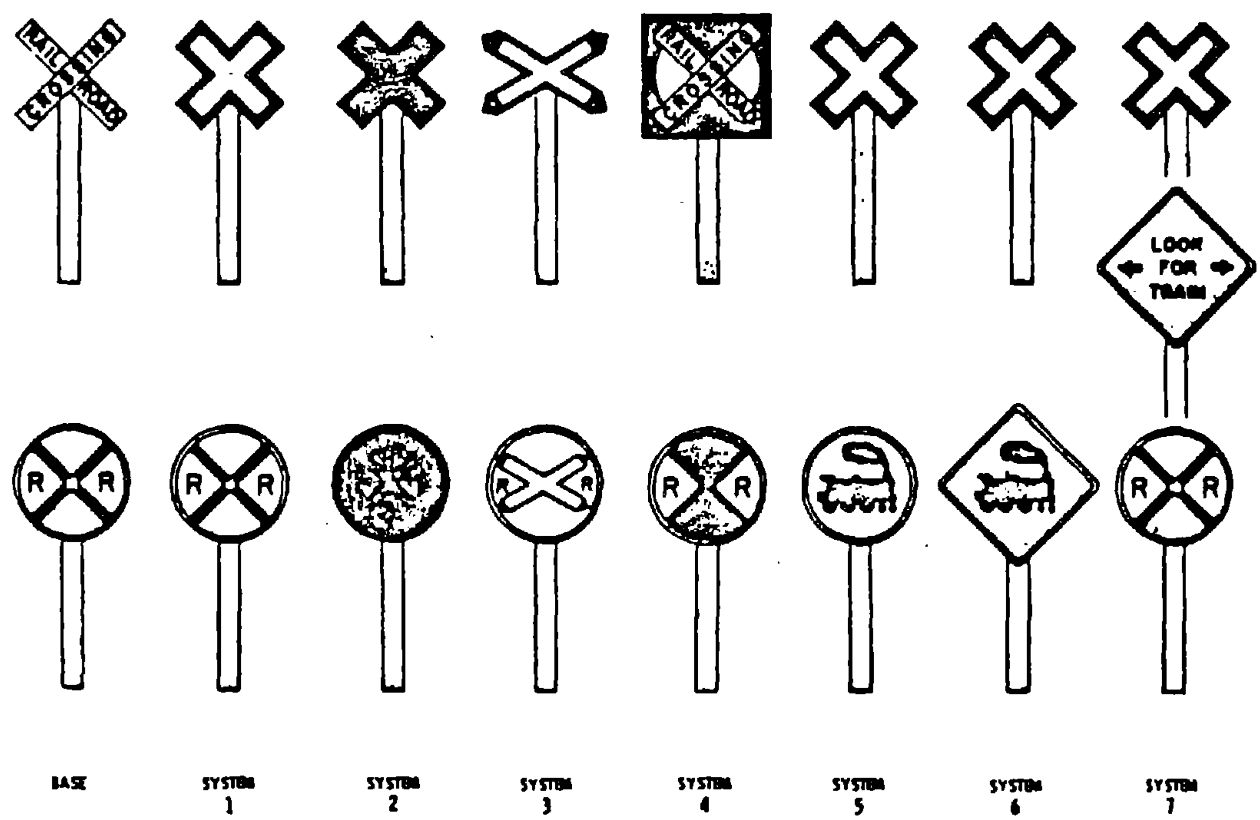


FIGURE 1. PHASE I SIGN CONFIGURATIONS

K/22.0

REFERENCE: Koziol, J. S. and Mengert, P. H., "Railroad Grade Crossing Passive Signing Study," Final Report, US DOT, FHWA, Report No. FHWA-RD-78-34, August, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone _X_ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	_X_ Design ___ Placement _X_ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes the results of a study to determine the effectiveness of new passive signing configurations in warning drivers of the potential hazards at railroad grade crossings. Experiments were conducted in two phases over a two-year period. The first phase was begun in March 1975 and evaluated seven sign configurations at five test sites in Ohio and one site in Maine. The purpose of Phase I was to determine at a few crossings whether any of the new signs showed promise of being more effective than the existing sign configuration and to evaluate a variety of experimental variables. The results of Phase I were previously reported and indicated improved effectiveness for the new signs tested. The purpose of Phase II was to test and verify, at a national level (18 sites in 14 states) the most effective signs as determined from Phase I and to concentrate on and refine, if necessary, the most important variables. In each phase, before-and-after data were collected at each site so that relative improvements provided by the new signs could be determined.

The results of Phase II confirmed the findings of Phase I in that drivers showed more awareness (that is, an increased percentage of head-movements or looking for trains) with the new signs at the crossings tested.

K/22.1

CRITICAL ANALYSIS:

The four sign conditions evaluated are shown on an attached sheet (notated as Figure 2). The 18 sites generally satisfied the following criteria: 1) approach speed $\geq$ 45 mph, 2) ADT between 1000 and 4000, 3) average 2-4 trains per day, 4) sight distance restrictions in at least one quadrant. Tests were conducted for one direction only and under good weather conditions. Subject vehicles were vehicles that were: 1) not required to stop, 2) following other vehicles or arriving within five minutes of a train crossing. Other independnt variables included time of day (day, night), observer location (van, car), and individual observer (A, B). Dependent variables were head movement at crossing, speed 800 ft from crossing and speed 200 ft from crossing. Advance warning signs were located 300-600 ft on both sides of the crossing. No data were collected over weekends, holidays or during bad weather. Testing during the day was equally distributed between morning and afternoon.

It should be noted that analyses showed that the inter-rater reliability of the head movement data was high.

Sign configuration 1 showed significant improvement over the base sign configuration averaging an increment of 6.7 percent more head movement (from 34.7 percent to 41.4 percent), with the the experimental advance warning sign accounting for about half of this improvement. Sign configuration 1 also showed an increment of 3.9 percent more head movement (from 37.5 percent to 41.4 percent) than sign configurations 2 and 3.

Also a higher percentage of head movement for all sign configurations occurred at one site which employed a "20 MPH" speed advisory plaque on the advance warning sign. The effect of this sign was not measured, although the authors conclude that this sign influenced driver behavior at that site.

None of the experimental signs showed a significant change in speed profiles compard to the base sign under day or night conditions.

Data were collected at a rate of 1 day per sign (2 days per sign on lower volumes). Each sign configuration was installed on the morning of testing. With this in mind, these Phase II differences may be attributed to the novel designs of the signs. Effects were evaluated for six sites after 6 weeks during Phase I. Longer term effects were not evaluated. Therefore, although these signs show "promise" as components for crossing information systems, the following cautions are offered:

a) the longer-term effects may not justify the signs, and

b) if implemented only at hazardous passive crossing as the authors recommend, then this practice might produce driver contempt for the standard advance RR crossing warning signs at other crossings.

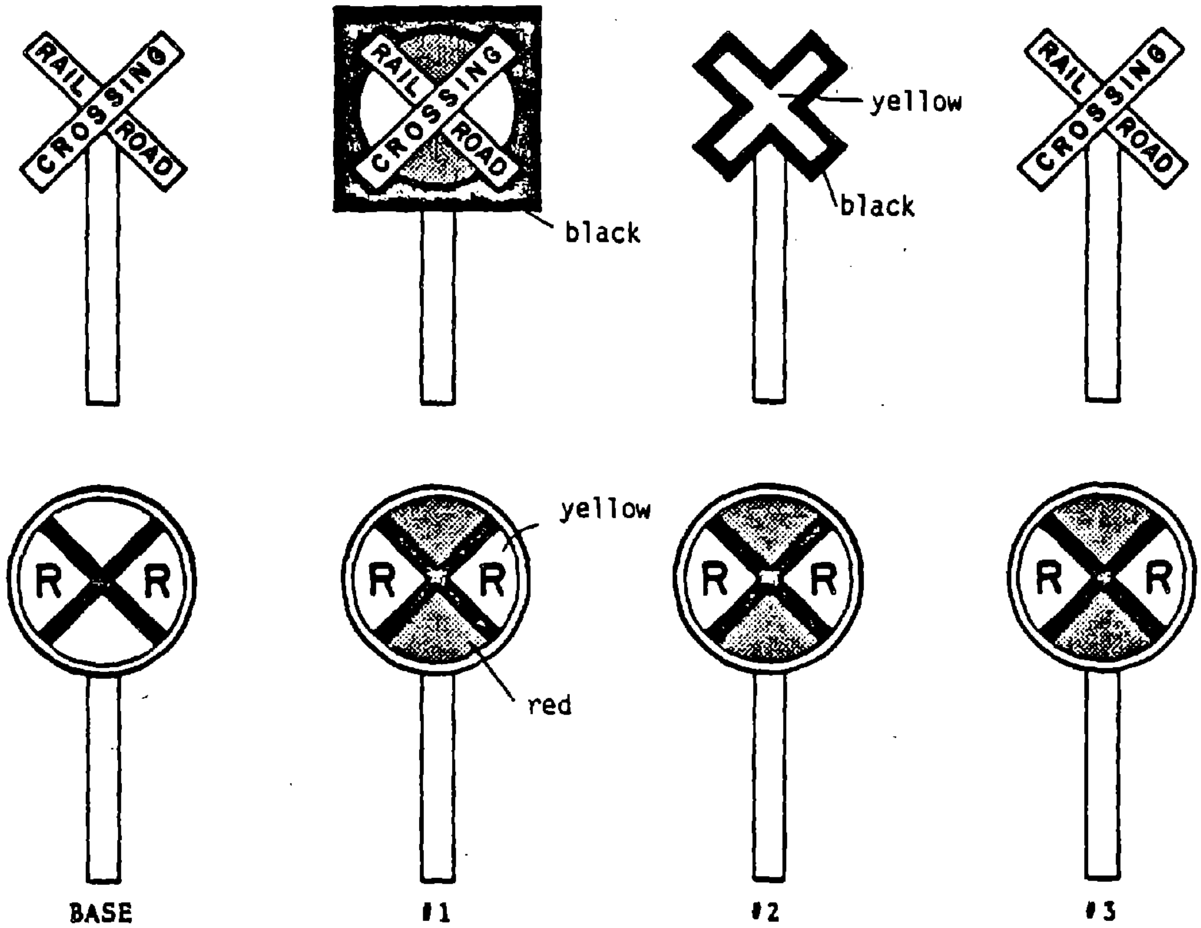


FIGURE 2. PHASE II SIGN CONFIGURATIONS

L/1.0

REFERENCE: Lanman, M. H., "The Maine Facility: Capabilities For Rural Road Research," ITE Journal, Volume 48, No. 12 (December, 1978).

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The Maine Facility consists of a 15-mile, instrumented section of rural two-lane road (US 2) in Central Maine, various fixed and mobile traffic data collection systems and a control center. The instrumentation is primarily geared toward automatically collecting and processing data on performance and behavior of non-cooperating subject drivers traveling the rural roads of Maine. The facilities fixed-based system consists of 409 "nodes" spaced every 200 ft for 15 miles along US 2. Each node includes four loops, buried in the pavement, and connected to an electronics enclosure by the roadside. A set of electronics, called a Vehicle Detector Station (VDS) detects vehicles over each loop, time multiplexes that information, and sends it via underground cable to the control center. There are only 37 VDS sets. They are semi-portable and are installed in areas selected for a given experiment. Using all available hardware, up to 3 miles of road can be instrumented at any one time.

Five sequential levels of processing have been developed, each with standard input and output formats.

A general van-based data collection system is also available. The system includes: up to 32 roadside sensors, eight operator-controlled

manual data inputs, control switches which interact with road data for active sign control or manual data correlation and a self-contained data collection and storage.

A standard Jeep passenger wagon, instrumented with a digital cassette interface and recorder and an observer data entry and control panel with same 15 switches, is also available. The Jeep can be instrumented with an antenna and receives for signals transmitted to the vehicle through loops in the road and used in conjunction with the fixed-base system.

CRITICAL ANALYSIS:

This document was reviewed as general background, in that the Maine Facility has the potential for serving as a test bed for evaluation of information systems for certain two-lane rural situations.

L/2.0

REFERENCE: Lanman, M. H., Lum, H. S., and Lyles, R. S., "Evaluation of Techniques for Warning of Slow-Moving Vehicles Ahead," US DOT, FHWA Report No. FHWA-RD-79-79, May, 1979.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing X O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: Slow-moving vehicle.

SUMMARY/ABSTRACT:

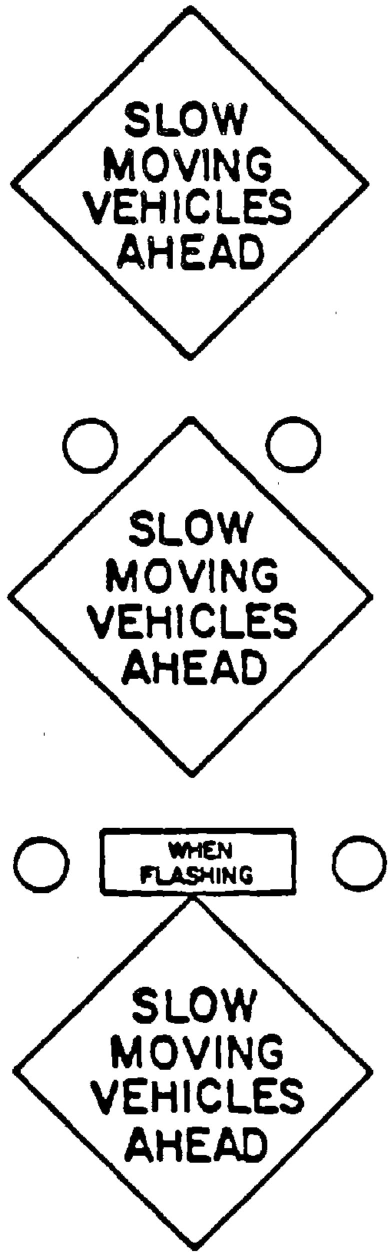
This report reviews an experiment undertaken to examine the relative effectiveness of roadside signs and vehicle markings for warning motorists of the presence of a slow moving vehicle on the road ahead in a rural two-lane situation. In the experiment a staged slow moving vehicle was introduced into the traffic stream, and data were taken on the reactions of motorists who overtook it. Samples of motorists were exposed to different combinations of roadside signs, vehicle markings and types of slow moving vehicles. The principal finding was that the use of standard four way flashers is an effective device for reducing the hazardousness of the overtaking situation relative to reaction distance, speed reduction and vehicle following characteristics. While the effects of the roadside signs were positive in the vicinity of the sign placement (out of sight of the slow vehicle), there were no lasting effects relative to the actual overtaking maneuver. The experiment was undertaken at the Federal Highway Administration's Maine Facility with cooperation from the Maine Department of Transportation and the University of Maine at Orono.

CRITICAL ANALYSIS:

A slow-moving vehicle was inserted into the normal traffic stream on a 5000 ft length section which varied in grade between three percent and seven percent. The test vehicle traveled at a fixed speed. A subject vehicle was identified if: 1) there were no other vehicles between the subject vehicle and the position where the staged vehicle was ready to enter, and 2) the subject vehicle was moving at least 15 mph faster than the staged vehicle. A large two-axle truck was used as one of the staged vehicle types and was operated at two different speeds (20 and 30 mph). The effects of using flashers were evaluated for this case. The other staged vehicle type was a cab-enclosed, utility trailer which was driven at 15 mph. The sign conditions deployed are shown on an attached page (notated as Figure 2). Data were only collected under good visibility and dry pavement conditions. Analysis distinguished between vehicles that passed and vehicles that did not pass the staged vehicle.

It was found that roadside signs were relatively ineffective as warning signs in this situation. Although there was a measureable positive effect in the vicinity of the signs themselves, the effect was not lasting. Motorists who were presented with the signs that caused the immediate reaction did not generally exhibit any significantly different behavior at the point of overtaking than those that were not presented with the sign. Where the roadside signs were effective, those that conveyed more emphatic information were generally more effective. However, the "positive" effects observed were primarily for those drivers who did not subsequently pass the slow-moving vehicle. Drivers that tended to pass the 15 mph tractor also tended to enter the study area at a higher speed, maintain a higher speed through the area, and be less responsive to any of the warning devices.

It is difficult to say whether the signs were ineffective or whether the evaluative measures were simply insensitive to the sign effects. The signs used did not indicate that drivers should in fact reduce speed, but, rather, indicated that drivers should be aware of a potential event (or an actual event in the case of sign configuration 3). Since driver awareness per se cannot be measured, it may be that some measure more closely related to a type of slow moving-vehicle-conflict would have produced more definitive results. The fact that drivers reacted, i.e., slowed, in the vicinity of the signs and did not remain at the reduced speed is not surprising. That is, the drivers were warned about a hazard and slowed until the hazard could be directly viewed, at which time they modified their driving in reaction to the slow-moving vehicle. Since no mention was made of conflicts with the slow-moving vehicle, it can be assumed that the reaction to the hazard per se was appropriate.



Sign Condition 0: Base condition; no sign present

Sign Condition 1: Basic warning sign 6" black letters on 48" x 48" yellow background

Sign Condition 2: Above basic sign as above augmented with continuously flashing 8" beacons

Sign Condition 3: Basic sign as above augmented with 12" x 36" plaque and vehicle activated 8" beacons

FIGURE 2 ROADSIDE SIGN CONDITIONS

L/10.0

REFERENCE: Larsen, M. B., "Liability Implications for Low Volume Rural Highways," ASCE Journal of Transportation Engineering, Vol. 106, No. 6, 1980, pp. 803-814.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Government Liability for Road Conditions.

SUMMARY/ABSTRACT:

Sovereign immunity of local governments has been diminishing. Tort liability plagues local governments and imposes heavy financial burdens. Actions may be taken by the highway engineer to limit the potential of and prepare defense for liability lawsuits. Low volume roads are unique. Criteria desgined for low volume rural highways should be used in establishing programs and defenses for liability. The use of "design standards" may place governments in a less defensible position. Design criteria or design guides permit more flexibiity and the use of professional judgement which is more defensible. Actions such as setting priorities, establishing and documenting design guides, using good signing, creating and following a road condition inspection system, a public awareness program, and keeping a record of actions and happenings provides the engineer with a basis for protection.

CRITICAL ANALYSIS:

This paper was included primarily as general background information, with no direct application to the current study. However the author does suggest, by way of example, several informational treatments that do not involve signing. Where informational problems are dealt with, there is an definite emphasis on intersection warnings and control. This emphasis is apparently reflective of the type of situation which is producing liability problems.

L/3.0

REFERENCE: Leisch, J. E., "Communicative Aspects in High Design," TRR 631, 1977, pp. 15-23.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The operation of a vehicle is a complex process for the driver. To ease the task and to improve operations and safety, it is necessary to incorporate communicative aspects in highway design, i.e., to make clear to the driver the messages conveyed by the facility. Numerous geometric and control features that have been formulated in response to human-factors inputs are presented in this paper. Particular attention is directed to various features of design. Among these are alignment, sight distance and cross-sectional features, and operational uniformity, route continuity, and marking and signing. The suggested guidelines permit immediate application and are a starting point for improving design criteria on a larger scale. They could significantly improve the operational efficiency and safety on both existing and new facilities, but the designer's input--his or her philosophy and skill--must play an important role in meeting the objective of achieving optimum design.

CRITICAL ANALYSIS:

This paper presents design measures that respond to positive guidance and provide communicative features. Although much of the paper is devoted to multilane freeways, some pertinent design guidelines are discussed:

- There should be no more than two horizontal or three vertical changes in the course of the longitudinal line.

- Spiral lengths should be increased to provide comfort, safety and appearance. (Note: He lists recommended minimums in a table in the paper).

- Variable landscape treatments and changing the form of the roadside grading should be used to assist the driver in judging speed, position, and change of direction.

Although these are helpful for design or redesign practices, no guidelines are presented which would apply directly to information systems on two-lane rural highways.

L/4.0

REFERENCE: Leish, J. E. and Associates, "Dynamic Design for Safety," Seminar Notes, US DOT, FHWA, October, 1975.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	X LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The basic purpose of this seminar series is to generate material which can be useful toward the development of design guidelines and criteria as well as design techniques for designing safer highways. Directly related to this is the need to disseminate the concepts and guidelines, developed from the seminar into design agencies. The second objective of this seminar is, therefore, to develop, with the participants, a program for implementation within their own areas. This would include a plan for continuing education within the particpants' own agency.

CRITICAL ANALYSIS;

Several driver tendencies were listed that relate directly to our study:

1) Drivers desire and tend to travel at relatively high speeds, upward of 80 km/h (50 mph), where deterrents are few and free-flow characteristics are present.

2) Drivers entering and leaving curved roadways do so by negotiating a transitional path.

3) Drivers traveling along a variable alignment tend to speed-up when the quality of the alignment improves.

4) Drivers tend to overdrive crest vertical curves on favorable horizontal alignments.

5) Drivers tend to overdrive turning roadways.

6) Drivers lose their sense of speed on long, sustained driving and tend to overdrive situations that require speed reductions.

7) Drivers orient themselves and choose their paths by following delineating features on or along the side of the highway.

L/11.0

REFERENCE: Livneh, M., Prashkner, J., and Uzan, J. "Visibility Problems in Crest Vertical Curves." Highway Research Record 312, 1970, 76-86.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical X Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing X O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: Selection

SUMMARY/ABSTRACT:

The length of a crest vertical curve is governed by visibility considerations. The minimum length is based on the stopping sight distance; the maximum length is based on the passing sight distance, and overtaking is allowed throughout its length. The object of the present paper is theoretical determination of the zone of overtaking visibility in a curve designed on a below-maximum basis. The analysis covers two cases: (a) overtaking vehicle inside and oncoming vehicle outside the curve and (b) both vehicles outside the curve. The corresponding curve geometries were also considered. The equations obtained were computer-solved for curves with slope differences ranging from 2 to 12 percent, passing sight distances corresponding to the design speed range of 50 to 110 km/hr, and length limits corresponding to the stopping and passing sight distances respectively. Results were rendered in convenient graph form, permitting determination of the type of division line and the length of the no-overtaking zone to be marked on a 2-lane 2-way highway in the vicinity of the curve. The length of the no-overtaking zone increases with the overall length of the curve, up to the maximum (unrestricted overtaking). The conclusion is that, in order to reduce the no-overtaking zone in below-maximum cases, it should preferably be as short as possible within the requirement limits of overtaking visibility and driving convenience.

L/11.1

CRITICAL ANALYSIS:

The theoretical analysis of passing sight distances for curves of varying slopes permits determination of overtaking visibility on a crest vertical curve on a two-lane, two-way highway. The proposed pavement markings include a warning line (series of short dashed lines with similarly short inter-line spaces), equal in length to the passing sight distance, indicating nearness to a zone of reduced visibility for overtaking. In this zone, a driver would be allowed to complete an overtaking move begun earlier but not allowed to attempt a new one once he has passed the initial point of the warning line in the right lane. This concept is similar to the marking recommended by the Texas Transportation Institute in their study of passing zones.

L/12.0

REFERENCE: Lonegrove, S. A., "Approach Speeds at Uncontrolled Intersections with Restricted Sight Distances," Journal of Applied Psychology, 63, 1978, pp. 635-642.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

An unobtrusive study was made of vehicles approaching low-volume uncontrolled cross-intersections, with restricted right sight distances, at which the give-way-to-the-right rule was operative. The hypotheses were that one factor that influenced motorists' approach speeds on the major road was the frequency with which vehicles emerged from the right and that most drivers exceeded the safe approach speed when this probability was low. The mean speeds at a low and high probability intersection were 31 mph (50 km/h) and 22 mph (35 km/h). The maximum safe approach speed at each intersection was calculated to be 18 mph - 29 km/h. It was concluded that many drivers deliberately overrely on their predictions about the typical behavior of other drivers and that this is responsible for the behavior defined as hazardous. Further, it was hypothesized that when drivers exceeded the safe approach speed, they were relying on taking evasive action to avoid a vehicle that might emerge from the right. Reduced friction at the low- and high-probability intersections was accompanied by speed reductions of 3.0 mph (4.9 km/h) and 3.5 mph (5.6 km/h) and ns = 28 and 48, respectively ($p = < .01$).

L/12.1
CRITICAL ANALYSIS:

Two free-field observation studies were made of drivers' intersection approach speeds at both a high probability (many crossing vehicles) and low probability (few crossing vehicles) intersection. Drivers were not aware of the study, and data were collected from motorists identified as having passed through the intersection of interest on at least two occasions (i.e. commuters). The approaches to the intersections were flat and straight; a crossroads sign was present at the high probability intersection but not the low one; there were no pavement markings or intersection control devices; from the major approach leg, the sight triangle for traffic approaching the intersection(s) from the right was restricted; the give-way-to-the-right-rule was operative at both intersections.

A comparison of spot speed data 35 ft prior to the intersections indicates that at both intersections, drivers' approach speeds were greater than required stopping distances. However, the departures from the maximum safe approach speed were smaller and less frequent (statistically) at the high probability intersection, and the variance in speeds within intersections was relatively small.

A second experiment was conducted at the same two intersections. In this study a loose layer of gravel together with a warning sign ("LOOSE SURFACE") were applied on the 30 feet prior to each intersection as well as at a mid-block site. Speed data were collected for the 34% fastest drivers in the normal condition study at the low probability intersection and from the 35% fastest drivers at the high probability intersection. The results indicated that at the midblock sites, speeds were not affected by the gravel and sign. At the low probability intersection, drivers reduced speed, on average, 3.0 mph, and at the high probability intersection, drivers reduced speed, on average, 3.5 mph.

These results were interpretted by the author to mean that drivers exceed stopping distance requirements on the basis of both their expectancy for an obstacle (cross traffic) and their estimation of their ability to take a successful evasive action if an obstacle is encountered. The expectancy effect is inferred from the observation of more and higher deviations from maximum safe approach speed at the high probability site, and from the observed speed reductions with gravel on the road, only at the two intersection sites. The evasive action influence is inferred from the observed reductions at the intersections with gravel on the road.

While the results are interesting and lend some inferential support to the widely held notions of the effects of driver expectancy, they have no direct application to the question of stop controlled intersections in that such decisions must take the unfamiliar driver into consideration.

L/5.0

REFERENCE: Louis, L. J., "Sight Distance Requirements of Rural Roads -- A Review," Australian Road Research, Volume 7, No. 2 (June, 1977) pp. 32-44.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent - Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Sight distance is a basic element of geometric road design and the standards set for minimum acceptable values of sight distance have a direct bearing on the cost of a road. This paper sets out the results of a study into the sight distance requirements of rural roads. This study involved a literature search, examination of some research results, and an analysis of the practices of various road authorities. While clear cut guidelines for the setting of minimum standards were not found in the literature or in the results of research, it was concluded that sufficient knowledge existed to enable satisfactory standards to be set. The traditional concepts of stopping and overtaking sight distance are examined and it is concluded that a different approach may be warranted. Different bases for the assessment of the minimum sight distance requirements and for overtaking requirements are suggested and values for design are given. While the various aspects of rural sight distance requirements are discussed, particular attention is given to the design of crest vertical curves. /Author/

CRITICAL ANALYSIS:

This paper is basically a review of literature on sight distance and standards related to sight distance.

L/5.1

Very few of the references are pertinent to our study. However, the one point that this paper does make is that little success has been achieved in correlating accidents with sight distance alone or with other individual geometric feature in isolation of other factors. This would reinforce the contention that accidents cannot be related to single geometric characteristics.

L/6.0

REFERENCE: Lunenfeld, H., "Evaluation of Traffic Operations, Safety and Positive Guidance Projects," US DOT, FHWA, Report :No. FHWA-TO-80-1.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This volume is for use by highway and traffic engineers and technicians in implementing an evaluation of Traffic Operations, Safety and Positive guidance projects. Evaluation should begin in the planning stage where evaluation designs are selected and measures of effectivenss (MOE's) identified. It should continue during the solution development phase where the measures are used as diagnostics and culminate in an evaluation where differences are in the measures taken before and after the improvement are used to assess the effectiveness of the solution. The Evaluation report provides a "cookbook" approach to implementing the procedure. This enables those engineers and technicians who are not versed in accident or accident surrogate MOE's, experimental design or statistical analysis to determine whether their solution is effective. Each step in the evaluation is structured in terms of inputs, outputs, and the logic involved in its execution. Tables and worksheets lead to the development of a detailed evaluation plan, data collection procedure and data analysis routine. Among the factors detailed are: the selection of appropriate MOE's; overcoming threats to the validity of the evaluation; ways to assure "Before" and "After" comparability; how to select the proper statistical test; establishing an appropriate confidence level and recognizing the importance of practical significance.

L/6.1

CRITICAL ANALYSIS:

This is essentially a user's manual to evaluate positive guidance improvements and is geared to local engineer/technicians.

The methodology could be employed for our field validation task (C-3), in which case the MOE's would be traffic performance measures.

The measures of effectiveness suggested for various highway situations may be applicable to the current study.

Data collection methods to obtain different MOE's and control site selection criteria are also discussed.

This document will serve as a source for identifying appropriate measures and for designing an evaluation scheme for traffic control devices.

L/7.0

REFERENCE: Lunenfeld, H., "Improving the Highway System by Upgrading and Optimizing Traffic Control Devices," US DOT, FHWA, Report No. FHWA-TO-77-1, April, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance _X_Other

OTHER DESCRIPTORS: Deficiency types.

SUMMARY/ABSTRACT:

An analysis was conducted to assess the effect of shifting program emphasis to promulgate traffic control device improvements on all public roads. Upgrading and optimizing the highway information system was evaluated in terms of human factors, safety, benefit-cost, and traffic engineering. It was found that those portions of the highway system not in compliance with the Manual on Uniform Traffic Control Devices (MUTCD) would experience significant safety benefits and improved system efficiency through upgrading to current standards. Among the factors leading to this conclusion are: 1) Traffic control devices deficiencies can lead to driver error and accidents; 2) roads with the lowest level of MUTCD compliance generally experience disproportionately high accident rates; 3) studies show significant, positive safety and efficiency benefits and driver error reductions with traffic control device improvements; 4) if optimizing the total information system reduced accidents by 10 percent, a benefit-cost ratio of from 10:1 to 20:1 would be realized. It was recommended that emphasis be given to upgrading all traffic control devices to MUTCD standards and optimizing through Positive Guidance.

CRITICAL ANALYSIS:

Lunenfeld lists five causes for driving errors: overload, deficient information display, missing information, deficient TCD design, and lack of uniformity. The first four may be useful in defining types of information deficiencies.

He also provides a table showing states compliance with the MUTCD. These data were gathered during a 1974 survey are partially updated in 1976, although the results were never published. This table definitely shows that almost half the "locals" are not in compliance with the MUTCD.

Lunenfeld also showed the cost (1977 dollars) of upgrading the entire system to comply with the MUTCD.

In view of these findings, the question arises, "Is it possible to recommend info systems when, for all intents and purposes, they will not be used?".

L/8.0

REFERENCE: Lyles, R. W., "An Evaluation of Signs for Sight Restricted Rural Intersections," US DOT, FHWA, Report No. FHWA-RD-80-002, February, 1980. (Lyles also published a condensed version in TRR 782, "Evaluation of Signs for Hazardous Rural Intersections.")

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report reviews an experiment undertaken to examine the effectiveness of six signs and sign sequences for warning motorists of a hazardous or sight-restricted intersection ahead in a rural two-lane situation. Signs examined ranged from the standard intersection symbol warning sign (cross) to vehicle actuated signs with flashing warning lights. Data collected during the experiment included: speeds of motorists as they approached and passed through test intersections (sometimes with a vehicle stopped on the side road); vehicle classification and registration information; and, for selected sign/site combinations, survey information for some motorists regarding their recollection of and reaction to the tested signs.

The principal findings were that emphatic type signs (warning sign with flashers or a regulatory sign) caused drivers to reduce their speed by about 5.0 kph (3 mph) more than standard warning signs, and to increase driver awareness (as measured by sign recall and noticing of a side road vehicle) by a factor of approximately two. Familiarity with a test site, type of vehicle being driven, and sex did not have a significant effect on drivers' reactions to the various sign/site conditions.

CRITICAL ANALYSIS:

The study was conducted on a low volume 2-lane road in rolling terrain with occasional houses and low volume side roads. Frequency of these intersections is 1 per mile. Main road ADT was 1600 vpd and side roads ADT was less than 100 vpd. Site 1 was on a tangent with an upgrade approach. Site 2 was on a gentle horizontal curve with a slight downgrade at the intersection. Data collected on weekdays between June and October, 1978. Approach speed limits were 50 mph. The roadway at both sites had adequate shoulders and good pavement conditions. The mean entry speed was used as a covariate. Vehicles which turned, had entry speeds less than 35 mph or were in queue behind a lead vehicle were discarded. A survey was distributed on nine different days to drivers to ascertain whether or not there was an increased awareness created by the four different sign conditions. The various sign conditions analyzed are shown on the attached sheet.

It was found that a slightly higher percentage of motorists recalled that there was an intersection for sign conditions 4 or 6, compared to sign conditions 2 or 3. (see signs on last page). Further, motorists were considerably more likely to have seen a vehicle stopped on the cross street at the intersection when sign condition 6 was deployed as when sign condition 2, 3, or 4.

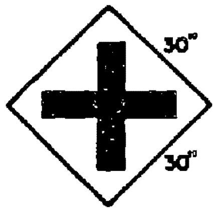
Both the speed zone configuration (sign condition 4) and the vehicle activated sign (sign condition 6) resulted in a much higher likelihood of correct motorist recall. Approximately twice as many recalled the correct signs for sign conditions 4 and 6, compared to sign condition 2 and 3. Regardless of what signs were displayed similar percentages of motorists indicated that they reacted by becoming more alert and/or slowing down.

The analysis (ANOVA) of the speed data showed that site and signs produced significant main effects. However speed was not differentially influenced by either motorist familiarity or by type of vehicle. Of the interactions, signs showed a significant interaction with the presence of a vehicle in the intersection.

With regard to the sign conditions, it was found that the active signs produced a significantly greater speed reduction than the passive sign. This was true of the measures made 500 feet upstream of the intersection, at the intersection, and for overall speed. While the differences were statistically significant, it should be noted that the maximum differences observed were in all cases less than 4 mph.

Even though the dynamic signs resulted in greater speed reductions than the passive signs, the reactions to the dynamic signs did not appear to occur substantially earlier than the passive. That is, the substantive portion of the deceleration occurred near the intersection in all cases. This suggests that evaluations of signing related to intersections need not include spot speed measures very far upstream of the intersection. Unless it is desirable to obtain an overall speed profile rather than spot speeds, this factor will be taken into consideration in designing the validation studies for the current effort.

SIGN CONDITIONS 1&2

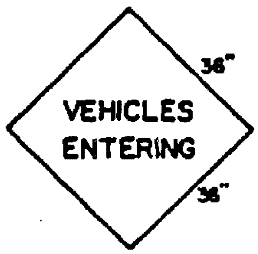


CONDITION 1 - WARNING SIGN PLACED AT PRESENT LOCATION

CONDITION 2 - WARNING SIGN PLACED APPROX. 700' FROM P.C.

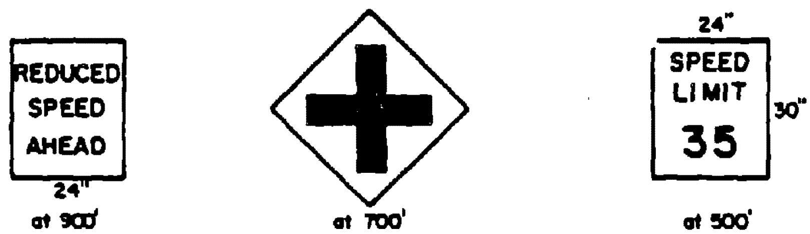
* (SEE MUTCD FOR SIGN CODES)

SIGN CONDITION 3



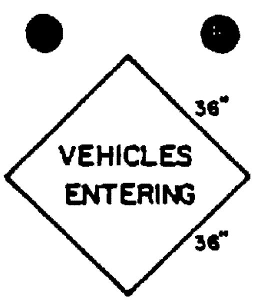
WARNING SIGN PLACED APPROX. 700' FROM INTERSECTION

SIGN CONDITION 4



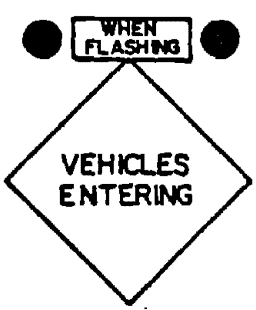
WARNING & REGULATORY SIGNS PLACED APPROX. AS INDICATED

SIGN CONDITION 5



WARNING SIGN WITH 2-8" CONTINUOUS FLASHING BEACONS PLACED APPROX. 700' FROM INTERSECTION

SIGN CONDITION 6



WARNING SIGN WITH ADDITIONAL "WHEN FLASHING" PLAQUE AND 2-8" BEACONS ACTIVATED BY SIDE ROAD TRAFFIC ONLY. PLACED APPROX. 700' FROM INTERSECTION.

LL/20.0

REFERENCE: Lyles, R. W., "An Evaluation of Warning and Regulatory Signs for Curves on Rural Roads," US DOT, FHWA, Report No. FHWA-RD-80-009, March, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design X Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

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

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

LL/20.1

CRITICAL ANALYSIS:

The author's suggestion that the proliferation of curve warning signs has lesened respect for the message conveyed is perhaps too general. It is possible that past "misuse" of advisory speed information has produced a credibility problem with that information and that the curve warning with advisory produces the same effect as the curve warning alone because drivers disregard the advisory. While this cannot be ascertained because the study did not involve a "no sign" condition, it could, in part, account for the lack of differentiation between sign conditions. Also, while the study did appear to be generally well conceived, the sample sizes for the speed data were relatively small.

L/9.0

REFERENCE: Lyles, R. W., "Effective Warning Devices for Parked/Disabled Vehicles," US DOT, FHWA, Report No. FHWA-RD-80-065. October, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	___ LanePlacemt/ Rd Following	___ Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	X Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		X Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report reviews an experiment undertaken to examine the effectiveness of three different warning device configurations for alerting motorists to the presence of an unattended parked/disabled vehicle (PDV) at the roadside and the need for caution in passing it by. The data collected were the speed profiles of passing (random) motorists as they approached and passed by the PDV location in a rural two-lane situation. The three warning configurations included four-way flashers used on the PDV, and the four-way flashers used in conjunction with warning triangles deployed in two different fashions (i.e., all behind PDV; one ahead two behind) around the PDV. For comparison purposes, data were also collected when the PDV was not present (a base condition). Data were collected during the day and night, on near and far lane vehicles, with the PDV at different offsets from the pavement edge, and on opposed and unopposed vehicles. A limited number of data were also collected during adverse weather/visibility conditions (night, rain, wet pavement).

Principal findings included the following: the presence of the PDV at the roadside made a difference in the speed profiles (motorists went somewhat slower); activated fourway flashers on the PDV slowed motorists even more; and the four-way flashers and triangles used together sometimes slowed motorists an even greater amount. Although not conclusive, the "all behind" triangle configuration seemed to have a somewhat more

positive effect than the "one-ahead/two behind" configuration. Analysis of limited bad weather data showed the potential for even more striking positive effects due to the flashers. Due to small sample size, the later effect could not be stated unequivocally. The basic conclusion was that use of four-way flashers on PDV's is an useful means for safety enhancement.

CRITICAL ANALYSIS:

Lateral placement was not obtainable due to data processing problems. Only speed measures were obtained and analyzed. The warning triangles employed were those specified by the Federal Motor Vehicle Safety Standard # 125. Placement was in accordance with Federal Motor Carrier Safety Regulations, Paragraph 392.22. Three different offsets were used (0', 2', and 4' from the pavement edge). Two sites with 24' pavement width and 10' shoulders, approximately 2000 ADT were used. One site was on a gentle horizontal curve on a slight grade varying from 2% (at the PDV) to 4.4%. The other was on a tangent, with the PDV located almost at the mid-point of a sag vertical curve connecting two downgrades (1.9% and 3.4%). Both had speed limits posted at 50 mph. Data was collected during the summer when 50% of the traffic is non-local. Days when the PDV was present were varied to minimize driver suspicion.

RESULTS:

Based primarily on the results from site 1, it was found that mean speeds at 200 ft before the PDV, at the PDV itself and 200 ft after the PDV were significantly different when the PDV was present relative to when the PDV was not present, for all three PDV offsets. Also, use of four-way flashers on a PDV generally resulted in lower speeds by passing motorists than when four-way flashers were not deployed. Finally, the use of four-way flashers on a PDV plus 3 triangles positioned behind th PDV resulted in lower speeds by passing motorists than when four-way flashers alone were used.

At night, the difference due to the PDV presence were more pronounced than during the day, (approximately 4.0 mph), and there was also a greater effect due to the use of four-way flashers, relative to day, (approximately 2.5 - 3.5 mph).

The fact that the study was conducted on a 24 ft. wide roadway with 10 ft. shoulders, makes it relevant only to the higher design two-lane rural roadways. The absence of lateral placement data along with the fact that the warning devices were not tested on more hazardous sites i.e., narrower lane widths and/or shoulders, makes the results less useful for the current project.

M/11.0

REFERENCE: McClean, J., "An Alternative to the Design Speed Concept for Low Speed Alignment Design." TRB Research Record 702, 1979, pp. 55-63.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	___ LanePlacemt/ Rd Following	___ Design
X Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	___ Other	___ Other
X Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: Design Speeds for Low Speed Roads

SUMMARY/ABSTRACT:

While the design speed concept originated from considerations of driver speed behavior, it is now treated as an arbitrary means of designing and matching geometric elements. The implicit assumption of a maximum uniform driving speed is examined in terms of Austrialian research into the relationships between driver speed behavior and alignment design. For alignments based on design speeds of 110 km/h or more, driver behavior appears to be in accord with the design speed concept. However, for alignments with design speeds between 90 and 110 km/h, driver speeds tend to vary according to the standard of individual features, but the speeds adopted on horizontal curves are generally below the curve design speed. For alignments with desgin speeds of 90 km/h or less, driver speeds vary along the route and are consistently in excess of the design speed. The results of the speed studies have been used to formulate an alternative approach for the alignment design of two-lane rural roads where topographic or financial difficulties preclude the adoption of design speeds greater than 90 km/h. The method is based on the estimation of a desired speed of travel as related to terrain classification and overall alignment standard. This is used to predict the speed behavior of drivers on individual horizontal curves as a function of the curve standard. This method provides quantification, in terms of driver speed behavior, of what represents a sub-standard curve relative to the overall alignment standard.

M/11.1

CRITICAL ANALYSIS:

The author identified several problems associated with the current design speed concept. In order to develop an alternative to the current concept, spot speed data were collected at 120 curve sites on 2 lane rural highways in Australia. Data were also collected on 20 level, tangent sections in the vicinity of the curve sites.

It was found that the "desired speed" (i.e. the speed at which drivers choose to travel under free flow conditions when they are not constrained by alignment features) was influenced by road function and typical trip purpose and length for traffic on the road, proximity to major center, and most important for design purposes, by the overall standard of alignment as specified by the overall design speed and terrain type.

The "speed standard of a curve" is the maximum speed at which a vehicle can negotiate the curve without exceeding the NAASRA side friction factor criterion. For curves with speed standards of 100 km/h or more, 85th percentile free speeds were found to be less than the curve speed standard, while for curves of lower standard, the reverse applies.

Regression analysis of 85th percentile curve speeds was dominantly influenced by desired speed of the road section prior to the curve, and by the curve radius. While available sight distance had a statistically significant effect on curve speeds, it represented less than 1% of the variability among the 85th percentile speeds.

On the basis of these results, the author recommends and develops an alternative approach to design speeds, expecially appropriate for roads with design speeds of 90 km/h or less. This alternative is based on predicted 85th percetile speeds and represents a return to the original notion of design speed as the predicted velocity for faster drivers.

The author also recommends designing for driver expectancies and makes a few specific recommendations. He begins by assuming that drivers expect consistency in roadway alignment standards.

He suggests that the speed standard for curves within a roadway alignment section should not differ by more than 10 km/hr from desired speed. Likewise, for a sequence of horizontal curves going from a high to a low standard, the predicted speed on sequential curves should not differ by more than 10 km/hr.

Finally, the predicted curve speeds for curves at the end of a straight section should not be more than 10 km/hr - and definitely not more than 15 km/hr - below the speed environment of the preceding section. A "straight section" relates to the overall alignment standard and ranges from 0.25 km for low standard alignments in difficult terrain to 3 km for high standard alignments in easier terrain.

The potential applicability of this study to the current study is that it could provide an operational definition of "problem" curves either for the purpose of choosing curve "sites" or for characterizing various types of two-lane rural roadways.

M/1.0

REFERENCE: McGee, H. W., Moore, W., Knapp, B. G., and Sanders, J. H., "Decision Sight Distance for Highway Design and Traffic Control Requirements," US DOT, FHWA, Report No. FHWA-RD-78-78.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge X L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass X Other	___Design X Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Decision sight distance (DSD) has been defined as the distance at which drivers can detect a hazard or signal in a cluttered roadway environment, recognize it or it's threat potential, select the appropriate speed and path, and perform the required action safely and efficiently. A research effort was devised and performed to relate this concept to specific road types, design speeds, traffic operating conditions, geometric features, and driver attributes. It was performed in two phases, with the following objectives:

Phase I: Critically evaluate and synthesize relevant literature pertaining to DSD and derive values for highway design. Phase I led to the identification of a hazard avoidance process model as a basis for quantifying decision sight distance. The process includes three elements of information processing detection, recognition and decision-making) followed by initial response and vehicle maneuver. The outcome of Phase I was the development of preliminary DSD values based on the estimated times for the various elements of the model as reported in the literature.

Phase II: Validate, via highway field study, derived DSD values. In Phase II, 19 subjects drove an instrumented vehicle through eight typical highway situations in order to validate the preliminary values. In general, the results of the field study supported the derived DSD

values, with some modifications, and confirmed that decision sight distance is operationally valid. Recommendations are presented on the decision sight distance criteria, and its application for design and traffic operations.

CRITICAL ANALYSIS:

The decision sight distance model is applicable to the current study. However, the recommended distances were derived from field work involving 22 subjects driving through lane reductions. As such, those values may be applicable to a truck climbing lane drop but may not be for other situations of interest.

M/12.0

REFERENCE: McLean, J. R. and Hoffman, E. R. "Steering Reversals as a Measure of Driver Performance and Steering Task Difficulty." Human Factors, 17, 1975, pp. 248-256.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	___ LanePlacemt/ Rd Following	___ Design
___ Horizont.	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
X Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Vertical Curve	___ OffRoadway	___ Bridge	X Other	___ Other
___ Grade	___ Other	___ L.W.Transit.		
___ Other		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: Driver Performance Measures

SUMMARY/ABSTRACT:

A review is made of past work in which steering reversal rates were used as a measure of driver performance. The data from two previously reported experiments carried out in a controlled situation, are used to compare steering reversal rates with other performance measures. It is shown that, while steering reversal rates correlate with other measures of control frequency, they do not necessarily correlate with measures of absolute steering performance. This result is consistent with the view that frequency characteristics provide a measure of steering task difficulty rather than steering performance. It is shown that, when considering steering task difficulty, care must be taken to differentiate between the difficulty imposed by the task constraints and the factors which affect the driver's ability to maintain a level of performance commensurate with those constraints.

CRITICAL ANALYSIS

These authors attempted to examine both the reliability and the validity of using reversal rate as a measure of driving performance. The method employed was post hoc analysis of 2 previous studies (McLean and Hoffman 1972, 1973). The first study required drivers to drive a 4000 foot straight lane under conditions of reduced preview distances (30, 60, 90 feet) at one of 2 speeds (20-30 mph). The second study required drivers to track the 4,000-foot straight lanes of varying width (8,10,12 feet) at one of 3 speeds (30, 40, 50 mph). These studies showed that drivers exhibited peaks in their steering reversal frequencies at 0.1 to 0.3 H_z; the frequency at such a peak is called a Primary Dominant Frequency (PDF). A second criterion measure related to reversal rates was High Frequency Area (HFA), or the proportion of area (under the spectral density curve) at frequencies greater than 0.4 H_z, especially at gap sizes of 0.5 to 0.7°. Also, the percentage variance in reversal rate that was explained by treatment variables was greatest over this same 0.5 to 0.7° gap size range.

The steering reversal rate correlates more highly with HFA than with PDF. The correlation is positive, i.e., as reversal rates increase, so do the proportion of frequencies greater than 0.4 H_z. Further, "the occurrence of a large HFA, usually due to a high-frequency peak, was irregular but was more likely to occur for the difficult driving situations (severly restricted preview or narrow lanes)." Steering control frequency characteristics varied consistently, positively and significantly with other performance measures for the preview distance study but not for the lane width study. This was interpreted by the authors as indicative of two sets of factors that affect task difficulty: first, task constraints, which are the tolerances or bounds on deviations and alignment errors - these bounds are primarily determined by speed; second, task achievement difficulty, which is the extent to which the driver experiences difficulty in complying with the task constraints. Related to this is the assertion by Kelley (1969) that control frequency characteristics tend to reflect control effort [i.e. difficulty] rather than absolute tracking performance. The authors conclude that it is difficult to infer the meaning from observed differences in reversal rates: for example, both a good but fatigued driver and a poor, but conscientious driver may perform poorly, but the former has a low rate of reversals while the latter shows a high rate.

While steering performance may have applicability in some of the situations to be studied for the current effort, it is not likely that the measure will be senstive to the types of information system evaluations to be conducted nor is it likely that the measure can be used to choose "problem" sites.

M/13.0

REFERENCE: McLean, J. R., and Hoffman, E. R., "The Effects of Lane Width on Driver Steering Control and Performance," Sixth Conference. Australian Road Research Board, 6, 1972, pp. 418-440.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	X LanePlacemt/ Rd Following	___ Design
___ Horizont. Curve	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
___ Vertical Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	___ Performance
___ Grade	___ OffRoadway	___ Bridge	X Other	___ Other
___ Other	___ Other	___ L.W.Transit.		
		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: Measures of Effectiveness

SUMMARY/ABSTRACT:

Driver steering and control and performance have been studied for straight lane driving in lanes of 8, 10, and 12 ft. widths at speeds of 30, 40, and 50 mph. The results have been compared with the theoretical models of driver control developed by Rashevsky, and with free speed measurements taken for driving conditions similar to those of the experiment. It appears that in most cases drivers were dominantly controlling the heading or path angle of the vehicle without close attention to lateral error. In doing so, most of their control was within a narrow frequency band located in the range 0.1 to 0.3 H_z. For extreme conditions of narrow lane width and high speed, drivers appeared to change their steering strategy to one dominantly involving direct control of lateral error. This apparent change in strategy was accompanied by a marked increase in the proportion of high frequency (> 0.4 H_z) control movements and in both heading rate and heading angle error. It is suggested that the need to modify steering strategy could provide the upper bound for free speeds in narrow lanes when other restrictions are not present.

M/13.1
CRITICAL ANALYSIS:

This study was conducted on an airport runway where five subjects (four male, one female) drove nine times over each of three lane widths: 8, 10, and 12 feet. Lanes were 4,000 feet long. Drivers were instructed to drive "comfortably" at a stipulated speed without excessive concern about speed control; three different speeds were stipulated: 30, 40, and 50 mph.

RMS (root-mean-square) heading angle and RMS heading rate where used as measures on steering accuracy. Spectral analyses of steering wheel angle records were examined against the RMS heading angle and RMS heading rate curves in an attempt to draw conclusions about control rates.

Results indicated that high frequency steering wheel control movements ($> 0.4\ H_z$) are more likely to occur in "tighter" driving situations. That is, the cumulative percentage of steering wheel movements with frequencies > $0.4\ H_z$ increases as lane width decreases and as speed increases. Steering performance (indicated by heading rate and angle) becomes markedly poor under the 8 foot lane - 50 mph condition. The high frequency steering only peaks are also notably high under the same condition. Finally, the high frequency steering wheel angle spectral peaks, and the corresponding heading rate spectral peaks for the higher speeds, occur at or near the natural frequency of the vehicle in yaw.

From the results of the experiment and consideration of Rashevsky's model of straight lane driving and Leong's free speed measurements it can be concluded that the proportion of high frequency ($> 0.4\ H_z$) steering control movements increases with increasing speed and decreasing lane width, that is, increases as the driving situation becomes 'tighter', in agreement with the results of McLean and Hoffman (1975). For moderate lane widths and speeds, drivers appear to use a strategy of dominantly controlling the path or heading angle of the car such that it will not deviate too close to a lane edge. This control is mainly carried out at frequencies of 0.1 to $0.3\ H_z$.

M/13.2

Under extreme conditions of narrow lane width and high speed, drivers find it necessary to change their steering strategy to one which appears to involve direct control of lateral error. A higher frequency control action, at or near the natural frequency of the vehicle, is apparently used for fine angular control. The need to modify steering strategy could provide the upper bound for free speeds in narrow lanes when other restrictions are not present.

M/10.0

REFERENCE: Mackworth, N. H., and Morandi, A. J., "The Gaze Selects Informative Details within Pictures," Perception and Psychophysics, 1967, Vol. 2, 547-551.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The visual fixations of 20 subjects viewing each of two pictures were measured. Each picture was divided into 64 squares, and 20 other subjects judged their recognizeability on a 10 point scale. Both measures gave high readings for unusual and for unpredictable contours. Although they were judged to be highly recognizeable, redundant (or predictable) contours received few fixations. Areas of mere texture scored low on both measures. The relations between fixation densities and estimated recognizeability suggest that a scene may be divided into informative features and redundant regions. Not only do the eyes have to be aimed, but also are usually aimed intelligently, even during the casual inspection of pictures.

M/2.0

REFERENCE: Markowitz, J. and Dietrich, C. W., "An Investigation of the Design and Performance of Traffic Control Devices," Bolt, Beranek, and Newman, Inc., Cambridge, MA, Report No. 1726, December, 1968.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

A design and experimental study of traffic control devices, carried out by a multidisciplinary team of psychologists, engineers and graphic designers is described. The work encompasses an appreciation of the background and operation of uniform traffic control devices, an extensive series of laboratory investigations, road tests, and a substantive group of graphic design exercises. The investigation of the basic design elements of a transportation graphics system included the study of legend, pictograph, symbol, color, shape, arrows, and destination signing. Both the laboratory and the road experiment design and data analyses draw heavily on recent advances in the theory of signal detectability, an application of statistical decision theory.

Applications of the study techniques to further problems are noted throughout this report. Also included is a graphic design discussion of the urban sign situation.

CRITICAL ANALYSIS:

This study evaluated background shapes, arrows, borders, colors and pictographs using an index of recognizability factors from laboratory tests.

Their results may be applicable to the current study in the media design effort (Task E-2). However, it is not within the scope of the project to evaluate our recommended systems using the methodology employed by BBN, Inc.

M/3.0

REFERENCE: Meyers, T. T., Ashkenas, I. L., Johnson, W. A., "Feasibility of a Grade Severity Rating System," US DOT, FHWA, Report No. FHWA-RD-79-116, August, 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve X Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Steep downgrade.

SUMMARY/ABSTRACT:

The objective of this study has been to determine the feasibility and format of a grade severity rating system (GSRS) so that existing countermeasures can be more rationally applied and the need for new countermeasures can be established. The study as conducted consisted of a literature review, the development of a truck downgrade braking model, a series of field tests to validate the model and the final development of a prototype grade severity rating system. With the grade severity rating system a downgrade may be given a numerical rating based on the severity of the grade. A speed selection model was also developed that can be used to determine a safe speed of descent based on the grade severity rating and the weight of the truck.

CRITICAL ANALYSIS:

The grade severity rating system (GSRS), if implemented, would operate in the following manner:

1) The approximate slope (grade angle, in radians) and the length of a particular grade would be used to compute a single numerical grade severity rating, using the truck downgrade braking model described in this report.

2) Maximum descent speeds would then be calculated for various weight specific classes.

3) Finally, signs would be erected on the downgrade.

Further evaluation of the braking model, the computation of maximum descent speeds and the design of GRADE SEVERITY RATING/WEIGHT SPECIFIC SPEED (GSR/WSS) sign should be conducted. This work is relevant to that aspect of the current study dealing with the information needs of truckers.

M/15.0

REFERENCE: Middleton, G., "Marking of Edgelines on Narrow Pavements," Australian Road Research, 6 (4), December 1976, pp. 25-30.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	X LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass X Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: Edgelines

SUMMARY/ABSTRACT:

Currently the Australian Standard dealing with Traffic Control devices for use in Australia permits the use of edge lines on two-lane, two-way pavements that are at least 6.8 m wide.

The reasons for not extending their use to narrower pavements are somewhat unclear but appear to emanate from considerations of cost and accidents.

This paper outlines the results of trials conducted on two-way pavements 5.5 m (18 ft.) wide, which is essentially the minimum width for two-way operations. The results indicate that there are definite economies to be derived from the marking of edge lines on these roads, as savings in shoulder maintenance costs outweight painting costs. Statistically significant accident effects were not obtained. However the presence of edge lining caused vehicles to travel further away from the centre of the road and this itself may lead to a reduction in head-on type accidents by increasing the lateral separation between approaching vehicles.

CRITICAL ANALYSIS:

The study used six test sites where a 5.5 m (18 ft.) pavement was marked with edgelines; and six control locations without edgelines.

A comparison of accident data for the 2 groups indicated that rates were always lower on the sites with edgelines, but never significantly so. Maintenance cost data indicated that the cost of required shoulder maintenance for sites without edgelines was higher than that for sites with edgelines and that these pavement maintenance costs exceeded the cost of line installation and maintenance.

The lateral position data indicated that on both groups of site the higher the speed, the closer the vehicle drove to the center of the road, and the higher the ADT, the closer the vehicles drove to the edge of the pavement. However, the total sample comparisons showed that vehicles drove closer to the center of the road on roads without edgelines than roads with edgelines. Further, on roads with edgelines, the movement away from the centerline resulted in mean positions closer to the centerline in comparison to the mean position of vehicles on roads without edgelines. Finally, the variance of the lateral positions were lower on roads with edgelines than on roads without edgelines.

These data refute the assumption that edgelines on narrow lanes may cause drivers to drive closer to the center of the roadway.

M/4.0

REFERENCE: Mounce, J. H., "Driver Compliance with STOP-Sign Control at Low Volume Intersections," TRR 808, Transportation Research Board, 1981, pp. 30.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The objective of the research was to determine whether stop-sign control under designated conditions was fulfilling the requirements for application as specified by the Manual of Uniform Traffic Control Devices. This was to be demonstrated by the percentage of observed motorist violations and compliance, assuming that these measures reflect confirmation of need and respect afforded by the public. The dependent variables of violation and compliance rate, conflicts, and accidents were compared in a factorial experimental design with the independent variables of major-roadway volume, minor-roadway sight distances, rural or urban traffic condition, and type of intersection geometry. Minor-roadway volume, signing control, roadway cross section, geography, and weather were all controlled variables. The results from 2830 observations at 66 intersections indicated that the violation rate decreases with increasing major-roadway volume and is significantly high ($p < 0.001$) up to the average-daily-traffic (ADT) level of 2000 and significantly low ($p < 0.001$) above the ADT level of 5000-6000. An interaction effect between major-roadway volume and minor-roadway sight distance results in a violation rate that is significantly higher ($p < 0.05$) when sight is unrestricted than it is when sight is restricted. No conclusive relationships could be established between violations at low-volume intersections either in the rural-urban traffic environment or in the intersection geometry type that had three to four legs. No correlation was established between violation rate and accidents across all study variables; however, conflict rate was reduced at the upper and lower

M/4.1

major roadway volume levels. It was concluded that the operational effectiveness of low-volume intersections could be enhanced with no observed safety detriment by the application of no sign control below major-roadway volume of 2000 ADT, yield-sign control at major-roadway volume between 2000 and 5000 ADT, and, depending on minor-roadway volume, stop-sign control or signalization above 5000 ADT. These recommendations should be modified based on adequate sight distance; yet the determination procedure used in this study seemed insufficient and requires further revision.

CRITICAL ANALYSIS:

One result, that may have implications for the current study, was that minor-approach sight distance and major approach volume had a highly significant influence on total violation rate. It was found that total violation rate at intersections with major approaches <2000 ADT was 75%, which was attributed to drivers' familiarity with low volume intersections. In other words, driver expectancy is that the potential for conflict is low. Also, total violation rate was found to be reduced by restricted intersection sight distance.

0/10.0

REFERENCE: Olsen, R. A. "Quantifying the Night Driver's Visual Environment."U.S. Department of Transportation. FHWA-RD-80-096, May 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. _X_Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Night Driving

SUMMARY/ABSTRACT:

The complexity of a driver's tasks in safely and efficiently utilizing the highway system is largely dependent upon the inputs presented to the visual senses. Visual complexity is determined by road geometry; maneuvering of other traffic; adjacent land uses; pedestrian activity; weather; traffic control devices, lighting, and maintenance of the road features; and many other factors. Darkness changes the visual environment by reducing many cues and by adding a few others. Some of these are added for the driver's benefit, some for other purposes, and some are uncontrolled or uncontrollable at least by highway agencies.

In this review of selected literature and research approaches, the objective is to suggest promising next steps toward making decisions on design, selection, and provision of aids to drivers for night driving.

CRITICAL ANALYSIS:

This article is an analytical review of those variables and factors that influence nighttime perception by drivers. No synthesizing theory or quantification of influential variables is attempted. Some comments are made regarding driver expectancies and route guidance information but these are of a general nature. The article serves primarily as a background/source document.

0/12.0

REFERENCE: Organization for Economic Cooperation and Development, Paris, "Road Safety at Night," 1980.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. _X_Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Night Driving

SUMMARY/ABSTRACT:

The road research group on "improving road safety at night" was established following discussions between the OECD Steering Committee for Road Research and the European Conference of Ministers of Transport (ECMT). The group's tasks were to define and describe the night-time road safety problem in member countries and to recommend suitable countermeasures. The present report was prepared as a result of five meetings held in 1977 and 1978 in Paris and Dublin. The study, in which experts from 14 countries and representatives of ECMT participated, placed a primary focus on measures for improving road safety at night without neglecting the possible effects on daytime safety as well. The first phase of the group's activities resulted in the preparation of a preliminary report on countermeasures immediately implementable; this report was transmitted to ECMT in 1978, and is included in Chapter I. The following two chapters present a discussion of specific statistical studies on night accident problems and an international comparison of night accident statistics. Chapters IV-VI provide state-of-the-art reviews of research on human factors in night driving, road engineering and traffic operations for night-time conditions, and vehicle engineering aspects. Finally conclusions and recommendations on countermeasures for improved night-time road safety and future research requirements are presented. A comprehensive bibliography is included.

0/12.1

CRITICAL ANALYSIS:

Not directly applicable to "Drivers Needs on Two-Lane Rural Roads" except as general background material. The report cites general night accident statistics and says night accidents are over-represented with respect to travel. But, says statistical base is inadequate. Calls for more research in effects of alcohol, lighting. Calls for more enforcement and extension of delineation to low-volume rural roads. Suggests a consideration of reduced speed limits at night. Also suggests the adoption and implementation of existing international regulations for vehicle marking and lighting so distinctions among cars, trucks, and slow moving vehicles are apparent to drivers.

0/13.0

REFERENCE: Oregon Department of Transportation, "Evaluation of the Chevron Design Directional Guidance Markers," Preliminary Report, January, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The Highway Division of the Oregon Department of Transportation investigated four devices (Type I Object Marker, Type III Object Marker, a Triangular Marker, and a Chevron Sign) and selected the Chevron sign to evaluate as a directional guidance marker. During this initial investigation, the chevron was found to be:

1) equivalent to three or more delineators,
2) universally understood,
3) a single uniform device which could emphasize changes in horizontal alignment (e.g. curves, turns, T intersections).

Moreover, the size of the chevron sign can be varied according to the sight distance required.

Ten test sites were chosen. Evaluation was to include a before-and-after accident data analysis.

CRITICAL ANALYSIS:

The results of the evaluation are not included in this preliminary report. The report was included because the chevron was chosen over other devices on the basis of engineering judgement and visual evaluation. This decision supports the decision of Georgia DOT to approve the use of chevron devices and therefore provides some evidence for the superior visual quality of the device.

0/1.0

REFERENCE: Owens, R. D., "Effect of Rumble Strips at Rural Stop Locations on Traffic Operation," HRR 170, 1967, pp. 35-55.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

In this study an investigation was made of the effect of rumble strips on traffic operation and behavior. Field studies were conducted at seven approaches to stop-controlled rural trunk highway intersections. Traffic operation and behavior were measured in terms of passenger vehicle speeds at predetermined points on the approaches together with stop sign and centerline observance studies.

The rumble strips consisted of a series of 25-ft long areas of rough-textured aggregate placed on the approach lanes at 50- to 100-foot intervals. The placing of the rumble strips in this study utilized four strips 25 ft long spaced 100 ft apart; six strips 25 ft long spaced 50 ft apart; and one at the intersection 50 ft long, which also acted as a nonskid treatment. The total length of the rumble area at each approach was 1,000 ft.

The field studies were conducted on a "before" and "after" basis during average weekday conditions. Effort was made to duplicate conditions so that uncontrollable or unknown factors could not influence the results.

It was found in this investigation that rumble strips significantly reduce the average speed of traffic approaching rural stop locations. The reduction in average speed is approximately equal at each observed

distance along the approaching paths. The degree of dispersion, however, is slightly increased after the installation of rumble strips. Rumble strips apparently do not affect all motorists uniformly.

The number of stop sign violations was materially reduced as a result of the installation of rumble strips.

No significant difference was found in the amount of centerline violations by traffic approaching the intersections after the installation of rumble strips.

A decreasing trend in the number of accidents was found at two locations, presumably as a result of the rumble strip installations. Unfortunately, not enough "after" time has elapsed at the other installations to determine any trends. No significant conclusions can be drawn concerning accidents at any of the intersections, however, because of the erratic accident patterns at the intersections during the past five years.

CRITICAL ANALYSIS:

The rumble strips reduced mean approach speed approximately 2.0 to 3.5 mph but also increased speed variance. They also increased the percentage of drivers who came to a full stop from a total of 37.2% to 63.3%. There were fewer or at least no change in the number of centerline encroachments at 6 of the 7 approaches.

While this paper showed some positive benefits of rumble strips, there remain questions as to cost effectiveness from the standpoint of both installation and maintenance.

R/1.0

REFERENCE: Reiss, M. L., "School Trip Safety and Urban Play Areas," Volume II, Student and Driver Perception of School Trip Safety and Traffic Control Devices, US DOT, FHWA, Report No. FHWA-RD-75-105, November, 1975.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. _X_Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The purpose of the School Trip Safety and Urban Play Areas research project was to develop guidelines for the protection of young pedestrians (5 to 14 years) walking to and from school, entering and leaving school buses, and at neighborhood play. A survey was administered to 354 motorists at school locations in New York, Maryland, and Virginia. Assessments were made of driver perception, attitudes, and behavioral changes when drivers approached and passed through a school zone, using radar speed guns and a free-response survey format. Research findings obtained under the project indicate that young students (5 to 9 years) are over involved in pedestrian accidents and are unaware of, or do not discriminate between, various traffic control devices when compared to older students (10 to 14 yrs). Drivers in school areas do not generally perceive school signs other than the flashing school speed limit signs. School trip safety programs incorporating walking trip maps prepared by traffic engineering personnel permit the school and the parents to focus on a tangible means of improving student safety.

CRITICAL ANALYSIS:

Four sites were employed, one of which was on a two lane rural road. The results showed tht twenty-two percent of the respondents replied that they changed their driving behavior through the area; yet, their was no significant difference in speed between those that said they slowed down and the rest of the sample, while 66% indicated that they saw school-related signs e.g., less than half of the total responses correctly identified the signs that were present. Of all respondents through the four sites, 89% traveled through the area one or more times/week.

The motorist survey showed that 72% said they were driving at or under the legal speed limit and 64% correctly identified the legal speed limit. However, 85% of the drivers whose speeds were obtained were exceeding the legal limit. Local drivers were found to drive at about the same speed as non-residents, but are more aware of signing and children on their way to school. Yet, this increased awareness of the school zone did not cause residents to drive significantly slower than non-residents in the school area.

R/2.0

REFERENCE: Reiss, M. L. and Robertson, H. D., "Driver Perception of School Traffic Control Devices (Abridgment)," TRR 600, 1976, pp. 36-39.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. _X_Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Drivers were found to be not observant of school advance warning and crosswalk signs. In general, the only school signs perceived were active signs with flashing lights, and these did not necessarily modify driver behavior or reduce speed to the level indicated on the sign.

CRITICAL ANALYSIS:

A critique of this research study can be found in the annotation of Reiss, M. L., School Trip Safety and Urban Play Areas. Volume II. Student and Driver Perception of School Trip Safety and Traffic Control Devices. US DOT, FHWA, Report No. FHWA-RD-75-105, November, 1975.

R/10.0

REFERENCE: Renshaw, D. L., and Carter, E. C., "Identification of High-Hazard Locations in the Baltimore County Road Rating Project," Transportation Research Record 753, 1980, pp. 1-8.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade X Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Accident Data by Functional Road Classes

SUMMARY/ABSTRACT:

One objective of the Baltimore County road-rating project was to identify problem sections of county-maintained roadway. A safety rating was determined for each roadway section in the county inventory; sections vary in length and average daily traffic (ADT) as well as in physical and environmental aspects. Two problems in rating roadway sections are the determination of an adequate number of years of accident data and the choice of clear measures of hazardousness. Short sections that have low ADT often produce rates that indicate high hazard, but with low certainty that they are high-hazard sections; however, the use of a longer sample period may involve many changes in the roadway's physical characteristics, which may invalidate results. The study team attempted to determine which roadway sections were most hazardous and represented the most critical needs. The relationship of the exposure available for analysis on each roadway section, the required exposure for the level of analysis, and the years of accident data required were studied and summarized in a nomograph. A three-year accident data sample was selected by using this nomograph. High-hazard sections were first identified with accident-number and accident-rate measures, and then they were ranked. More sophisticated measures were used to rate and rank sections for hazardousness, and all rankings were compared. Finally all sections were reevaluated, and those that were hazardous with a high level of certainty were identified.

R/10.1

CRITICAL ANALYSIS

The objective of this study was to identify specific sections within Baltimore County that were definitely hazardous according to accident statistics. The article goes into detail with regard to the particulars of this identification process. Apparently, this data is on computer. From it, the relationship between accident rates and various roadway characteristics may be discernible.

The only data presented that may be of some interest concerns accident rates and the number of locations that are "hazardous with certainty" for different functional classes of roads in Baltimore County; the table below presents this information.

Functional Classification	Average Accident Rate	Locations Hazardous with Certainty
Major Arterials	3.46	7
Minor Arterials	2.93	18
Collectors	3.02	12
Local Roads	4.21	1

* Note that the sites in the last column could be visited.

R/12.0

REFERENCE: Richards, H. A., and Hooks, D. L., "Establishing Priorities for the Installation of Traffic Control Devices: The Rail-Highway Intersection Example," HRB Special Report 107, 1970, pp. 70-80.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone _X_ RR Crossing ___ Other Cross. _X_ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance _X_ Other

OTHER DESCRIPTORS: Cost

SUMMARY/ABSTRACT:

From a study of protective device installations at rail-highway intersections, a procedure is developed that establishes priorities for the improvement of safety at these intersections. Techniques are reported for computing installation and maintenance costs, prorated annually, of rail-highway traffic control devices. In addition, the benefit-cost relationship is demonstrated, i.e., the intersections are ranked in descending order on the basis of the relationship between incremental benefits, or the reduction in accident costs, and incremental costs of additional protection. Although the paper does not deal with all factors included in the economic evaluation of safety at intersections, it contains procedures that should be of use to city, county, and state traffic engineers in establishing priority ratings for the installation and improvement of traffic control devices at highway and street intersections as well as for rail-highway intersections.

CRITICAL ANALYSIS

The procedure described in this article provides a method of comparing the relative cost of traffic control alternatives at rail-grade crossings with the benefits provided by each of the respective information systems.

R/12.1

The equation for computing costs considers hardware installation and maintenance costs as well as a capital recovery factor. The equation for computing benefits considers an effectiveness rating for each device and accident costs and rates. Benefits divided by costs provides a relative priority index.

R/11.0

REFERENCE: Ritchie, M. L. "Choice of Speed in Driving through Curves as a Function of Advisory Speed and Curve Signs." Human Factors, 1972, 14(6), pp. 533-538.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent Horizont. X Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass X Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: Speed Choice

SUMMARY/ABSTRACT:

Fifty drivers drove through 162 curves on a 110 mile course on Ohio rural highways. They drove faster and produced more lateral acceleration when (a) a curve sign was present and (b) an advisory speed sign was present than under the opposite conditions. Drivers exceeded advisory speeds of 15 to 35 mph, but did not exceed advisories of 45 and 50.

CRITICAL ANALYSIS:

Of the 162 curves, 79 had signs on the approach and 83 had no signs at all. Sixty-eight of the 79 curves with signs also had advisory speed plates ranging from 15 to 50 mph. The dependent variables were the maximum lateral acceleration on the curve and the forward velocity at the time of the peak acceleration. The latter variable was used to group curves according to the average "curve speed" at the peak.

It was found that curve speed was inversely related to lateral acceleration, i.e. as curve speeds increased, drivers tolerated lower levels of acceleration. With regard to curve warning signs it was found that significantly higher levels of lateral acceleration were tolerated on curves with signs than on curves without signs and significantly higher levels of lateral acceleration were tolerated on curves with speed advisories than on curves without such advisories.

The 11 curves with signs but no advisories seemed to be particularly influential in inflating the F ratio for the sign/no sign effect, implying that the highest levels of acceleration were tolerated on curves with signs and no advisories. A comparison of curve speeds with advisory speeds indicated that below 40 mph the advisory is exceeded but above 40 it is not. For the curves with advisories of 15 through 35, the recorded speed was at least 2 standard deviations faster than the advisory. When the advisory was 40 or 50, the recorded performance was very close to the recommended speed. The recorded speeds for the three signs 35, 40, and 45 were found to differ from each other by less than 1 standard deviation although the 10 mph difference of the 35 and 45 sign values is more than two standard deviations.

The author notes that the shape of the V - g curve was the same for curves with signs versus without signs. Further, the effect of the V - g relationship was judged as stonger than the effect of the speed advisories. The author infers that the effect of the signs is to reduce driver uncertainty and allows the driver to proceed in greater confidence.

The author concludes that: "It appears likely that the speed choice is a complex interrelation between personal, vehicle, and roadway variables which provide the driver with a subjective estimates of safety or stability. Lateral acceleration appears to be a key variable in this judgment along with an increase in safety margin as speed increases. In this framework the role of roadway signs may be seen as reducing uncertainty and thereby increasing the confidence with which the driver proceeds."

The results of this study suggest that when driver uncertainty about a curve is at a maximum, the level of lateral acceleration that he will tolerate in the curve will be at a minimum. This would imply that the use of lateral acceleration as a measure of the effect of driver information systems for curves is not appropriate.

R/4.0

REFERENCE: Rockwell, T. H. and Hungerford, J. C., "Use of Delineation Systems to Modify Driver Performance on Rural Curves," Final Report. US DOT, FHWA and Ohio Department of Transportation, Report No. FHWA-OH-79-007, August, 1974.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	X LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This research was initiated to show if roadway delineation systems could be designed to affect driver behavior in negotiating rural curves at night through early warning and better lane guidance. After laboratory tests in lateral and vertical placement effectiveness of delineators and field evaluation of various delineator types, six systems were deployed on six rural curves to ascertain before-after delineation treatment effects, effects due to curve direction, day versus night, high speed drivers, and the effect of treatment on test driver visual search. Road user velocities at six points before and into the curve as well as curve lateral placement were recorded. Results indicate that novel use of delineators can provide positive perceptual influences and cause drivers to reduce speeds prior to and into rural curves. Centerline encroachments are usually reduced with these treatments. The better systems were raised pavement markers (life lites), ascending in/out deployment of delineators and transverse striping. High speed drivers were shown to react differently than the average driver suggesting they may make use of delineators to further their high speed objectives. While novel delineation systems were more effective in velocity reduction and lateral placement in the curve as compared to the design in the Manual for Uniform Traffic Control Devices, (MUTCD), the MUTCD system was significantly better than the same curves without any delineation. The effects of these delineation treatments were insignificant 30 days after installation suggesting effects would be found for transient or unfamiliar drivers rather than local drivers.

R/4.1

CRITICAL ANALYSIS:

Laboratory simulation techniques were used to ascertain the better configurations of delineators to be post mounted. The "jury technique" was employed to evaluate the subjective responses of 51 subjects. The four systems selected for field testing from this evaluation were:

1) Six (6) standard (3" white) delineators in an ascending in-out configuration,

2) Four (4) carsonite (6' long, 3" wide, flat reflector posts) delineators with a large curve warning sign,

3) Three (3) large chevrons in a standard configuration, and

4) Six (6) standard delineators in a standard configuration.

Two other systems were evaluated:

5) Life lite delineators (raised pavement markings mounted on the centerline,

6) Traverse reflective stripes with decreasing spacing through the curve.

The field tests consisted of speed data collected using radar at six locations and lateral placement data collected using tape switches at one location. The four performance measures used in the evaluation were: 1) speed approaching curve; 2) speed reduction measured from the approach to the location approximately near the tape switches located in the curve; 3) lateral placement at the tape switches; 4) speed approximately halfway through the curve.

A total of 10 evaluations were made involving the six systems and the six sites. It was found that: 1) the three large chevrons were not very effective. They produced little effect on any of the speed measures and had little positive influece on centerline encroachments. Similar results were obtained with carsonite systems.

Standard delineators in a standard (MUTCD) configuration positively affected speed through the curve, speed reduction and encroachments, and were particularly effective on sharp rural curves. The treatment involving an ascending "in-out" pattern (AIO) seemed to produce the desired perceptual effect on drivers, causing a significant overall reduction from approach speed to the speed in the curve. This system also tends to result in a shift to the right in the visual search pattern.

The transverse stripe treatment had a tendency to decrease approach speed and to cause a downward shift with test drivers' eye movements. High speed drivers seem to be affected in a positive way most by the AIO and "life lite" delineation systems, (i.e., reduced velocities). Finally, the "life lite" system was most effective with regard to overall speed reduction and lateral placement.

Long term effects were much less than the immediate effect deserved, suggesting adaptation by local drivers. Since rural accidents are often associated with unfamiliar drivers, this result does not negate the safety benefits of the treatment. However, the cost effectiveness of the treatments would be dependent upon the percentage of unfamiliar drivers using the site.

R/5.0

REFERENCE: Rockwell, T. H., Malecki, J., and Shinar, D., "Improving Driver Performance on Rural Curves Through Perceptual Changes - Phase III," Ohio Department of Transportation, Report No. Ohio-DOT-08-75, March, 1975.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. _X_ Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	_X_ LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_ Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

As a follow-up to Phases I and II of this project, five rural curves in Delaware County were modified to influence user behavior. Two were given special signing, three special pavement markings: one transverse striping, one a widening of the inside edge marking at the curve and one with markings designed to make the roadway appear narrower at the beginning of the curve (Wundt illusion). Both regular road users and test drivers in instrumented vehicles were studied before and after the modifications of the site and thirty days after modification at three positions prior to the curve. Test driver visual search patterns were affected by the pavement markings but not by the special signing. Early curve detection allowed a wider dispersion of fixation. Road user mean speed reductions were noted early for the widened inside edge marker and inter car speed variation was substantially reduced by this treatment, although the effect was gone thirty days later, suggesting that transient rather than local driver behavior would be affected. The Wundt illusion produced speed reductions late (at the beginning of the curve). Signs had little road user effect. What was most obvious was the reduction in the high speeds as a result of the modifications.

CRITICAL ANALYSIS:

Speed profiles were unobtrusively measured at four points (640 ft from curve, 320 ft from curve, just prior to curve, and immediately following the modified curve) for five test sites. Velocity and lateral placement in the curve was recorded via a hidden 16 mm movie camera. Five test drivers were also employed in instrumented vehicles, which measured driver's eye movements and fixations, control movements (gas pedal application) and vehicular dynamics (velocity, lateral acceleration and distance travelled). Modifications were: (1) "Deceptive Curve" warning sign 400 ft from curve, (2) Same as [1], only preceded by a diamond shape on road 200 ft ahead, (3) Gradual widening on inside edge marking to a maximum of 14" at apex of curve, (4) Transverse stripes decreasing in stripe spacing prior to curve, (5) Wundt's Illusion [stripes spreading out from the median]. Curves ranged from 7° to 19° and were approximately 0.04 miles in length with short tangent sections. Three were left curves and two were right curves.

It was found that the effects of the pavement marking modifications on speed reduction prior to the curve were much greater than the effects of the sign modifications. In general, these effects were site specific. Also, the effect of the transverse marking modification was much more pronounced for trucks because the increased driver eye height enhanced the modification.

There were changes in search patterns after the modifications. However, these were not associated with any substantial speed differences. While mean speed differences were slight, there were reductions in speed variances for the Wundt illusion modification and the edgeline modification and drivers traveling at higher speeds were most affected by the modification.

The accent of the inside perspective angle (edgeline and modification) had the greatest effect of all the modifications. However, the effect of the modifications were, for the most part, not found thirty days later.

The eye movement data showed that there were relatively few eye fixations on the curve warning sign, in spite of the fact that one of the signs was unique in terms of the "DECEPTIVE CURVE" message. There are two possible explanations for this. First it is possible that the sign was located in an area where the drivers were more concerned with acquisition of other cues relating to lane placement, degree of curvature, oncoming vehicles, etc., and that this information had greater priority than the "advance" warning. The other explanation is that drivers detected the shape and color of warning sign peripherally or at a glance and processed the information in general terms as a "curve warning." Certainly it is unlikely that the message "DECEPTIVE CURVE" would have sufficient "glance" legibility to be read without a fixation. Either explanation suggests that the location of curve warning signs relative to the curve itself should be far enough upstream so that drivers are not yet into the type of search pattern which characterizes curve driving. The latter exlanation also suggests that a "unique" curve warning sign should perhaps be more unique than simply using a unique legend; otherwise drivers may not actually acquire the actual message but simply assume that, because of the conventional shape, size, and color, it conveys a typical message.

RR/20.0

REFERENCE: Rosenbaum, M. J., Byington, S. R., and Basham, W., "Speed Control In Rural School Zones," TRR 541, 1975, pp. 12-25.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. _X_Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Initial results are presented of a comprehensive experiment dealing with speed control in a rural school zone on a high-speed, two-lane highway. Data were collected in a school zone located on the Maine Facility, an electronically instrumented roadway where a 15-mph (24-km/h) speed limit is in effect during certain times of the school day. The experiment was to determine the effects on drivers of the Manual on Uniform Traffic Control Devices mandatory and advisory school zone signs, including beacon flashers, and the effect of a new, dynamic speed violation sign. Speeds for automobiles and large vehicles were measured for one dynamic and four passive sign conditions when the 15-mph (24-km/h) speed limit both was and was not in effect. No enforcement was used during the experiment. Results showed that (a) vehicle velocities at the school were less when the driver was advised by flashing beacons that the 15-mph (24-km/h) speed limit was in effect, (b) the average vehicle velocity was relatively constant at the school when the speed limit was not in effect, and (c) the lowest average speeds at the school (34 mph (55 km/h)) were obtained when the dynamic speed violation sign was used.

CRITICAL ANALYSIS:

Traffic volumes ranged from 600 to 800 vehicles for the 8 1/2 hr school day. School buses entered or exited the school entrance 22 times a day. Speed limit before and after school zone was posted at 60 mph. Only data collected on east-bound non-turning vehicles which were not impeded by leading vehicles or turning vehicles from either direction were used in the analysis. Data from 24 days of clear visibility were selected to balance the exposure of drivers to the experimented signs, the time-of-day exposure and the scheduled time periods of data collection.

The speed profiles and signing conditions are attached for review. The general results are as follows:

Sign Condition 2:

Drivers started to reduce speed sharply at about 400 ft in advance of the flashing school speed limit sign. They reduced speed to about 40 mph.

Sign Condition 3:

No significant differences from # 2.

Sign Condition 4:

Drivers started to reduce speed as much as 800 ft. in advance of the flashing reduced speed ahead sign. 3- to 5-mph lower average average speeds were experienced at the school intersection compared to # 2.

Sign Condition 5:

A more gradual speed reduction and an additional 2-mph lower average speed was experienced at the school intersection compared to #4.

Sign Conditions 2, 3, 4, and 5:

The rate of speed reduction was approximately 1.25 ft/sec, which is approximately the deceleration rate achieved with the engine engaged and no brakes applied.

All Sign Conditions:

When the school speed limit sign was in effect, the differences in the average speeds between adjacent vehicle-sensing stations became significant no closer than 700 ft to the school.

All Sign Conditions:

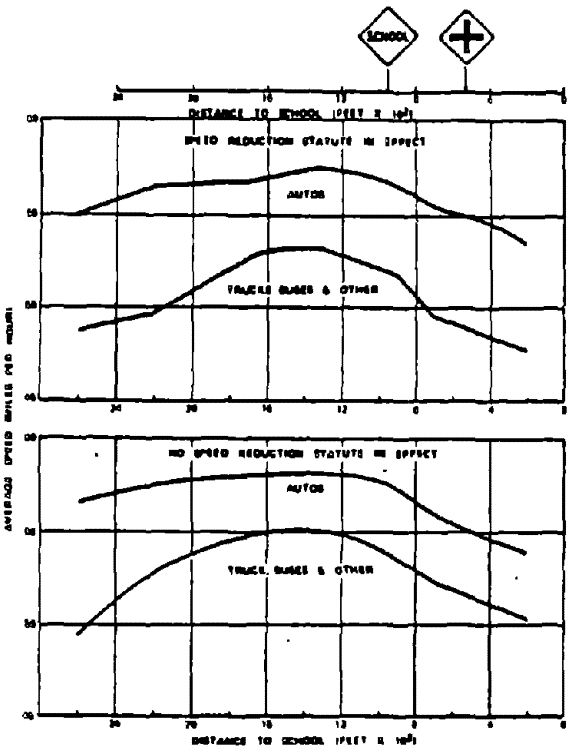
The difference in average automobile speeds, between when the school speed limit was in effect and when it was not,

- was not significant at any station for sign condition 1,
- became significant at 1300 ft. to the school for sign conditions 2 and 3,
- became significant at 2200 ft. to the school for sign conditions 4 and 5.

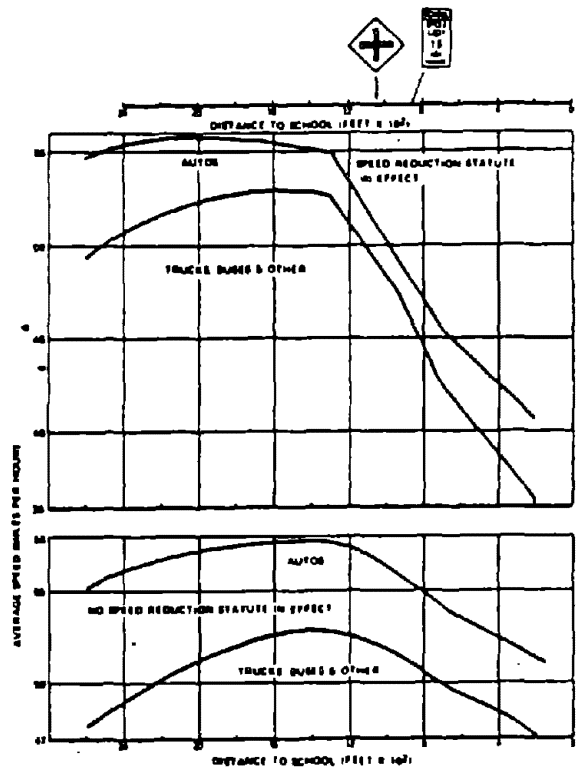
A speed of 15 mph for rural school zones where there are very few children walking to the school area and where adjacent posted speed limits are 50 to 60 mph apparently cannot be achieved by MUTCD signing.

The Advance School Zone sign had no significant effect on speed reduction over that experienced with only the School speed Limit When Flashing sign. As with most warning signs, the impact or effect may not be measurable in terms of traffic performance data.

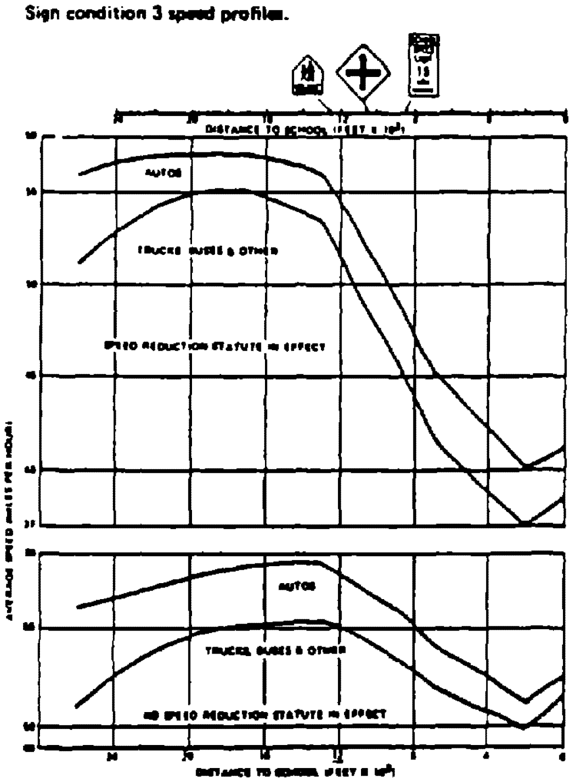
Sign condition 1 speed profiles.



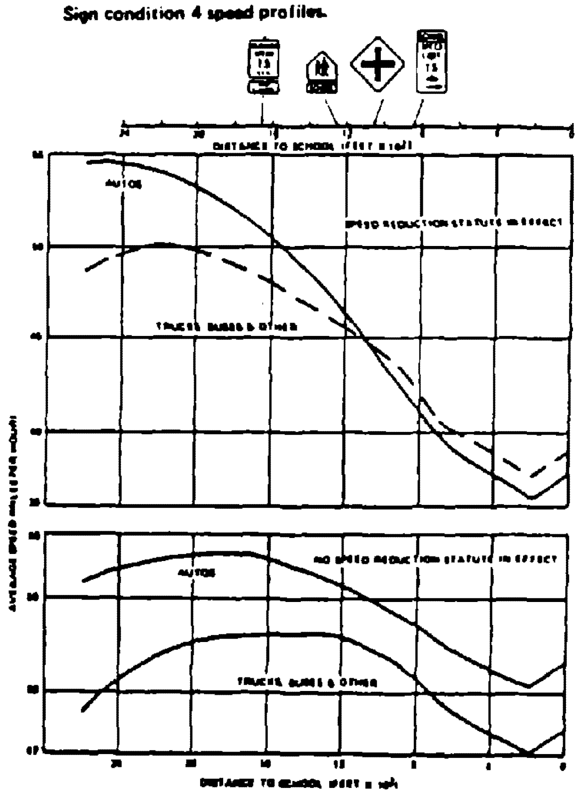
Sign condition 2 speed profiles.



Sign condition 3 speed profiles.



Sign condition 4 speed profiles.



Sign condition 5 speed profiles.

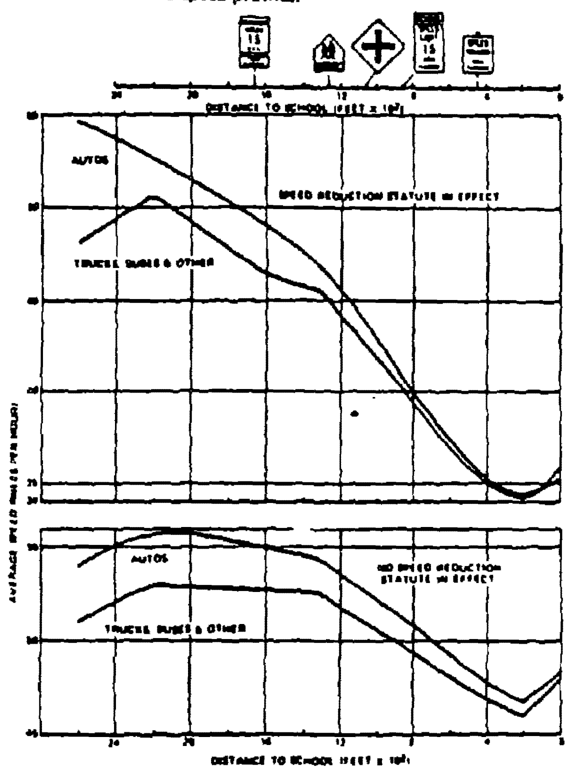
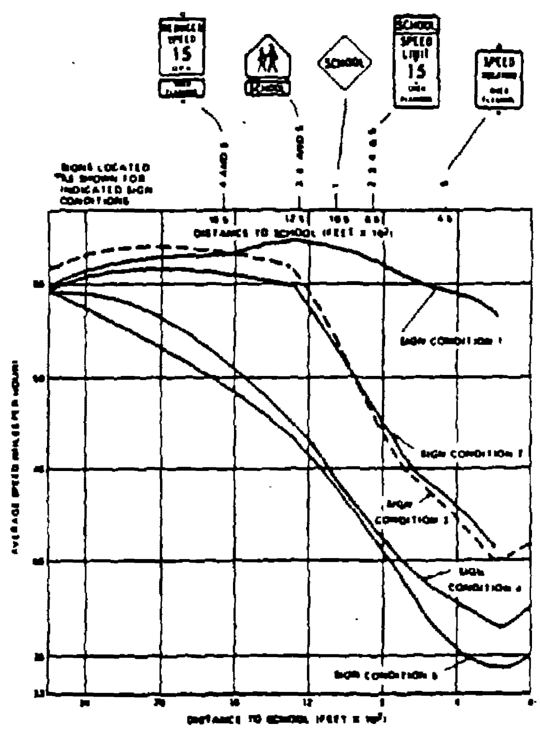


Figure 9. Automobile speed profiles when statute in effect.



Ave. Speed reduction, overall average speeds, and speed variance by sign condition, as measured from 2600 ft to 200 ft from the school intersection

Speed Statute	Sign Condition	Speed Reduction (mph) Automobiles	Speed Reduction (mph) Other	Average Speed (mph) Automobiles	Average Speed (mph) Other	Speed Variance (mph) Automobiles	Speed Variance (mph) Other
In effect	1	1.8	1.1	55.8	50.5	8.8	10.4
	2	12.8	13.0	50.1	48.9	11.5	9.9
	3	15.4	14.3	48.2	46.1	12.1	11.4
	4	18.1	11.0	44.2	43.8	11.6	8.7
	5	20.4	13.8	43.0	41.3	12.2	10.8
Not in effect	1	1.8	-0.9	56.6	52.6	8.7	7.5
	2	3.7	0.5	55.3	50.3	9.5	7.5
	3	4.8	1.2	55.2	52.7	8.8	8.1
	4	5.4	1.9	54.1	50.3	9.6	8.9
	5	7.2	5.2	51.5	49.8	10.4	9.9

R/6.0

REFERENCE: Rowan, N. J. and Woods, D. L., "Diagnostic Studies of Highway Visual Communication Systems," Final Report, Texas Transportation Institute, Texas A & M University, Report No. 606-9F, 1972.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance _X_Other

OTHER DESCRIPTORS: Evaluation

SUMMARY/ABSTRACT:

This report emanates from a multi-state sponsored research project entitled "Diagnostic Studies of Highway Visual Communication Systems." The objective of the research was to examine current driver communication practices from the viewpoint of the highway user and suggest improvements, thereby improving highway safety. The method for evluation involved the use of multidisciplinary study teams driving selected unfamiliar study routes and reporting the difficulty associated with the communication system.

It is concluded that the roadway geometry is the primary source of information to the driver and that the formal communication devices (i.e., signs, signals, and markings) serve a supplementary function in the driver communication system. Further, it is concluded that a vast majority of the driver communication problems can be effectively solved within the existing standards provided that the communication devices are properly integrated with geometry during the design process.

The importance of expectancy in determining the effectiveness of traffic control devices was confirmed and methods of designing to meet the driver's expectancy are suggested.

R/6.1

CRITICAL ANALYSIS:

This report presents tips for local highway engineers. These were selected by the Project Policy Committee to serve as an educational tool of driver expectancy concepts. The tips pertinent to our project are:

- The addition of an advance name plate to the intersection warning sign is highly recommended.
- Consideration should be given to the use of raised reflective markers for all installations where snow removal methods will permit or where snow is not a problem.
- Continuous edge striping should be seriously considered for use on virtually all facilities (The MUTCD requires only multilane rural roads to have edgelines).
- Use extraordinary edgelines to guide the driver past hazards.

Drivers in fact use the roadway geometry as their principal cue. Then signs/markings act as redundant information sources when the information is obtainable from the geometry. This could account for the lack of measurable effectiveness of signs when driver performance is used as the evaluative measure. Signs may be effective only during reduced visibility or in restricted sight distance situations.

This fact should be taken into consideration in identifying driver information needs in the current study.

R/7.0

REFERENCE: Ruden, R. J. and Wasser, C. F., "Motorists' Requirements for Active Grade Crossing Warning Devices," US DOT, FHWA, Report No. FHWA-RD-77-167, October, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone _X_ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	_X_ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report describes a two-year study of some of the basic problems involved in improving the design of active warning devices intended to make motorists more aware of grade crossing hazards. Emphasis was placed upon improvement of the attention-getting aspect (conspicuity) of active crossing warning devices which was presumed to positively correlate with improvements in grade crossing safety. An indoor laboratory test was conducted in the FAA Low Visibility Research Facility located at the University of California. In excess of 150 subjects gave over 20,000 responses to flashing light displays. Results were analyzed to determine effects of color, flash rate, brightness, size and placement under daylight, darkness and daytime fog conditions. The laboratory tests resulted in development of two improved devices which were field tested on actual grade crossings. The first device consisted of an array of three eight-inch white (clear) strobe lights added to a standard flashing warning system at a high accident rate urban crossing in Richmond, CA. The second was a gate arm add-on device consisting of three small strobes, red, white (clear) and blue in color installed at a rural highway grade crossing with high speed truck and automobile traffic. Due to project constraints, no long term safety improvement analysis could be conducted. Because there was no evidence of driver confusion during the conduct of these field tests, it was concluded that colored lights other than red can be used in moderation as add-on to existing active crossing warning devices to increase the attention getting property of the warning system. The high composite (not from a single source) flash rate devices that were installed did not result in any erratic driving behavior on the part of approaching motorists.

R/7.1

CRITICAL ANALYSIS:

The use of the types of devices tested would be restricted to high-volume train crossings and/or high-volume, high speed rural roadways. In other words, the devices will be considered as "special" treatments and will not be considered as candidates for widespread application.

R/8.0

REFERENCE: Russell, E. R., Michael, H. L. and Butcher, T. A., "Driver Reaction to Improved Warning Signs at a Rural Grade Crossing (Abridgment)," TRR 611, 1976, p. 68.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The primary objectives of this research were: 1) to analyze the effect on motorists of 12-inch activated flashers supplemented by additional strobe lights warning devices at a high accident rural grade crossing and, 2) to relate accident changes to changes in motorist reaction. A photographic system employing a 16-mm variable-speed movie camera positioned on each approach approximately 750 ft from the roadway and 600 ft from the railway track was used to obtain spot speeds at eight points on each approach. The study concluded: 1) that the new devices produced consistent lowering of mean entry speeds 1100 ft from the crossing, possibly because the greater visibility of the gate arms in the raised position made drivers aware of the crossing sooner; 2) that the vehicle approach speed profiles were independent of signal type; and 3) that no deceleration rates observed could be classified as emergency stops.

CRITICAL ANALYSIS:

Deceleration rate at a RR crossing does not appear to be sensitive as a measure of effectiveness for evaluating crossing information systems. The authors state that mean speed is a relatively weak measure of effectiveness because they do not isolate the occasional unsafe driver. To the extent that it is only the occasional unsafe driver that produces problems at RR grade crossings, the use of driver performance measures for evaluation of crossing information would not appear to be very cost-effective.

R/14.0

REFERENCE: Rutley, K. S., "Advisory Speed Signs for Bends," Department of the Environment, TRRL Report LR 461, 1972. Crowthorne: Transport and Road Research Laboratory.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. X Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance X Other

OTHER DESCRIPTORS: Speed Advisories and Warning Signs

SUMMARY/ABSTRACT:

Panels showing advised maximum speeds for bends have been attached to bend warning signs on some 150 bends in East Sussex, Dorset, and Worcestershire. Observations of their effects on speeds and on accidents have been made over a period of two years since they were erected.

Although there appeared to be a reduction in the numbers of accidents on bends in all three counties when compared with the numbers of all other accidents on A roads in the counties, the reduction was only statistically significant in Dorset. It is suggested that the greater effect in Dorset may be due to the high number of non-local drivers in the summer months.

Average speeds of vehicles in the bends were affected by the signs when the signs showed a speed different from the mean speed of vehicles before the signs were erected. The mean speed moved toward the advice given by the sign.

CRITICAL ANALYSIS:

For this study, speed advisories for signed horizontal curves were determined on the basis of "comfortable radial acceleration" through the curve according to the criteria established by Palmar (1958). These criteria range from about 0.26 g at 15 mph to 0.18 g at 40 mph (via visual inspection of curve provided).

Speed data obtained at each of the 150 bends signed with advisories were recorded: (1) before the bend warning signs, (2) after the bend warning signs but before the advisories, (3) 1 week after advisories, (4) 1 month after advisories, and (5) 1 year after advisories. Comparison of measures (1) and (2) indicated that the warning signs had no effect on mean speeds.

Comparison of measures (2) and (5) indicated that there is a significant shift in mean speeds toward the advisory speed, when the advised speed was different from the mean speed of vehicles prior to the posting of the advisory speed. On slow bends, where the speed advised was below the previous mean speed, vehicles tended to slow down more than before; and on fast (40-45 mph) bends, where the reverse was the case, the mean speed of vehicles in the bend was higher than before.

The author concludes that the comfortable radial acceleration curve, as a function of speed, may be steeper than indicated by Palmer (1958). Finally, an analysis of variance showed that the spread of the speed distributions was not affected by any of the signs.

R/15.0

REFERENCE: Rutley, K. S., "Control of Drivers' Speed by Means other than Enforcement," Ergonomics, 1975, 18, pp. 89-100.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent Horizont. X Curve ___ Vertical Curve ___ Grade X Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone X Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: Speed Advisories and Transverse Stripes

SUMMARY/ABSTRACT:

Many accidents are caused by drivers going too fast for the conditions then prevailing. Mandatory speed limits are one way of controlling drivers' speed, but they have their limitations. A fixed speed limit is not necessarily suitable for all times of the day and night, nor is it suitable when the reduced speed is only required over a very short length of road such as on a bend or the approach to a road junction.

This paper discusses the use of advisory speed signs, the effect of having a speedometer which can be seen whilst the driver is looking at the road ahead, and finally the use of carriageway markings which give the driver the illusion that his speed is increasing, causing him to slow down.

CRITICAL ANALYSIS:

This author conducted three independent studies to determine the effects of advisory speed signs, heads-up display speedometers, and transverse pavement markings, respectively, on drivers' speed. The findings are discussed below.

Advisory Speed Study: Advisory speed signs carrying the message "Maximum Speed XX" were attached to curve warning signs on 150 curves in three counties in England. The speed shown was the maximum speed which still gave a comfortable radial accleration for drivers and passengers. These criterion values had been previously determined under controlled conditions and ranged from 0.26 g at 25 km/hr to 0.18 g at 65 km/hr. These values were found to be quite insensitive to type of car.

The effects of the advisory signs were observed over a period of 2 years. The data indicate that in comparison to mean speeds prior to the signs, the mean speeds with the signs was closer to the advised speed. Also, there was an absolute reduction in the number of accidents at the bends in one county and an effective reduction in the other two counties in comparison to accident rates on Class A roads elsewhere.

Head-up Display Speedometers: In this study, 63 volunteer subjects drove two identical cars - one with conventional speedometer, the other with the heads-up display - over a 160 km route with 19 signed bends. With the heads-up display, the vehicle speed was projected in digital mode onto the windshield in front of the driver such that the numerals were superimposed on the road ahead. Results indicate that both mean speed and 85th percentile speeds of the vehicles when negotiating the bends were lower for the vehicles fitted with the heads-up displays than for the other cars.

Carriageway Markings: A series of transverse pavement lines were applied at 8 sites at the ends of lengths of a high speed dual carriageway. Each site had 90 yellow transverse lines, each 0.6 m wide covering the last 0.4 km of road before a roundabout. Initial spacing was 7 m reducing exponentially to 2 m. Data are still being collected.

Results to date indicate that at Site I, there was a 10% reduction in the average speed of vehicles entering the roundabout during daylight and a 19% reduction at night. At Site II, one year after application of the lines, mean speeds were 16% lower and 85th percentile speeds were 8% lower (immediately after application, these reductions were 30% and 23%, respectively).

R/15.2

Large reductions in the numbers of traffic accidents at these sites are also being observed. Testing of this marking system has been extended to 50 other sites.

S/1.0

REFERENCE: Safety Operations Unit, Traffic and Safety Division, NYDOT, "Passing Zones and Intersecting Roads," New York State Department of Transportation, October, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone X No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The study investigated intersections of 2-lane rural state highways and local roads in passing zones. Concern was raised when, as a result of a statewide survey, many no-passing zones were eliminated at sideroads. It was found that most accidents result from vehicles turning left being struck by overtaking vehicles and not from vehicles exiting the sideroad.

Guidelines to assist in the investigation of specific intersection striping changes are offered.

CRITICAL ANALYSIS:

The investigation revealed that eight passing accidents occurred at 7 of 66 intersections investigated over a period of three years, but there were no passing related accidents involving motorists entering the state highway and interfering with a passing maneuver.

Seven of the eight accidents involved a motorist trying to pass another motorist turning left into the side road.

The guidelines that were developed may be useful for the current study. These are shown below.

GUIDELINES

The following are guidelines which should be used when reviewing intersections for the removal of a passing zone:

- Any investigation should concentrate on left turning mainline movements. T-intersections to the right should not be investigated unless the turning movements at the intersection are determined to be high enough to warrant further investigation based on possible signalization needs.

- Intersection warning signs may be warranted on the state system in advance of any T-intersection to the left or 4-way intersection when a passing zone is present.

- A passing zone should be eliminated at an intersection if the more restrictive striping does not eliminate the subject passing zone but only shortens the subject passing zone and/or the travel time through the subject section is not reduced.

- The functional classification of the side road should be reviewed. Any side road with a functional classification higher than local should be a candidate for passing zone elimination.

- Passing zones should be eliminated if the passing related accidents at the subject intersection for the last three years are greater than the following rates:

S/1.2

AADT	Accidents
5000 or less	1
5000 - 10,000	2
10,000 or more	3

S/3.0

REFERENCE: Sanders, J. H., "Driver Performance in Countermeasure Development at Railroad-Highway Grade Crossings," TRR 562, Transportation Research Board, 1976, pp. 28-37.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_ RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This paper summarizes the findings of a field demonstration study to determine the requirements for grade-crossing-accident countermeasures. Information was obtained on driver behavior, knowledge, and attitudes by using the traffic-evaluator system, time-lapse photography, and questionnaires. A review of the safety-related factors brought to the grade-crossing situation by the driver also was made. The review included licensing and education, safety programs, attitudes and habits, and driver-vehicle capabilities and limitations. An extensive analysis of these data suggested countermeasure concepts and determined target populations for countermeasure intervention. Behavior measures were isolated that may be used to discriminate among candidate countermeasures when they are applied in the field-evaluation program presented in the study.

CRITICAL ANALYSIS:

(This paper is a summary of Sanders, J. H., Kolsrud, G. S. and Berger, W. G., "Human Factors Countermeasures to Improve Highway-Railway Intersection Safety," Biotechnology, Inc., June, 1973).

Nine grade crossings were evaluated using the TES system, time lapse photography and visual observations (of head movement, signal activations, train arrival times and speed readings with radar) which were coded onto the magnetic tape. A systematically selected sample of motorists (N = 1,267 also completed a questionnaire).

The four MOE's used to evaluate grade crossings were: head movement, speed reduction (measured over a section of 500 ft. from the crossing, distance from the track at which maximum deceleration occurred, and mean speed at the crossing. The authors state that the sensitivity of these measures to a change in protection devices was found only for crossings where sight distance is restricted until the driver is within 150 ft. of the crossing. The noted lack of sensitivity is, at least in part, due to the fact that a substantial portion of the sample was made up of drivers who were familiar with the crossing. As such, the behavior was based more on past experience than on the protective devices used. This is reflected in the speed reduction measure which showed that the measure was directly related to crossing roughness.

Since speed reduction was calculated over a 500 foot area beginning at the track, only familiar drivers would have reliable experiential information as to the roughness of the crossing itself. Although even unfamiliar drivers may slow on the basis of general past experience with rough crossings. This version of the study report did not specify differences between familiar drivers and unfamiliar drivers as determined from the interview sample. The issue of driver familiarity with the characteristics and/or train volume of the crossing is something which must be seriously considered in the current study if RR Crossing information systems are studied using subject drivers.

Another interesting finding that could perhaps be capitalized upon in designing Crossing information systems, is that, on the average, drivers underestimated their speeds by about 30%. Whether this underestimation is an artifact of the questionnaire i.e., drivers not wanting to admit that they were driving at a speed they feel would be considered unsafe, or whether it was because they were searching for trains and not attending to the speedometer or speed cues is not known. However, if the reason is the latter, it is possible that presentation of speed advisory information in conjunction with the other information would increase the probability of speedometer use and would result in an overall speed reduction on the approach to RR grade crossings.

S/4.0

REFERENCE: Sanders, J. H., McGee, H. W., and Yoo, C. S., "Safety Features of STOP Signs at Rail-Highway Grade Crossings," Volume II. Technical Report, US DOT, FHWA, Report No. FHWA-RD-78-41, March, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_ RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design _X_ Placement _X_ Performance _X_ Other

OTHER DESCRIPTORS: Application

SUMMARY/ABSTRACT:

The study objectives of this research project were to determine the advantages and disadvantages of selective use of highway stop signs as safety improvements at rail-highway grade crossings and to develop guidelines for their appropriate use or non-use.

The study elements included a literature review, inventory and accident analysis, and field studies. Literature and inventory investigations were performed to determine current uses of stop signs. Accident analyses were performed to compare accidents for crossings with crossbucks only to accidents for crossings with crossbucks and standard highway stop signs. Field studies were performed to compare driver behaviors for crossbuck-only crossings to driver behaviors for similar crossings having a standard highway stop sign in addition to the crossbuck. Driver behaviors included speed profiles, looking behavior, and observance of stop signs.

The study results indicate that stop signs are used more frequently in urban areas and crossings having stop signs tend to have higher train

volumes. Accident analysis results indicate that rates for stop sign crossings are lower than rates for crossbuck-only crossings to driver behaviors for higher vehicle-train exposure values. Field studies show that stop signs, when properly used, result in improved driver behaviors adequate for the detection and avoidance of trains.

The study conclusions suggest that stop signs should be applied selectively only at hazardous passive grade crossings and should not be used indiscriminately at all passive grade crossings. Requirements for effective use of stop signs at grade crossings are listed in the report.

CRITICAL ANALYSIS:

Stop signs at RR grade crossings were evaluated at 17 stop sign and 8 crossbuck sites, using the TES system and observation of stopping and looking behavior at the grade crossing and, for some sites, intersections near the crossing.

It was found that significantly higher percentages of drivers stopped and looked at crossings with stop signs that at crossings with crossbucks. Drivers also reduced speed more at stop sign crossings than at crossbuck crossings. These values are shown below for rural sites:

		LOOKING BEHAVIOR	
	Percent Not Look	Percent Look	Total Number Sampled
Crossbuck Controlled Crossings	51.1	48.9	601
Stop Sign Controlled Crossings	22.3	77.7	1752
		STOPPING BEHAVIOR	
	Percent Not Stop	Percent Full Stop	Total Number Sampled
Crossbuck Controlled Crossings	89.4	10.6	601
Stop Sign Controlled Crossings	54.2	45.8	1752

It was also found that the presence of a STOP AHEAD warning sign not only alerts drivers who do not expect to stop but also lends a large measure of credibility to stop sign installation. Crossings with advance STOP AHEAD signs exhibited significantly greater looking and stopping behavior at stop sign controlled crossings than those without STOP AHEAD signs.

Their recommendations are pertinent to our study. Requirements for STOP SIGN installation at grade crossings are shown on an attached sheet. However, when the sight distance measured from the stop line along the track is less than the values shown below, a STOP sign should not be used.

Train Speed (mph)	Distance Along Track (ft)
10	150
20	300
30	450
40	600
50	750
60	900
70	1050
80	1200

When an intersection is within 100 ft of the crossing, then a STOP sign also should not be used. Rather an activated device should be used.

When a STOP sign is warranted, the following placement distance are recommended for the required information devices in rural areas.

Information Source	Distance From Crossing (ft)
Railroad Advance Warning Sign	760-815
STOP AHEAD Warning Sign	Half Distance between crossing and Railroad Advance Sign, but not less 210-215
STOP SIGN	10-15
CROSSBUCK SIGN	Adjacent to STOP Sign
RAILROAD PAVEMENT MARKINGS STOP BAR	As close to tracks as possible, but not less than 10
RAILROAD CROSSING (RXR)	Variable but not less than 50

REQUIREMENTS FOR STOP SIGN INSTALLATION AT RAILROAD CROSSINGS

1) The installation must be believable. The driver must be able to perceive a reason for the stop sign which satisfies his requirements for validity. These requirements include low visibility to train detection, high train expectancy, and enforcement.

2) The vehicle-train exposure value should exceed 100. Translated into trains per day and AADT values, this means that the train volumes must be higher than average and AADT's lower than average. At less than three trains per day, the stop sign should not be used without a compelling reason. Rough guidelines are that stop signs are acceptable for an AADT under 2000, temporarily acceptable while awaiting active protection up to 4000 AADT, and impractical above 4000. The vehicle delay imposed by the stop sign and the potential for vehicle-vehicle conflicts should be acceptable at these levels.

3) The driver should be unable to adequately detect trains unless he nearly stops. It is also necessary that the driver be able to perceive that a stop may be required.

4) The level of enforcement must at least equal that applied to intersection stop signs. The courts must also agree that the offense of failure to stop is equal for grade crossings and intersections.

5) The stop sign must be selectively used so that expectancy is reinforced. If a driver is exposed to improperly used grade crossing stop signs, his respect for those which are properly used will be reduced. (The driver does not confuse intersection applications with grade crossing applications.)

6) A high level of traffic engineering is required so that hazardous traffic conflicts are not created at nearby locations by the grade crossing stop sign.

7) The stop sign installation must be treated as a system, including proper deployment and maintenance of advance warning for both the grade crossing and the stop sign.

8) The crossing must be periodically reviewed to insure that the original conditions which prompted the stop sign use still exist.

Shinar.0

REFERENCE: Shinar, D., McDowell, E. D., Rockwell, Thomas H., "Eye Movements in Curve Negotiation," Human Factors, Vol. 19, Number 1, February 1977, pp. 63-71.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent Horizont. X Curve Vertical ___ Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Eye movements and fixations of five drivers were recorded and superimposed on a videotaped recording of the dynamic visual scene as they drove on a two-lane rural road. The results showed that: (1) on curved roads, the fixation pattern follows the road geometry, whereas on straight roads, the search behavior is less active, and most of the fixations are close to the focus of expansion. The results indicate that in driving through curves drivers direct foveal fixations to lateral placement cues rather than rely on peripheral vision; (2) the process of curve scanning begins in the approach zone prior to the curve itself, suggesting that perceptually the curve negotiating process precedes the curve by several seconds; (3) the search patterns on right and left curves are not symmetrical; visual excursions to the right on right curves are greater than eye movements to the left on left curves; and (4) fixation duration statistics may be related to accident rates on curves. Implications of this study for the location of curve warning signs are given.

CRITICAL ANALYSIS:

This study provides empirical support for theoretically derived arguments by Fry (1968) and Gordon (1966) regarding differences in search patterns on straight and curved roads. Generally speaking, these authors argued that on straight roadways drivers fixate the eyes on the focus of expansion and monitor lateral position peripherally by responding to changes in the relative position of the road edge or edgeline. However, on curved roads the eye fixations shift intermittently from the car, i.e., an "out-in" pattern, using primarily foveal vision to acquire information. The reason for the "out-in" pattern on curved roads is that the direction of the car relative to the focus of expansion is not constant in the approach and curve zones and the driver must rely on cues other than peripheral cues for lateral placement in the lane, while still previewing the road ahead. This study and a previous study by Rockwell (1972) suggest that drivers attempt to maintain a preview distance of 2.5 to 3.5 seconds. It should be noted, however, that the subjects in this study were told to drive at a speed of approximtaly 60 mph. The extent to which the same preview times would obtain on lower design/lower speed two lane roadways is not known.

Another finding was that the scan pattern in the approach to the curve was more similar to the curve scan pattern than to the pattern associated with straight roads. As the authors point out, this suggests that the curve negotiation process perceptually begins well in advance of the curve.

Because of the scan pattern associated with curves the authors suggest that the optimal placement for advisory curve signs may be just prior to the beginning of the curve approach zone. Since in the curve per se the driver is occupied in fixating on the roadway itself for directional guidance and lateral placement cues, the authors suggest that in any case signs should not be in the beginning of the curve itself.

The finding that while in the curve drivers spent significantly more time viewing off-road scenes (27% of the fixations) than the road itself (23% of the fixations) suggests that in the assessment of curvature tree lines, embankments, etc. are potentially useful information sources for drivers; as such these potential sources will be identified in the conduct of the "site" analyses for the current project.

S/5.0

REFERENCE: Shinar, D., McDowell, E. D., and Rockwell, T. H., "Improving Driver Performance on Curves in Rural Highways Through Perceptual Changes," Interim Report, Ohio Department of Transportation, Report No. OHIO-DOT-04-74, 1974.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	X LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The perceptual processes involved in curve negotiation were studied in road and laboratory tests. Visual search patterns and motor control movements were measured on the road, and curve psychophysics, information processing abilities and susceptibility to visual illusions were studied in the laboratory. The major results of the study were a) traditional measures of curve length and central degree were unrelated to accident statistics, drivers' perception of curvature, and drivers' tendencies to decelerate before the curve. b) Two driver-performance indexes of curvature were developed and were found to be significantly related to accidents on curves. Curves' perspective angle (as viewed by the driver) correlated highly with accidents (r = .51) but drivers are relatively insensitve to this information. Eye-movement patterns showed that drivers tend to successively fixate the edge-line of the curve before entering it, indicating that drivers perceptually negotiate the curve several seconds before entering it.

CRITICAL ANALYSIS:

The report covered Phase I and II of this study. The methodology consisted of research conducted on five test subjects driving an instrumented vehicle on the road and on 11 test subjects (including the five test drivers) in the laboratory and statistical analysis of curve-accidents. For the road experiment: eye-movement search and scan patterns were videotaped, and vehicle velocity, brake pedal applications, gas pedal applications, and lateral acceleration in the curves were recorded. The test route consisted of 22 curve and two tangent study sections and was approximately 21 miles in length. While the laboratory experiment is not pertinent to our study; the road test experiment is.

The results of the road tests showed that the visual search pattern as indicated by foveal fixations follows closely that of the road geometry. The curve scan process starts in the approach zone, approximately 2.5 seconds before the curve. Also, when the curve is partially or wholly obscured, drivers rely on contiguous scenery for curvature cues.

Fixation durations are shorter and travel distance between fixations is longer in curves than on the straight road. Both are indicators of increased uncertainty in the curve. The approach section immediately prior to the curve produced eye movements more similar to those in curves than to those on straight roads. Thus, the perceptual process of curve negotiation is assumed to start well in advance of the curve.

A Preview Index (PI) defined as the velocity differential between approach and curve velocity, divided by the length of the approach zone, correlated with accidents, $r = .51$. The more time the driver has to assess the curve; i.e., the longer the approach zone, the lower the accident liability of the curve.

Another performance-based measure of termed Effective Curvature (EC) was developed. The EC is defined as the ratio between maximum lateral acceleration and the squared velocity. This measure also yielded a high correlation with accidents, $r = .57$. That is, curves having $EC < 100$ are considered safe, whereas when $EC \geq 100$, a curve may be accident liable.

One final finding that is perhaps relevant to curve warning warrants was that tree-lined roads elicited slower speed than open roads. While under instructions to drive at 60 mph test driver's average speed was seven miles faster on the unbordered open road, supporting the hypothesis that peripheral structured patterns enhance speed perception and increase the velocity estimation.

The results of an accident analysis are also pertinent. They performed a correlational analysis for a set of 37 high accident curves and 74 no-accident curves. The following variables were used in the analysis: number of curves within 1 mile, maximum angle of curve, maximum length of curve, maximum central degree curvature of curve, type of curve (high/no accident), and accident rate at curve. In general, it was found that the correlations were very small. The multiple-R of number of curves, maximum central degree and maximum angle was only .18 or, in other words, these variables accounted for at most 3% of the variance.

The authors implications about their findings that are applicable to our study and will be considered in developing recommended information system for curves. These are shown on the following pages.

TABLE 15

SUMMARY OF RESULTS AND THEIR IMPLICATIONS FOR HIGHWAY DESIGN

Present Findings Road Studies	Implications for Modifications
1. Drivers scan the road curvature in the approach zone approximately 2.5 seconds before the curve.	Curvature information should be provided in advance.
2. The visual search pattern follows that of the road geometry.	Road geometry should be visible or be conveyed through secondary cues (trees, signs).
3. Drivers rely on secondary cues for curvature when the curve is not visible.	Secondary cues should provide appropriate and unambiguous information.
4. Fixation patterns are not symmetrical on right and left curves and approaches. Drivers concentrate predominantly on the right side of the road.	Information about curvature should be conveyed on the right side of road: Improve markings or signs on pavement.
5. High-accident curves elicit longer fixation durations than low-accident curves; resulting in less area scanned, given a constant speed.	Uncertainty of the visual scene should be reduced on high-accident curves, or approach speed should be reduced to allow more processing time.
6. Fixation rates are higher and fixation durations are shorter on curve and curve approaches.	Provide as much preview information as possible, or reduce approach speed.
7. Curve perception is essentially a sequential process.	Primary problem is to provide the driver with information at the correct time. Curve information should increase as distance to it decreases.

TABLE 15 (Continued)

SUMMARY OF RESULTS AND THEIR IMPLICATIONS FOR HIGHWAY DESIGN

Present Findings	Implications for Modifications
Road Studies	
8. Two driver performance-based measures of curvature (EC, PI) were significantly related to accident frequency.	Test driver behavior can be used to quantify and measure changes in curves' accident liability.
9. Contiguous structure elicits slower speeds than open scenery.	Approach speed can be reduced through the use of roadside delineators.
Analysis of ODOT File	
10. Accident rate is practically unrelated to traditional measures of curve geometry (central angle plus length, r = .13).	Design measures should be based on driver related measures (EC), or perceived curvature (below).
11. There is no strong directionality effect for one vehicle accidents for most high-accident curves.	Most curves are either "good" or "bad" from both directions.
12. Indirect measures of expectancy had very low correlations with accidents (r = .18).	Needs further more direct study.
Laboratory Studies	
13. The error in arc radius estimation is inversely proportional to the length and radius of the arc visible.	Improving sight distance into the curve (i.e., the extent visible) will improve vertical curve assessment.
14. Visual illusions can be combined to enhance or attenuate each other's effects.	Perceptual illusions can be used to enhance perceived curvature.
15. High-accident curves are not perceived as sharper or more dangerous, and do not elicit slower approach speed.	The phenomenal curvature is not related to its accident rate.

TABLE 15 (Continued)

SUMMARY OF RESULTS AND THEIR IMPLICATIONS FOR HIGHWAY DESIGN

16. High-accident curves appear to be more visible than in fact they are, relative to low-accident curves.	Supplement information about the length of the curve can facilitate judgments.
17. High-accident curves have sharper perspective angle (based on inside edge) than low-accident curve.	Vertical curvature may be contributing factor to accidents. Design criteria should include perspective angle.
18. Inside perspective angles vary more between low and high accident curves than do outside perspective.	The emphasis should be in directing the driver's attention toward the inside road edge and improving the delineation.
19. Inside perspective angle conveys more information about the curvature than outside perspective angle.	
<u>Individual Differences</u>	
20. Field dependent drivers show less adaptive scan pattern.	Such drivers require more time to process the curve information.
21. Slow information processors maintain their fixations closer to the center of the visual field. Implication: such drivers are liable to miss relevant information away from the center.	Curve information should be presented close to or on the straight road in the approach zone.

S/10.0

REFERENCE: Shinar, David; Rockwell, Thomas H., Malecki, Joseph A., "The Effect of Changes in Driver Perception on Rural Curve Negotiation," Ergonomics, Vol. 23, No. 3 (March 1980), pp. 263-275. (Phase III of a three-part study.)

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. _X_ Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	_X_ Design _X_ Placement _X_ Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

When the driver's limited perspective view of a curve differs significantly from the "bird's-eye" view of that curve, he or she is likely to misperceive its demands. In this study an innovative sign and permanent marking modifications presumed to affect the driver's perception of curvature and road width were applied to rural curves with high accident rates. Approach speeds of regular road users and the visual search patterns of test drivers were measured before and after modifications. The results indicated that: (1) the innovative sign had little effect on road users' approach speed and on test drivers' visual scanning; (2) modifications yielding an increase in the perceived angle of the curve, narrowing of the road, and increased speed perception had significant, but different, effects on drivers' approach speed, and on selected visual search parameters; (3) the effects on road users' speed were limited to the sites of the test curves and did not extend to the sites of following curves, and (4) in two of the three modofication sites they dissipated within thirty days. It is concluded that perceptual modifications may be an effective tool to affect the behavior of transient drivers unfamiliar with the high accident curves.

CRITICAL ANALYSIS:

See "The Effect of Changes in Driver Perception on Rural Curve Negotiation," Shinar, David; Rockwell, Thomas H., and Malecki, Joseph A., Ergonomics, Vol. 23, No. 3 (March 1980), pp. 263-275.

S/6.0

REFERENCE: Smith, B. L., "Handbook of Traffic Control Practices for Low Volume Rural Roads," Kansas DOT and Kansas County Engineers Association, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. X Curve ___ Vertical ___ Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel X Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing X Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The main purpose of the Handbook is to assist the local government officials in providing traffic control and guidance for persons driving on LVR roads. The suggested practices in the Handbook are in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) and, in some cases, address more specifically the application of the MUTCD to LVR roads. The Handbook also includes background information on the characteristics of LVR roads and persons who drive on them.

CRITICAL ANALYSIS:

The handbook is geared to the local engineer. Three types of Low Volume Roads (LVRs) are described. The basic distinction is due to surface type/riding quality: Type A (paved or gravel; no adverse effect on riding quality), Type B (gravel, sand or dirt; may cause some reduction in speed), Type C (natural surface possibly with some sand or gravel; typically poor riding quality). The handbook has many excerpts from the MUTCD pertaining to signs. The practices pertinent to our study, which we mau wish to include in our media selection criteria/recommended information systems (Task E, F-1), include signing treatments for intersections, horizontal curves, railroad grade crossings, narrow bridges, and low water crossings.

S/6.1

While the handbook does not deal with some of the situations/problems encountered in rolling and mountainous terrain, it serves as a model of the type of documentation required for distribution to local engineers. Also, it should be noted that the roadway classification system has been tested over a wide range of individuals and it has been found that it can be reliably applied.

S/11.0

REFERENCE: Smith, B. L., "Upgrading Existing Highways for Safety," Engineering Bulletin of Purdue University, Proceedings of the 61st Annual Road School, March 11 to 13, 1975, No. 146, pp.45-69.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent	___ Pavement	___ Intersection	___ LanePlacemt/	___ Design
Horizont.	___ Lane Width	___ Driveway	Rd Following	___ Placement
X Curve	___ Shoulder	___ Tunnel	___ CarFollowing	___ Performance
___ Vertical	___ OffRoadway	X Bridge	___ O.T. & Pass	___ Other
Curve	___ Other	___ L.W.Transit.	___ Other	
___ Grade		___ Schl. Zone		
___ Other		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		X Other		

OTHER DESCRIPTORS: Driver Expectancy

SUMMARY/ABSTRACT:

Techniques and approaches are discussed which could aid in analysis of the problem, generation of alternative solutions and selection of cost effective solutions for highway improvement projects. The speed differential vs. safety analysis of a highway facility is considered, and the development and use of a speed profile for existing highways is described. Data are presented which indicate the need for careful analysis of a design with regard to deviations from the average speed of traffic on the highway. Factors affecting speed include upgrades, horizontal curvature, vehicle type, acceleration. Speed profile development and ways in which speed profile analysis may be used in design are outlined. The application of the Positive Guidance technique at a narrow bridge location is described; the application of the driver expectancy checks are discussed, and the procedure for evaluating safety improvements for roadside hazards on the Texas freeway system is outlined.

CRITICAL ANALYSIS:

This paper is primarily of general background interest. The discussions of Positive Guidance and the role of driver expectancy are consistent with the proposed approach to identifying driver information problems on the current project.

S/12.0

REFERENCE: Soliday, S. M., "Lane Position Maintenance by Automobile Drivers on Two Types of Highway," Ergonomics, 18, 1975, pp. 175-183.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	X LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass X Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Lateral Position Measurement

SUMMARY/ABSTRACT:

Lane position maintenance was studied by using a photoelectric device that, when mounted on an automobile, made it possible to record the vehicle's track in real-world driving. Twelve subjects were tested on four-lane and two-lane highways during the daytime. Results showed that, in general, the drivers tended to stay almost exactly in the center of their lanes; and that dispersions of positions about the center in individual tracks were small in size and nearly normal in shape. More small oscillations near the centre were recorded on the two-lane highway than on the four-lane highway, but otherwise driving patterns were almost identical on the two. One of the most interesting findings was that intrasubject and intersubject variation were extremely small.

CRITICAL ANALYSIS:

Lateral placement data were gathered in this study via a photosensitive, car-mount camera that uses the luminance contrast between the pavement and shoulder stripe as a referent for measuring lateral position. This measurement system may have some application on the current study if informational treatments expected to influence lane placement are evaluated. However, the use of such a system would be restricted to those roadways which are wide enough to warrant the use of edgelines. It is possible that the system could be used on narrower roadways having centerline only, but the dashed lines in passing zones would probably require some modifications to the measurement system.

It should be noted that the results of the study, while of interest as background, have no direct applicability to the current study.

Sonefeld.O

REFERENCE: Sonefeld, O. F., "Railroad-Highway Grade Crossings: Not Just an Engineering Problem," Transportation Research News, No. 91, November 1980, pp. 7-9.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_ RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

While more than 50,000 rail/highway grade crossings--about a quarter of all such public intersections--have some form of automatic warning device and such installations are being made at an increasing rate, the frequency of grade crossing accidents at these locations is also increasing. The author discusses this and other facets of the crossing problem and makes recommendations for reduction of accidents: All levels of government and the railroad industry need to communicate and cooperate; better research is needed on driver behavior; and driver education must incorporate rail/highway crossing safety as an integral part of the instructional package.

CRITICAL ANALYSIS:

While this is not a study of driver behavior the author provides some observations which can be taken into consideration on those portions of the current research which involve the use of subject drivers. The observations are as follows:

(1) Drivers think of crossings in terms of delays and bumps rather than the train.

Sonefeld.1

CRITICAL ANALYSIS:

(2) Drivers don't realize that a train can't do anything to evade them.

(3) Drivers are confused about their legal obligation at crossings.

(4) Automatic warning devices at railroad crossings differ from conventional traffic signals. It isn't known how drivers perceive them.

On the basis of a study of several hundred crossings accident reports and personal investigations of a few hundred crossing where accidents have occurred the author states that he is frequently forced to conclude that there is no reasonable explanation for the accident except for driver attitude or other preconditioning that either prevents the driver from recognizing the crossing as a hazard or forces him or her to act against good judgment even if the hazard is recognized.

S/13.0

REFERENCE: Sparks, J. W., "The Influence of Highway Characteristics on Accident Rates," Public Works, 99(3), March 1968, pp. 101-103, and 120.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade _X_Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway _X_Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: Accident Rates and Physical Characteristics

SUMMARY/ABSTRACT:

This study attempted to define an adequacy index on the basis of physical roadway features and then demonstrate a high correlation of the adequacy index with accident rates. The variables that were subjectively rated on a five point scale as input to the index were: (1) surface width, (2) surface type, (3) shoulder width and type, (4) curvature, (5) gradient, (6) stopping sight distance, (7) passing opportunity, (8) hazard rating, (9) surface condition, and (10) shoulder condition. These ten variables, in the form of the resulting adequacy index, accounted for 45% of the variance in accident rates. Also a positive relationship was found between all ten independent variables, suggesting continuity in design and maintenance with respect to the physical characteristics of the roadway.

Note that data were collected for non-intersection accidents in Oklahoma on rural sections of two-lane highways where average speeds are nearly 50 mph.

CRITICAL ANALYSIS:

This report of the study does not provide a detailed discussion of the rating scheme used; it states only that the variables were rated from excellent to very poor. Other versions of the report will be sought in order to determine the applicability of the scales for the current study.

S/8.0

REFERENCE: Stimpson, W. A., McGee, H. W., Kittleson, W. K., and Ruddy, R. H., "Field Evaluation of Selected Delineation Treatments on Two-Lane Rural Highways," US DOT, FHWA. Report No. FHWA-RD-77-118, October, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
X Tangent	___ Pavement	___ Intersection	X LanePlacemt/ Rd Following	X Design
___ Horizont.	___ Lane Width	___ Driveway	___ CarFollowing	___ Placement
X Curve	___ Shoulder	___ Tunnel	___ O.T. & Pass	X Performance
___ Vertical Curve	___ OffRoadway	___ Bridge	___ Other	___ Other
___ Grade	___ Other	___ L.W.Transit.		
___ Other		___ Schl. Zone		
		___ Speed Zone		
		___ No Pass.Zone		
		___ RR Crossing		
		___ Other Cross.		
		___ Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The objectives of this research project were to establish relationships between traffic performance and accident probability on two-lane rural highways; to develop an experimental design for field testing the effectiveness of conventional and novel delineation treatments; to evaluate the effect of selected delineation treatments on traffic performance and associated accident probability; and to make recommendations for the design and use of delineation treatments. In the first phase of study, regression analysis was used to correlate delineation-related accident potential to a few systematically derived speed and lateral placement measures. In the second phase of study, additional accident and traffic performance data were collected to test the correlation models and to evaluate the safety effectiveness of 21 unique delineation systems.

Chapters of this Final Technical Report cover the conceptual planning, traffic performance studies, accident analyses, and regression modeling of Phase I, plus the experimental design, field studies, model checking, and treatment effectiveness evaluations of Phase II. The two most sensitive indicators of hazard were found to be off-center driving and longitudinal changes in lateral placement variance. Recommendations are offered with respect to a generalized delineation evaluation methodology, as well as for the immediate implementation on two-lane rural highways of a 10:30 broken centerline pattern, narrower edgelines, and the selective use of raised pavement markers and post delineators.

S/8.1

CRITICAL ANALYSIS:

Speed and lateral placement data were collected at 32 study sites in six eastern states during Phase I. Sites were two-lane, two-way roads in the low to moderate volume range, generally having tangent, winding, or isolated horizontal curve alignments. At each site, a minimum of 100 free-flowing observations were obtained during daylight and darkness in dry weather. Analysis of the traffic performance data revealed that mean speed and speed variance did not vary significantly along the various types of horizontal alignment. However, lateral placement was found to be strongly influenced by geometrics and, to some extent, delineation.

Twelve experimental treatments were evaluated during Phase II. These are shown in Table 1. Traffic performance data were then collected at nine sites (5 tangent sections, 2 winding sections, and 2 isolated horizontal curves) for 3 or 4 delineation treatments. An improved "Z-trap" method of roadway instrumentation was used to collect the speed and lateral placement data. The results are summarized in Table 2.

On the basis of this exhaustive data analysis, the following recommendations were made.

TANGENTS:

- 4-inch, 10:30 centerlines with 4 inch edgelines should be applied to all rural two-lane highways.
- Where quality control associated with painting equipment will allow, the edgelines may be 2 to 3 inches wide.
- If 4 inch, 5:35 centerline with 4 inch edgelines are used, consideration should be given to the use of reflective raised pavement markers (with spacings recommended at 80 ft for passing and 40 ft for no-passing).

- Where severe visibility conditions occur due to frequent fog or blowing sand, consideration should be given to using RPMs as a supplement to the 10:30 centerline, (spacing is recommended above).

- Where RPMs cannot be applied (i.e., snow-plowing problems), continuous post-mounted delineators should be installed at 400-528 ft intervals.

HORIZONTAL CURVES:

- Where feasible, RPMs are preferred over post-mounted delineators.

- One-way amber RPMs should be installed on the centerlines at 40 ft intervals and should face traffic moving to the left on the curve.

- When RPMs cannot be applied, consideration should be given to installing post mounted delineators on the outside of the curve at intervals recommended in the MUTCD.

- Two colors of retroreflectors on delineators are desirable. Drivers moving on the outside curve should see crystal reflectors on their near right, and drivers moving on the inside curve should see amber reflectors on their far left.

IMPLICATIONS:

These results imply that lateral placement may be a better measure of effectiveness than speed in evaluating horizontal curves. The recommendations for delineation systems should be considered in developing our recommended information system.

Table 1. Conceptual treatment comparisons selected for phase II testing.

Experimental Delineation Treatment[1]	Base Delineation Treatment [1]	Research Priority Ranking[2]
Reduced stripe-to-gap ratio for centerlines and lanelines	Standard stripe-to-gap ratio of 3:5	1½
Single solid stripe as centerline where passing is prohibited	Double striping	1½
RPM's as *replacement* for painted centerline or lanelines	Paint stripes only	3½
Substantially variant spacing of PMD's (i.e., greater than 500 ft.)	Traditional close spacing of about 200 ft.	3½
Narrower striping for some centerlines, lanelines, and edgelines	Standard 4- to 6-inch wide striping	5
Continuous edgelines on *narrow* roads (< 22 ft.)	Centerline only	6
RPM's as *supplement* to painted centerline or lanelines	Paint stripes only	7
PMD's just on curved sections of roadway	Centerline only	9½
PMD's just on curved sections of roadway	Centerline with continuous edgelines	12
RPM's just on curved sections of roadway	Standard paint striping only	13
RPM's as *supplement* to painted edgeline	Standard painted edgeline	14
Continuous PMD's as *supplement* to edgelines	Standard continuous edgelines	20½

[1] RPM = raised pavement marker and PMD = post-mounted delineator; 1 ft. = 0.305 m. and 1 in. = 2.54 cm.

[2] Among 38 candidate comparisons

Table 2. Evaluation of costs and effects of continuous delineation systems.

Delineation Category	Experimental Delineation System: Description[1]	No.	Study Site No.	% Changes to Base Characteristics[2]: Initial Cost to Install	Night Variances[3]: Speed	Night Variances[3]: Placement	Predicted Dry-Night Hazard[4]
Striping Only	Single solid centerline						
	• w/o edgelines	G-1	6	↓74	↓60	↓30	-
	• w/4-in. edgelines	G-2	6	↓26		↓30	↑71
	4-in., 5:35 centerline						
	• w/4-in. edgelines	G-3	3	↓8	↓25	↑30	↓82
	2-in., 10:30 centerline						
	• w/o edgelines	G-4	4A	↓78	-	-	-
	• w/2-in. edgelines	G-5	4A	↓20	↓40	-	↓31
	4-in., 10:30 centerline						
	• w/o edgelines	G-6	4B	↓75	-	-	↑+ +
	• w/2-in. edgelines	G-7	4B	↓16	-	-	-
	• w/4-in. edgelines	G-8	4B	↓4	-	-	-
			4A	↓4	-	-	↓49
Striping and RPM's	4-in., 5:35 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-9	3	↑71	↓35	-	↓27
	4-in., 10:30 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-10	3	↑75	↓35	-	↑96
	4-in., 15:25 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-11	2	↑78	-	↓25	↓41

Table 2. Evaluation of costs and effects of continuous delineation systems. (continued)

Delineation Category	Experimental Delineation System: Description[1]	Experimental Delineation System: No.	Study Site No.	% Changes to Base Characteristics[2]: Initial Cost to Install	Night Variances[3]: Speed	Night Variances[3]: Placement	Predicted Dry-Night Hazard[4]
Striping and RPM's (cont'd)	4-in., 15:25 centerline • RPM's on both sides of lane @ 80 ft. (w/4-in. edgelines)	G-12	2	235 ↑	-	30 ↓	45 ↓
	4-in., 15:25 centerline • RPM's on both sides of lane @ 40 ft. (w/4-in. edgelines)	G-13	2	471 ↑	60 ↑	-	48 ↓
	Centerline of reflective & non-reflective RPM's						
	• w/4-in. edgelines	G-14	5	783 ↑	-	-	3 ↑
	• w/4-in. edgelines supplemented by RPM's @ 40 ft.	G-15	5	888 ↑	-	-	68 ↓
Striping and PMD's	4-in., 15:25 centerline • w/PMD's @ 528 ft. (w/4-in. edgelines)	G-16	1	78 ↑	-	30 ↓	21 ↓
	4-in., 15:25 centerline • w/PMD's @ 264ft. (w/4-in. edgelines)	G-17	1	157 ↑	30 ↓	25 ↓	32 ↓
RPM's Only	Centerline of reflective & non-reflective RPM's • w/o edgelines	G-18	5	736 ↑	50 ↑	-	12 ↑

1 1 in. = 2.54 cm and 1 ft = 0.305m.; RPM = raised pavement marker and PMD = post-mounted delineator

2 Base-condition delineation system consisted of edgelines with double solid centerline at sites 5 and 6 and 15:25 centerline at other sites, all striping 4 inches (10 cm) wide
(↑ means a statistically significant increase of percentage shown).
(↓ means a statistically significant decrease of percentage shown),
(– means any change was statistically insignificant).

3 Dry-night values for upstream trap at tangent sites (Nos. 1, 2, 3, 4A, and 4B) and midpoint-of-inside-curve trap at winding sites (Nos. 5 and 6)

4 From two-variable accident-probability model based on centrality within the lane and longitudinal change in placement variance.

S/9.0

REFERENCE: Stockton, W. R., Brackett, R. Q., and Mounce, J. M., "STOP, YIELD, and NO Control at Intersections," US DOT, FHWA, Report No. FHWA-RD-81-084, June, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Observations and measurements were made at 140 low volume intersections in three regions of the United States. Control type, region, location (urban/rural), geometry (3-leg/4-leg), major roadway volume and sight distance are examined to determine their individual and interactive effects on driver behavior, accident experience, and travel time.

Region, location and geometry have an essentially negligible effect on safety and operations at low volume intersections. Increasingly restrictive control did not result in reductions in accident experience. STOP control produced the highest travel times and thus the highest total road user costs; YIELD control resulted in the lowest road user costs of the three control types considered.

Less than 20% of the drivers observed voluntarily stopped, regardless of control type (STOP = 19%, YIELD = 8%, NO Control = 9%). Accident rates were very low (0.13 accidents/intersection/year). A significant increase in accidents was observed at major road volumes above 2000 vehicles per day (vpd). Travel times were about two seconds higher at locations with major road volumes above 2000 vpd. Sight distance had no discernible effect on either safety or operations.

S/9.1
CRITICAL ANALYSIS:

This paper concerns itself with traffic control systems rather than information systems. As such, it can be considered to be beyond the scope of our project. For the sake of completeness, the suggested control criteria are shown on an attached sheet.

It should be noted that 'Low-Volume" intersection, in this case, is defined as an intersection with one approach having an ADT of less than 500.

TABLE 4. Summary of Suggested Control Criteria.

<table>
<tr><th rowspan="2">Sight Distance</th><th rowspan="2">Accident History</th><th colspan="2">Major Roadway Volume</th></tr>
<tr><th>≤ 2000 vpd</th><th>> 2000 vpd</th></tr>
<tr><td rowspan="4">Adequate</td><td>0</td><td>No Control</td><td rowspan="2">YIELD</td></tr>
<tr><td>≤2</td><td>YIELD</td></tr>
<tr><td>3</td><td colspan="2">STOP*</td></tr>
<tr><td>4+</td><td colspan="2" rowspan="2">STOP</td></tr>
<tr><td>Not Adequate</td><td></td></tr>
</table>

*If minor roadway is greater than 300 vpd, YIELD control is appropriate for intersections with less than 4 accidents in 3 years.

S/20.0

REFERENCE: Stockton, W. R., Mounce, J. M., and Walton, N. E., "Guidelines for Application of Selected Signs and Markings on Low-Volume Rural Roads," TRR 597, 1976.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent Horizont. X Curve Vertical ___ Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone X No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance X Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Existing standards and guidelines for the application of signs and markings are unsuited and inefficient for use on low-volume rural roads (roads with less than an average of 400 vehicles/day). To alleviate this inadequacy, several potentially hazardous situations were evaluated to ascertain actual needs for signs and markings as they related to economy and safety. These evaluations were based on recent research and on probability of conflict analyses with regard to the needs for signing and marking of intersections, horizontal curves, and sections of inadequate passing sight distance. The research revealed that more efficient intersection control can be attained from the careful application of stop signs and crossroad warning signs based on approach speed, sight distance, and combined intersecting volumes. Treatment of horizontal curves can be made more efficient through the application of more stringent guidelines without adversely affecting safety. Striping of no-passing zones was found to be very inefficient in most instances because the probability of conflict in these situations is virtually nil; guidelines for alternative treatments are presented. Overall, the authors felt that application of guidelines suited to the rural context would result in savings in time, money, and frustration on the part of responsible agencies.

S/20.1

CRITICAL ANALYSIS:

The basic premise in this paper is that the application of MUTCD guidelines may result in too little intersection control and too much horizontal curve and no-passing zone warning in rural areas. The authors formulated revised guidelines based on considerations of accident probability and economics. These guidelines were not accepted by FHWA. These guidelines are not applicable to our study.

S/14.0

REFERENCE: Summola, H., and Naatanen, R., "Perception of Highway Traffic Signs and Motivation," Journal of Safety Research, 1974, 6, pp. 150-154.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance _X_Other

OTHER DESCRIPTORS: Recognition and Motivation

SUMMARY/ABSTRACT:

The intent of this study was to determine whether previous findings of low percentages of drivers' immediate recall of signs they have just passed (47%) can be attributed to limitations in drivers' capacity versus motivation.

Nine subjects were instructed to drive as safely as possible over a highway route of 257 kilometers (160 miles) and to name all the traffic signs along the route. These subjects were able to report approximately 97% of the signs on the entire route and virtually all of the signs in the non-urban, non-intersection areas, while driving safely.

Since 97% of the 581 signs seen by each subject were correctly verbally reported in this study, these authors conclude that subjects are able to "register" signs but are simply not typically motivated to do so.

S/14.1

CRITICAL ANALYSIS:

It was found that route difficulty resulted in differences in rates of sign reporting; only 0.24 percent of the signs were unreported on rural roads while 8.95 percent were unreported for the most demanding intersections and urban areas. Also, type of sign seemed to be associated with differences in rates of reporting; most of the unreported signs were "mandatory and informative" ones that may have not been relevant to drivers (e.g. "Compulsory Cycle Track") or redundant (e.g. "Priority Road" sign after each intersection). However, these signs also tended to be located at intersections or other difficult places. The danger and prohibitory signs were reported with a high frequency.

Three traffic violations were detected among subjects: these all involved cases where speed was decreased too late on entering a reduced speed zone. Finally, subject reporting was found to deteriorate somewhat as a function of distance covered; an apparent fatigue effect.

T/1.0

REFERENCE: Taylor, J. I., McGee, H. W., Seguin, E. L., and Hostetter, R. S., "Roadway Delineation Systems," NCHRP Report 130, Highway Research Board, 1972.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent Horizont. X Curve Vertical ___ Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	X Intersection ___ Driveway ___ Tunnel ___ Bridge X L.W.Transit. ___ Schl. Zone ___ Speed Zone X No Pass.Zone ___ RR Crossing ___ Other Cross. X Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design X Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

A comprehensive state-of-the-art summary covering the application of various delineation treatments to highway situations, delineation material properties, the human factors literature pertinent to delineation, and cost effectivenss considerations was compiled. Emphasis was given to current practices--particularly departures from the standard manuals--and recent research findings. Practices and research results of other countries were included.

Specific driver performance requirements at eight "classical" geometrical situations were defined. An Information-Decision-Action (IDA) task analysis procedure was utilized to translate performance requirements to information requirements. Essentially, the desired actions were defined, the decisions necessary to effect these actions were determined, and the information needed by the driver to make the required decisions was then specified.

The experimental program consisted of two major types of studies. Laboratory studies, conducted primarily by experimental psychologists, were carried out to develop and evaluate concepts basic to all delineation requirements, such as positive vs negative delineation, clutter of the visual environment, overdelineation, target value, and the various aspects of color and shape coding. Field experiments, directed primarily by the engineers on the project staff, were conducted under naturalistic

conditions to evaluate the effectiveness of specific treatments or systems at specific situations. Studies included the use of post delineators and/or raised pavement markers at horizontal curves, the use of colored pavements, variations in center line marking patterns, and variations in color and spacing of post delineators at stop approaches.

Recommendations for the application of the various treatments at each of the "classical" situations were drawn up on the basis of these studies, discussions with other researchers and practicing engineers, and careful review of the literature. Widespread and consistent application of these recommendations will lead to reductions in accident experience and significant intangible benefits, such as increased driver comfort and reduction of uncertainty in critical situations.

CRITICAL ANALYSIS:

The delineation treatment recommendations from the study are too voluminous to effectively excerpt. They will however, be considered as candidate treatments for Task F-2 of the current study. Also the task analyses (Information-Decision-Action models) of classical situations will be used as a basic input to the task analysis effort to be conducted in conjunction with the current study.

T/2.0

REFERENCE: Taylor, J, I. and Thompson, H. T., "Identification of Hazardous Locations," Final Report, US DOT, FHWA, Report No. FHWA-RD-77-83, December, 1977.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent	___Pavement	___Intersection	___LanePlacemt/ Rd Following	___Design
___Horizont. Curve	___Lane Width	___Driveway	___CarFollowing	___Placement
___Vertical Curve	___Shoulder	___Tunnel	___O.T. & Pass	___Performance
___Grade	___OffRoadway	___Bridge	___Other	___Other
___Other	___Other	___L.W.Transit.		
		___Schl. Zone		
		___Speed Zone		
		___No Pass.Zone		
		___RR Crossing		
		___Other Cross.		
		___Other		

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The principal objectives of the research project were to develop and verify procedures for identifying hazardous locations on all highway facilities except freeways and those systems within the Central Business District (CBD). A Hazardousness Rating Formula (HRF) was developed which incorporates both accident and non-accident measures, or predictors. The intent of such a formula is to supplement, rather than replace, accident record systems in establishing the relative hazardousness at spot locations within the highway system.

The formula provides a means for establishing a Hazardousness Index for any suspect site. The HRF incorporates data inputs regarding the number of accidents per year, accident rate (accidents per million entering vehicles), accident severity, sight distance, volume/capacity ratio, traffic conflicts, erratic maneuver counts, and two subjective indicators--driver expectancy and information system deficiencies. The form, control values for establishing three levels of hazardousness (normal, hazardous, and very hazardous), and scaling charts necessary to convert raw data values into a Hazardousness Indicator Value are presented for each indicator.

The concept of the Hazardousness Rating Formula to assess relative hazardousness at spot locations appears to be valid, based on the results of workshops conducted as part of the research project, and limited statistical analysis of data from 12 study sites.

T/2.1

CRITICAL ANALYSIS:

Without reliable accident data, this Hazard Rating Formula cannot be used. Consequently, the overall formula cannot be used for the current project.

However, pertinent to the current study, are two indicators used within the Hazard Rating Formula: Driver Expectancy and Adequacy of Information System. The rating forms that Taylor and Thompson developed for these two indicators may be applicable to our study and will be considered for use in the site analysis. These are shown on the next pages.

DRIVER EXPECTANCY PROBLEMS RATING FORM

__Ratings__:

0 -- Nothing unexpected or unusual at this location.

Actions required (if any) entirely consistent with driving strategy on approach.

Standard geometry, with pathway(s) for intended movement(s) clearly evident.

No interferences by other traffic likely.

1 --

2 --

3 -- Situation somewhat unexpected.

Driver must be alert, but should be able to respond adequately at "last minute" to most combinations of adverse circumstances.

Some initial confusion on intended path(s) or movement(s).

Interference from other traffic may create some degree of confusion or uncertainty for average driver.

4 --

5 --

6 -- Very unusual situation; will "surprise" many unfamiliar drivers.

Driver required to make major change in driving tactics from those employed over past few miles.

At least a "near accident" almost __expected__ if driver is even moderately inattentive; evasive actions likely to be required.

Intended pathway(s) confusing under fairly normal traffic or lighting conditions.

Other traffic, or lack of it, aggravates situation and misleads driver or deprives him of important cues.

__Approach__	__Rating__ 0	1	2	3	4	5	6
A							
B							
C							
D							

Figure 14. Driver expectancy problems rating form.

INFORMATION SYSTEM DEFICIENCIES RATING FORM

Ratings:

0 -- Information for required decisions complete and unambiguous.

Signs, markings, delineation in good repair, clean, highly visible.

"Positive guidance" leads driver to appropriate path; makes "error" difficult.

Approach speeds of most drivers are appropriate.

Light decision load; easy and obvious.

1 --

2 --

3 -- Some information lacking or somewhat misleading.

Signs should be moved or augmented for better visibility or to provide more decision time.

Visibility of signs, markings, and delineation barely adequate.

Advisory speed information should be changed slightly, or added.

Medium decision load; average driver will be able to handle situation, but may be a little uncomfortable.

4 --

5 --

6 -- Important information missing.

Complete new "information system" needed -- design and installation.

Present signs and markings in very poor condition; need replacement.

Speed limit and/or advisory speed needed; either missing or totally inappropriate at present.

"Positive guidance" on appropriate path lacking; a clutter of negative delineation only.

Heavy decision load; complete attention of average driver required; a "tense" situation at best.

Approach	Rating 0	1	2	3	4	5	6
A							
B							
C							
D							

Figure 16. Information system deficiencies rating form.

T/10.0

REFERENCE: Taylor, J. J., "A Study of Roadway Delineation Systems," HRB Special Report 107, 1970, 81-88.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	X LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement X Performance X Other

OTHER DESCRIPTORS: Delineation

SUMMARY/ABSTRACT:

The primary objectives of this study are to determine the driver's delineation requirements during various traffic and environmental conditions, establish techniques for determining the effectiveness of delineation treatments, test some of the more promising delineation systems, and develop practical criteria for the selection of delineation treatment systems. This paper describes the techniques utilized in the review of past and current research, the assessment of current practices in the various states and selected foreign countries, and the structuring of information. Particularly relevant findings and conclusions derived from this compilation are enumerated. The definition of driver's delineation requirments through information-decision-action models is described. The IDA analyses are used to transform the driver performance requirements to information requirements; i.e., actions required to effect the desired performance, decisions required to effect the actions, and information required to elicit the desired decisions and actions are identified.

CRITICAL ANALYSIS:

This article is an interim report of NCHRP 130. "Present delineation techniques include the use of pavement markings, post delineators, raised pavement markers, colored pavements, rumble strips, and curbs. They also include, either intentionally or unintentionally, contrasting shoulders, reflectorized guardrails, rows of luminaires, parallel fence lines, and advertising signs.

T/11.0

REFERENCE: Taylor, William C., Foody, Thomas J., "Ohio's Curve Delineation Program - An Analysis," Traffic Engineering, Vol. 36, No. 9, (June 1966), pp. 41-45.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. _X_ Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement _X_ Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The objective of the research was to determine the parameters to be used in establishing warrants for curve delineation. The basis for evaluating the effectiveness of delineation was the reduction in accidents. It had been reasoned that the greatest savings in accidents would be realized at severe curves on high volume roads. A program had been set up to delineate all curves with a degree of curvature of 5 degrees or greater on Ohio's First Priority Road System - approximately 1,400 curves. The study used that program as a data base. The results indicated that the program reduced accidents signficantly. However, the analysis showed that the program was not efficient. It was determined that nearly all of the accident reduction occurred in about 1/5 of the curves.

CRITICAL ANALYSIS:

The variables used in the analysis were geometric properties of the curve: degree of curvature, total central angle, and the interaction of these two. The degree of curvature varied from 5 degrees to 8 degrees and over, the central angle from 20 degrees and under to 80 degrees and over, and the interaction covered all the combinations of these two ranges. The study did not compare roadside delineation with edge line delineation. The edge lining program in Ohio included the same locations as the roadside delineation program. Therefore, the effectivness of roadside delineators was tested in addition to, not in lieu of, edge lining. The delineators used in the program were three-inch circular, center-mount reflectors. They were mounted four feet above the pavement and at the outside edge of the shoulder. The spacing was such that at least five delineators were visible to the driver at all times. All the accident data came from 1959 through 1964. The curves were delineated in 1961 and 1962. Two-year before-and-after periods were therefore available for each curve. Control sections also were used: The control sections consisted of curves that were included in the original program but had not been delineated by 1963. 1960 and 1961 control data corresponded to the "before" data, and 1962 and 1963 control data corresponded to the "after" data. There were 557 curves used as test sections and 357 as control sections. The others (of the approximately 1400) were eliminated because of delineator installation dates or road construction. Accidents that occurred beyond the limits of the curve, but within the delineation, were included because it was felt that the curve probably contributed to the accidents. An equal length of such highway was included in the control sections. The chi-square test was used. There was no mention of warning signs that may have preceded the study curves, or their possible effect in combination with delineators.

It was shown that dividing curves into small groups (5°, 6° - 7°, 8° - 9°, 10° - 17°, 18° and over) did not provide a more efficient parameter than summing all curves over 5 degrees. Not one of the goups yielded results (percent change on study sections minus percent change on control sections) that could be used <u>with confidence</u>. The groups totaling the highest accident reduction were the curves with a degree of curvature of 9 degrees or less.

When curves were grouped according to total central angle the largest net accident reduction occurred on curves with a central angle between 20 degrees and 40 degrees. For the remainder of the curves, the net accident reduction was off sharply. The 20 to 40 degree central-angle curves were 37 percent of the curves in this analysis and accounted for 85 percent of the total accident reduction on the delineated curves. The central angle range of 20° to 40°, included long, gentle curves; short, sharp ones; and those of medium length and sharpness. However, the analysis of degree of curvature indicated that delineators were not effective in the latter two groups.

An analysis of degree of curvature and central angle together was conducted. Central angle groups were 0° to 20°, 20° to 40°, and over 40°. They were subdivided by degree of curvature. All three central angle groups had a higher total percentage of net accident reduction on curves of 9° or less than on curves above 9°. Furthermore, the net accident reduction percentages for curves in the 20° to 40° central angle group were higher than those in the other two groups. The chi-square values for this combined range of degree of curvature and central angle (90° and less curvature, 20° to 40° central angle) were also higher than for the other central angle groups.

Those curves on which delineation was effective were those with a degree of curvature between 5° and 10° and a central angle between 20° and 40°.

Perhaps measurements of degree of curvature and central angle can be obtained for analysis of horizontal curves in "Driver Needs on Two-Lane Rural Roads."

T/3.0

REFERENCE: Texas Transportation Institute, A Procedural Manual for Diagnostic Studies, Texas Transportation Institute. Texas A & M University, Report No. 606-8, September, 1971.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance _X_ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

"Diagnostic evaluation" literally means "a detailed examination of a case based on the facts as they actually exist in the field." Therefore, the results obtained through diagnostic studies apply only to the specific combination of circumstances observed. The generalization of the results of diagnostic evaluation based on only one study is difficult, if not altogether impossible. Generalization is possible only after similar patterns have been identified in several studies. This implies that diagnostic studies will be conducted in a systematic manner and that the review process will be dynamic in nature. That is, the process includes the planning, design, and operation of the facility. Thus, the conceptual framework of the diagnostic evaluation procedure must include all three levels.

CRITICAL ANALYSIS:

The methodology, which is a questionnaire survey of a "diagnostic team" conducted as an interview during a 20 minute drive, may be useful, in a modified form, for the test subject driver data collection or truck driver data collection on the current project. The authors recommend a tape-recorded interview, although they found that it took 4 hours to reduce 30 minutes of interview tape. Their questionnaires for day and night drivers on 2-lane rural highway sections will be reviewed and used as input for the design of the "site" analysis portion of the current project.

T/4.0

REFERENCE: Tidwell, J. E. and Humphreys, J. B., "Driver Knowledge of Grade-Crossing Information," TRR 811, 1981, pp. 28-32.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone ___No Pass.Zone _X_RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

Questionnaires were completed by 829 licensed drivers or candidates for licenses in an effort to ascertain their level of knowledge concerning highway-railroad grade-crossing information. Questions were asked concerning traffic-control devices, facts relating to grade-crossing hazards, and driver responsibilities at grade crossings. Respondents were stratified by age and elements of training and/or experience. Major findings of the study include the following: (a) Collection of interview data at a driver's-license examining station is an effective method of determining driver knowledge, (b) more than 50 percent of all respondents believed that all grade crossings except those rarely used by trains have active warning signals, (c) most drivers have adequate knowledge concerning the hazards of grade crossings, (d) most drivers do not know the required driver response at passive grade crossings, (e) drivers perceive little law enforcement related to driver actions at grade crossings, and (f) driver knowledge and/or understanding of the traffic-control devices used to warn of grade crossings is inadequate. Recommendations are made regarding driver knowledge items that should be considered for inclusion in public infomration campaigns on grade-crossing safety. Future research regarding different advance warning signing for active and passive crossings and enforcement as a countermeasure is also recommended.

T/4.1

CRITICAL ANALYSIS:

Although the interview methodology is not applicable to the current study, the results are pertinent, even if the sampling location was in an urbanized area of Tennessee.

The results of the study pertaining to lack of knowledge by the driving public will be taken into consideration in the development of recommended information systems.

T/12.0

REFERENCE: Tignor, S. C., and Lindley, J. A., "Accident Rates on Two-Lane Rural Highways Before and After Resurfacing," Public Roads, 44(4), March 1981, pp. 137-139.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	X Pavement ___ Lane Width ___ Shoulder ___ OffRoadway X Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: Accident Rates

SUMMARY/ABSTRACT:

Accident rates for the one year prior to resurfacing of two-lane rural highways were compared with rates for the one year following resurfacing over 83 test sections from at least 16 states; the total length of roadway sampled was 657 km from one data base and 51 km from another.

Findings from both data sources indicated that the accident rates before and after resurfacing were not significantly different ($p > .05$).

CRITICAL ANALYSIS:

While the specific criteria for resurfacing are not specified, the implications are that surface characteristics of paved roadways are not critical to safety. This, in turn, implies that warning drivers of poor surface conditions may not be cost effective.

U/10.0

REFERENCE: Urbanik, Thomas, II., "Driver Information Systems for Highway-Railway Grade Crossings," Purdue University, July 1971.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone ___ No Pass.Zone X RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	X Design ___ Placement ___ Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The reduction in accidents at highway-railway grade crossings is a desirable objective. To fulfill this objective past research was examined and a new direction was taken relative to improving safety at highway-railway grade crossings. This new direction was to improve the warning systems at individual crossings rather than an examination of priorities for improvement of railroad crossings or an examination of the effectiveness of present warning systems.

The research utilizes an attitudinal survey in order to meet four broad objectives. These objectives were: an evaluation of driver attitudes concerning the hazards at railroad grade crossings; an evaluation of priorities for improving safety at railroad grade crossings; an evaluation of warning systems for railroad grade crossings; and development of a typical design for a new advance warning system.

The research indicates that the respondents considered railroad grade crossings more hazardous than several other highway hazards. However, all hazards were, at most, only considered moderately hazardous by the respondents. The improvement of safety at railroad grade crossings was given high priority by the respondents. An overhead changeable message sign was the preferred method of warning at railroad grade crossings. It was concluded that a field installation is desirable.

U/10.1

CRITICAL ANALYSIS:

Data derived from a series of paired comparisons by 259 respondents of 6 different highway situations on a two-lane rural road indicated the following rank order of hazardousness as perceived by drivers:

		Scale Value
most hazardous	railroad grade crossing	0.59
	crossroad	0.53
	yield ahead	0.45
	stop ahead	0.29
	signal ahead	0.05
	curve ahead	0.00

Data derived from an absolute rating of these same six hazards via a 7 point scale (not very hazardous = 1, very hazardous = 7) yielded the following results:

		Mean Rating
most hazardous	crossroad	4.93
	yield ahead	4.60
	railroad crossing	4.59
	curve ahead	4.22
	stop ahead	4.00
	signal ahead	3.37

Each of the above two ratings was obtained by showing respondents a photograph of the same two-lane rural highway scene illustrating the approach to a vertical crest; just prior to the crest was one of 6 different warning signs with a message corresponding to one of the six hazards rated.

A seven point scale was also used to ascertain driver priorities for different types of highway improvements; the scale was anchored by 1 = unimportant and 7 = important. The data indicated the following mean ratings.

most important:	Mean Rating
improve the road surface on major highways	5.77
improve warning devices at railroad grade crossings	5.74
improve maintenance of painted lines on roads	5.42
improve signs giving directions	4.97
provide free emergency telephones connected only to the highway department and police department	4.84
install more traffic lights	4.05
improve roadside rest areas	3.76
provide mowing of grass along the sides of highways	3.16

A series of paired comparisons concerning driver perferences for 5 different types of railroad warning systems indicated the following rank order:

		Mean Rating
most preferred	overhead changeable message sign	1.39
	standard flashing lights	1.00
	in-car radio audio message	0.60
	in-car visual message	0.52
	present warning sign	0.00

A seven point scale (1 = undesirable, 7 = desireable) of these same five alternatives provided the following mean ratings:

		Mean Rating
most desireable	overhead changeable message sign	6.03
	standard flashing lights	5.17
	in-car radio audio message	4.19
	in-car visual message	4.07
	present warning sign	3.37

The installation cost for two overhead changeable message signs was estimated to total $33,300, and the cost of maintaining these two signs was estimated to be $6,420 annually. Given, the cost, warning signs of this type would be economically feasible only at crossings which were deemed extremely hazardous.

W/2.0

REFERENCE: Weaver, G. D. and Glennon, J. C., "Design and Striping for Safe Passing Operations (Abridgment)," HRR 390, 1972, pp. 36-39.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone _X_No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing ___O.T. & Pass ___Other	___Design ___Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The goals of this study were to examine passing behavior on rural 2-lane highways; to compare study parameters with the current passing sight distance design standards; and to develop, where appropriate, design and striping standards compatible with current operating conditions. Of primary concern were passing maneuvers on highways with operating speeds of 50 to 80 mph.

Current standards for designing passing sight distance and for striping rural 2-lane highways to restrict passing are based on different criteria. Passing sight distance is designed by using "A Policy on Geometric Design of Rural Highways," whereas no-passing zones are set by using the "Manual on Uniform Traffic Control Devices for Streets and Highways" (MUTCD). Unfortunately, the striping operation is done after the highway is constructed, when alignment changes are economically unfeasible.

The current standards for design and striping were critically evaluated with particular emphasis given to the inequities between design and operations. From this evaluation, and based on the operating characteristics of the passing maneuvers observed in the field studies, a new concept was developed that integrates design and striping to accommmodate the safety and operational aspects of the passing maneuver.

W/2.1

CRITICAL ANALYSIS:

The paper is concerned with designing and striping passing zones. Field studies were conducted using photographic equipment and "staged" vehicles, and involved 500 completed passing maneuvers.

Based on these results, values were proposed for revising passing zone standards and are shown below:

Design Speed Speed (mph)	Minimum Sight Distance Throughout Zone	Minimum Desirable Length of Passing Zone	Minimum Sight Distance at Beginning of Zone	AASHTO Design Standard	MUTCD Operation Standard
50	1,135	885	2,020	1,800	800
60	1,480	1,185	2,665	2,100	1,000
65	1,655	1,135	2,990	2,300	-----
70	1,825	1,485	3,310	2,500	1,200
75	2,000	1,785	3,635	2,600	-----
80	2,170	1,935	3,955	2,700	-----

These criteria are very restrictive and may not be practical. However, further research was conducted and is documented in: Weaver, G. D. and Woods, D. L., "Passing and No-Passing Zones: Signs, Markings, and Warrants. US DOT, FHWA, Report No. FHWA-RD-79-5, September, 1978.

W/3.0

REFERENCE: Weaver, G. D. and Woods, D. L., "No-Passing Treatments for Special Geometric and Traffic Operational Situations," Summary Report, Texas Transportation Institute, Report No. RF-3828-6, March, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	X Intersection ___Driveway ___Tunnel X Bridge X L.W.Transit. X Schl. Zone X Speed Zone X No Pass.Zone ___RR Crossing X Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing X O.T. & Pass ___Other	___Design ___Placement X Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The MUTCD states that where center lines are installed, no passing zones shall be established at vertical and horizontal curves and elsewhere on two and three-lane highways where an engineering study indicates passing must be prohibited because of inadequate sight distances or other special conditions. The MUTCD states further that the no-passing marking may also be used on approaches to railroad grade crossings and other locations where passing should be prohibited.

Accepted practice has been to designate no-passing zones where insufficient safe sight distance to an opposing vehicle exists (horizontal and vertical alignment). There exist many sections of two-lane rural highway where adequate opposing vehicle sight distance is provided; however, the normal passing maneuver expectancy condition is interrupted by a geometric feature or by the unexpected introduction of a vehicle into the passing lane. Guidelines for application of no-passing zones at these special situations are less clearly specified; hence, no-passing zones are being applied by traffic engineers using varied criteria.

W/3.1

This report presents suggested guidelines for uniform application of no-passing zone treatments on rural two-lane highways at uncontrolled and controlled intersections, railroad grade crossings, narrow two-lane bridges, one-lane bridges, school zones, roadside development, and transition sections between two-lane and divided highways.

Two sets of guidelines are presented: (1) utilizing MUTCD standard signs and markings, and (2) utilizing an experimental advance treatment consisting of a short dotted line marking adjacent to the approach centerline and the NO-PASSING ZONE pennant sign. The guidelines include suggested lengths of no-passing zones to provide sufficient driver expectancy conditioning for the situations and suggested guidelines for installation. Minimum distances between successive no-passing zones for operational safety are also presented.

CRITICAL ANALYSIS:

Conceptual models were developed for approaches to various "special" situations to determine "critical conflict distances" for both aborted pass and complete pass maneuvers. These conceptual models formed the basis for their recommended guidelines. The assumptions of these models appear to be both reasonable and correct.

They recommended a minimum distance between no-passing zones of 400 ft, which was derived from an analytical consideration of maximum acceleration rates. They also suggested lengths of no-passing zones for each "special" situation with the information system consisting of the a "NO PASSING ZONE" warning sign, solid yellow, no-passing stripes, and appropriate warning signs. (This system conforms with the MUTCD). The suggested devices and their locations are identified. This information will be considered in Task F-2 of the current study.

W/4.0

REFERENCE: Weaver, G. D. and Woods, D. L., "Passing and No-Passing Zones: Signs, Markings, and Warrants," US DOT, FHWA, Report No. FHWA-RD-79-5, September, 1978.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___Tangent ___Horizont. Curve ___Vertical Curve ___Grade ___Other	___Pavement ___Lane Width ___Shoulder ___OffRoadway ___Other	___Intersection ___Driveway ___Tunnel ___Bridge ___L.W.Transit. ___Schl. Zone ___Speed Zone _X_ No Pass.Zone ___RR Crossing ___Other Cross. ___Other	___LanePlacemt/ Rd Following ___CarFollowing _X_ O.T. & Pass ___Other	_X_ Design _X_ Placement ___Performance ___Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

The report presents suggested criteria, warrants, and traffic control devices to design safe passing operations and designate no-passing zones on rural two-lane highways. The criteria are based on vehicle performance during the passing maneuver, the premise that sight distance should be provided at the critical position when the passing and passed vehicle are abreast, and evaluation of traffic control devices in providing the required visual information at this critical position. An advance pavement marking system consisting of a short dotted yellow line adjacent to the roadway centerline throughout the pass completion distance is proposed, in conjunction with the no-passing zone pennant sign, to advise the passing driver that passing should not be initiated beyond the start of this parking system because there is not sufficient distance to complete the maneuver before reaching the no-passing zone. Warrants for no-passing zones are presented with lengths of advance treatment and minimum distances between successive no-passing zones for a range of expected operating speeds. An economic analysis of the expected benefits to be derived if the system were to be implemented nationwide indicates a high probability of being cost-effective.

CRITICAL ANALYSIS:

The combination of low volume on much of the two-lane rural system and the time and difficulty associated with collecting accurate, passing behavior data, makes the likelihood of directly evaluating passing-related information systems low for the current project. As such, much of the information in the report is not directly relevant to either the planning or the conduct of the study. However, the information system recommended by Weaver and Woods is one which is judged to meet driver needs more adequately than existing systems. As such, it is likely to be included, by reference, as one of the recommended information systems identified in Task F.

W/5.0

REFERENCE: Weaver, G. D., Woods, D. L., Allen, C. J. and Matlock, N. L., "Pilot Field Tests of Experimental No-Passing Zone Treatments," Texas Transportation Institute, Report NO. RF-3828-7, March, 1981.

LITERATURE DESCRIPTORS				
Alignment	Cross Section	Situation	Maneuver	Info Media
___ Tangent ___ Horizont. Curve ___ Vertical Curve ___ Grade ___ Other	___ Pavement ___ Lane Width ___ Shoulder ___ OffRoadway ___ Other	___ Intersection ___ Driveway ___ Tunnel ___ Bridge ___ L.W.Transit. ___ Schl. Zone ___ Speed Zone X No Pass.Zone ___ RR Crossing ___ Other Cross. ___ Other	___ LanePlacemt/ Rd Following ___ CarFollowing ___ O.T. & Pass ___ Other	___ Design ___ Placement X Performance ___ Other

OTHER DESCRIPTORS: None

SUMMARY/ABSTRACT:

This report documents research conducted to pilot field test three experimental no-passing zone advance warning treatments for rural two-lane highways that were developed in a previous study, "Passing and No-Passing Zones: Signs, Markings, and Warrants" (Report No. FHWA-RD-79-5, Contract No. DOT-FH-11-9164).

The three experimental treatments included (1) the NO PASSING ZONE pennant sign placed in accordance with the MUTCD: (2) a short dotted line pattern extending upstream from the no-passing zone barrier stripe and adjacent to the dashed centerline marking; and (3) combination of the pennant sign and the advance dotted treatment. The experimental devices were installed at three locations on two-lane highways in each of three States: North Carolina, Texas, and Utah. Passing performance was measured for more than 2600 passing maneuvers executed in the nine study sites (about 240 miles, 386 km of study sites) with conventional MUTCD no-passing zone demarcation and with the experimental treatments. Driver understanding and opinion surveys were administered to 561 drivers who were observed executing a pass within the study sites.

Each of the treatments exhibited favorable characteristics with respect to providing advance information that a no-passing zone is being

approached; however, the combination treatment accomplished this better than either device alone. The treatment(s) appear to be more effective in flat or rolling terrain than in mountainous terrain. No negative safety effects on passing performance were found from use of the dotted marking system even though it was totally unique. Drivers stated that the treatment(s) greatly increased the visibility characteristics of the solid yellow no-passing stripe. Further evaluation on a more wide spread basis with perhaps driver education is suggested as a result of this pilot study.

CRITICAL ANALYSIS:

Data was collected using an instrumented "floating" vehicle proceeding through the speed limit at 5 mph less than the normal running speed of the traffic stream. Speed, time and positional data were recorded for all vehicles passing the instrumented vehicle. Passing drivers were later surveyed. Nine sites (with each site having 20 no-passing zones) in 3 states were used. Data collection consisted of a driver, a "front" recorder and a "back" recorder. Computed measures of effectiveness included "clipping" distance, "clipping" frequency, number of passes initiated within 1000 ft of the No-Passing Zone, total passing distance of vehicles initiating a pass within 1000 ft of the no passing zone, and the number of "passing" zones through which the vehicles trailed prior to initiating a pass.

Only 159 drivers returned completed questionnaires (31% response rate). Of the questionnaire, one finding may be pertinent to the current study. The most common misinterpretation of the pennant sign was that drivers believed that they should not pass beyond the point where they could first see the sign. The pennant could be seen for about 1200 ft whereas only 750 ft is needed to complete a high-speed pass from the "critical" position. Fifty-four percent recognized that the pennant designated the beginning of a no-passing zone.

A 13-point scale was used to evaluate driver opinion on how well these treatments provided assistance in passing situations and on how well these treatments could be recognized. These findings are not pertinent to our study.

The NO PASSING ZONE pennant sign was found to perform very satisfactorily as a highly visible device to designate the beginning of a no-passing zone in most environmental conditions. Limited nighttime studies indicated that it is highly visible at night and that drivers initiating a pass were prone to abort the maneuver when seeing the reflective sign downstream after moving to the left. Although it did not significantly reduce "clipping" distance, it offers several desirable features and should be included in the recommended information system for no-passing zones.

During the course of this study, it was found that drivers were observed to execute a passing maneuver very aggressively in the mountainous study sites, probably because they were offered relatively short passing opportunities at infrequent intervals. It is understandable that drivers, familiar with these constraints, would accept passing opportunities with greater risk factors since it may be the only opportunity for several miles. Discussion with local drivers in this terrain indicated that they accept passing opportunities primarily on the criterion of no visible approaching vehicle. They stated that the severe geometry with obvious "blind" curves immediately conveyed to them the approximate location of the next expected no-passing zone. Realizing this, their decision to attempt to pass was based solely on whether or not there was an opposing vehicle within this distance. Their passing practices were predicated on their visual interpretation of the roadway geometry rather than traffic control devices. Hence, use of additional traffic control devices at these locations may not be necessary for other than maintaining demarcation uniformity (legal purposes). The presence of a no-passing zone downstream is clearly designated by the severe terrain sight restrictions.

INDICES

GENERAL INDEX

SITUATION (Continued)

No Passing Zone

Railroad Crossing

Other Crossing

MANEUVER

Lane Placement/ Road Following

Overtaking & Passing

Speed Control

DESIGN

PLACEMENT

PERFORMANCE

MEASURES INDEX

DRIVER PERFORMANCE (cont)

Railroad Crossing

ACCIDENT STUDIES

Horizontial Curves

Pavement

Lane Width

Intersection

Intersection (Continued)

Bridge

No Pass Zone

Railroad Crossing

ANALYTICAL

Horizontial Curve

MEASURES INDEX

ANALYTICAL (Cont.)

OTHER SITUATIONS

OTHER SITUATIONS (Cont)

School Zone

Speed Zone

Other Crossing

GENERAL

Geometrics

Driver Behavior