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SEVEN EXPERIMENT DESIGNS ADDRESSING PROBLEMS OF SAFETY AND CAPACITY ON TWO-LANE RURAL HIGHWAYS
Volume I: Introduction, Description of Experiments and Common Elements

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16. Abstract

This is Volume I, 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. The titles of the seven volumes are:

Vol.	pp.	Title
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
IV	58	Develop and Evaluate Remedial Aids to Warn Drivers of Slow Moving Vehicles Ahead on a Grade
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

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PREFACE

The present report, consisting of eight volumes, details the designs for seven experiments to be performed at or near the Maine Facility of the US Department of Transportation. These experimental designs were developed by KLD Associates of Huntington Station, New York, under contract DOT-TSC-992 with the Transportation Systems Center, US Department of Transportation, Cambridge, Massachusetts.

In the Development of these experimental designs, KLD Associates received significant assistance from Mr. Joseph S. Koziol, Jr., Contract Manager at TSC in Cambridge, and Mr. Maurice H. Lanman, Resident Manager at the Maine Facility. The contributions of Mr. Stanley R. Byington and Mr. Merton J. Rosenbaum, Jr., of FHWA, and of Mr. Frederick M. Boyce, Jr. and Mr. Al Gross of the Maine Department of Transportation should also be acknowledged.

Preliminary drafts of all experimental designs were reviewed by and discussed with members of the Maine Facility Advisory Committee. This review process provided considerable assistance in the development of the final designs.

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1. INTRODUCTION

1.1 Background - Safety Problems on Two-Lane Rural Roads

Rural two-lane roads are important in terms of extent, usage, and accident rate. Conditions such as oncoming traffic, slow vehicles on a grade and restricted passing opportunities tend to lower average vehicle speed, correspondingly increasing travel time and irritating the driver. Situations of this kind may cause a driver to make unsafe passing attempts, tailgate or overtake a slow vehicle at high speeds.

Precise statistical information on two-lane rural roads in the United States is not available. Rural road mileage comprises approximately 22% of the U.S. total, but carries 32% of the total traffic. This traffic is involved in an even larger share of the fatal road accidents (48%).

The primary problem is how to increase safety, improve traffic flow, and lower operating costs without incurring major capital expenditures to rebuild and upgrade existing roads.

1.2 Overview of Contract

This contract (DOT-TSC-992) was awarded in early 1975 and was completed in August 1977. The original contract called for ten experimental designs to be chosen by TSC from a list of 17 experiments. The contract was modified so that the number of experimental designs was reduced from ten to seven. Preliminary and draft designs were submitted to TSC and the Maine Facility Advisory Committee for comments and revisions. In one experiment, a pilot study was performed to verify distributions of basic variables. The comments and revisions were incorporated into the final experimental designs which are presented as a series of seven volumes that accompany this volume.

1.3 Maine Facility

The Maine Facility is a computer-controlled data acquisition system that can detect vehicles and track their positions in real time as they travel on an electronically instrumented two-lane rural highway. These traffic data are stored on magnetic tape for subsequent off-line data reduction and evaluation of traffic behavior.

Table 1

Traffic Measures Obtainable from the Maine Facility System

Individual Vehicle

Direction of travel
Spot speed
Acceleration and deceleration
Speed variance
Number of speed changes
Number of stops
Stopped time
Travel time
Journey speed
Delay
Travel pattern (turns from the main road)

Two or More Vehicles

Space-mean speed
Time-mean speed
Volume (over any time period: 5 minutes, hour, day, etc.)
Time headways (between successive vehicles)
Spacing (between same points on successive vehicles)
Density
Passing times
Number of overtakings
Number of passes
Distribution and size of queues
Gap acceptances (for left turns, crossing maneuvers and passing maneuvers
Cumulative speed distributions
Total number of stops
Total delay
Accumulation (volume/time-mean speed)
Time spent in queue
Number of hazardous maneuvers (acceptance too small gaps: passing aborts)
Speed violations (at curves, on tangents, entry town speed zones, etc.)
Traffic distribution by direction

Table 2

Site Characteristics

System length	15 miles
Speed limits	15, 35, 45, 60 mph
Road type	Two-lane asphalt
Maximum grade	7 percent
Maximum curve	4°30'
Number of bridges	2
Number of railroad crossings	1
Average daily traffic	1,000 to 4,000 VPD
Percent truck traffic	8 to 12 percent
Estimated capacity (two-way)	700 to 1,600 VPH
Directional traffic distribution	0.60
Pavement width	20 to 24 feet
Shoulder width	2 to 10 feet
Percent passing sight distance	31 percent
Highway intersections	9
Entrances	280

2. DESCRIPTION OF SEVEN EXPERIMENTS

A total of seven experimental designs were completed during the course of the contract. Several of these experimental designs have been implemented; detailed planning for implementation of the others is currently in progress. Reports on completed experiments will be forthcoming. These reports, as well as information on the implementation status of all the experimental designs can be obtained by contacting the

Resident Manager
The Maine Facility
RFD Box 421
Pittsfield, ME 04967.

The detailed experimental designs will be found in Volumes II through VIII of this report. The specific research objectives of each of these proposed experiments is given below.

2.1 Experiment A - Develop and Evaluate Dynamic Aids for Narrow Bridges

Narrow bridges, defined as those having a clear two-way roadway width less than the width of the approach pavement, have a high potential for serious accidents. The objective of this experiment was to develop and test dynamic remedial aids to reduce the hazards and vehicle conflicts on narrow bridges. A dynamic aid system is one which has the capability of detecting approaching traffic and warning approaching motorists by actuating the appropriate display. The display can indicate that a hazard potential exists, identify the nature of the potential hazard, and/or advise the motorists of the appropriate action to be taken to avoid or minimize the hazard.

The final experimental design called for the evaluation of six distinct dynamic aid systems falling into three broad categories:

Attention Enhancement Systems

- I. Actuated Flashing Beacons on the Advance Warning Sign
- II. Actuated Flashing Strobe Light on the Advance Warning Sign
- III. Structure Lighting (night only)

- A construction/maintenance activity (e.g., full-depth patching) that requires a short, less than 100 feet (30 metres), closure and, therefore, does not require positive traffic control.

For each of these maintenance/construction activities, the effect of three distinct traffic control systems is to be investigated. These systems represent, respectively,

- The standard MUTCD system,
- An enhanced MUTCD system,
- A system relying heavily on symbol signing.

Measures of effectiveness based on the speed, the headway, the path and the interaction of vehicles, as well as vehicle trajectories, are to be used for assessing the differential effectiveness of the traffic control systems tested. Speed flow and headway based parameters are to be used to evaluate the capacity effects of the lane closures.

2.3 Experiment C - Develop and Evaluate Remedial Aids to Warn Drivers of Slow Moving Vehicles Ahead on a Grade

The sudden appearance of slow moving vehicles is a recognizable hazard facing drivers on all types of highways. Rural highways have many sections of steep ascending grades 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. The objective of this experiment is to develop and test remedial aids to warn drivers of slow moving vehicles on a grade on rural two-lane roads.

The final experimental design calls for the evaluation of both active and passive devices. Both cooperative and non-cooperative lead vehicles are to be involved. 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.

2.5 Experiment E - Comparative Evaluation of Warning-Advisory and Regulatory Traffic Control Devices

The MUTCD contains specifications for both regulatory and warning-advisory signs. Under certain conditions, either type of signing may be appropriate. There appears to be a lack of specific guidelines for the proper use of regulatory and warning advisory signs and a wide variation in the application of these two types of traffic control devices. Combinations of the two types to warn of potential hazards and to spell out applicable regulations may or may not be more effective in some situations. The objective of this experiment is to determine the relative merit of warning-advisory and regulatory signing used individually or in combination for speed zones, intersections and other problem locations on two-lane rural highways.

The final experimental design calls for four separate sub-experiments addressing distinct signing situations. These four situations include

- Curves,
- Intersections,
- No-Passing Zones
- Downgrades.

For each of these situations, between four and six distinct signing treatments are to be evaluated. These distinct treatments incorporate various combinations of warning-advisory and regulatory signing as well as these two types of signing used by themselves.

Evaluation MOEs are directly geared to the type of driver action desired and include speed based parameters, brake light applications, lateral placements, passing behavior and down-shifting. It is also recommended that a number of these sub-experiments be performed off the Maine Facility since the Facility does not have all the required geometric and traffic situations.

2.6 Experiment F - Develop and Evaluate Measures for Reducing the Effects of Roadside Friction on Traffic Flow

Roadside friction elements interfere with the smooth flow of traffic. These elements create conflicts in traffic flow and result in unsafe and/or erratic movements of the compare the devices among themselves and with the base line condition. MOEs based on the approach speed distributions and on the stopping behavior of vehicles on the side street will be used for the analysis.

Table 3

Traffic or Highway Situation

Situation	Experiment
1. Narrow Bridges	A
2. Long Lane Closure with Positive Control	B
3. Short Lane Closure without Positive Control	B
4. Following Slow Moving Vehicles	C
5. Curves	E
6. Intersections	E
7. No-Passing Zones	E
8. Steep Downgrades	E
9. Driveways	F
10. Parked or Disabled Vehicles on Shoulders	F
11. Bicycles	F
12. Combination of Nos. 9 and 10	F
13. Intersections with Inadequate Sight Distance	G

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.

These response measures may be the dependent variables of the individual experimental designs (see Section 3.2 below) or they may be functions of one or more dependent variables.

3.2 Experimental Variables

Experiments are designed to measure the change in one or more variables, called dependent variables, due to changes in other variables, called independent variables. For data analysis and experimental design purposes, a subset of the set of independent variables, referred to as concomitant variables, is sometimes defined.

3.2.1 Dependent Variables

For each experimental design, the set of dependent variables is selected that

- is feasible to collect;
- has the greatest probability of showing significant results;
- involves the smallest commitment of manpower, time and other resources;
- leads to the determination of response measures for which the direction of improvement is uniquely determined.

In accordance with these criteria, dependent variables are selected which, insofar as possible, can be collected

- using the existing instrumentation and software of the Maine Facility, and
- do not require additional manpower.

Table 4

<u>Summary of Dependent Variables</u>

Experiment	Situation	Speed				Path				Action[4]				Interaction				Reaction[4]			
		M[1]	O	C	N	M	O	C	N	M	O	C	N	M	O	C	N	M	O	C	N
A	1	√					√						√				√		√		
B	2	√[2]							√		√					√					√
	3			√			√				√					√					√
C	4	√[2]							√		√			√[2]					√		
E	5[6]		√	√			√[5]				√[5]						√				√
	6[6]		√	√							√[5]						√				√
	7[6]				√				√		√						√				√
	8[5]		√						√		√						√				√
F	9			√			√						√				√				√
	10			√			√						√				√				√
	11			√			√						√				√				√
	12[3]		√				√				√						√				√
G	13[3]		√						√		√						√				√

[1]M - Maine Facility Instrumentation
O - Other Methods
C - Combined
N - Not Used as Dependent Variable

[2] - Augmented
[3] - Not Performed at the Maine Facility
[4] - Data Cannot Be Obtained with Maine Facility Instrumentation
[5] - Data Desirable. To Be Collected If Feasible.
[6] - May Not Be Performed at the Maine Facility.

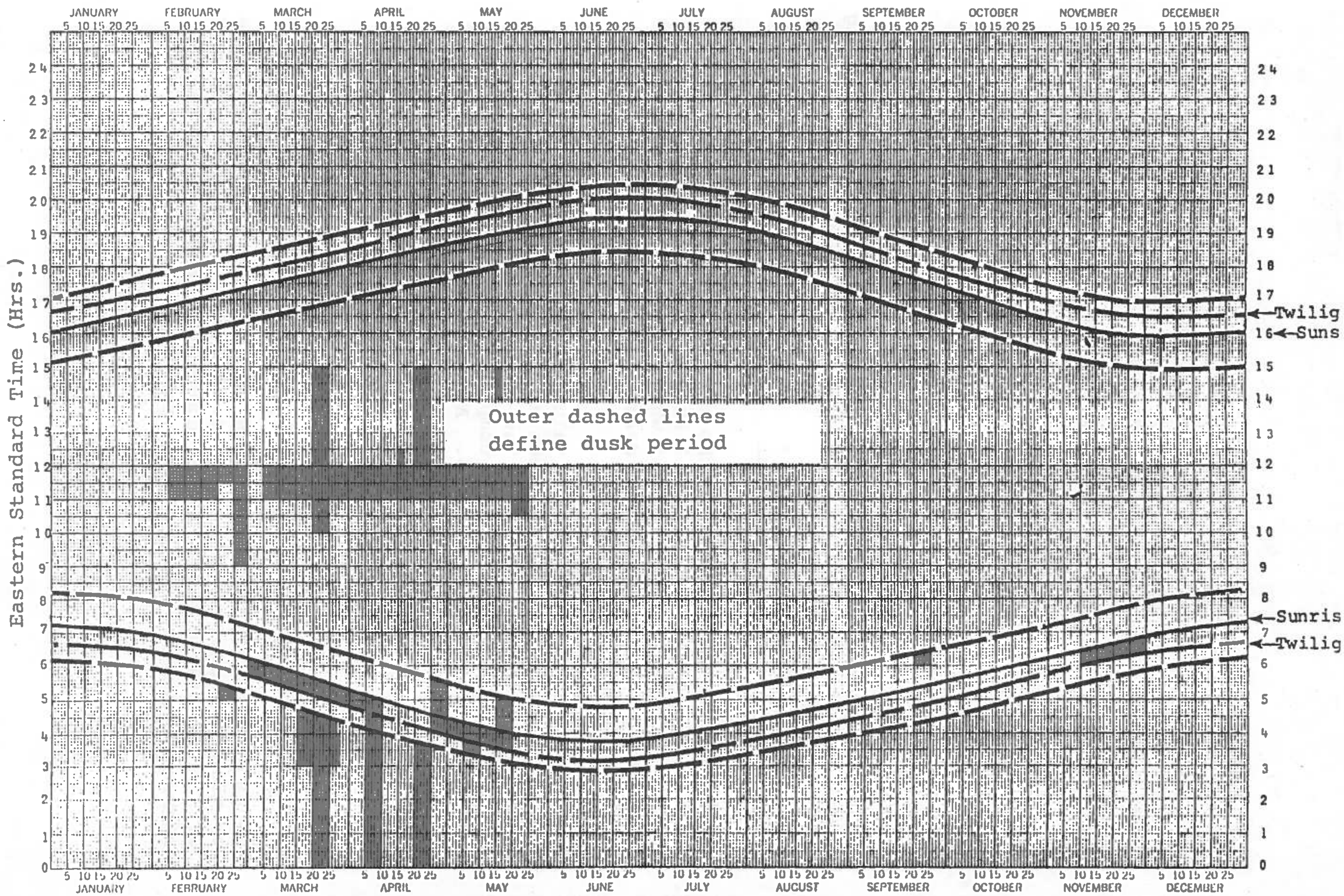

FIGURE 1. - Bangor, Maine - Latitude 45°, Longitude 69°

Sample size estimates for changes in 85th percentile speeds have been based on the binomial quantile test. Speed is assumed to be normal and the formula to compute the lower limit and upper limit is:

$$Z_k = \frac{(V_{85} \pm \varepsilon) - \mu}{\sigma} \tag{2}$$

where ε is the change in the 85th percentile which can be measured. In all applications of this formula, the standard deviation, σ, was assumed to be equal to 8 mph. For V_{85}, values of 55 and 63.3 mph were used; for ε, values of 2 and 1.5 mph were used; and for the mean, μ, values of 46 and 55 mph were used. Applying the formula for the confidence interval of a percentile, r:

$$r = np \pm Z_{\alpha/2} \sqrt{np(1-p)} \tag{3}$$

where n = sample size
$p = .85$
$\alpha = .05$
$Z_{\alpha/2} = 1.96$

and by iterating over values of n until a confidence interval of ±5% (determined by the upper and lower limits) is reached, appropriate sample sizes were computed. It was found that in order to detect a change of ± 2 mph, a sample size of 200 vehicles is needed; whereas, to detect a change of ± 1.5 mph, 300 vehicles are needed. The specific numerical computations are carried out, where appropriate, in the final experimental design reports.

To estimate sample sizes necessary to estimate proportions between .1 and .9, a nomograph was constructed. This is shown in Figure 2 for maximum errors of 10% and 20%.

Sample size requirements have also been refelected in the scheduling of experiments. For example, in Experiment D, in order to obtain adequate data on the effect of recreational vehicles on roadway capacity, the experiment was to be run largely during the summer months; that is, the peak period for recreational travel on the Maine Facility.

In all cases, standard statistical methods, such as equations (1),(2) and (3) were used to compute required sample sizes. These formulas are indicated in the appropriate section within each of Volumes II through VIII and the required parameters were obtained from past data on the Maine Facility.

3.4 Data Collection

The data collection task for each experiment is outlined in each experiment volume. Basically, the Maine Facility system is used to collect all speed data. In each experiment, the site on the Maine Facility is specified and the particular sensors to be used for data collection are identified. In several experiments, TDC* sensor equipment is used to supplement the data collection obtained through the existing system. In the Time of Arrival Mode, the TDC equipment is used to obtain headway data. In the Narrow Bridge experiment, lateral placement of vehicles is measured by the TDC equipment. The necessary sensor configuration is described fully in Volume II.

The TDC configuration for lateral placement consists of a diagonal sensor (coaxial cable) in conjunction with two perpendicular sensors across the road. A roadside unit, the Traffic Data recorder, computes and stores differential speed data (Figure 3). The primary modifications needed to incorporate this equipment into the Maine Facility system involves software modification and, in fact, has been used by Maine Facility personnel and found to be adequate and compatible with their system. Using three channels of a TDC recorder, both inside and outside wheel positions can be obtained and the width of the vehicle can be computed.

The basic premise throughout the data collection activities is to utilize automatic data acquisition wherever possible and minimize the need for any form of manual data collection. However, in some cases, it has not been possible to completely eliminate the need for an observer. Thus, in Experiment B, an observer is used to record details of the path of vehicles and also to note erratic maneuvers. Requirements for manual observers are indicated whenever necessary and the details of data collection or special techniques for data gathering are fully described in each of the following volumes.

In several experiments, a structured interview or questionnaire is included in the data collection task. This is done at a location well beyond, and out of sight of, the experimental site. The specifications and hypotheses of the survey instruments are detailed in the appropriate volumes. Responses to the questionnaire are recorded by the interviewer on a standard form designed for the purpose. Standard techniques for questionnaire design and analysis have been employed and the interview instruments are included as part of the experimental design data collection process.

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* Transportation Data Corporation

3.5 Data Analysis

The data analysis tasks outlined in each experiment volume include a description of the data reduction, computational procedures and statistical tests which are recommended for evaluating the recorded data. These activities transform the raw data into statistical results on the basis of which the remedial aids and/or experimental hypotheses will be evaluated.

3.5.1 Data Reduction

Data reduction procedures include the computations necessary to convert the data recorded by the roadway sensors, such as clock times, into statistics such as speed, mean speed, or speed variance, and is generally accomplished by the software which is part of the Maine Facility system. Any necessary reductions which are not currently available through the Maine Facility system are specifically described, and recommended procedures for performing these additional reductions are given.

3.5.2 Statistical Analysis

The final step in the analysis task is the implementation of statistical tests which will yield significant evaluative results. These are all standard statistical procedures and are related to the hypothesis sections. The specific tests to be used are either completely described or referenced to some standard statistical sources.

The analysis sections permit the user of these experimental designs to fully analyze the data and indicates the form of the conclusions which can result. In some cases, alternative analyses procedures are given which can be implemented if time, economy and preliminary results indicate their feasibility.

APPENDIX

REPORT OF INVENTIONS

The objective of this study was to develop seven experimental designs to be implemented at the Maine Facility. These experimental designs were developed and represent a new application and efficient means for evaluating and analyzing various traffic control techniques. The designs developed under this contract include the following:

- o Dynamic aids for narrow bridges;
- o MUTCD and other traffic controls for highway construction and maintenance operations on two-lane highways;
- o Remedial aids to warn drivers of slow-moving vehicles ahead on a curve;
- o Vehicle equivalency and capacity including effects of commercial and recreational vehicles on rural non-controlled access highways;
- o Warning-advisory and regulatory traffic control devices;
- o Measures for reducing the effect of roadside friction on two-lane rural highways;
- o Remedial aids for intersections with inadequate sight distance.

The results and information obtained from the actual experiments based on these new designs may lead to the definition of new procedures, guidelines and warrants for improved safety or new traffic control devices.

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