REPORT NO. DOT-TSC-FHWA-78-2,IV

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 Urban Drivers of Slow Moving Vehicles on a Grade

G. F. King
P. Abramson
J. W. Cohen
M. R. Wilkinson

KLD Associates, Inc.
300 Broadway
Huntington Station NY 11746

MAY 1978
FINAL REPORT

DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC
THROUGH THE NATIONAL TECHNICAL
INFORMATION SERVICE, SPRINGFIELD,
VIRGINIA 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
Office of Research
Washington DC 20590

Technical Report Documentation Page

1. Report No. DOT-TSC-FHWA-78-2,IV	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle 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		5. Report Date April 1978
		6. Performing Organization Code
7. Author(s) G.F. King, P. Abramson, J.W. Cohen, M.R. Wilkinson		8. Performing Organization Report No. DOT-TSC-FHWA-78-2,IV
9. Performing Organization Name and Address KLD Associates, Inc.* 300 Broadway Huntington Station NY 11746		10. Work Unit No. (TRAIS) HW801/R8202
		11. Contract or Grant No. DOT-TSC-992-4
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration Office of Research Washington DC 20590		13. Type of Report and Period Covered Final Report April 7, 1975 - August 1977
		14. Sponsoring Agency Code

15. Supplementary Notes

*Under contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. 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. This Technical Report consists of seven other volumes. They are:

Vol.	pp.	Title
I	38	Introduction, Description of Experiments and Common Elements
II	70	Develop and Evaluate Dynamic Aids for Narrow Bridges
III	72	Evaluation of MUTCD and Other Traffic Controls for Highway Construction and Maintenance Operations on Two-Lane Highways
V	62	Vehicle Equivalency and Capacity Including Effects of Commercial and Recreational Vehicles on Rural Non-Controlled Access Highways
VI	54	Comparative Evaluation of Warning-Advisory and Regulatory Traffic Control Devices
VII	50	Develop and Evaluate Measures for Reducing Effects of Roadside Friction
VIII	70	Remedial Aids for Intersections with Inadequate Sight Distance

17. Key Words Experimental Design, Highway Signs, Dynamic Aids, Slow Moving Vehicle, Grades, Remedial Aids	18. Distribution Statement DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	58	

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

TABLE OF CONTENTS

LIST OF FIGURES (Continued)

LIST OF TABLES

1. INTRODUCTION

This volume contains the Experimental Design entitled, "Develop and Evaluate Remedial Aids to Warn Drivers of Slow Moving Vehicles Ahead on a Grade."* It is Volume IV of an eight-volume report. Volume I contains background information and discussion of the seven experimental designs.

This volume includes:

- Background and Objective;
- A State-of-the-Art Review;
- The Experimental Design;
- A Bibliography.

1.1 Background

The sudden appearance of slow moving vehicles is a recognizable hazard facing drivers on all types of highways. This type of hazard occurs frequently at reasonably predictable locations. A prime example of such a hazardous location is an ascending grade. Rural highways have many sections of steep ascending grade where no passing is permitted. Slow and/or heavy vehicles ascending these grades present a potential hazard to faster moving vehicles overtaking them. The driver of the overtaking vehicle has poor judgment of the leading vehicle's speed. It is possible that much poorer judgment may result where a queue of passenger cars is following a slow moving truck. Often during such occurrences the minimum safe following distance is violated. While enforcement might provide one method of alleviating this safety problem, it poses more practical problems (e.g., how to determine the violation; who is the offender?). A more encompassing approach would be to avoid or minimize the hazard by making traffic move safely. This may be achieved through proper roadside advisory signing. For example, the hazards involved in overtaking long queues may be reduced by providing following drivers with information regarding the queue as they approach. This information would possibly include optimum approach speed. This will tend to smooth out the traffic flow and reduce resulting conflicts assuming that the overtaking drivers accept the suggested speeds and use caution as they join the end of the queue.

---

* This experiment is referred to as Experiment C in Volume I.

2. STATE-OF-THE-ART

A summary state-of-the-art is presented below. The principal areas that were investigated in the literature search were:

- Passing;
- Grades, including truck performance on grades and accidents on grades;
- Slow moving vehicle warning devices.

2.1 Passing

Most rural highways are two-lane roadways on which vehicles frequently overtake slower moving vehicles. This maneuver must be accomplished in the lane regularly used by opposing traffic. Passing can be safely completed only if a sufficient gap in opposing traffic exists so that the passing maneuver can be completed without cutting off the passed vehicle and without forcing any oncoming traffic to swerve or brake. The passing driver must therefore be able to see a distance ahead sufficient to identify the required gap. The AASHTO Blue Book (1) has specified certain minimums for passing sight distance. Table 1 gives minimum values of sight distance for various design speeds.

TABLE 1. - MINIMUM PASSING SIGHT DISTANCE FOR DESIGN OF 2-LANE HIGHWAYS

Design Speed, mph	Assumed Speeds: Passed Vehicle, mph	Assumed Speeds: Passing Vehicle, mph	Minimum Passing Sight Distance, ft.
30	26	36	1100
40	34	44	1500
50	41	51	1800
60	47	56	2100
65	50	60	2300
70	54	64	2500

The Blue Book also indicates that most cautious drivers will not attempt to pass under less than minimum circumstances and states that designing the roadway on this basis would reduce the usefulness of the highway. Studies made by Jones and Heimstra (34), Recent studies (71) have essentially reconfirmed these past performance studies. The Highway Capacity Manual (30) states that, although the horsepower of trucks has tripled in the past 25 years, performance has not increased radically due to the increasing weight that is now carried by trucks (34). Figure 1 shows grade performance of 400 lb/hp truck.

A relatively new entry into the traffic stream is represented by the recreational vehicle (RV). These vehicles have performance characteristics similar to trucks (67) and should be treated as trucks due to a relatively high weight-to-horsepower ratio. In addition to RVs, the auto utility trailer combination (54) should also be treated as a heavy vehicle.

The length of the grade is of importance in considering truck hill-climbing abilities. Studies by Taragin (60) represented one of the first sytematic efforts to find the effect of grade length on truck grade climbing. Taragin also derived an equation to calculate speed changes for any vehicle weight class, load or grade. More recent studies by Firey and Peterson (20) devised methods for calculating speed-versus-distance trajectories of large trucks on a variety of vertical curves. Graphs are presented in the Blue Book (1) to determine critical grade lengths (Figure 2).

Many research reports deal with congestion caused by slow moving vehicles on grades. One solution to this problem is to install truck climbing auxiliary lanes. Results of studies by Dunn (16), Willey (68) and others have led researchers such as Glennon (23, 58) and others (18, 32) to develop design standards and criteria for truck climbing lanes. The criteria for consideration of this type of lane are given in the AASHTO Blue Book (1).

In addition to the field tests performed, there are models available to calculate the effect of grades on the speed of heavy vehicles. The most comprehensive model is the SAE Truck Ability Prediction Procedure (50). This procedure is a step-by-step work book approach for estimating truck performance on grades. Parameters included are: horsepower, weight, tires, altitude, rolling and air resistance, chassis function, grade and roadway. Other investigators, such as Carlsson (12) have also developed models to estimate the effects of grades on trucks.

A complete review of current truck performance literature can be found in a paper by Glennon and Joyner (24). Results reported in this paper are in general agreement with the Blue Book (1).

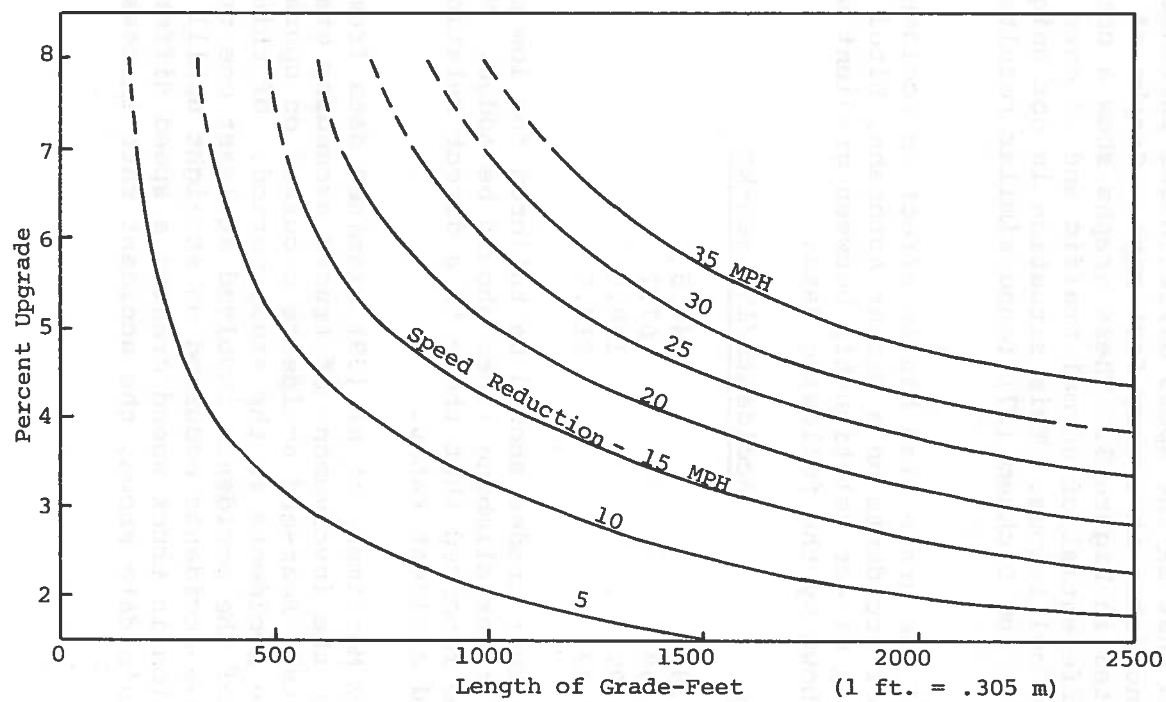

FIGURE 2: Critical Lengths of Grade for Design
Assumed Typical Heavy Truck of 400 lb/hp (243 kg/kw)

Source: AASHTO Blue Book (1)

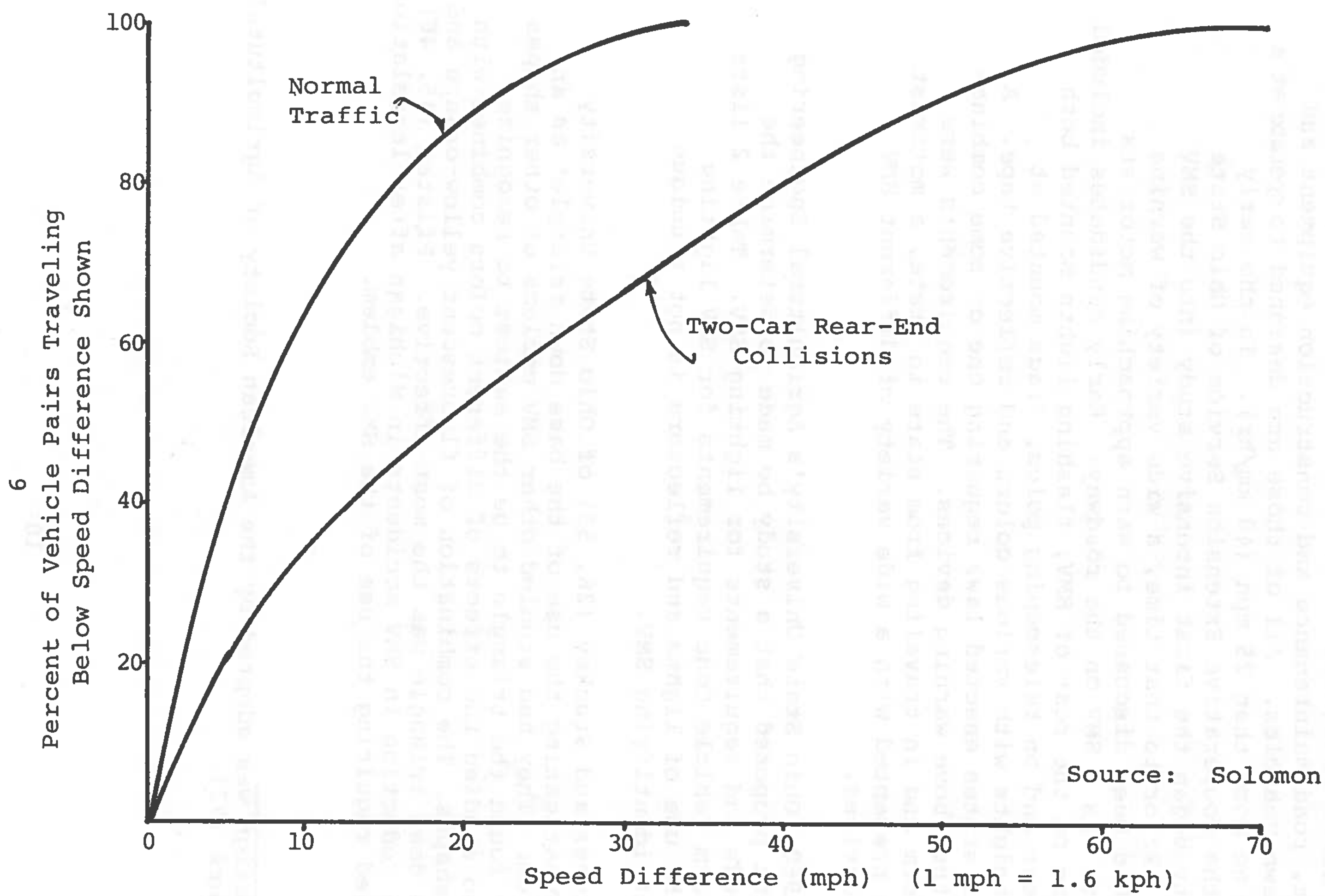

FIGURE 3: Speed Difference Between Passenger Cars Involved in Two-Car Rear-End Collisions Compared with Normal Traffic - Day and Night Combined

Source: Solomon (47)

Wardle (65) compared various color combinations of flags, flashing lights and the SMV emblem. He concluded that no one warning device was adequate. He found that flags were seen best in daylight, SMV emblem at dusk and a flashing red light best at dark. The SMV emblem was found to be effective during the day with the flag and at night with the flashing light.

The National Safety Council (41) issued a policy statement in 1966 urging the standardization and acceptance of the SMV emblem and the education of the driving public as to its meaning. The policy statement is included as Exhibit 2.

The efforts to develop SMV warning devices, particularly the SMV emblem are described by Schmidt (52) and by Rooney (47).

In addition to the SMV emblem mentioned above, there have been other efforts to develop alternate warning devices. Field measurements in New Zealand, by Francis (17), of the warning capabilities of a similar device showed positive results. A base down triangle was used with flashing lights at each of the vertices, actuated by low speeds. (Details of the American and New Zealand SMV emblem are shown in Figure 4.)

Eight millimeter movies were made from the rear of a SMV as vehicles approached and passed the SMV. The distance data in the table below is the distance from the rear of the truck to the passing vehicle at the time the passing maneuver is initiated. The time is measured from the instant when the passing vehicle crossed the roadway centerline until it passed the rear of the SMV. A sample size of 40 was used for each of the two variables.

	With SMV Emblem		Without SMV Emblem	
	Distance	Time	Distance	Time
Mean	200' (61 m)	5.2 sec.	171' (52 m)	3.7 sec.
Standard Deviation	50' (15 m)	1.5 sec.	45' (14 m)	1.2 sec.

Drivers moved to pass the SMV further away, but the variance of time and distance increased. These results are significant at the .99 level.

In a comparison of the red flag, required by law in some states, and the U.S. SMV emblem, Asper (5) found that the SMV emblem could be seen at significantly further distances. These results held for such demographic variables as sex, age and place of residence. He concluded that at 50 mph (80 km/hr), the motorist would have an additional 270 feet (82 m) of warning on level roadways. Properly displayed, the SMV emblem increased the safety margin over high mounted red flags.

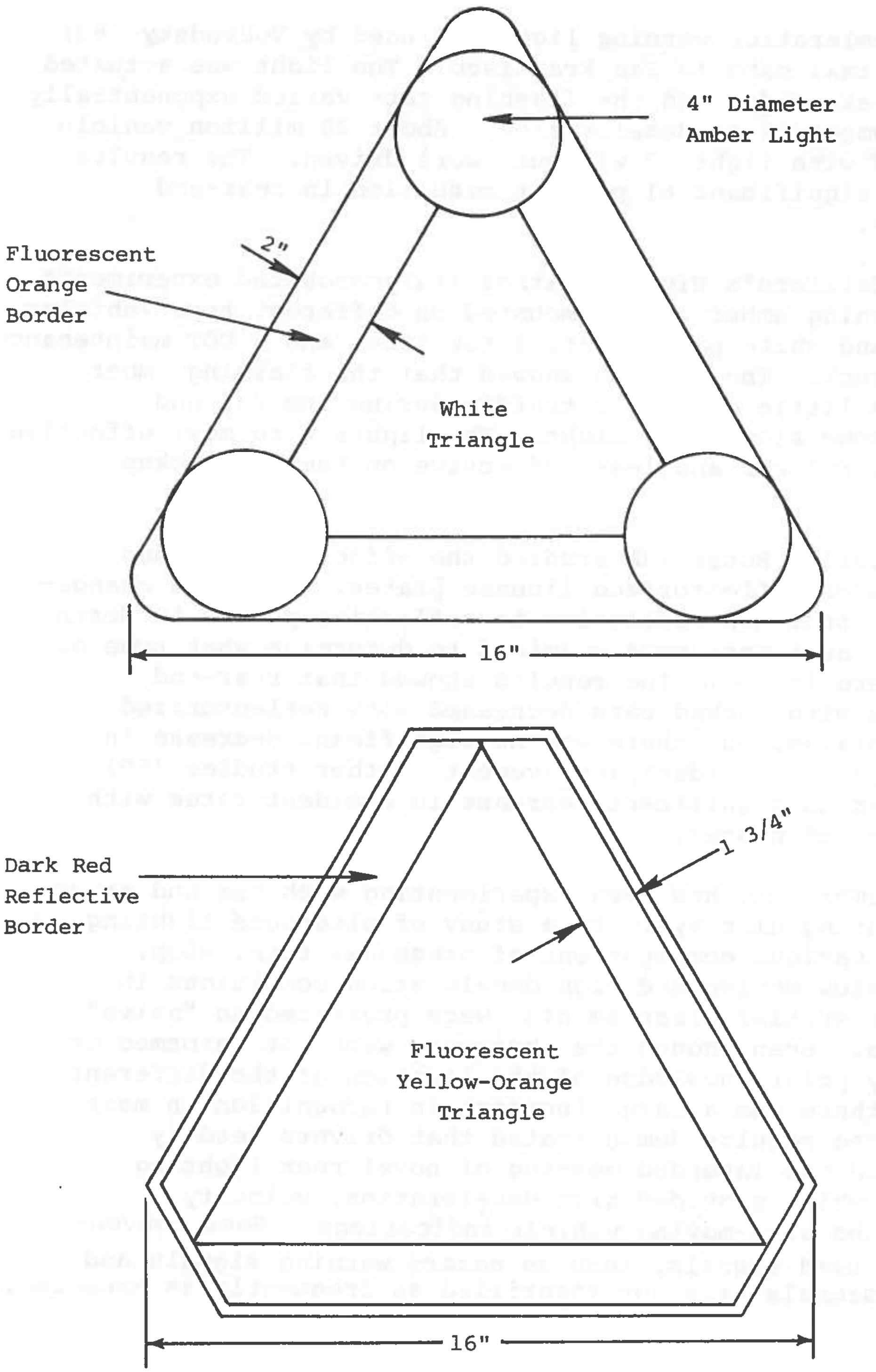

FIGURE 4: New Zealand (top) and U.S. Slow Moving Vehicle Emblems (1" = 0.254 m)

3. EXPERIMENTAL DESIGN

The experimental design is based on the premise that potentially unsafe behavior by a motorist catching up to a slow moving vehicle on a grade is due to a failure by the following motorist to perceive the speed differential between his vehicle and the leading vehicle properly. This incorrect perception leads to incorrect speed control behavior by the following motorist.

In this experiment, the slow moving vehicle will be under the control of the experimenter and injected on the roadway. On the other hand, the "following" vehicles, whose performance is to be measured, will be random components of the traffic stream.

Any device or treatment which improves the perception of speed differential by the following motorist will reduce potentially unsafe driving behavior. The evaluation of a number of treatments or devices, singly and in combination, are included in the experimental design.

3.1 Independent Variables

The independent variables to be investigated in this experiment are summarized in Table 3, which also represents a summary of the experimental design. These variables include roadside devices, devices attached to lead vehicle, ambient lighting conditions, lead vehicle type, and finally, lead vehicle speed. A general discussion of independent variables not included in the experimental design (i.e., day of week, season of year, inclement weather) may be found in Volume I of this report.

3.1.1 Devices

The principal independent variable, or set of independent variables, to be selected contains the devices to be tested in the experiment. These devices may be stratified as road signs and vehicle signs and will be investigated separately and in combination. The purpose of these devices, or treatments [which may be active or passive], is to alert following vehicles to the presence of slow moving lead vehicles ahead. These devices may also be classified as cooperative or non-cooperative. Within the context of this experiment, an active device is defined as one which requires activation and shows an alternating display. A passive device is one which does not require activation and shows a constant display. A cooperative device is one which requires instrumentation or positive action on the part of the lead (i.e., slow moving) vehicle. A non-cooperative device is one which does not involve such instrumentation or positive action.

The devices to be tested for this experiment are listed below.

Road Sign Conditions

Including the experiment control or null condition; i.e., no sign at the test site (Base Condition), four sign conditions are to be tested. Sign Condition 1 is a passive non-cooperative device. It is a 48-inch (120-cm) yellow diamond standard advisory sign with the words "SLOW MOVING VEHICLES AHEAD" in black letters. Sign Condition 2 is also a passive non-cooperative device. It is identical to Sign Condition 1 except that this sign is supplemented with two 8-inch yellow beacons that are continuously flashing. Sign Condition 3 is an active non-cooperative device and requires instrumentation of the roadway. It is identical to Condition 2 except that the flashers will be activated and a standard yellow rectangular shaped "WHEN FLASHING" advisory plaque is erected beneath the diamond-shaped sign. It should be noted that the base condition is tested after each road sign condition is completed. This will aid in answering two important questions which must be investigated:

- Whether the effects of this sign condition just completed has any after effect on the driver;
- Whether the site characteristics have changed to the extent that the driver perception is different.

Examples are foliage, roadside stands, bicycles, etc. If the answers are affirmative, all analysis must take this into consideration. (Investigating only one speed, 15 mph, will be sufficient to answer these questions.)

Lead Vehicle Sign Condition

Two types of lead vehicles are included in the experiment. These represent, respectively, a vehicle which is often, but not always, slow moving; e.g., a truck and a vehicle which is always slow moving; e.g., a farm tractor. Different lead vehicle devices are to be tested on each of these vehicles. Each particular device is to be tested in combination with each

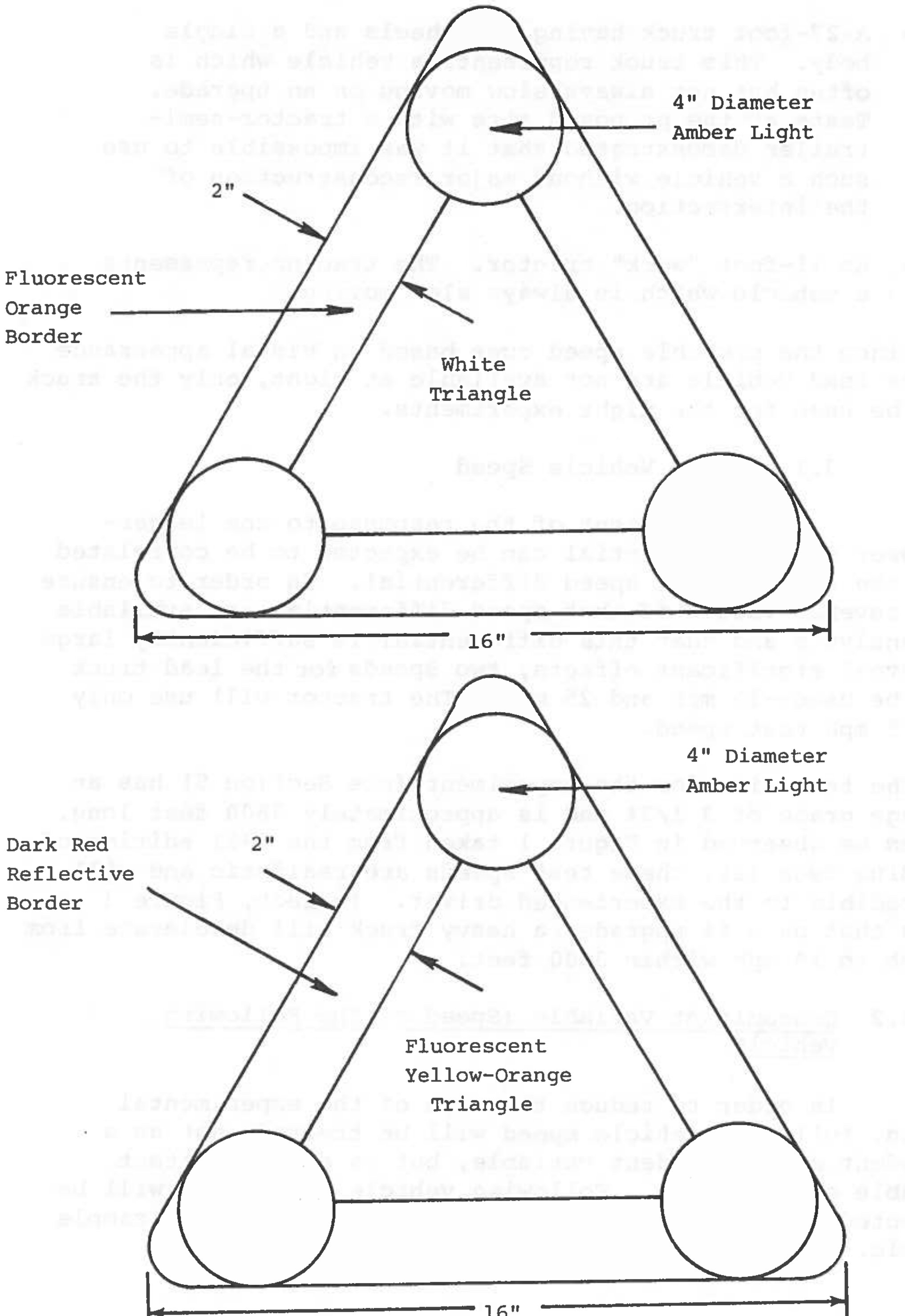

FIGURE 5: Original New Zealand Slow Moving Vehicle Emblem (Top) and Modification (Bottom)

The following criteria will be used for the selection of following vehicles. Data will be collected on the selected vehicles if they

- are passenger cars or vehicles with similar wheel-base dimensions;
- are free-flowing vehicles;
- are traveling at a speed in excess of 45 mph when the lead vehicle is traveling at 25 mph;
- are traveling at a speed in excess of 35 mph when the lead vehicle is traveling at 15 mph.

3.3 Dependent Variables

The set of dependent variables consists of those parameters which change in value, qualitatively or quantitatively, in response to changes in the independent variables discussed above. A subset of these contains the parameters whose values will be measured during the proposed experiments. These response measures are discussed below.

For the planned experiment, these response measures will be limited to parameters for which changes can be measured externally to non-cooperative vehicles, except as indicated in Section 3.3.3 below. The quantities to be measured and the statistics to be derived therefrom will be mainly those which characterize

- changes in speed of the following vehicle;
- changes in the space and time headways between lead and following vehicles.

3.3.1 Speed

Data will be collected to characterize the entire speed profile of the following vehicle starting at the point of initial deceleration from the steady state approach speed and terminating near the crest of the grade which forms the test section.

3.4 Experimental Hypotheses

The intent of the experimental hypotheses is to structure the experiment and data analysis in advance of experimentation so that the relative effectiveness of each warning device can be evaluated. The null hypotheses can then be stated in terms of the dependent variables which are to be used as measures of effectiveness. Each hypothesis implies the comparison of the observed value of the dependent variable under a set of test conditions with some prior value obtained either from the control case or one of the device configurations.

There will be three sets of hypotheses for this experiment. In general, the null hypotheses to be tested for the overall experiment can be stated as follows:

H_0 - the use of device, D_i, or combination treatment, T_i, will lead to safer highway operations under visibility conditions, V_j.

The safety effects of each device, or of each combination treatment, will be assessed by evaluating the smoothness of the deceleration pattern, the adequacy of the terminal headway and the absence of erratic maneuvers over the entire range of initial speed differentials.

One null hypothesis of this generic type can be stated and evaluated separately for every device and treatment tested for each level of the independent variables included in the experiment.

The experimental hypothesis, as stated, cannot, however, be tested directly by standard statistical methods. The superiority of any one traffic control configuration over any other, all other factors remaining constant, is evaluated against a set of pre-established criteria. The application of these individual criteria may lead to apparently contradictory results which must be resolved by trade-off analysis. The response to each individual criterion is ascertained by examining changes in a specific response measure. The first response measure will be the velocity noise of the following vehicle from the time it enters the test section until a stable terminal headway of the following pair has been reached. Velocity noise can be described as the standard deviation of the following vehicle's velocity over distance.

H_0: Under ambient lighting condition, L_j, lead vehicle type, T_k, and lead vehicle speed, V_s, there is no difference in initial reaction differences for all devices/treatments.

The alternate hypothesis is:

H_1: Under the above conditions the initial reaction distance for device/treatment D_i is not equal to the initial reaction time for device/treatment D_j.

It is recommended that a significance level of $\alpha = .05$ be used in testing the above sets of hypotheses.

3.5 Experiment Site Characteristics

The criteria for a test site include, as a minimum, the following:

- Within the facility electronics and as near center as possible;
- Fairly long hill with maximum grade obtainable;
- Good side road for injection of test "slow" vehicles;
- Minimum regular traffic on side road;
- Opportunity for turn around of test vehicles;
- Approach speeds in excess of 45 mph.

Several possible locations, which are part of the Maine Facility (see Volume I) were investigated for this experiment on Ell Hill and Sibley Pond Hill including:

- Eastbound, from Vehicle Detector Station Box No. 235;
- Westbound, from Box 203;
- Eastbound, from Box 295;
- Eastbound, from Sibley Pond.

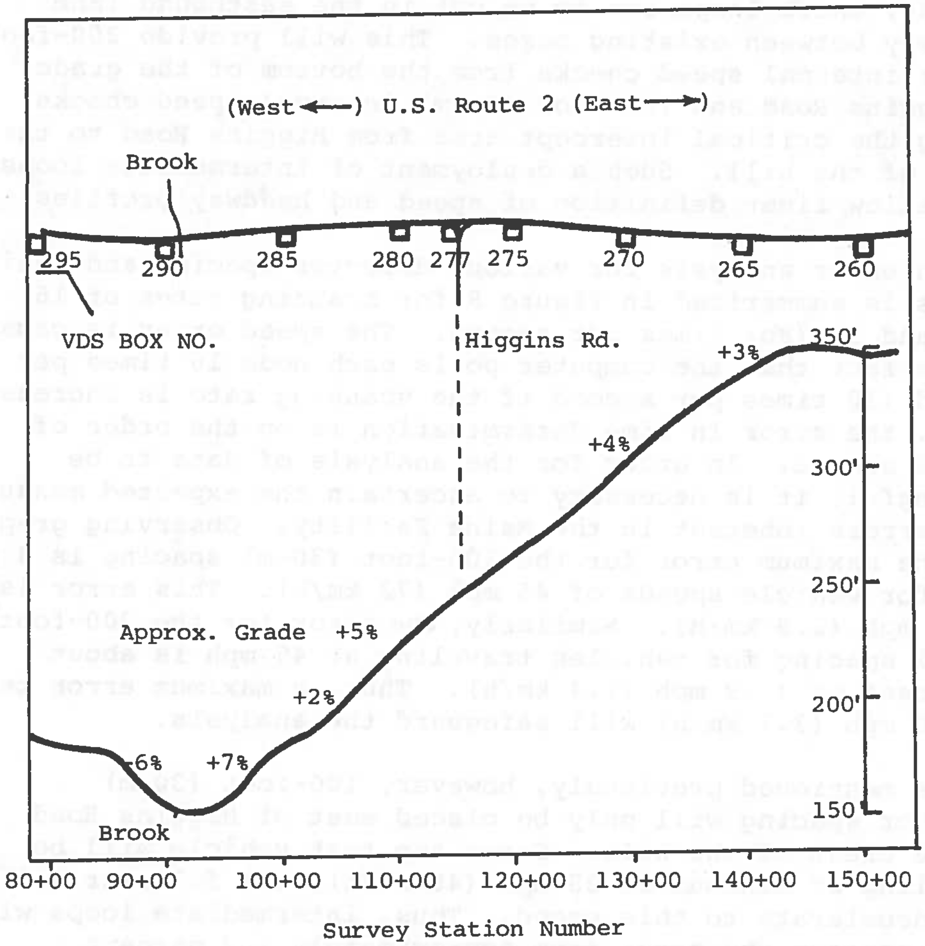

FIGURE 6: Test Site Plan and Profile

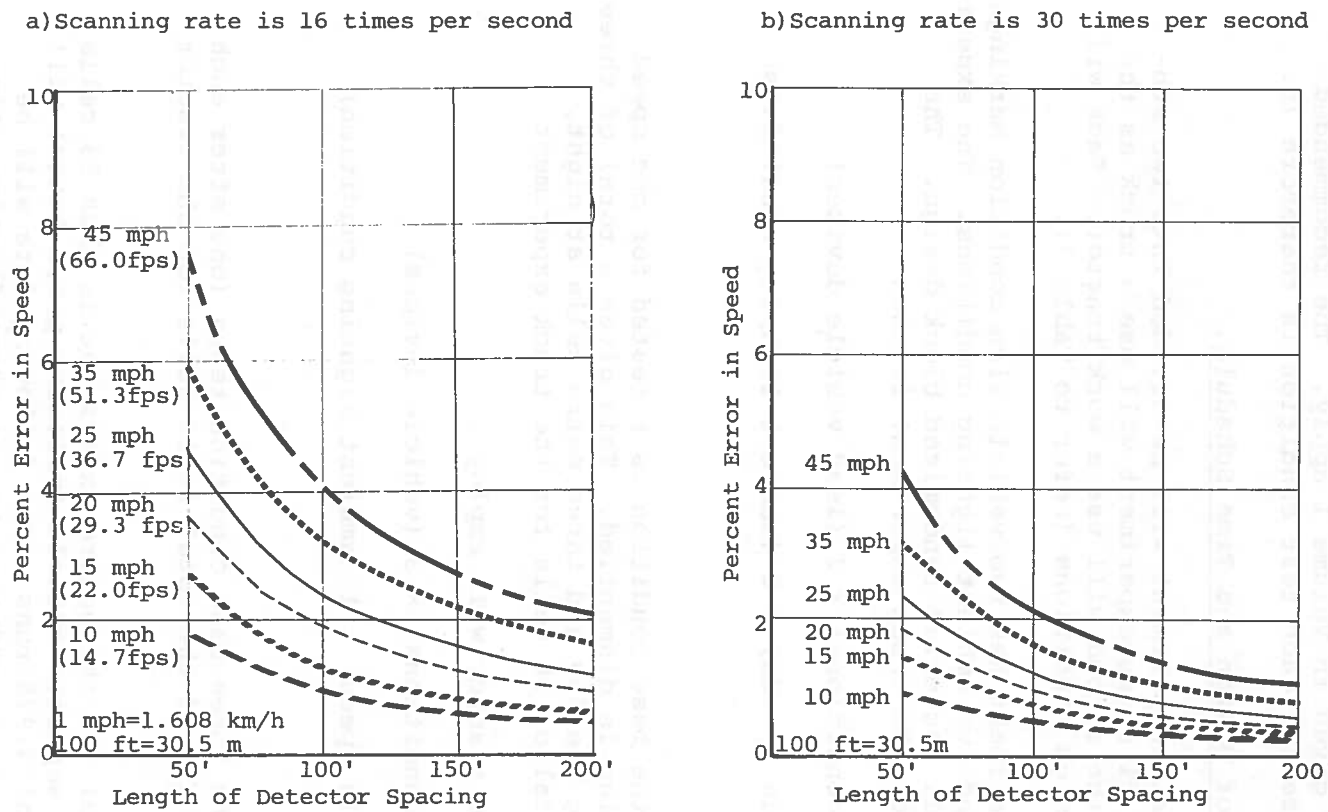

FIGURE 7: Percent Error of Speed Relative to Detector Placement

- Speeds of lead and following vehicles over distance;

- Headway of each vehicle over distance;

- Initial reaction point of following vehicle (determined by deceleration profile);

- Entry speed of following vehicle.

In addition, if manual observers are used, the following data will also be collected:

- Erratic maneuvers of following vehicle;

- Horn or headlight displays;

- Attempted or actual passing maneuvers.

A questionnaire is provided in Appendix A if a decision is made to conduct structured interviews of the drivers of following vehicles.

The entire experiment for all day tests may be completed in 4 months. This would depend on two not unreasonable assumptions:

1) That a minimum of five runs can be completed in one hour during the day;

2) The experiment is done at the time of the year when, under the restrictions adopted for data collection, 8 hours of daylight are available.

Due to the nature of the experiment, the two lead vehicles on site can be used during the same time period. One can climb the test grade while the other is returning from test runs. In this way, experiments with similar test conditions can be run at the same time, minimizing the total time for the experiment. It is therefore expected that five runs per hour can be accomplished without much difficulty.

Hence, during the night hours, four sign conditions result in 300 runs per sign condition. At five runs per hour, each sign condition will take 50 hours. Thus, conducting tests for five hours nightly results in a total of ten nights to complete each road sign condition.

Therefore, once the road signs are in place, 10 nights are needed to complete testing for each sign condition, exhausting all independent variables under consideration. Three nights will be needed to complete each base condition. Thus, a total of 13 entire nights are needed before a new sign condition can be installed. Allowing for bad weather (expected to be greater than during the summer), dismantling sign, etc., an estimate of 20 days (1 calendar month) is needed per sign condition. Hence, 4 months are needed to complete the night experiment.

3.9 Data Analysis

The speed and headway of the vehicle pair as it traverses the test section will be recorded. From this data, velocity noise and terminal headways will be computed. In addition to these parameters, the initial reaction distance of the following vehicle to the lead vehicle will be determined from the vehicle's deceleration profiles.

In addition to speed and headway data, the entry speed for each following vehicle will be recorded. Entry speed data will be collected far enough upstream of the test section so that the free speed of the follower can be measured. This is anticipated to be recorded between VDS Boxes 295 and 294.

3.9.1 Velocity Noise

The parameter "velocity noise" is the standard deviation of velocity over distance. It is computed using the following:

$$\sigma = \frac{1}{k-1} \sum_{i=1}^{k} (V_i - \bar{V})^2 \quad i = 1, \ldots \; k = i^{th} \text{ detector.}$$

Treatments which minimize velocity noise; i.e., smooth the deceleration profile, would be considered as improvements over existing conditions.

At terminal headway, it is expected that the following vehicle will reduce the speed to that of the lead vehicle, thus setting

$$V_f = V_\ell = V.$$

Therefore,

$$a = V \quad [2V \; (h-T + \frac{V}{2d}) \; - \; 2L_\ell]^{-1}$$

or

$$a = \frac{V^2}{2V(h-T + \frac{V}{2d})-2L_\ell} = \frac{V}{2(h-T)+\frac{V}{d} - \frac{2L_\ell}{V}}$$

where

V = 15 mph (and 25 mph for the truck) (24 and 40 km/h)
T = 1.5 seconds (estimate)
L_ℓ = 30 feet for truck (9.1 m)
14 feet for tractor (4.3 m)
assumes 3-foot (1-m) clearance
d = 25 ft/sec² (7.6 m/sec²). This is the most dangerous situation where the lead truck is capable of a panic stop of 25 ft/sec². This assumes dry pavement, new tires and brakes, a 4% grade and a coefficient of friction of .76.

Figures 9 and 10 summarize the results of the required deceleration rates for given terminal headways.

The 1964 edition of the Traffic Engineering Handbook (7) states, "At a deceleration of 14 ft/sec² (4.3 m/sec²) packages may slide off the seat and the occupants of the vehicle find this rate uncomfortable." Therefore, for the purposes of the experiments, all required deceleration rates greater than 14 ft/sec² (4.3 m/sec²) may be deemed unsafe and all below this may be deemed safe. Thus, as can be observed in Figures 6 and 7, the following are safe terminal headways for this particular experiment.

		Safe Terminal Headway		
Vehicle	Speed	Seconds	Feet	Metres
Truck	15	$\geq$ 3.20	70.4	21.5
Truck	25	$\geq$ 2.90	106.3	32.4
Tractor	15	$\geq$ 2.50	55.0	16.7

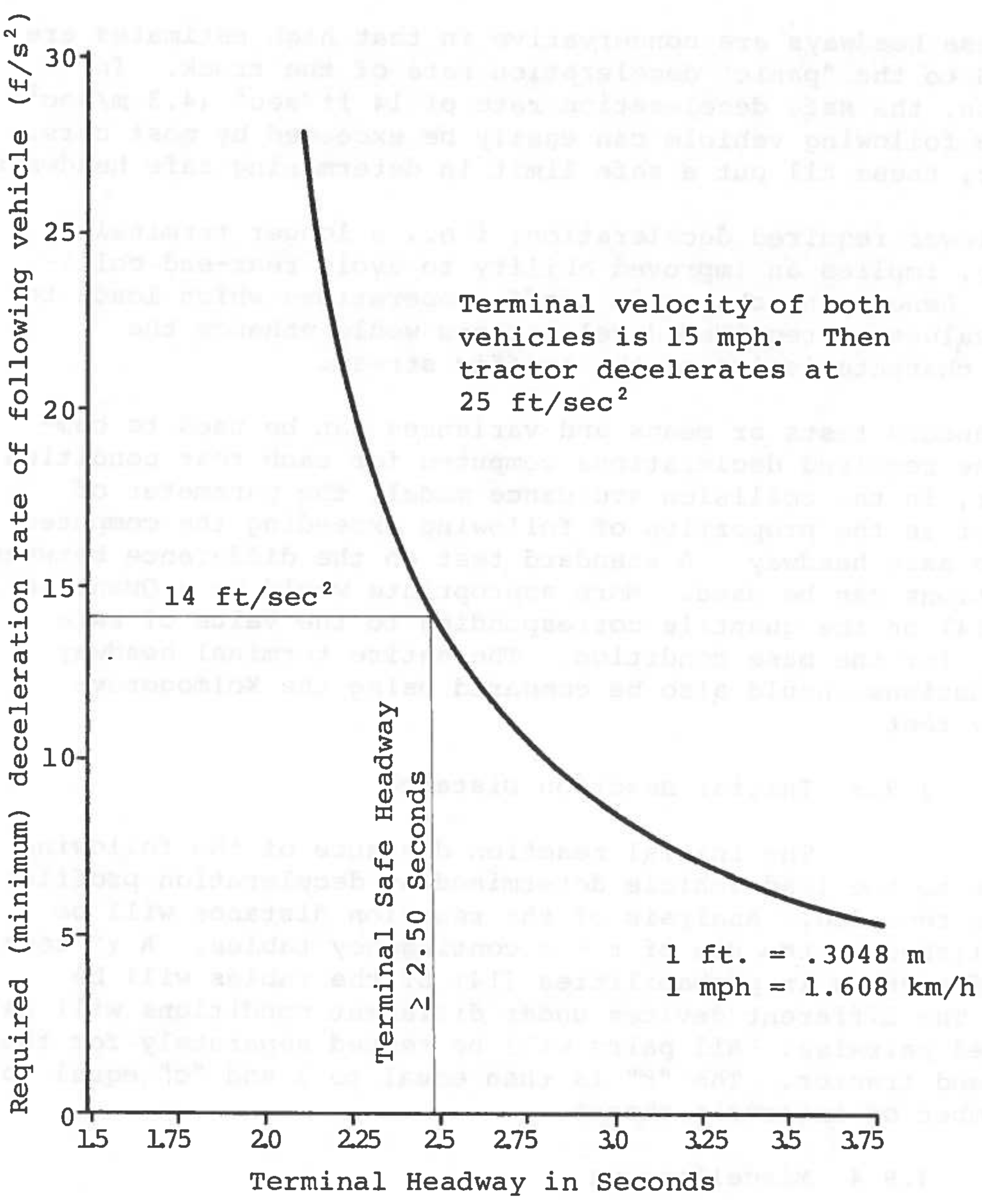

FIGURE 9: Required Deceleration Rate of Following Vehicle, Given Leading Length of 14 ft. (includes 3 ft. clearance)

REFERENCES

1. AASHO, "A Policy on Geometric Design of Rural Highways-1965," Washington, D. C., 1966.

2. AASHO, "Highway Design and Operational Practices Relating to Highway Safety," Washington, D. C., 1967.

3. American Society of Agricultural Engineers, "Slow Moving Vehicle Identification Emblem," ASAE Standard S276.1, St. Joseph, Mo., 1966.

4. Ashton, N. R., Buckley, D. J., Miller, A. J. and Chapman, R. A., "Some Aspects of Capacity and Queuing in the Vicinity of Slow Vehicles on Rural Two-Lane Roads," Australian Road Research Board Proceedings, Vol. 4, Pt. 1, pp. 595-612.

5. Asper, O., "The Detectability of Two Slow Moving Vehicle Warning Devices," Journal of Safety Research, Vol. 4 No. 2, June 1972, pp. 85-9.

6. Automotive Safety Foundation, "Sight Distances for SMV Emblems," Traffic Research Engineer, no date (from National Safety Council).

7. Baerwald, J. E., Ed., Traffic Engineering Handbook, Institute of Traffic Engineers, Washington, D. C., 1965.

8. Bitel, F., "Accident Rates on German Expressways in Relation to Traffic Volumes and Geometric Designs," Roads and Road Construction, January 1947, pp. 18-20.

9. Boughton, C., "Accident Involvement of Long Vehicles," Australian Road Research Board, 1972.

10. Cambell, B. J. and Rouse, W. S., "Reflectorized License Plates and Rear End Collisions at Night," Traffic Safety Research Review, Vol, 12 No. 2, pp. 40-45.

11. California Highway Patrol, "Warning Light Study No. B-1-43."

24. Glennon, J. C. and Joyner, C. A., "Re-evaluation of Truck Climbing Characteristics for Use in Geometric Design," Texas Transportation Institute, Texas, 1969.

25. Goldblatt, R. B., "Guidelines for Flashing Traffic Control Devices," Final Report, FHWA Contract No. FH-11-8532.

26. Gustavsson, J., "A Model for Overtaking on a Two Lane Road with Limited Visibility," Vehicular Traffic Science, Proceedings of 3rd International Symposium on the Theory of Traffic Flow, New York, 1965.

27. Hall, W. and Dickinson, L. V., "Truck Speeds and Accidents on Interstate Highways," Presented at 53rd Meeting HRB, January 1974.

28. Harkness, K. A. and Stucky, W. E., "Effective Approaches to Reducing Accidents Involving Slow Vehicles," Ohio State University.

29. Heimback, C. L. et al, "Relating No Passing Zone Configurations on Rural Two Lane Highways to Thruput Traffic," HRR 437.

30. Highway Capacity Manual - 1964, Highway Research Board Special Report 87, National Academy of Sciences, Washington, D. C., 1966.

31. Hiller, J. A. and Wardrop, J. G., "Effect of Gradient and Curvature on Accidents on London-Birmingham Motorway," Traffic Engineering and Control, Vol. 7, No. 10, pp. 617-621, February 1966.

32. Huff, T. S. and Scrivner, F. H., "Simplified Climbing Lane Design Theory and Road Test Results," HRB Bulletin 104, pp. 1-11, 1955.

33. Jacobs, F., "Queues and Overtaking on Two Lane Roads," Transportation and Traffic Theory, 6th International Symposium on Transportation and Traffic Theory, Sydney, 1974.

34. Jones, H. V. and Heimstra, N. W., "Ability of Drivers to Make Critical Passing Judgments," Journal of Engineering Psychology, Vol. 3, No. 3, pp. 117-122.

47. Rodney, P. J., "Origin, Diffusion, Acceptance and/or Rejection of Slow Moving Vehicle Emblem," Michigan State University, 1970.

48. Saal, C. C., "Comparison of Methods for Determining the Hill Climbing Abilities of Trucks," HRB Proc. No. 18, Part 1, p. 362.

49. Saal, C. C., "Relation between Gross Weights of Motor Trucks and Their Horsepower," Public Roads, 29: No. 10, pp. 233-238, October 1957.

50. "SAE Truck Ability Prediction Procedure - J688, SAE Handbook Supplement 82," Society of Automobile Engineers, Inc., New York, N. Y.

51. St. John, A., "Grade Effects on Traffic Flow Stability and Capacity," Final Draft, NCHRP 3-19, Midwest Research Institute, 1974.

52. Schmidt, P. E., "The Slow Moving Vehicle Emblem Story," Farm Department, National Safety Council, Chicago, revised January 1972.

53. Schwender, H. C., Norman, O. K. and Granum, J. O., "New Methods of Capacity Determination for Rural Roads in Mountainous Terrain," Highway Research Bulletin 167, pp. 10-37, 1957.

54. Siria, B. S. and Deen, R. C., "Auto Utility Trailer Combinations on Rural Highways in Kentucky," Bureau of Highways, Kentucky DOT, Lexington, 1973. Abridgement in Highway Research Record No. 489, pp. 19-33.

55. Snedecor, G. W. and Cochran, W. G., "Statistical Methods," Iowa State University Press, 6th Edition, Ames, Iowa, 1967.

56. Solomon, D., "Accidents on Main Rural Roads Related to Speed, Driver and Vehicle," Bureau of Public Roads, Washington, D. C., 1964.

57. Soyster, A. and Wislon, G. R., "A Stochastic Model of Flow Versus Concentration Applied to Traffic on Hills," Highway Research Record No. 456, pp. 28-39.

70. Wood, H. T. and Cowley, J. E., "Vehicle Length Factor in Truck Accidents in Australia - A Pilot Study," Paper No. A81, 7th Conf., Australian Road Research Board, Adelaide, 1974.

71. Wright, J. M. and Tignor, S. C., "Relationship between Gross Weights and Horsepowers of Commercial Vehicles Operating on Public Highways," Paper No. 937B, October 1964.

72. "Vehicle Identification Emblem," ASAE S276.1, American Society of Agricultural Engineers, St. Joseph, Michigan, 1966.

APPENDIX

Questionnaire Specifications for Experimental Design to Develop and Evaluate Remedial Aids to Warn Drivers of Slow Moving Vehicles on a Grade

Slow moving vehicles on grades represent a serious safety problem which, due to technical and economic reasons, cannot be resolved by decreasing the weight-to-horsepower ratio of heavy trucks. The problem is acute on rural roads that lack truck grade climbing lanes. Accident data examined by Solomon and Mortimer show that the slow moving vehicle represents an invitation to a rear-end collision.

Intended Use of Survey

This questionnaire is intended to provide measureable data which can be used to analyze and evaluate motorist reactions to proposed warning devices for slow moving vehicles on grades. It is assumed that many questions can be formulated on a seven- or five-point scale, to obtain quantifiable results. These results can then be used to compare responses to different aspects of several dynamic aid treatments. This information is intended to supplement the data on motorist behavior as measured in the field tests and to aid in evaluating the safety and motorist acceptability of the systems being tested.

The questionnaire will be used as the format of a structured interview of motorists who have just driven through the experimental site in Maine. This will probably be implemented by stopping motorists at the side of the road or some other safe and convenient location, beyond and out of view of the test site, and having a trained interviewer record their responses to the items on the questionnaire. For the contemplated test site, either the Maine Facility parking lot or the adjoining rest area can be used.

Aims

The purpose of the questionnaire is to determine whether the proposed aids are performing their function by attracting the motorist's attention and providing an appropriate warning of a potentially hazardous situation.

2. Better warning devices are needed to warn of slow moving vehicles on grades.

   A. Did you notice any different signs as you approached the upgrade?

   B. Did you notice anything different about the vehicle you followed up the grade?

   C. Did you begin to slow sooner than normal when you saw the vehicle?

   D. If there was no opposing traffic as you approached the slow vehicle, did you consider passing?

3. Nighttime visibility conditions represent a potentially hazardous situation.

   Were you able to see the slow moving vehicle in time to prevent a hazardous or erratic movement on your part?

The remaining hypotheses refer to the warning device system through which the motorist has just passed on the Maine test Facility, that is, the device currently being tested. As there will be two different types of lead vehicle, trucks and a tractor, the treatments for the truck experiment will be denoted as "Treatment X_i (i=1,2,...9). The tractor experiment will be denoted as Y_j (y=1,2,...15).

Each interviewee will be questioned about <u>only one</u> of these systems, that is, the system he has just driven through, to obtain his reactions to it. Since 30 interviews are to be performed for each system experiment, the following hypotheses will be tested by comparing interviews performed during <u>different</u> system experiments. The hypotheses are:

Treatment X_i is a better attention-getting device than the other tested devices.

Treatment X_i gives more information than the other tested devices.