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Run-Off-Road Collision Avoidance Using IVHS Countermeasures

Task 6 Supplemental Report:
Computer Simulation Studies of Countermeasure System Effectiveness

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16. Abstract

This document presents performance guidelines for the design and development of road departure warning systems to improve vehicle safety by eliminating or mitigating road departure crashes through driver notification or warning. Performance guidlines are presented for two classes of road departure warning systems, Lane Drift Warning Systems (LDWS) and Curve Speed Warning Systems (CSWS). A LDWS is designed to warn in the event of an unintentional drift out of the travel lane, typically due to driver drowsiness, distraction or inattention. A CSWS is designed to warn if the vehicle is approaching a curve too fast for the current conditions.

All aspects of system performance are addressed, including sensing requirements, warning algorithm requirements, driver interface requirements, test proceedures, and estimation of associated benefits.

These guidelines are intended to be used by manufactures and developers of road departure warning systems as a tool to:
1. Standardize system requirements
2. Standardize driver interface and control across systems developed by different manufacturers.
3. Standardize test procedures to verify proper system operation.

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EXECUTIVE SUMMARY

TASK 6 SUPPLEMENTAL REPORT

COMPUTER SIMULATION STUDIES OF COUNTERMEASURE SYSTEM EFFECTIVENESS

The primary purpose of Task 6 was to design and develop a test bed. To this end, activities involved expanding the RORSIN4 software that was developed during Phase I of this program. RORSIM simulates the combined effects of vehicle dynamics, a driver, an in-vehicle sensor, environmental effects and an in-vehicle countermeasure system. The sensor measures the vehicle position with respect to the roadway. This expanded version of RORSIM was needed in order to acquire insight into the countermeasure characteristics that will be tested during Phase III and was used during Phase II to conduct Monte Carlo simulation studies. The primary focus of the simulation studies was Counter Measure Systems effectiveness for Run-off-road crashes caused by disengagement of the driver.

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1.0 Introduction

1.1 Background

The team of Carnegie Mellon University (CMU), Battelle, Calspan and the University of Iowa was awarded the contract DTNH22-93-R-07023, "Run-Off-Road Collision Avoidance Using IVHS Countermeasures." This contract is in support of the mission of the U.S. Department of Transportation's National Highway Traffic Safety Administration (DOT/NHTSA) to ensure safety of the U.S. highway system. The overall objective of this contract, which was created as a three-phase, five-year program, is to develop practical performance specifications for in-vehicle countermeasure systems to avoid single vehicle roadway departure (SVRD) crashes, referred to as Run-Off-Road (ROR) events.

This preliminary draft report represents a summary of the project team's efforts during Phase II of this ROR project and was based on work that began during Phase I. During Phase III, this preliminary report will be expanded into a complete report. The preliminary nature of this report is based on the requirement to make the results of the Phase II work available as soon as possible so that it can be reflected into planning for Phase III of this project. The details concerning the various project phases are discussed below.

1.1.1 Motivation

The motivation for the ROR specification program is that ROR crashes represent the most serious problem within the national crash population in terms of fatalities and injuries. For example, according to the 1992 NASS GES file, which was assessed during Phase I of this program, there were approximately 1.21 million police-reported crashes of this type for that year and accounted for 20.1 percent of the cases. Additionally, more than 520,000 vehicle occupants were injured in ROR crashes in 1992 (i.e, 26.8 percent of the injuries in the 1992 NASS GES data base for that year). According to the FARS database, there were 14,031 fatalities for this crash type in the U.S. during 1992 and accounted for 41.5 percent of all crash fatalities (33,846).

From the work accomplished during Phase I of the ROR project, several causal factors were identified. These are: driver inattention (12.7 percent), vehicle speed (32 percent), evasive maneuver

(15.7 percent), driver incapacitation (20.1 percent), loss of directional control on road surface (16.0 percent), and vehicle failure (3.6 percent).

1.1.2 Overall Program Scope and Objectives

Phase I of the program was conducted during the period from September 1993 to September 1995 with the scope of "Laying the Foundation." Phase I consisted of the following four tasks:

Task 1: Establish ROR crash subtypes and causal factors by thoroughly analyzing the crash problem.

Task 2: Establish functional goals of candidate countermeasures based on intervention opportunities and mechanisms.

Task 3: Obtain basic operational, performance and functional data by performing hardware testing of existing technologies.

Task 4: Develop preliminary performance specifications based on critical factors and models of crash scenarios.

Phase II of this program, "Understanding the State-of-the-Art," started in October of 1995 and will conclude at the end of September 1996. It consists of two tasks:

Task 5: Conduct a technology state-of-the-art (SOA) review.

Task 6: Design and develop a test bed.

Phase III, "Test and Report," will involve two tasks, which are construct/acquire a test bed (Task 7) and conduct testing to support the development of performance specifications (Task 8).

1.1.3 Program Organization

The conduct of the ROR program is sequential in that the output of one task serves as the input for the next. The purpose of Task 1 was to determine the circumstances associated with ROR crashes and the reasons for them. The results of this work provided the basis of Task 2, where a taxonomy was developed to classify ROR scenarios so that countermeasure functional goals could be defined. Task 3 applied the results of the preceding task to formulate and test hardware, whose operating characteristics embodied these functional goals. Using the previous tasks as a foundation, Task 4 involved the development of mathematical models embedded in a computer simulation that included effects due to vehicle dynamics, the driver, sensors, environmental conditions and in-vehicle countermeasures, The results of exercising the mathematical model were used to develop preliminary performance specifications for countermeasure systems for the avoidance of ROR crashes.

During Phase II, a technology state-of-art review (Task 5) was conducted regarding hardware systems and subsystems that may be useful as ROR countermeasure systems. A thorough technology assessment was performed earlier during Phase 1. However, a subsequent review was needed to explore new developments in the intervening two years, especially regarding some of the integrated collision avoidance prototype systems engineered in Europe. Several activities were undertaken in Task 6, which concerned the design and development of a test bed. These sub-tasks included: design of improved counter-measure algorithms, design and begin normative driver data collection experiments and the development and application of improved mathematical models. Battelle was responsible for the mathematical models and SOA review work.

1.2 Task 6 Overview

The primary purpose of Task 6 is to design and develop a test bed. To this end, activities involved expanding the RORSIN4 software that was developed during Phase I of this program. RORSIM simulates the combined effects of vehicle dynamics, a driver, an in-vehicle sensor, environmental effects and an in-vehicle countermeasure system. The sensor measures the vehicle position with respect to the roadway. This expanded version of RORSIM was needed in order to acquire insight into the countermeasure characteristics that will be tested during Phase III and was used during Phase II to conduct Monte Carlo simulation studies.

The primary focus of the simulation studies was Counter Measure Systems effectiveness (CMU) for ROR crashes caused by disengagement of the driver. For the purposes of the study, driver disengagement is defined as no change to either the steering wheel position, throttle, or brake settings from those at the last moment that the driver was engaged. Relatively short time durations of disengagement reflect momentary driver inattentiveness (caused by changing the radio station, looking in the glove box, etc.), while longer durations of disengagement represent situations such as unconsciousness. The model also represents impairment due to drowsiness or intoxication through the driver "aggressiveness of response" and "duration of driver disengagement" parameters. The results of the simulation studies include the effect of these types of disengagement and impairment.

In the Monte Carlo studies, RORSIM was run by varying several variables simultaneously to determine the performance "envelope" of the in-vehicle countermeasures system (CMS) to avoid ROR crashes. Variables for this simulation were:

1. Roadway radius of curvature
2. Lane width
3. Road friction
4. Shoulder friction
5. Shoulder rolling resistance
6. Vehicle speed
7. Driver steering reaction time
8. Driver lane keeping performance
9. Driver aggressiveness of response
10. Time of onset of driver disengagements
11. Duration of driver disengagements
12. TLC (time to line crossing) or TTD (time to trajectory divergence) threshold
13. TLC or TTD accuracy.

RORSIM was modified to accommodate appropriate distribution functions for each of these variables.

Three Monte Carlo studies were undertaken. The first study was performed to ensure that the range of values selected for each of the eight variables yielded normal driving circumstances when RORSIM is exercised (i.e., few, if any, ROR results occur). In the second study, the driver was disengaged at various times and for different intervals of time in order to create ROR events. For the third Monte Carlo study, the same set of trajectories from the second study was employed, but with a CMS that could warn the disengaged driver, causing him to resume control of the vehicle.

1.3 Organization of this Report

The remainder of this report is organized as follows with regard to the expansion of RORSIM and the conduct of the Monte Carlo simulation studies. Section 2 describes the analytical approach. The results of the analysis are presented in Section 3. Conclusions are given in Section 4. Recommendations are discussed in Section 5.

2.0 Analysis Approach

In Phase I of the ROR program, an analytical approach was developed specifically for evaluating CMS effectiveness in preventing ROR incidents over a wide range of driving scenarios. This approach was implemented in the software package RORSIM, which was developed and delivered to NHTSA at the end of Phase I. RORSIM is a menu-driven time-domain simulation program that predicts driver/vehicle/CMS dynamic interaction.

To meet the need for the ability to evaluate large numbers of driving scenarios and the influence variations in several vehicle, driver and CMS parameters, the analytical approach was expanded in Phase II, resulting in a more powerful and flexible version of RORSIM. The Phase II analytical approach is described in this section. Details of RORSIM are provided in the Phase I / Task 4 report, and in Appendix A of this report.

2.1 Analytical Method

The analytical model has three primary elements. These are:

1. A vehicle dynamics model,
2. A driver model, and
3. A CMS model.

A time domain simulation approach was adopted for the study. A lumped parameter model of the driver/vehicle/CMS system was used. A time-domain model was selected because the inherent nonlinearities of the vehicle and driver would be extremely difficult to model in the frequency domain.

In addition to representation of the dynamics of vehicle motion, the model must also capture the realistic dynamic interactions of vehicle-road, driver-vehicle, and CMS-driver interfaces. An explicit driver model was included that models the delays due to driver reaction times to braking and steering commands. The model captures the driver's nominal lane-keeping behavior and behavior in response to warnings issued by a CMS. Driver inaction can be simulated using this model. The driver model takes into account the different delays associated with the different response modes of a human driver. The CMS includes a sensor system that acquires the data required by the decision module of the system. The decision module then uses this data with available vehicle state information to determine whether the driver requires a warning.

Several CMS methodologies have been proposed for studying ROR events. A detailed description of these methods and their benefits was included in the Task 4, Phase I report [Pape et. al., 1995]. The methods model three types of warning systems:

1. A longitudinal system for warning of excessive speed when approaching a curve.
2. A lateral system for warning of lane departure danger based on the Time to Trajectory Divergence - (TTD) algorithm.
3. A lateral system for warning of lane departure danger based on the Time to Line Crossing - (TLC) algorithm.

In this phase, only one CMS, TLC, was studied. The methodology developed could as easily be applied to other CMS methodologies.

Each simulation run corresponds to one combination of input parameters. In order to generate enough data to statistically characterize the CMS better, the model developed in Phase I studies has been modified to automatically execute simulation studies using Monte Carlo techniques.

2.2 RORSIM

RORSIM is an enhancement to VDANL (Vehicle Dynamic Analysis, Non-Linear), which is a general-purpose rubber-tired vehicle simulation program developed for NHTSA by Systems Technology, Inc. in Hawthorne, California [Allen et.al., 1992]. VDANL provides the basic vehicle dynamics model for the simulation as well as the closed-loop driver model. VDANL includes a 17-degree-of-freedom model of a general vehicle. The nonlinear differential equations of motion are integrated numerically by VDANL. The project team has written enhancements to VDANL for use in evaluating ROR countermeasure systems. Capabilities have been added to simulate some of the driver's actions (and inactions), model the performance of various proposed countermeasure systems, and provide representative roadways.

The model is deterministic in the sense that almost every parameter, including the moment when the driver becomes inattentive, is fixed before a simulation begins. The only place where pseudo random numbers are used is in the lateral disturbance function for modeling driver lane keeping behavior.

The RORSIM package can simulate a complete scenario: a situation develops, it is sensed by the CMS, the driver responds to the warning and regains safe control of the vehicle. When applied like this, RORSIM is useful for demonstrating that a CMS can successfully prevent a ROR crash under the particular circumstances modeled.

The scope of the RORSIM simulation studies under Phase II was to conduct extensive parameter studies using a Monte Carlo like approach in an effort to provide a more comprehensive characterization of the effectiveness of CMS schemes in incipient ROR events. The goal was to demonstrate the effectiveness of one or more proposed countermeasure systems in preventing ROR crashes in a variety of circumstances. A more fundamental objective was to develop and exercise a methodology for evaluating the effectiveness of a proposed countermeasure system.

To implement this approach, the simulation program RORSIM was expanded in the following manner:

- Upgraded Vehicle Dynamics Model - The new RORSIM model is based on the latest version of VDANL, 5.02.
- New RORSIM Capabilities - an improved driver model, algorithms for generating CMS effectiveness estimates.
- Multiple Simulation Runs - The software was modified so that it could execute multiple runs autonomously. A module called RORMCRUN generates multiple simulation runs.
- Input files generation - A statistical package, RORSTAT, has been developed to automatically generate input files for Monte Carlo Runs.

Figure 2.1 shows a block diagram of the RORSIM package. Details of the above modifications to RORSIM are provided in Appendix A.

2.3 Latin Hypercube Approach

The analytical study involved a statistical approach in which all the key parameters were varied simultaneously according to a scheme that ensured good coverage of the range and distribution of each parameter value. This scheme, known as the "Latin hypercube" approach [Stein, 1987 and McKay et.al., 1979], is essentially similar to but more efficient than a pure Monte Carlo approach.

2.3.1 Theory and Use of the Latin Hypercube Method

Latin hypercube sampling is a Monte Carlo simulation procedure that provides an appealing alternative to generating independent and identically distributed random vectors. Latin hypercube sampling generally produces estimates with a lower variance than simple random sampling of input vectors. Roughly speaking, Latin hypercube sampling stratifies each marginal distribution of the input vector as much as possible but otherwise picks the vectors randomly.

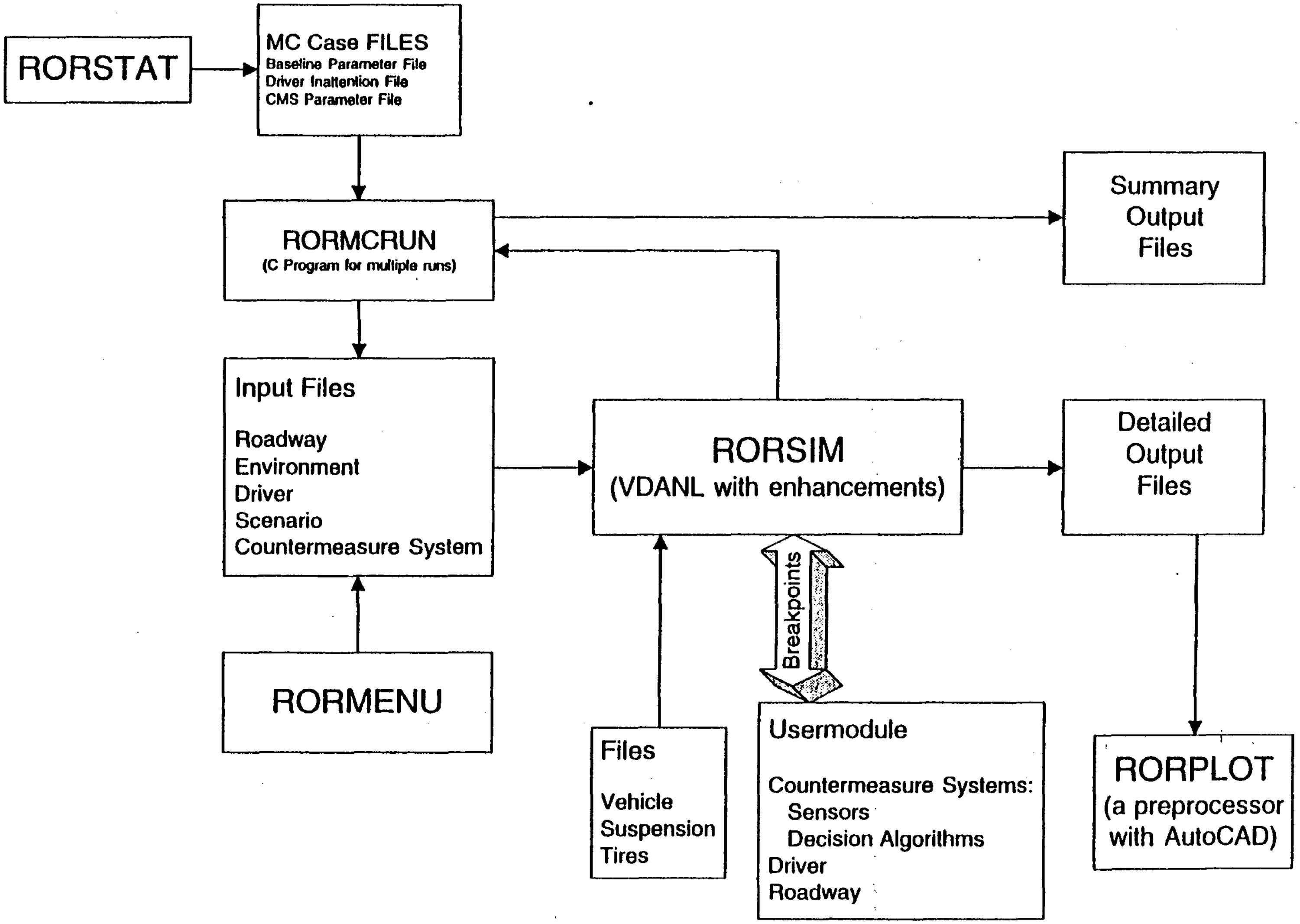

Figure 2-1. Block diagram of RORSIM Version 2.0.

In Phase II studies, approximately six hundred random input vectors, e.g., values for vehicle speed, lane keeping performance amplitude, driver reaction time etc., were generated using a series of Latin hypercube samples. Three Latin hypercube samples of (nearly) equal size were produced for each road curvature. The entire set of simulation input vectors consisted of twenty-seven Latin hypercube samples.

Applying Latin hypercube sampling structure to the random generation of input vectors optimized the ability to estimate the effect of the independent input variables, such as vehicle speed and driver reaction time, on simulation response variables without compromising estimates of overall effectiveness. Division of the input vectors into separate Latin hypercubes for each road curvature optimized estimation of input variable effects by road curvature. Division was also necessary because the distribution of vehicle speed depended on the curvature. Use of three separate Latin hypercubes within each road curvature is intended to provide improved estimates of variability.

2.3.2 Parameter Distributions

A summary of the input parameters, corresponding distributions and the basis for selecting the distributions is outlined in Table 2-1. The basis for selection of these distributions is reported test data, existing literature, and standard highway design handbooks. A brief discussion on the selection of distributions for some of the input parameters is in the next few paragraphs.

Vehicle Design. Vehicle parameters were selected to represent a 1994 Ford Taurus. These were the same vehicle parameters that were used in the Phase I - Task 4 simulation studies.

Roadway Design. Nine different roadways (two-lane, crowned and with shoulders) were adopted for the Phase II studies. These include a straight road and roads with left-hand and right-hand curvatures of 250 ft, 500 ft, 1,000 ft and 2,000 ft. The curved road consisted of a straight section followed by a curved section and finally followed by an infinitely long straight section. The curved section consists of a curve entry spiral, a fixed radius of curvature arc corresponding to a quarter of a circle arc length and an exit spiral. With the road curvature defined, the corresponding spiral lengths, crown angles and superelevation angles have been determined using AASHTO guidelines.

For most of the analyses conducted for this study, a uniform distribution of the nine roadway curvatures was used in order to estimate countermeasure performance over a wide range of circumstances. However, the Task 1 analysis conducted for this program found that 34.3 percent of all driver inattention and 62.5 percent of all driver impairment crashes occur on straight sections of road. Therefore, selected

Table 2-1. Distributions of parameters for the Latin hypercube simulation studies

Parameter	Definition	Distribution	Limits	Basis	Interdependence
Roadway Curvature	Radius of curvature for constant curvature portion of roadway segment, ft Nine Discrete Roadway Segments (Straight-to-Spiral-to-Curve): One straight, 4 right-hand curves, 4 left-hand curves	Treated as a fixed effect--each road was assigned an equal number of observations.	Radii of Curvature: 250 ft 500 ft 1000 ft 2000 ft Straight	AASHTO [1994] Table III-6. Set superelevations to typical values for each curvature.	A specific speed distribution was defined for each curvature See Table 2-2.
Lane Width	The subject vehicle's planned course will be in a single lane of fixed width throughout the simulation.	The lane width was fixed at 12 ft for this study.	12 ft	FHWA [1994], Table HM-33.	None
Road Friction	Coefficient of friction between tire and road when the tire is within the lane	Beta[*] Shape parameters are 5 and 2. (mean: 0.71 s.d.: 0.16)	min: 0 max: 1	Wong [1978], Fig 1.28 Selected to provide mostly dry pavement with some wet pavement	Determines value of shoulder friction
Shoulder Friction	Coefficient of friction between tire and shoulder	Identical to road friction	min: 0 max: 1	precipitation and surface same as travel lane	Identical to road friction

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[*] Beta distribution density functions, $f(x) = Ax^a (1-x)^b$, where $0<x<1$ and a and b are shape parameters. For road friction, the shape parameters result in a distribution roughly similar to a skewed normal distribution.

Table 2-1. (Continued) Distributions of parameters for the Latin hypercube simulation studies

Parameter	Definition	Distribution	Limits	Basis	Interdependence
Shoulder Rolling Resistance	Coefficient of rolling resistance between tire and shoulder (This is a negative number in the data file.)	Log normal with an offset mean: 0.046 s.d.: 0.135 offset: 0.015	min: 0.015 max: 0.90	Wong [1978], Fig 1.4. Mostly paved shoulder, but some hard soil and soft shoulders included.	None
Vehicle Speed	Constant speed of vehicle throughout simulation	Normal mean depends on curvature sd: 3 fps See Table 2-2 for details.	No limit was imposed.	design guidance from AASHTO; actual practice from FHWA [1994] Table VS-2 ; biased upward to provide hazardous conditions.	The posted speed is based on AASHTO guidelines for the selected curvature.
Driver Lane-Keeping Performance	Amplitude of a lateral wind gust disturbance.	Uniform	min: 0.10 max: 0.35	See Figs. 2-3 and 2-4.	None
Driver Reaction Time	Time delay between issuance of alarm and driver's response, s	Log Normal mean: 0.82 s s.d.: 0.24 s	min: 0.0 s no upper limit	Malaterre & Lechner [1990]	None
Driver Aggressiveness of Response	Amplification factor applied to the feedback gain in driver model in response to an alarm (K_{panic})	Uniform	min: 0.4 max: 2.5	Needed a perceptible variety, with a reasonable fraction of unstable responses. Selected through a pilot study.	None
Initial Time of Driver Disengagement	Time at which driver ceases steering corrections and handwheel position becomes fixed, s	Uniform	min: 3 s max: 17 s	Places disengagement period in or near the curved segment of curved roads.	Selected as a pair with Time Duration of Driver Disengagement

Table 2-1. (Continued) Distributions of parameters for the Latin hypercube simulation studies

Parameter	Definition	Distribution	Limits	Basis	Interdependence
Time Duration of Driver Disengagement	Time interval over which driver does not make steering corrections, s	Uniform	min: 2.2 s max: 13.2 s	Places disengagement period in or near the curved segment of curved roads.	Selected as a pair with Initial Time of Driver Disengagement
TLC Threshold	Values below which an alarm is issued to the driver	Each threshold was tested once for every Study 2 condition.	Five fixed values: -0.6, 0.0, 0.6, 1.2, and 1.8 s.	Results of Studies 1 and 2	None
CAS Accuracy	A bias offset applied to the sensor measurement of lane position.	Uniform	Seven fixed values: 0.0 ft 0.25 ft, -0.25 ft 0.50 ft, -0.50 ft 1.00 ft, -1.00 ft	Actual performance of RALPH, as reported by Pomerleau [1996]	None

analyses were also conducted for this report to independently determine countermeasure performance on straight (or nearly straight) road segments.

Vehicle Speed. The rated speeds for all the curves adopted in the Phase II study were obtained from AASHTO guidelines. A constant speed of a vehicle throughout simulation is assumed. Vehicle speeds for each road design were normally distributed with a standard distribution of 3 fps. The mean speed on the tighter curves (250 and 500 ft radius) was 10 percent above the rated speed. The mean speeds on the remaining curves were selected to provide reasonably uniform coverage over the entire range of speeds. See Table 2-2.

Table 2-2. Road designs and corresponding speed distributions

Road Number	Radius of Curvature, ft	Super-elevation	Rated Speed, mph	Rated Speed, fps	Mean Speed, μ fps	Extreme Speeds, μ-3σ fps	Extreme Speeds, μ+3σ fps
1,2	250	0.10	30	44	48.4	39.4	57.4
3,4	500	0.08	40	59	64.9	55.9	73.9
5,6	1000	0.08	55	81	80.0	71.0	89.0
7,8	2000	0.04	60	88	92.5	83.5	101.5
9	straight	0.02 (crown)	65	95	102.0	93.0	111.0

Driver Lane Keeping Performance. The software implementation of driver lane keeping performance was based on data collected from actual driving tests by Carnegie Mellon University and by Rockwell International [Rockwell 1995]. NHTSA's SAVME and DASCAR programs, both currently in progress, should provide further information on normal driving performance. The application of a varying lateral wind gust forcing function produced normal driving vehicle lateral deviation results similar to that obtained from the collected data. Hence, this method was adopted. Figure 2-2 shows the variance in vehicle lateral deviations obtained from RORSIM simulations, compared to the variances in vehicle position from actual driving data (CMU). The results in Figure 2-2 correspond to a fixed maximum lateral wind gust velocity, $W_{gust,vel}$. This is the input to the lateral wind gust forcing function. A random number generator ensures that the wind gust velocity varies uniformly between +/- $W_{gust,vel}$. The results obtained from simulation have a close correspondence to actual driving data in the medium velocity range. Figure 2-3 shows the variance in lane position with increasing maximum lateral wind gust velocity

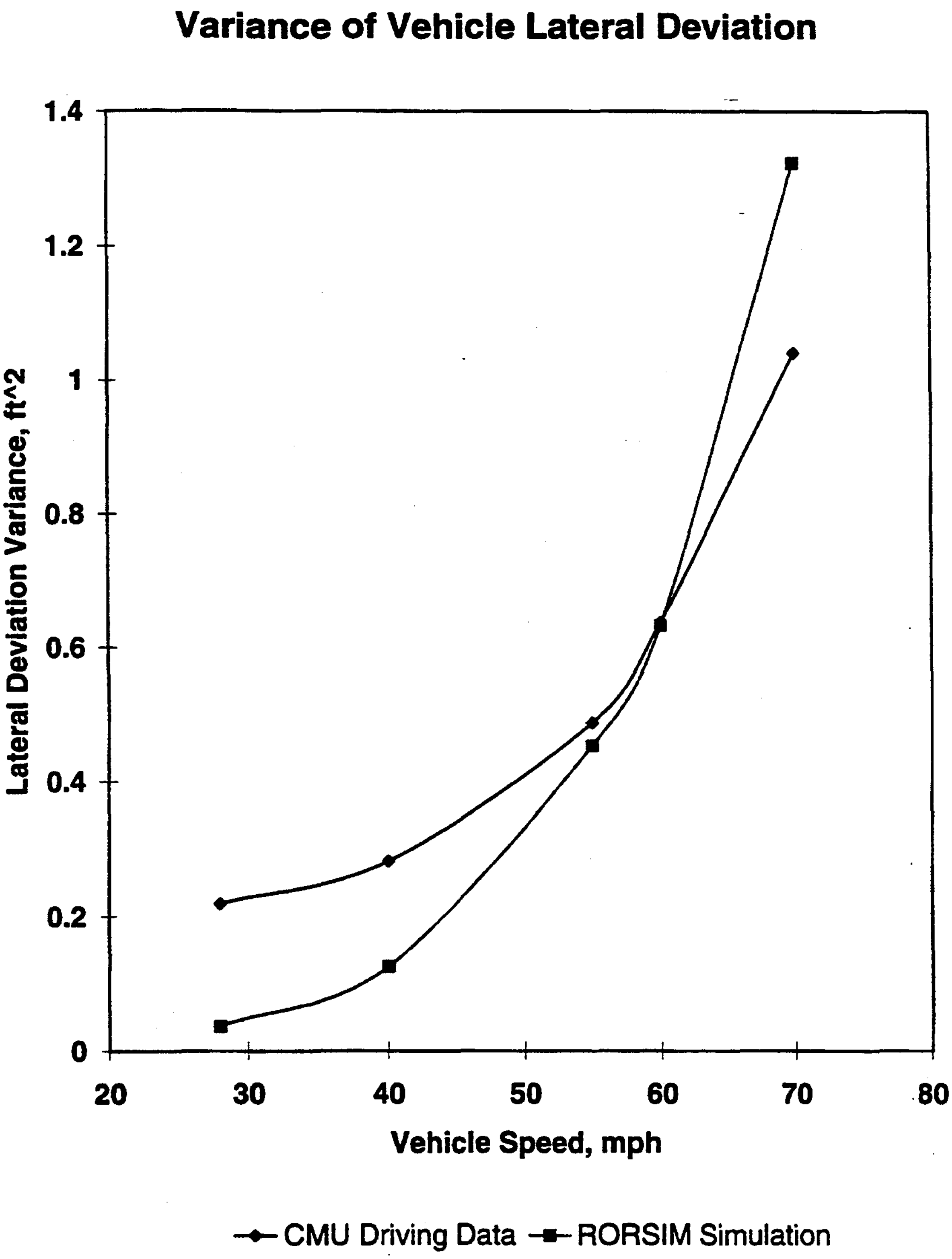


Figure 2-2. Driver lane keeping behavior - variance of vehicle lateral deviation, simulated versus actual.

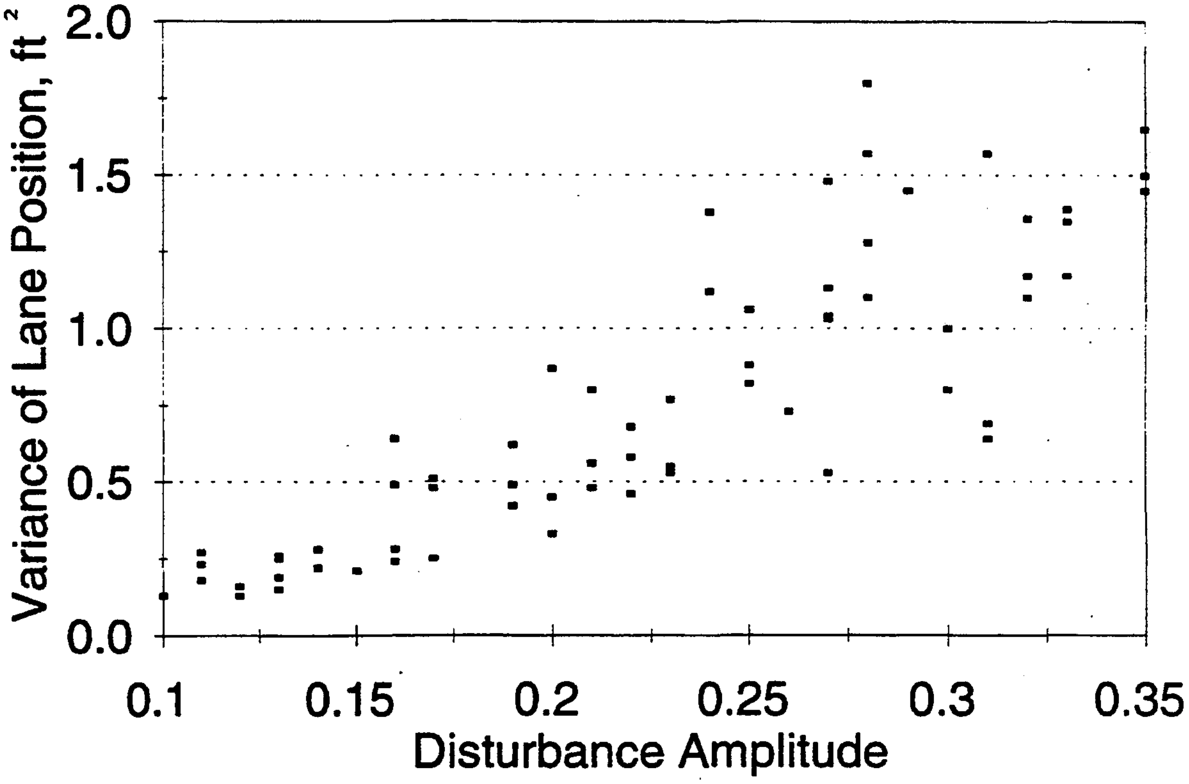


Figure 2-3. Driver lane keeping behavior - variance of vehicle lateral deviation as a function of disturbance amplitude (straight roads).

amplitude. Further analysis of the collected driving data indicates that the driver lane keeping performance spectrum is similar to that of a random walk (1/f noise). Figure 2-4 is a plot of the RORSIM simulated driver lane keeping frequency response compared to the 1/f noise spectrum.

Aggressiveness of Response. The driver aggressiveness of response is modeled by varying the gain associated with the nominal driving response. A multiplicative factor on the gain models over-correction and under-correction tendencies of drivers when subjected to an alarm. A high multiplicative factor corresponds to a driver who panics when an alarm is issued while a low value approximates a sluggish (e.g., drowsy or intoxicated) driver. The multiplicative factor is uniformly distributed between 0.2 and 2.5. The limits have been chosen based on pilot studies. The factor value exponentially returns to a nominal value of 1. This ensures that the driver reverts to his normal driving tendencies in some time after the alarm is issued. This parameter is invoked only if a warning is issued during the period of time in which the driver is disengaged.

Time and Duration of Driver Disengagement. Since each curved roadway is preceded and followed by a straight section, improper selection of times of onset of driver disengagement and duration of disengagement could lead to a disproportionately large number of near roadway departures on straight sections of the road. Since a straight road is already included, the statistics would be skewed. Also, it is important to study possibilities of ROR on entry and exit spirals of curved sections of roadways. Hence, for each curved roadway, assuming a constant speed of travel, time of entry of the vehicle into the entry spiral and time of exit from the exit spiral of the curve were calculated. These calculations were made for the (mean +/- 3 sigma) speeds selected for each curve. The range of values for duration of disengagement were obtained from pilot studies. The earliest and latest times of onset of disengagement are then selected such that the driver disengagement period is most likely to occur in the curved section of the road. This is repeated for each roadway. The most representative set of earliest and latest driver disengagement onset times are adopted for all the cases. The actual time of onset of disengagement is determined uniformly between these two limits for each simulation run.

Figure 2-5 is a pictorial representation of the parameter distributions used for the Monte Carlo cases generated in Phase II studies.

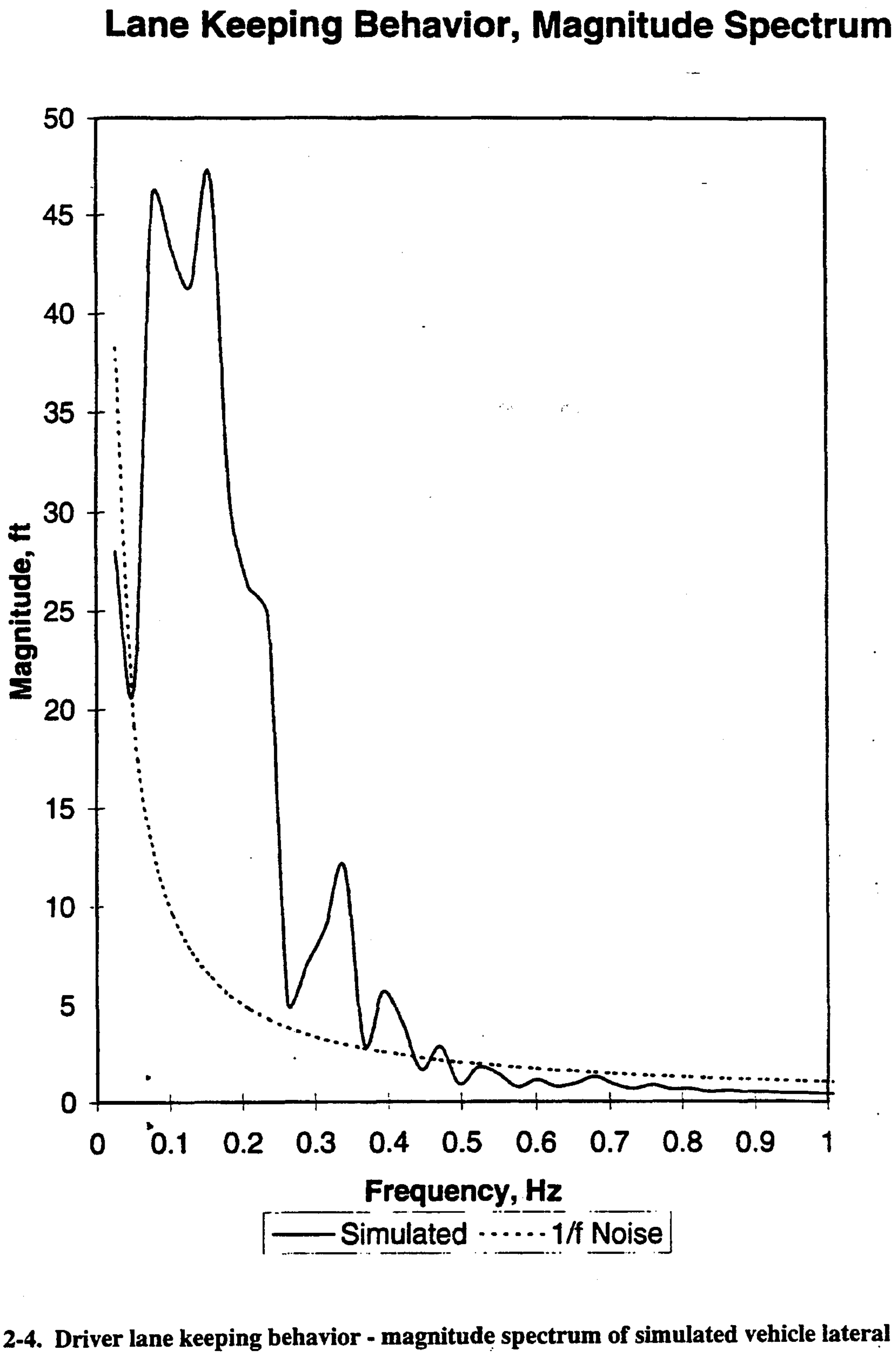


Figure 2-4. Driver lane keeping behavior - magnitude spectrum of simulated vehicle lateral deviation.

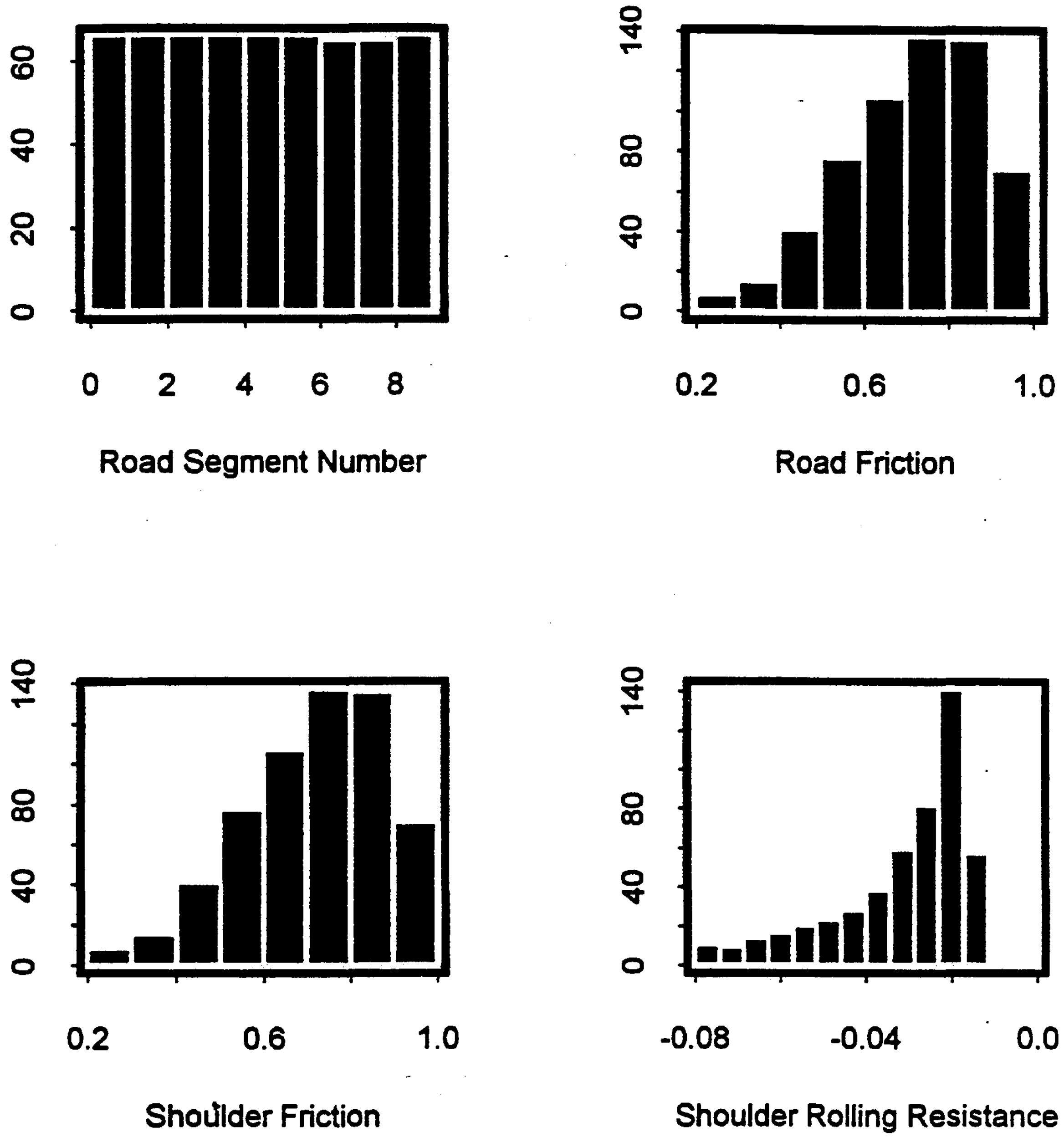


Figure 2-5. Distributions used in Phase II "Monte Carlo" studies (In all plots, the ordinate is the number of cases).

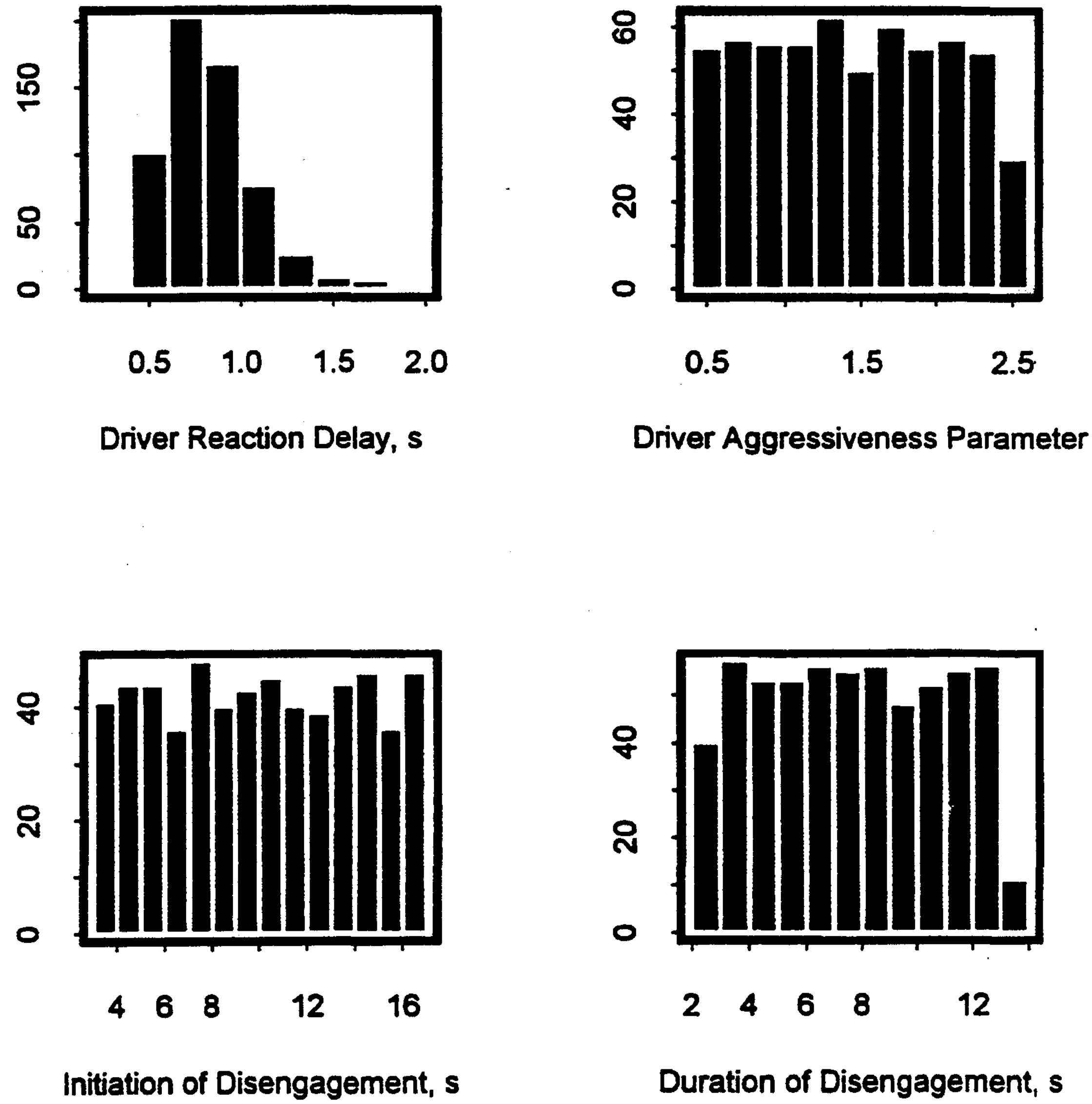


Figure 2-5. (Continued) Distributions used in Phase II "Monte Carlo" studies (In all plots, the ordinate is the number of cases).

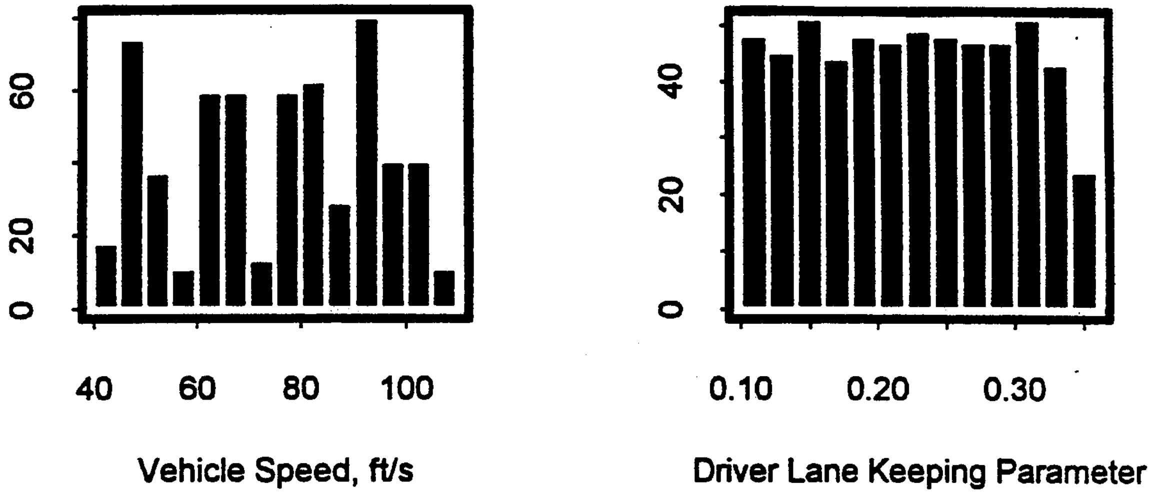


Figure 2-5. (Continued) Distributions used in Phase II "Monte Carlo" studies (In all plots, the ordinate is the number of cases).

2.4 Effectiveness Measures

RORSIM, Version 2.0 can be used to simulate ROR events under a variety of input conditions. The collected data is then used to obtain the performance measures for estimating effectiveness based on pre-defined ROR criteria. In this section, the procedures for collecting the data, definition of ROR criteria, and performance measures for evaluating the effectiveness of the CMS are discussed.

2.4.1 Data Collection

A study of the effectiveness of a proposed countermeasure system involves the generation of degraded response modes of a vehicle (i.e. ROR events) and studying vehicle performance improvements with and without a countermeasure system to warn the driver of potential degraded mode of operation. In order to ensure that one can exactly account for the performance of the vehicle with and without a countermeasure system under the same set of input conditions, three types of studies were performed.

Study 1: Development and verification of normal driving cases. A suite of normal driving cases (as defined by the input parameter combinations) was selected. No driver disengagement was imposed and the CMS was not active.

Study 2: Development of disengaged driver cases. The normal driving cases selected in Study 1 were subjected to a driver who is disengaged at varying onset times and durations. The CMS was not active. The objective of the study was to generate potential ROR events from the normal driving cases.

Study 3: Application of the CMS. The same disengaged driver cases (i.e., trajectories) from Study 2 were simulated again but this time with the CMS in effect. The objective of the study was to evaluate the effectiveness of the CMS in preventing potential ROR events.

Table 2-3 shows the list of input parameters used in each of the studies.

When RORSIM is used in conjunction with RORMCRUN to generate several hundred simulation runs, storing time histories of even a few variables becomes infeasible. Data collection must be streamlined to include only absolutely necessary statistics from each simulation run.

In Study 1 it is sufficient to note the maximum excursion of the vehicle from the lane center, and log the total number of departures of the vehicle from the lane in each run. However, in Studies 2 and 3, it is essential to be able to differentiate between vehicle performance during the time that the driver is disengaged from the vehicle performance corresponding to the period before the driver is disengaged.

Table 2-3. Summary of key parameter characteristics for Monte Carlo Simulation studies

		Variable	Effective in Study 1	Effective in Study 2	Effective in Study 3	Selected as Part of Study
Driving Environment	Physical Properties	1. Roadway curvature	yes	yes	yes	1
		2. Lane width (not used in this phase)	yes	yes	yes	1
	Weather-Related Properties	3. Road friction	yes	yes	yes	1
		4. Shoulder friction	yes	yes	yes	1
		5. Shoulder rolling resistance	yes	yes	yes	1
Driver Characteristics	Normal Driving	6. Vehicle speed	yes	yes	yes	1
		7. Lane-keeping performance	yes	yes	yes	1
	Response to an Alarm	8. Reaction (delay) time	no	no	yes	1
		9. Aggressiveness of response	no	no	yes	1
	Dangerous Practice	10. Initiation time of disengagement	no	yes	yes	2
		11. Duration of disengagement	no	yes	yes	2
CMS Properties		12. CMS type and threshold	no	no	yes	3
		13. CAS accuracy	no	no	yes	3

In the Phase II studies, three regions of interest are considered (R1, R2, R3) which are shown in Figure 2-6. Region R1 corresponds to the period prior to driver disengagement. Region R2 is the driver disengagement period, during which the driver is distracted or incapacitated and hence does not steer the vehicle. Region R3 extends from the time the driver is re-engaged, resumes his steering (after a prescribed delayed response time), to the end of log time, when the simulation is terminated. It is important to note that the driver will start to steer at the end of the prescribed period of disengagement that is specified for each run, unless a warning is issued by the CMS (Study 3 only). The end of log time is defined with respect to Study 2. It is defined as 5 seconds after the driver resumes steering in Study 2. The 5 seconds is the time required for the transient performance, associated with the driver resuming steering, to die down.

If a warning is not issued and the prescribed period of disengagement expires, then the driver is re-engaged with the same driving behavior that he had prior to being disengaged. If a warning is issued during disengagement, then the driver is re-engaged with his driving behavior modified by the "driver aggressiveness" parameter.

In each region, the following information is noted:

1. The maximum front tire position of the vehicle (measured from the lane center).
2. Time at which maximum excursion occurs.
3. Whether a warning was issued.
4. The number of times a warning is issued.
5. The total time for which the warning signal is on.

Once these parameters are stored for each of the simulations, the ROR criteria and the CMS performance criteria described in the next few paragraphs can be used to evaluate the effectiveness of the CMS.

2.4.2 Run-Off-Road Criteria

A key issue in the development of an effective ROR countermeasure system that is not overly restrictive or annoying is the establishment of limits of acceptable vehicle excursions. Perhaps the least ambiguous but most restrictive ROR criterion is any situation in which at least one tire crosses over the lane edge (this is referred as a "lane excursion" in this study). This criterion, which for the purposes of this study is defined as the "1-Tire ROR Criterion" implies that either there is no shoulder available or it is unsafe for the vehicle to use any part of the shoulder during normal driving or for maneuvering to avoid a potential accident.

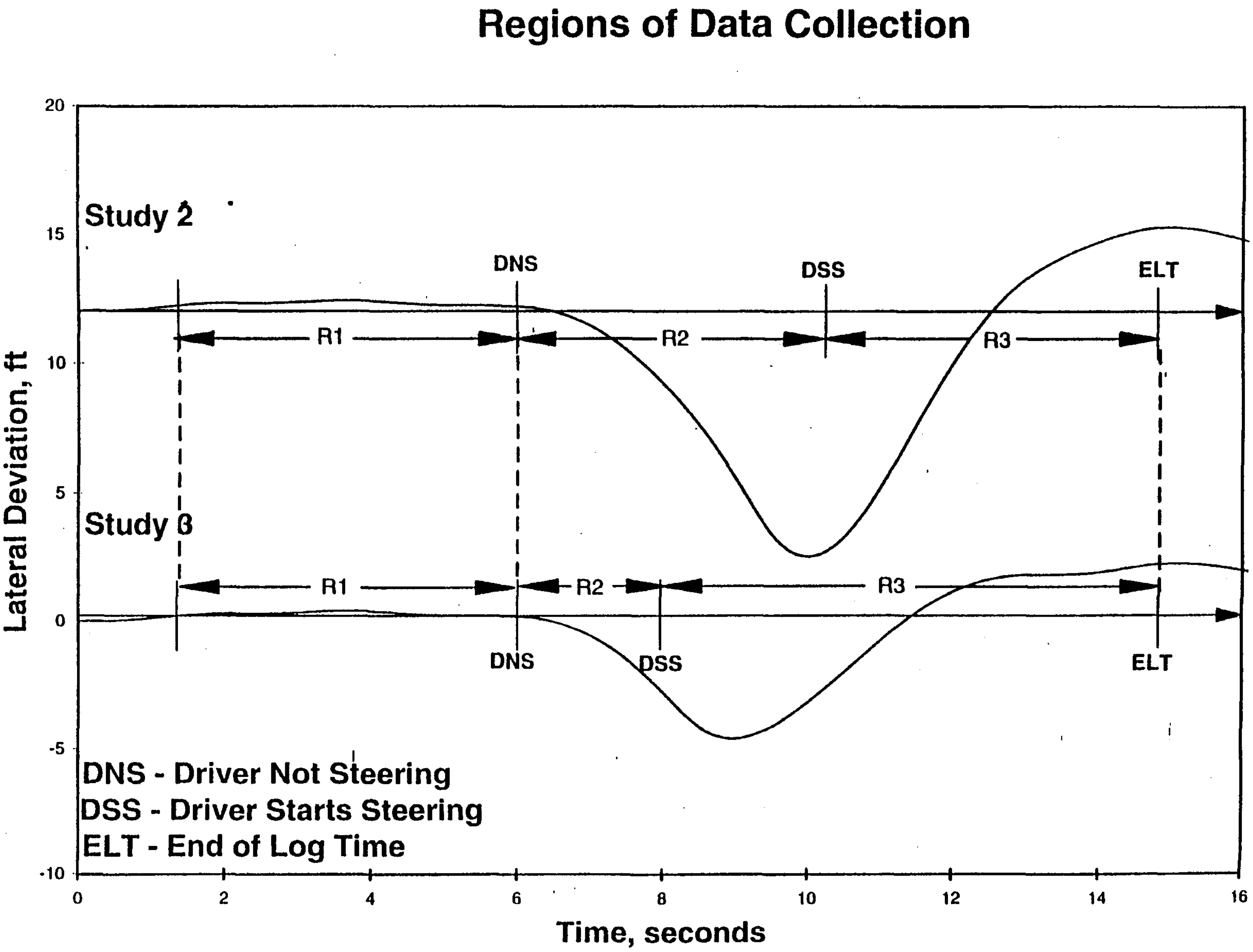


Figure 2-6. Regions of data logging for CMS effectiveness studies.

In practice, typical driving behavior sometimes involves excursions of the vehicle onto the shoulder (e.g., "lane-cutting" during curving) without a resulting accident. Consequently, it may be more practical to define a more "forgiving" ROR criterion. Thus, a second ROR criterion was established for the purposes of this study. This "2-Tire ROR Criterion" defines a ROR as an event in which both front tires are in or beyond the shoulder. The "2-Tire ROR Criterion" permits more vehicle lateral excursion (equivalent to the wheel spacing on the front axle or about 5.125 feet for the vehicle used in this study) before the result is considered to be an ROR event.

It is important to note that these ROR criteria are used only for classifying vehicle trajectories into "crash" and "noncrash" events. The criteria used by the countermeasure for triggering a warning in this study is independent of these ROR criteria, and is based solely on TLC, the time until one tire will cross the lane boundary and enter the shoulder.

In reality, roadways have a wide range of shoulder widths and surfaces, including no shoulder. Thus, it may be necessary to adapt the CMS to changes in the conditions adjacent to the roadway lanes (e.g., by adjusting the TLC based on previews of the shoulder width and identification of obstacles that limit vehicle lateral excursion to less than the wheel spacing).

2.4.3 Performance Criteria

A CMS must be extremely reliable and at the same time must not be a nuisance to the driver. The performance criteria for the CMS address these issues. Post processing of the data obtained from the Monte Carlo simulation runs reveals a wealth of information. This information can be tested against the performance criteria defined in this section to evaluate the overall effectiveness of the system.

Each pair of Study 2 and Study 3 simulations (one situation with and without CMS assistance) was categorized as one of six outcomes to determine CMS effectiveness:

- ***Safe Correct Detection (SCD)*** - An alarm is triggered on a sequence where a lane excursion (a situation in which one tire crosses the lane boundary onto the shoulder) happened in Study 2, and no road departure subsequently happens in Study 3.

- ***Late Correct Detection (LCD)*** - An alarm is triggered on a sequence where a lane excursion happened in Study 2, and a road departure subsequently happens in Study 3.

- ***Missed Detection (MD)*** - The system failed in Study 3 to issue a warning in a situation where a road departure occurred in Study 2.

- ***Correct Nondetection (CND)*** - The system didn't issue a warning in Study 3 in a situation where no road departure occurred in Study 2.

- ***Safe False Alarm (SFA)*** - The system issued a warning in Study 3 in a situation where no lane excursion occurred in Study 2, and no road departure subsequently occurred.
- ***Unsafe False Alarm (UFA)*** - The system issued a warning in Study 3 in a situation where no lane excursion occurred in Study 2, and a road departure subsequently occurred (e.g., due to driver startling).

Table 2.4 is a summary of the logic used to categorize the various possible outcomes of the simulation studies.

The simulation cases were designed so that the driver could react to a warning only during a disengaged period. Thus, LCDs and UFAs were possible only during the disengaged period. Further, MDs were possible only (1) if the CMS was not perfectly accurate or (2) if the TLC threshold was set to a negative value.

Table 2-4. Definitions of the possible outcomes of a Study 3 simulation.

Case	Lane Excursion in Study 2	ROR in Study 2	Warning Issued	Subsequent ROR	Result
1	Yes or No	No	No	No	Correct Nondetect
2	Yes or No	No	No	Yes	(Not Possible)
3	No	No	Yes	No	Safe False Alarm
4	No	No	Yes	Yes	Unsafe False Alarm
5	No	Yes	Yes or No	Yes or No	(Not Possible)
6	Yes	Yes or No	Yes	No	Safe Correct Detect
7	Yes	Yes or No	Yes	Yes	Late Correct Detect
8	Yes	Yes	No	Yes	Missed Detect

The sum of safe and unsafe false alarms, and the sum of safe and late correct detections, are the same for the two criteria. However, the proportions of safe events are influenced strongly by the choice of criteria. Specifically, an "unsafe" or "late" event is defined as one front tire off the lane edge for the 1-Tire ROR criteria. In contrast, an "unsafe" or "late" event requires two front tires off the lane edge for the 2-Tire ROR criterion.

3.0 Results

In this section we present the results of the parameter studies using RORSIM. The results focus on one of the three methods of CMS that were evaluated in Phase I: lane departure warning based on the time to line crossing or TLC. The TLC-based method appeared nearly equivalent to the TTD (time to trajectory divergence) method in preventing ROR events. TLC was selected for these Phase II studies because it is a more widely employed and studied algorithm for lane departure warning. The third method, considered in Phase I, was the curve warning method, and such "longitudinal" CMS were not studied in Phase II. The results of the studies are presented in three parts, corresponding to the three studies comprising the simulation studies.

3.1 Study 1: Normal Driving

The first step in studying CMS effectiveness was to establish a set of "normal" driving cases to use as a baseline. These cases were to be "safe" in that the vehicles stayed within their lane in nearly all circumstances, but were purposely chosen to be rather aggressive so that the CMS could be given an opportunity to perform.

The criterion to judge the outcome of a simulation case is the maximum tire excursion, as was shown in Figure 2-6. The cumulative frequency distribution (CFD) of maximum tire excursion of "normal" driving simulation cases is shown in Figure 3-1. The front track width of the modeled vehicle is 5.125 ft, so there are no values less than approximately 2.5 ft. For all of the studies, the lane width was taken to be 12 ft. Thus, if the maximum tire position was less than 6 ft, then the vehicle remained within its lane for the entire simulation. Of the 591 cases, only seven had tire excursions outside a 12-ft lane. Therefore, the 591 cases were considered to be a reasonable representation of "normal" on-road driving cases.

The influences are different at relatively slow driving on tight curves than at higher speeds on straight roads. The incidence of maximum tire excursion is shown separately for each of the nine road segments in Appendix C, Figures C-1 and C-2, and for selected road segments in Figures 3-2 and 3-3. As expected, the simulation showed that negotiating a relatively tight curve at a high speed makes controlling lane position more difficult. Consider Figure 3-2(a). The cluster of points tends to slope upward to the

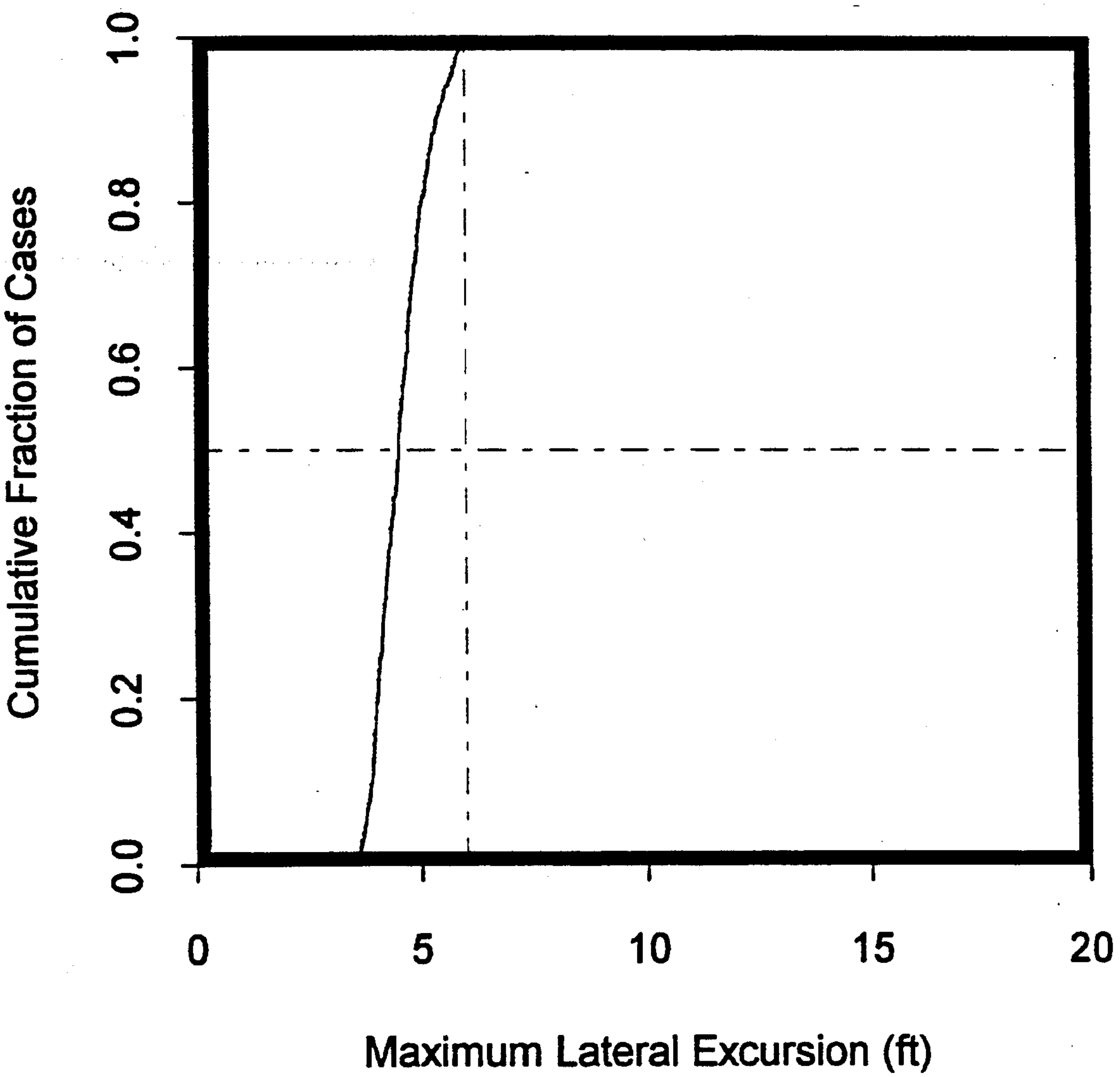
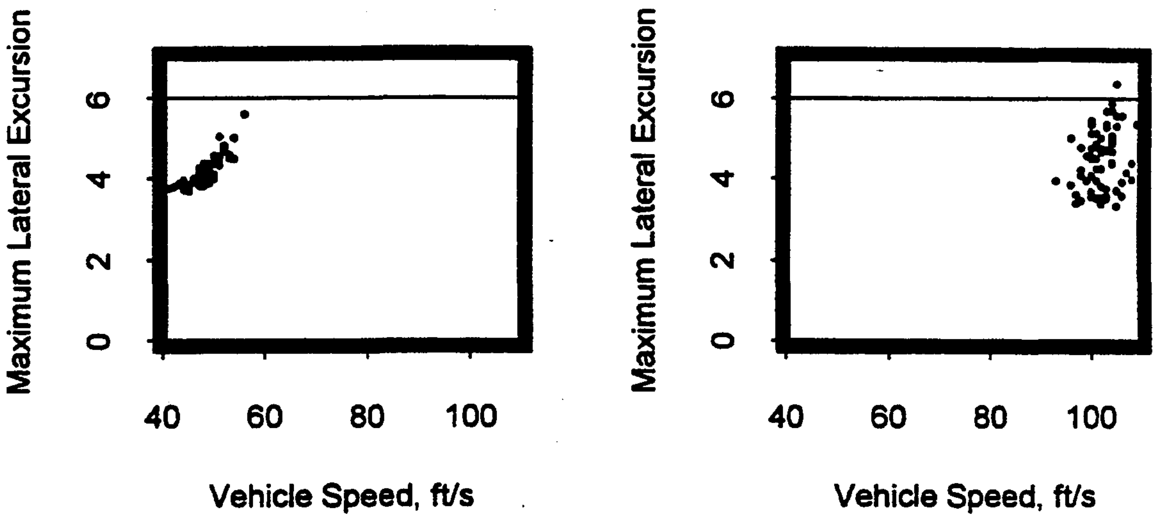
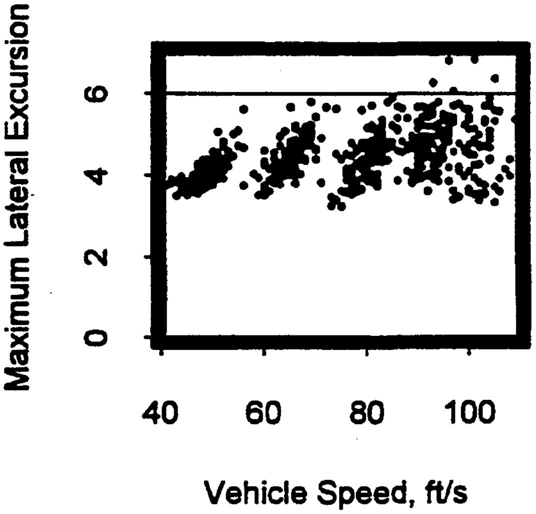


Figure 3-1. Study 1 results: Cumulative frequency distribution (CFD) of maximum tire position over the 591 cases of "normal" driving.



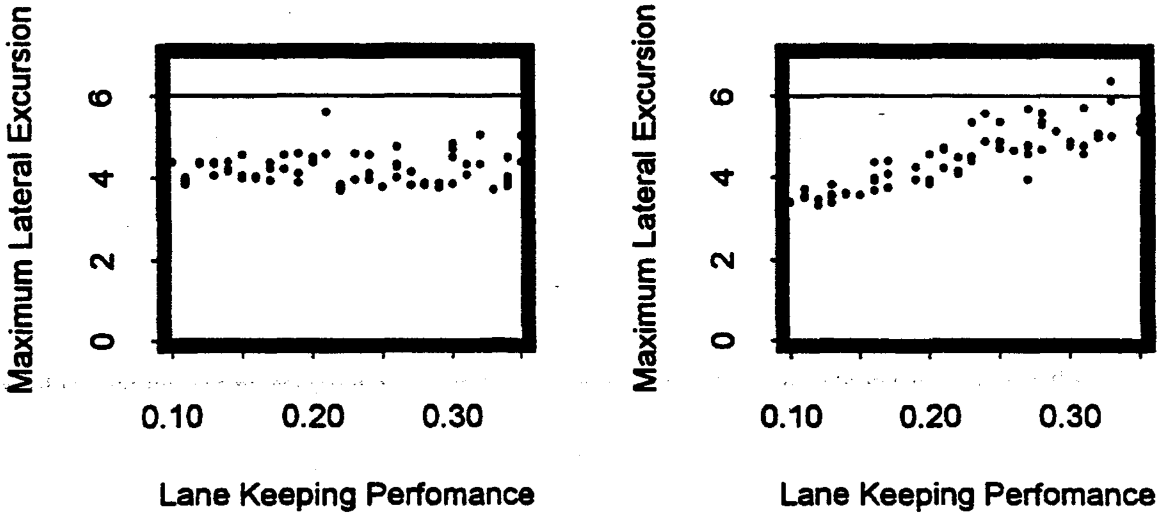
a) Right-Hand Curve - R=250 ft

b) Straight Road



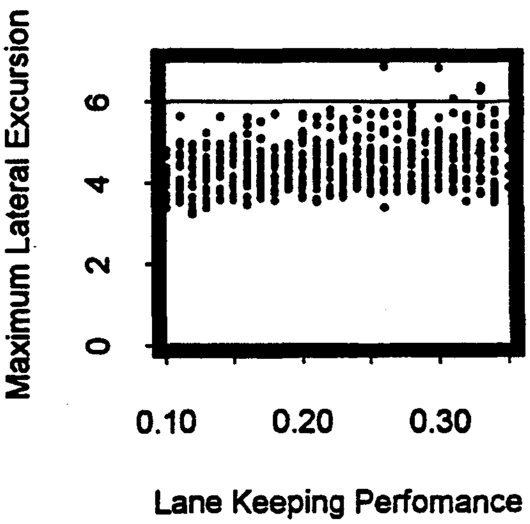
c) All Road Segments

Figure 3-2. Study 1 results: distributions of maximum tire excursion (in feet) as a function of vehicle speed for nine road segments - normal driving.



a) Right-Hand Curve - R=250 ft

b) Straight Road



c) All Road Segments

Figure 3-3. Study 1 results: distributions of maximum tire excursion (in feet) as a function of lane-keeping performance for nine road segments - normal driving.

right, indicating that vehicles that were traveling faster on this 250-ft-radius curve came closer to the edge line. In contrast, the curve for the straight road (Figure 3-2(b)) has no perceptible dependence on vehicle speed. As shown in Figure 3-3(b), the main influence on the vehicle's maximum tire position in normal driving on a straight road is the driver lane keeping behavior.

Plots of minimum TLC versus maximum lateral excursion and vehicle speed are shown in Figure 3-4 for the 591 "normal driving" cases comprising Study 1. The figures indicate that there is a strong decrease in TLC with increasing maximum lateral excursion, while TLC decreases only slightly with increasing vehicle speed. Further, the scatter in the TLC minima decreases with increasing maximum lateral excursion. TLC minima of zero indicate an ROR event, based on the criterion that one front tire rides in the shoulder area (This has been defined as the "1-Tire ROR Criterion.").

3.2 Study 2: Disengaged Driver Without a CMS

In Study 2, driver disengagement was prescribed for each of the 591 cases of normal driving established in Study 1. The purpose of this activity was to develop a baseline set of disengaged driver scenarios for which CMS effectiveness could be evaluated in Study 3. Each of the 591 cases from Study 1 was assigned an onset time and a duration of the disengaged period. Figure 3-5 shows the distribution of maximum tire excursion for the 591 cases of Study 2. As expected, driver disengagement caused a much larger population of lateral excursions beyond the lane edge. This is also indicated in Figures 3-6 and 3-7, which show plots of maximum lateral excursion versus vehicle speed and lane-keeping performance, respectively, for each individual case for selected roadway segments considered in the study. A complete set of plots for each of nine roadway segments is provided in Appendix C, Figures C-3 and C-4.

There were 50 cases where the maximum tire position was less than 6 ft from the lane center; the vehicle stayed in its lane for the duration of the simulation and a ROR event did not occur. These cases represent the "control" group, on which the CMS was tested but for which it was not expected to generate an alarm. There were 541 cases of lane excursions that met the "1-Tire ROR Criterion" (i.e., at least one front tire was in or beyond the shoulder), and 450 cases that met the "2-Tire ROR Criterion" (i.e., both front tires were in or beyond the shoulder). These results are summarized in the table shown below:

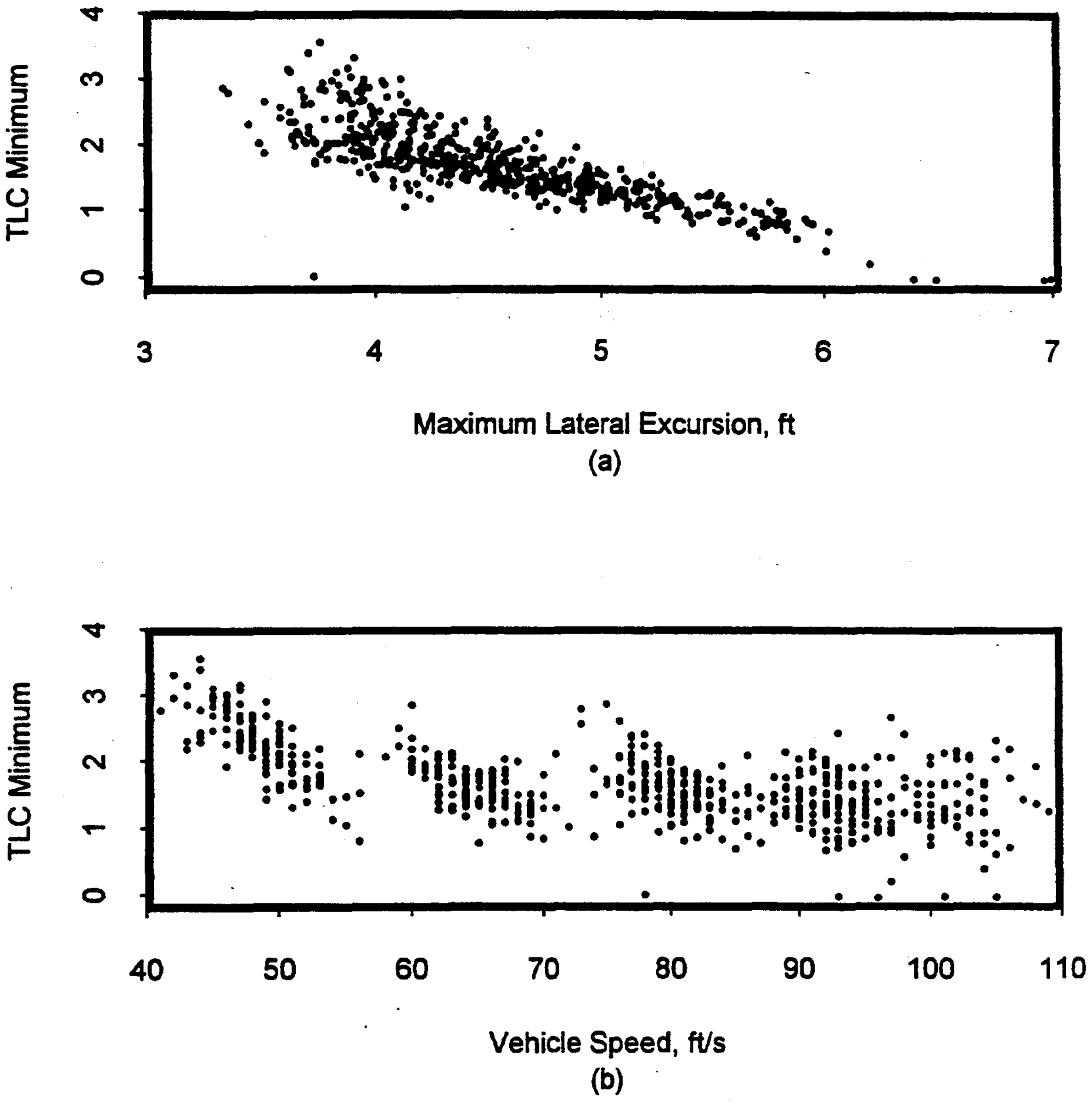


Figure 3-4. Study 1 results: influence of maximum lateral excursion and vehicle speed on minimum TLC during normal driving.

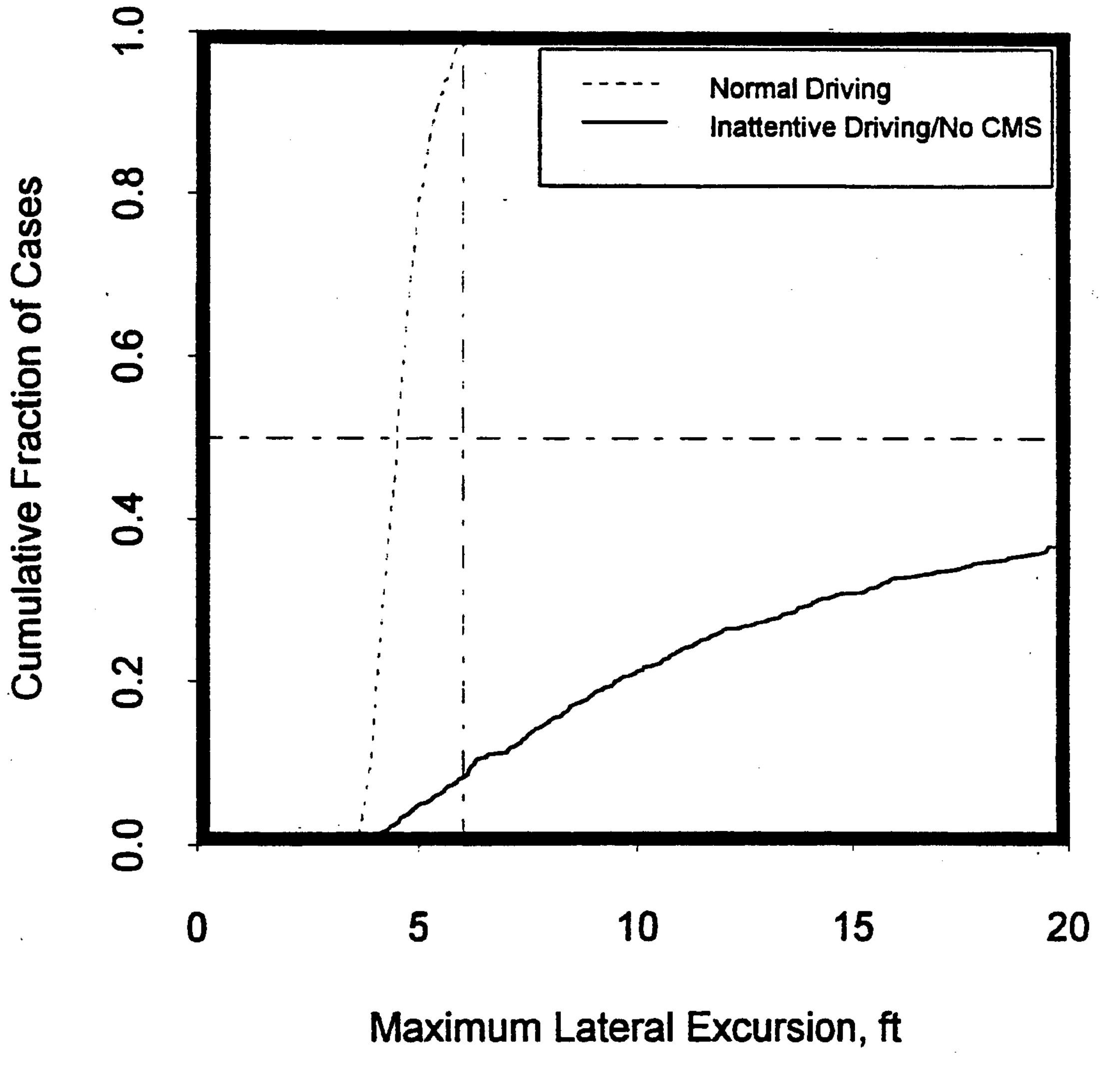
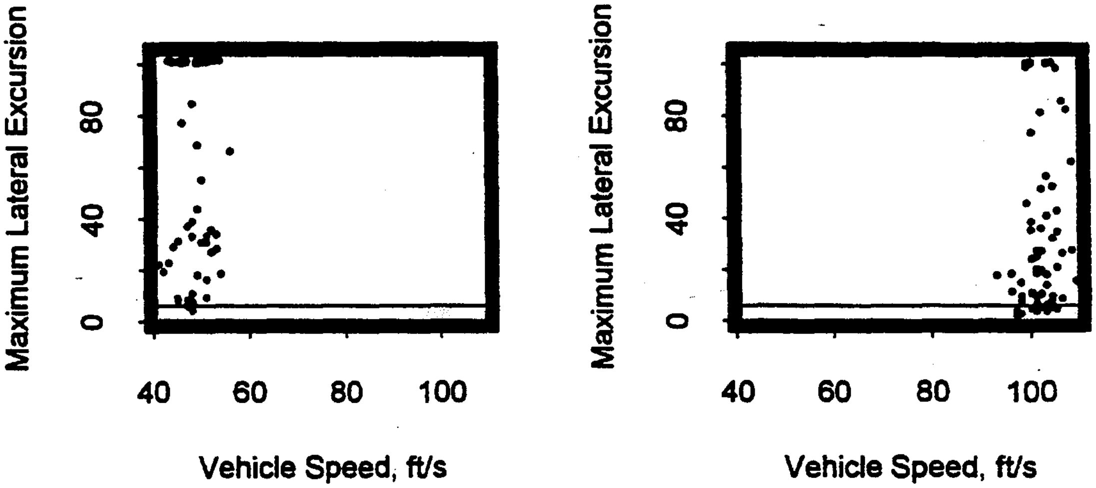
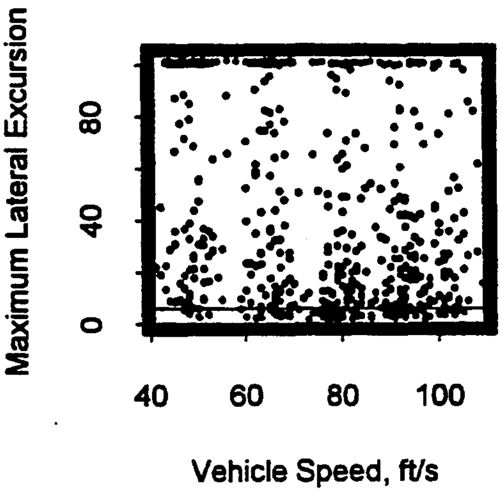


Figure 3-5. Study 2 results: comparison of cumulative frequency distributions (CFDs) of maximum lateral excursion - normal versus disengaged ("inattentive") driving without a CMS.



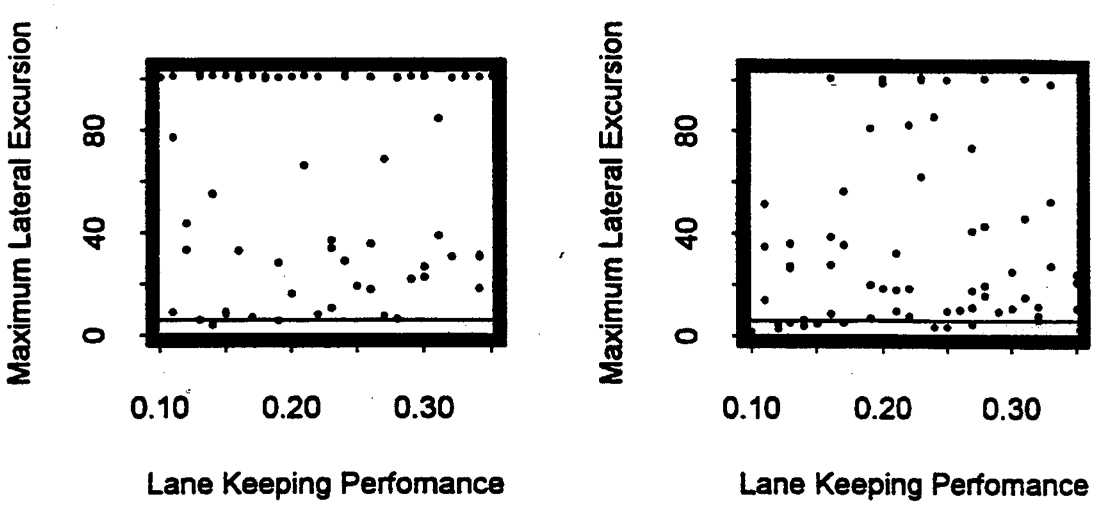
a) Right-Hand Curve - R=250 ft

b) Straight Road



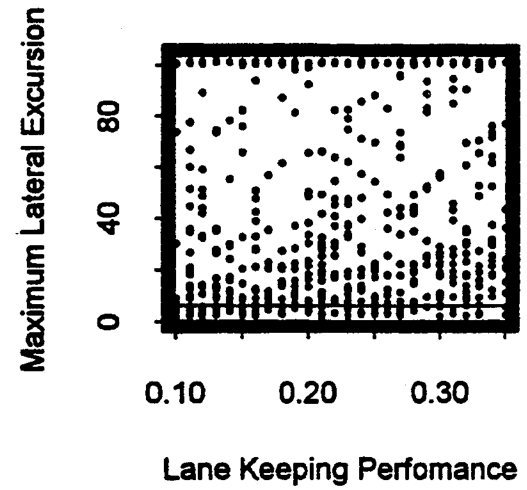
c) All Road Segments

Figure 3-6. Study 2 results: distributions of maximum tire excursion (in feet) as a function of vehicle speed for nine road segments - disengaged driving without a CMS.



a) Right-Hand Curve - R=250 ft

b) Straight Road



c) All Road Segments

Figure 3-7. Study 2 results: distributions of maximum tire excursion (in feet) as a function of lane-keeping performance for nine road segments - disengaged driving without a CMS.

Table 3-1. Number of ROR events in normal and disengaged driving

Outcome	Maximum Lateral Excursion (y) Criteria	No. Cases Study 1	No. Cases Study 2
Vehicle Stayed in Lane	$y \leq 6$ ft	584	50
Only One Front Tire on Shoulder	6 ft $< y \leq 11$ ft	7	91
Two Front Tires On/Beyond Shoulder	$y > 11$ ft	0	450
	Total	591	591

Plots of minimum TLC versus maximum lateral excursion and versus vehicle speed are shown in Figure 3-8 for the Study 2 cases.

The characteristics of the 591 cases of disengaged driving scenarios were considered effective for evaluating CMS performance in Study 3, because (a) they contained a strong cross-section of typical driver, operating, and environmental characteristics, and (b) they included a population of ROR and non-ROR cases, with which CMS effectiveness could be evaluated under conditions when a warning should be issued, as well as when a warning should not be issued.

3.3 Study 3: Disengaged Driver With a CMS

The purpose of Study 3 was to determine whether vehicles equipped with a CMS would be expected to have fewer collisions than with vehicles not equipped with a CMS. An associated issue was to determine the extent to which CMS effectiveness is compromised by

- Safe False Alarms (warnings issued when there is no impending ROR event -- safety is not affected but a high false alarm rate can be annoying and could decrease the sensitivity of the driver to a warning),
- Missed Detections (no warning issued while the driver is disengaged and when there is an impending ROR event), and
- Late Correct Detections and Unsafe False Alarms (warnings that were issued while the driver is disengaged and when there is or is not an impending ROR event, respectively, but caused the driver to respond in a manner that resulted in a separate ROR event).

Each of the 591 ROR test cases of Study 2 was run with an operating CMS, and the characteristics of the CMS were varied to evaluate the influence on its effectiveness. Five thresholds of the system were tested, each with seven levels of error in the sensor, (including a zero CMS error case). In addition, an existing passive system, shoulder grooves ("rumble strips" similar to those of the SNAP system used in Pennsylvania), was tested as a comparison.

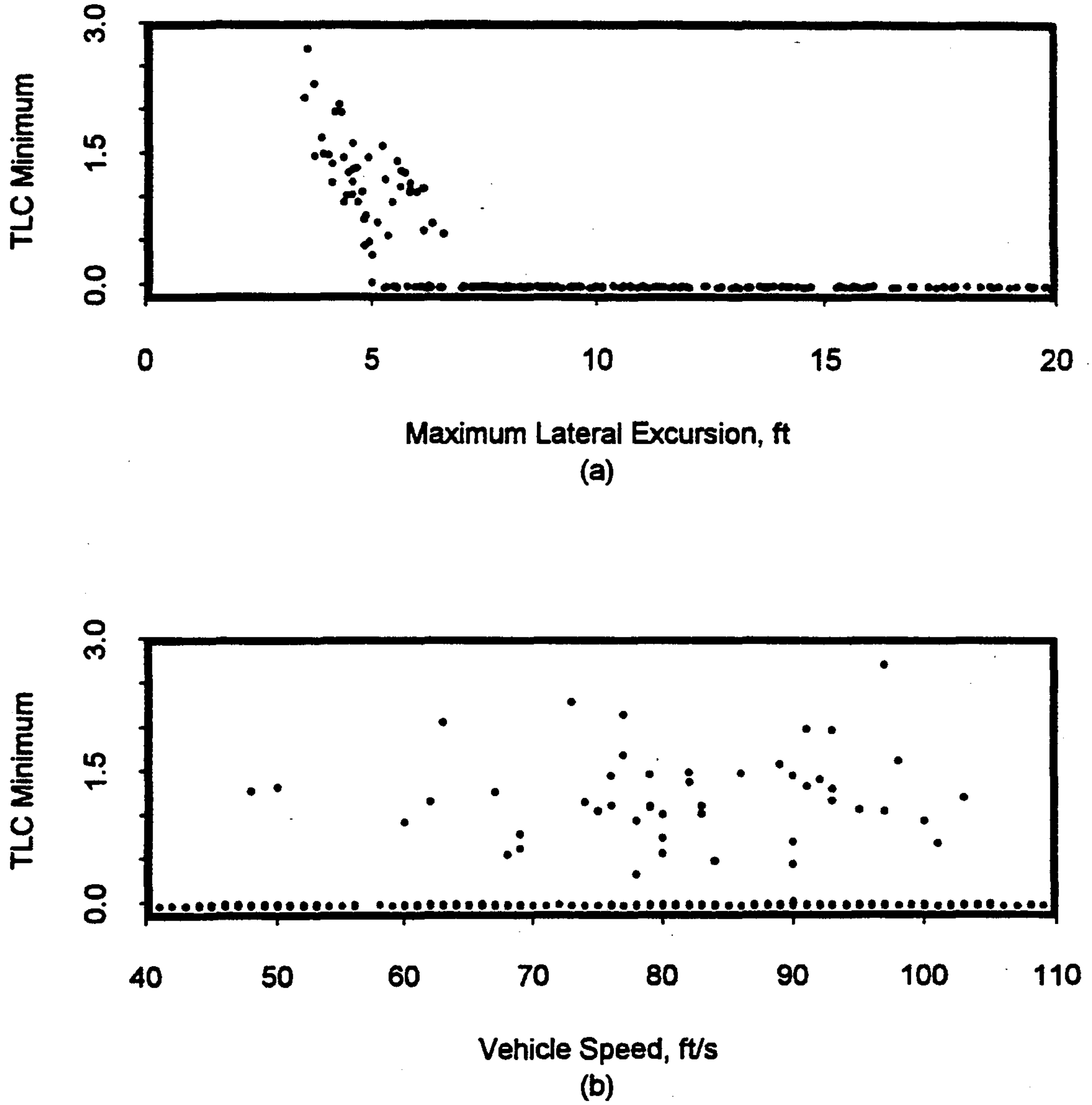


Figure 3-8. Study 2 results: influence of maximum lateral excursion and vehicle speed on minimum TLC during disengaged driving without a CMS.

The results have been plotted a number of ways to study different trends, but the basic question underscoring the analysis is whether the vehicle in a particular simulation left the 12-ft lane, and if so, by how much. For simplicity, cases with no error in the countermeasure's sensor are considered first.

3.3.1 Influence of TLC Threshold

Cumulative Frequency Distributions (CFDs) of maximum lateral excursion are shown in Figures 3-9(a) and (b) for disengaged driver cases without a CMS (Study 2 results) and with a CMS with TLC thresholds set at -0.6 meters, 0.01, 0.6, 1.2 and 1.8 seconds. Figure 3.9(a) shows CFDs for all road segments while Figure 3.9(b) shows CFDs for straight roads only.

A negative value of TLC is associated with a tire position that is on (or beyond) the shoulder. The TLC metric of seconds tends to lose physical meaning for negative values. Consequently, a negative TLC is defined as distance beyond the lane edge (in units of meters) when the tire has entered the shoulder. Thus, the TLC threshold value of "-0.6" shown in the figures corresponds to a warning that is issued when a tire is at least 0.6 meters past the lane edge.

As shown in Figure 3-9(a) and (b), the presence of the CMS generally reduces the population of large vehicle lateral excursions. For example, in Figure 3.9(a) about 80 percent of the maximum lateral excursions for the cases without a CMS were above 10 feet. In contrast, less than 10 percent of the cases were above 10 feet using a CMS with a TLC threshold of 1.8 seconds, and the percentage of these cases increased with decreasing TLC threshold to the point where there was only a small improvement for a TLC threshold of -0.6.

The results in Figures 3-9(a) and (b) indicate that for successively higher TLC thresholds, the curves diverge from the "No CMS" case at lower values of maximum lateral excursion. This trend indicates that with higher thresholds, the driver is warned earlier in the roadway departure sequence, resulting in a greater number of successful corrections for any given lateral excursion. Further, the slopes of the CMS curves at the points where they diverge from the "No CMS" curve increase with increasing TLC threshold. This may be due to the increased ability of a driver to successfully correct his path with earlier warnings. With late warnings (low TLC thresholds), the driver may already be in a dangerous situation (past a "point of no return") and may be unable to successfully correct the vehicle. This implies that the "early warning" capability of vehicle-based electronic CMS, such as the type evaluated in this study, offers a distinct performance advantage over an infrastructure-based system like SNAP, which provides a ROR warning only after the ROR event is underway. A comparison of the CFDs in

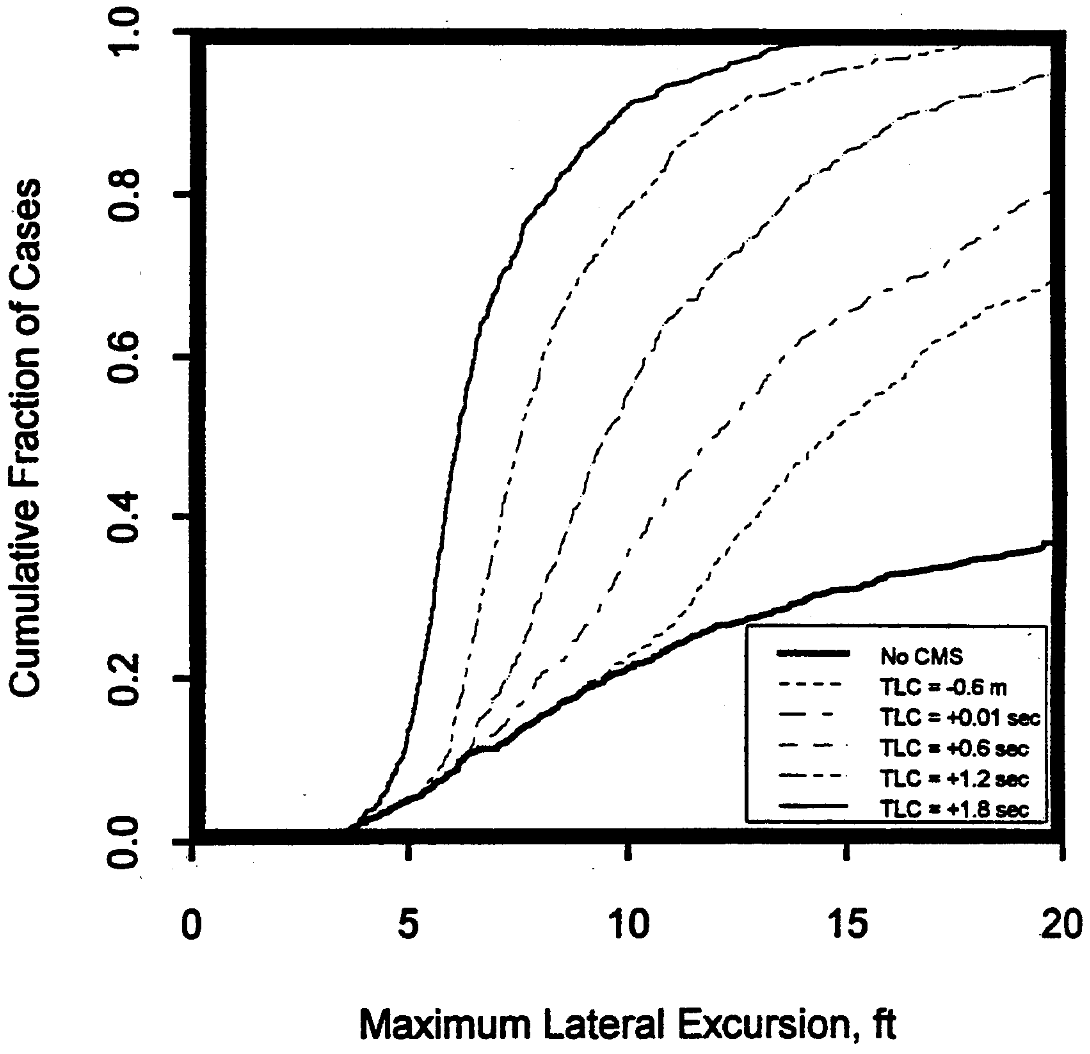


Figure 3-9(a). Study 3 results: CFDs of maximum lateral tire excursion for disengaged driving with a CMS set at several TLC threshold levels for all roads.

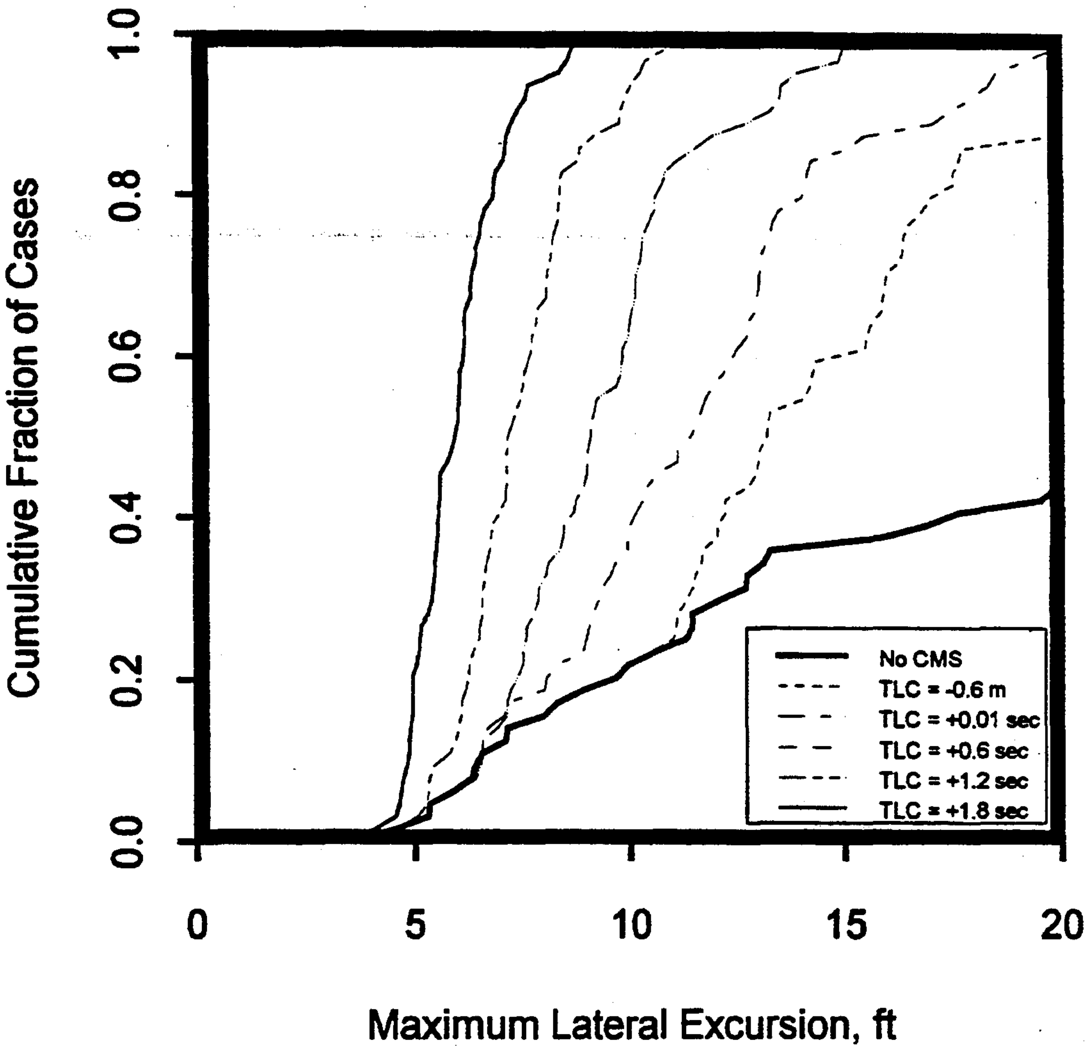


Figure 3-9(b). Study 3 results: CFDs of maximum lateral tire excursion for disengaged driving with a CMS set at several TLC threshold levels for straight roads.

Figures 3.9(a) and (b) shows that vehicle lateral excursions are lower and CMS performance is better on straight roads.

These results provide a good indication of the potential of a CMS in reducing ROR events by limiting vehicle lateral excursions. Further analyses of the data identified a few cases where the excursions were greater with a CMS than without it. These cases were evaluated in greater detail and determined to be associated with the driver's response to being warned, which resulted in unsafe maneuvering of the vehicle.

The curves presented in Figures 3-10 and 3-11 show the fundamental relationships between the six basic measures of CMS effectiveness for the 2-Tire ROR Criterion. For these curves, the sum of all false alarms and correct nondetections equals the total number of non-ROR cases generated in Study 2, while the sum of all correct detections and missed detections equal the total number of ROR cases generated in Study 2. As shown in the figures, the CMS with no measurement error and a positive TLC threshold will always detect an incipient ROR event and have no missed detections. Further, a perfectly accurate CMS will have missed detections only for negative TLC threshold levels greater than the maximum allowable lateral excursion (i.e., 11 feet for this study). With increasing TLC threshold level, the driver is provided with more time to react to the warning, but the number of false alarms increases.

3.3.2 Influence of ROR Criterion

Both the "1-Tire" and "2-Tire" ROR Criteria were applied to the Study 2 and 3 results to evaluate CMS effectiveness. The results of this exercise are summarized in Figures 3-12 and 3-13.

In Figure 3-12, the percentage of cases with maximum lateral excursions exceeding 6 ft (1-Tire ROR Criterion) and 11 ft (2-Tire ROR Criterion) are plotted versus TLC threshold. For comparison, the fraction of cases that exceeded these levels for disengaged drivers without a CMS (i.e., Study 2 results) are shown. These data are shown for straight and curved roads in Figure 3-13. As expected, the benefits of a CMS are more obvious with straight roads regardless of the type of ROR criterion used.

These results imply that the perceived effectiveness of a CMS depends strongly on how a ROR event is defined. For example, if the driver is allowed to use the shoulder to maneuver the vehicle to avoid a ROR event, then the CMS can be credited with many more ROR preventions compared to a policy of defining any instance of a tire on the shoulder as a ROR event. The influence of using the available shoulder on the ability to prevent ROR events is shown in Figure 3-14. As indicated, the reduction in ROR events increases dramatically on roads with wider shoulders. For example, with a TLC threshold set

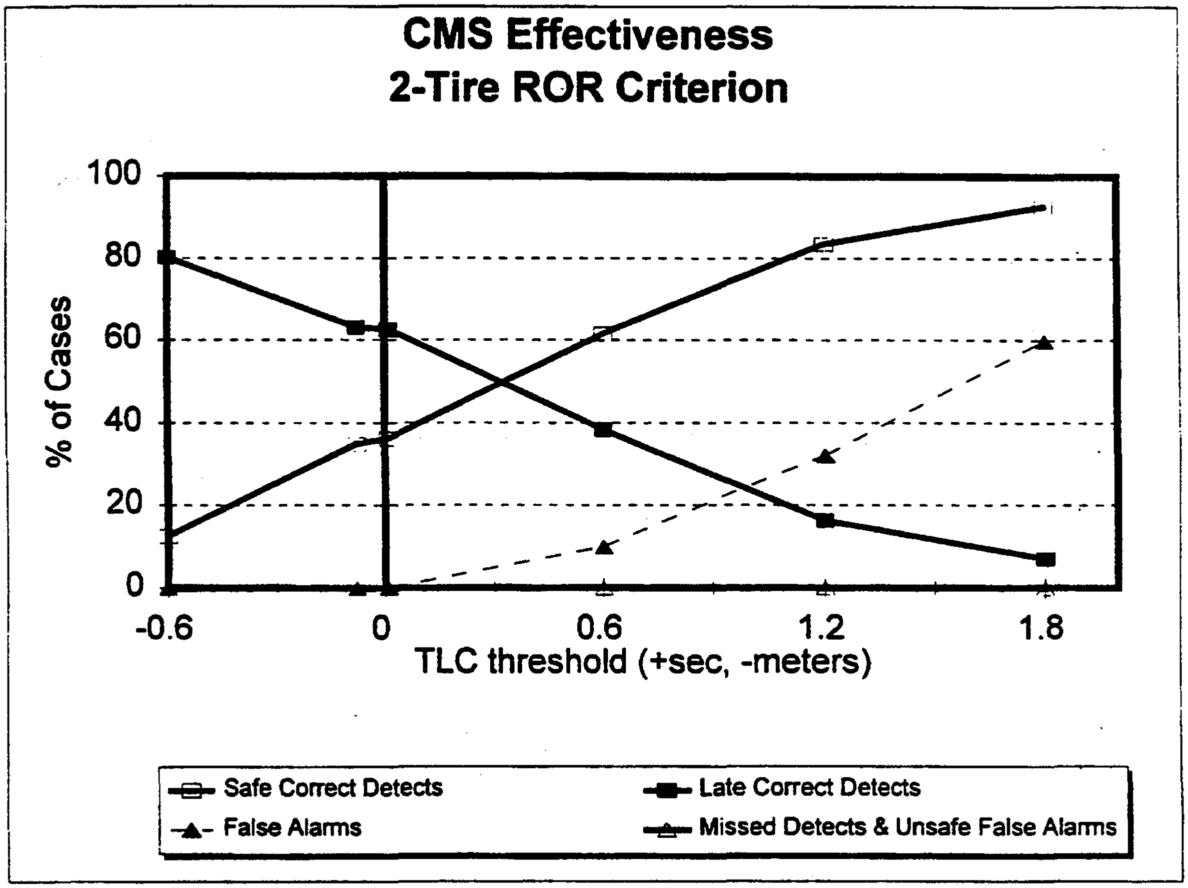


Figure 3-10. Study 3 results: influence of TLC threshold on CMS performance - comparison of safe and late correct detections, safe and unsafe alarms, and missed detections, based on the 2-Tire ROR Criterion.

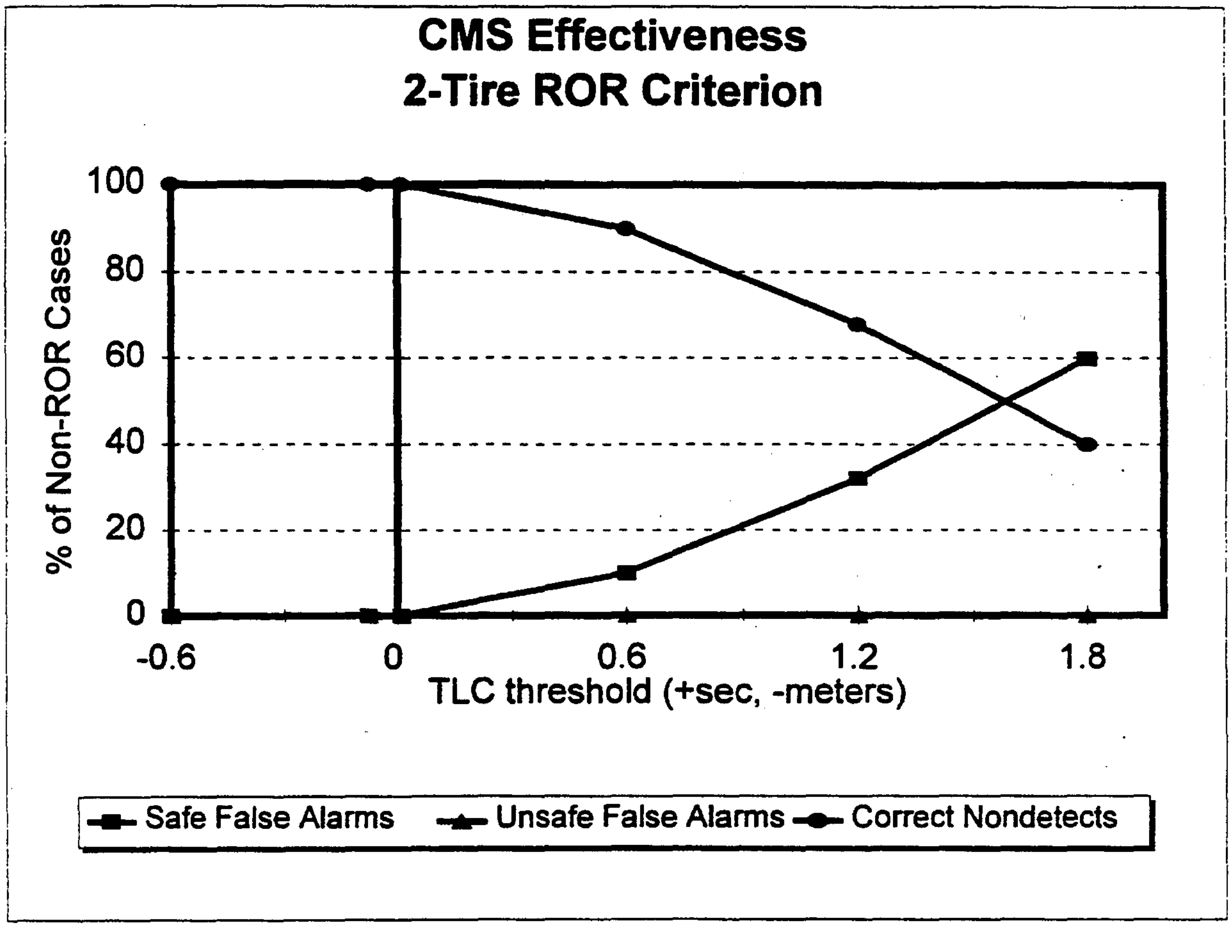


Figure 3-11. Study 3 results: influence of TLC threshold on CMS performance - comparison of safe and unsafe false alarms, and correct nondetections based on the 2-Tire ROR Criterion.

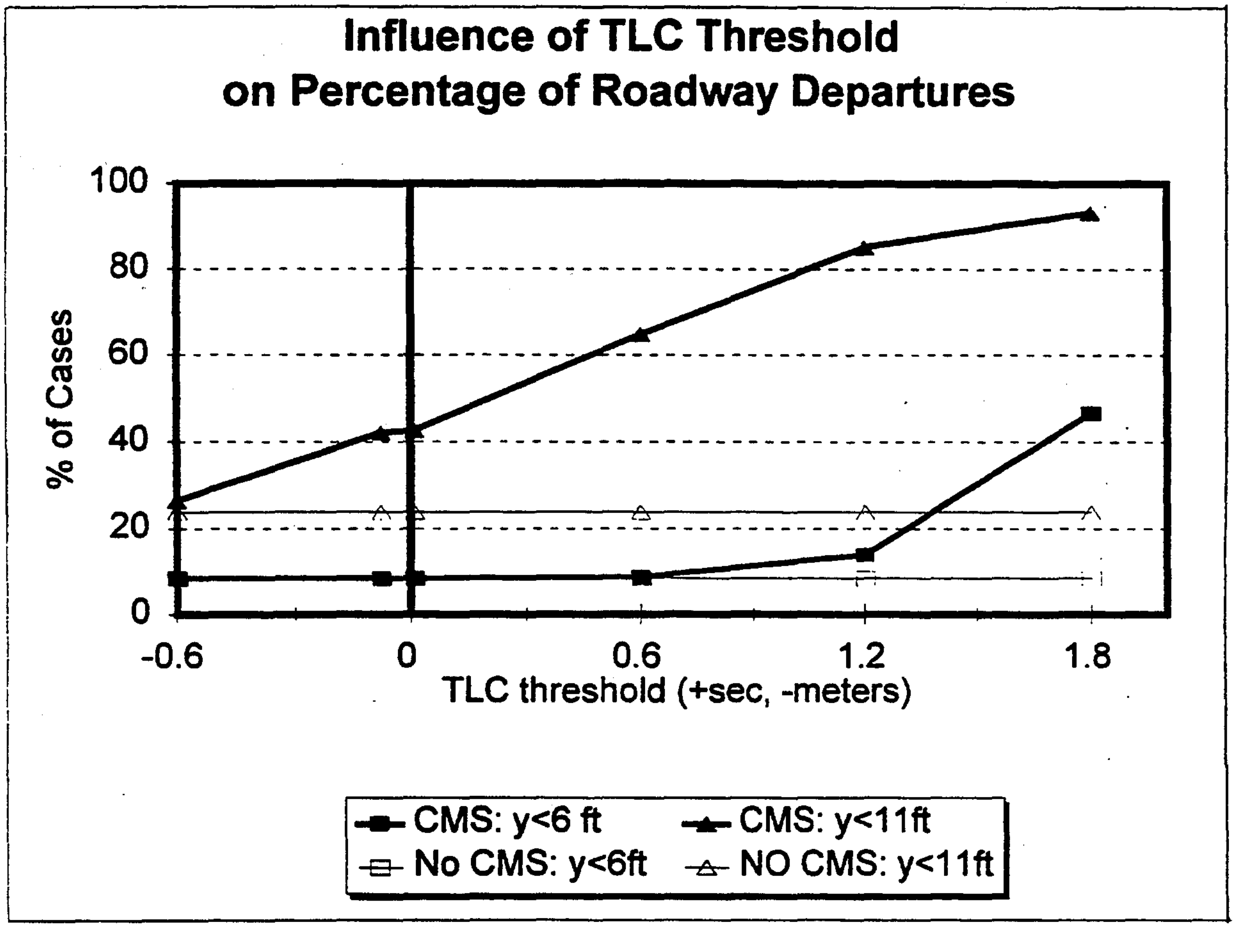


Figure 3-12. Study 3 results: influence of TLC threshold on CMS performance - comparison of roadway departures based on 1-Tire and 2-Tire ROR Criteria.

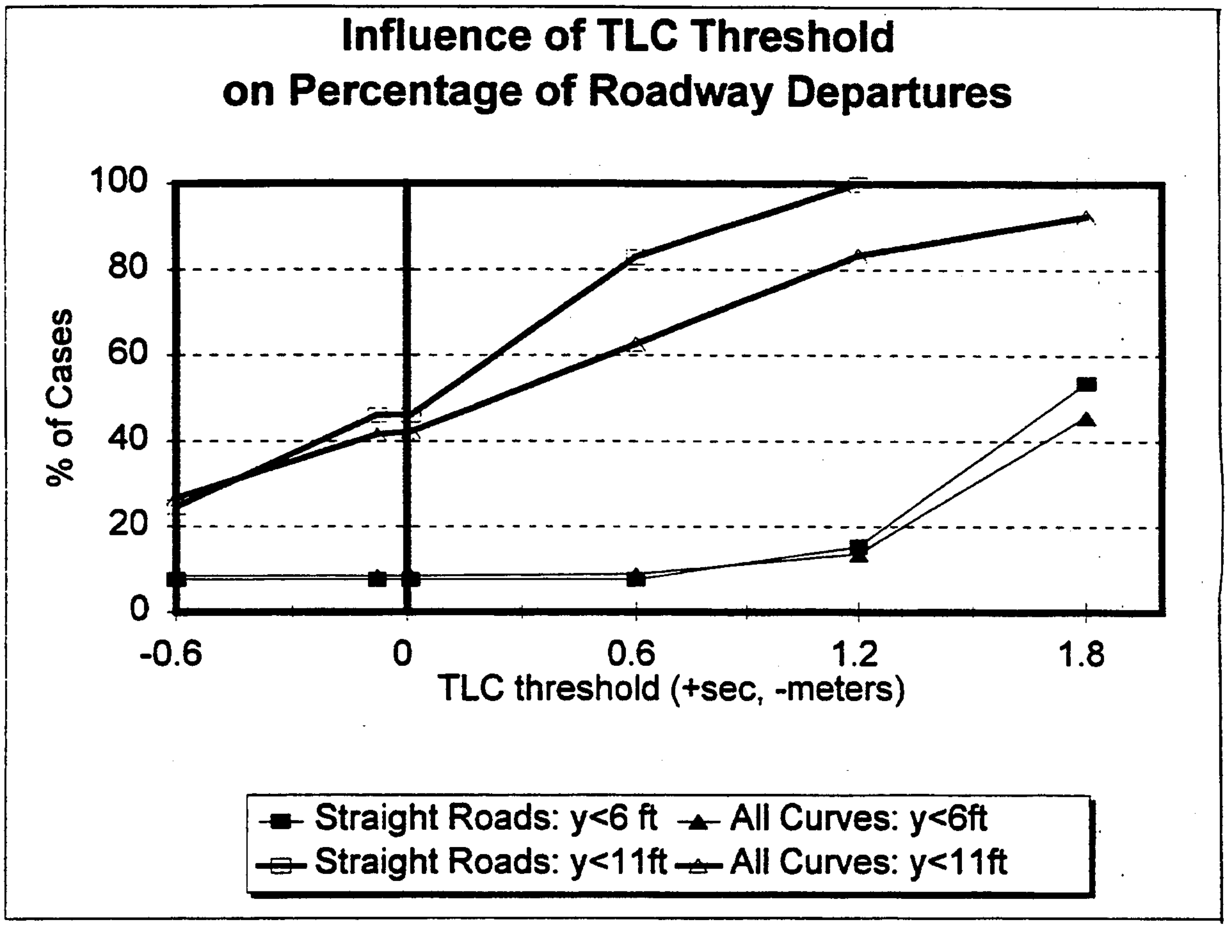


Figure 3-13. Study 3 results: influence of TLC threshold on CMS performance - comparison of roadway departures on straight and curved roads, based on 1-Tire and 2-Tire ROR Criteria.

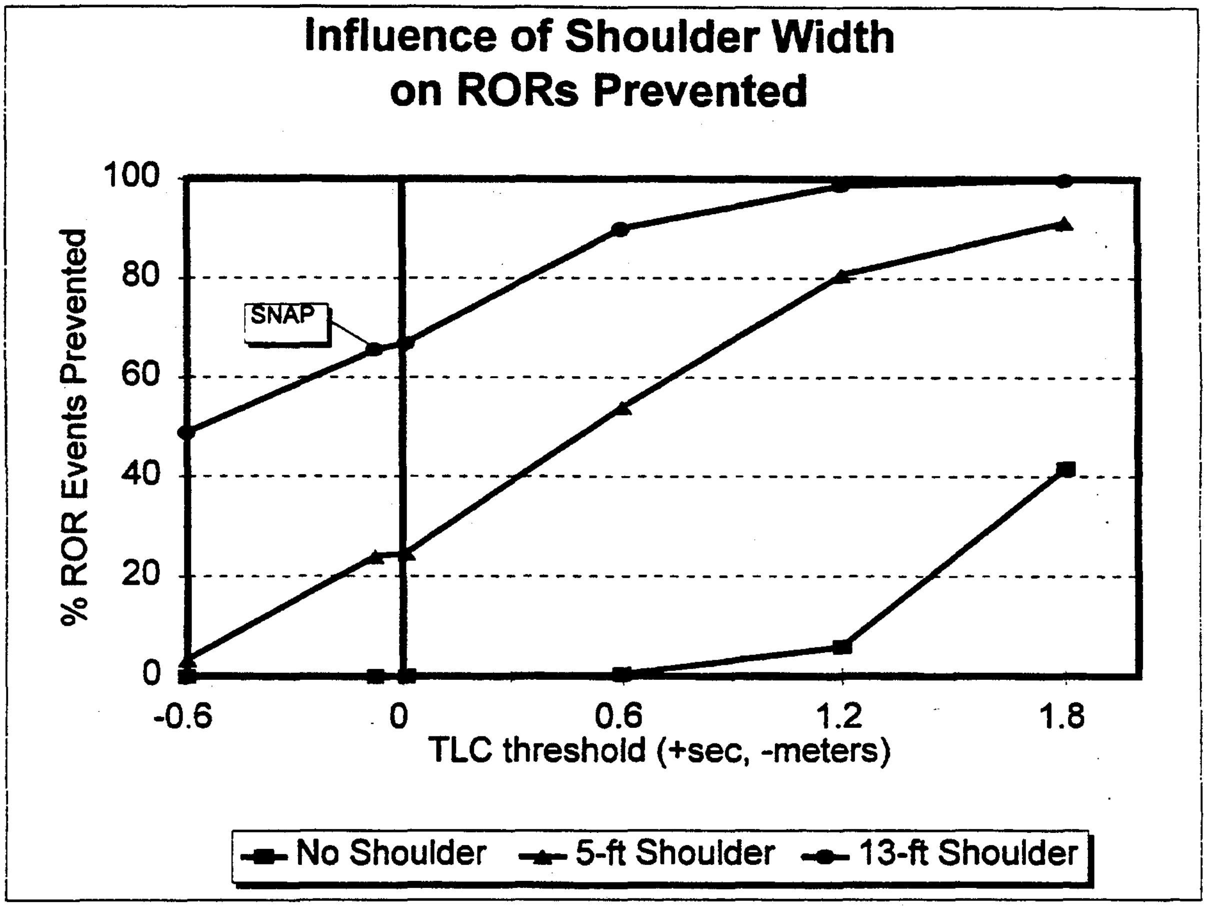


Figure 3-14. Study 3 results: influence of TLC threshold on CMS performance - influence of shoulder width on ROR events prevented.

of 1.2 sec, the percentage of RORs prevented on roads with no shoulder, a 5-ft shoulder and 13-ft shoulder were about 8, 80 and 98 percent, respectively. These results suggest that a higher TLC threshold is needed on roads with narrow shoulders, and that it may be desirable to have a variable TLC threshold in a CMS.

Additional results from Study 3, showing the influence of roadway curvatures, are presented in Figures 3-15 and 3-16. In Figure 3-15, the percentage of cases involving safe correct detects and false alarms are plotted as a function of TLC threshold. In Figure 3-16, the percentage ROR events prevented is plotted as a function of TLC threshold. As indicated in these figures, the percentage of safe correct detects and RORs prevented increase monotonically with increasing TLC threshold, on both straight roads and curves. Further, CMS performance on straight roads is noticeably better than that on curves. However, this beneficial trend of increasing correct detects is offset by an increase in the percentage of false alarms (and corresponding decrease in correct nondetects). These results stress the need for careful optimization of a CMS to provide the best combination of high correct detections, tolerable false alarm rates and minimal missed detections.

3.3.3 Performance Comparison: CMS versus SNAP

Simulations were made to compare CMS performance with a representation of the Sonic Nap Alert Pattern (SNAP), an existing countermeasure system for which actual effectiveness data are available. The Sonic Nap Alert Pattern (SNAP) was developed and implemented by the Pennsylvania Turnpike Commission (PTC). It consists of a series of grooves cut into the shoulder of the turnpike, about 3 inches outside the white edge line. If an inattentive (or napping) driver drifts outside the lane, the grooves make a loud sound (about 80 dB in a sedan at 60 mph), which quickly restores the driver's attention. SNAP was initially deployed in 31 miles of roadway where the incidence of ROR crashes was relatively high--0.51 per month. During a trial period of 1 to 3 years, the ROR crash rate was only 0.16 per month. SNAP helped reduce the ROR rate by 70 percent. Comments from drivers have been favorable, and the pattern is being deployed along the entire Turnpike. Other states and authorities are adopting variations of the idea as well.

In practice, SNAP is used on shoulders that are about 13 ft wide. Thus, to provide a meaningful comparison of CMS and SNAP effictiveness, a ROR was defined as an excursion of greater than 13 feet past the lane edge.

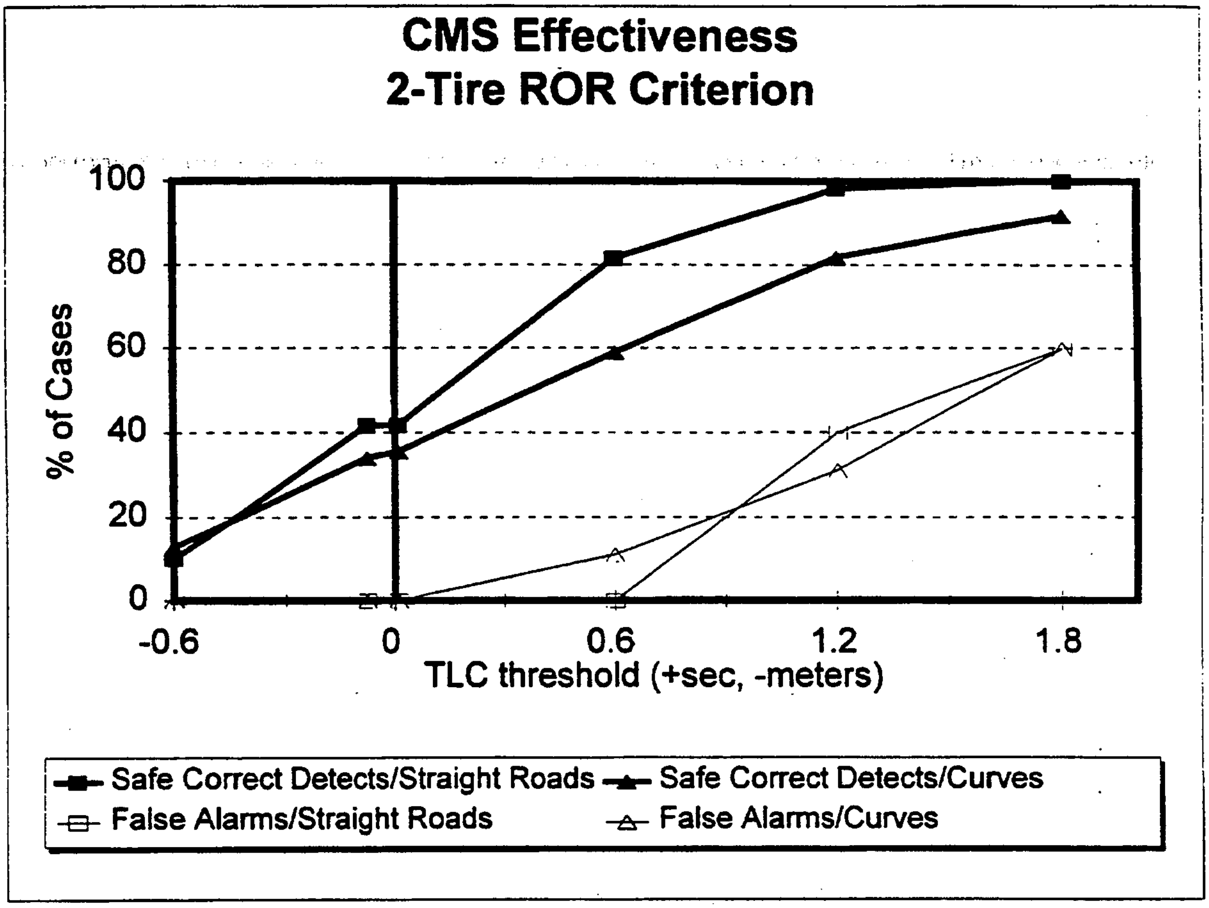


Figure 3-15. Study 3 results: influence of TLC threshold on CMS performance - comparison of safe and late correct detections, and false alarms on straight and curved roads.

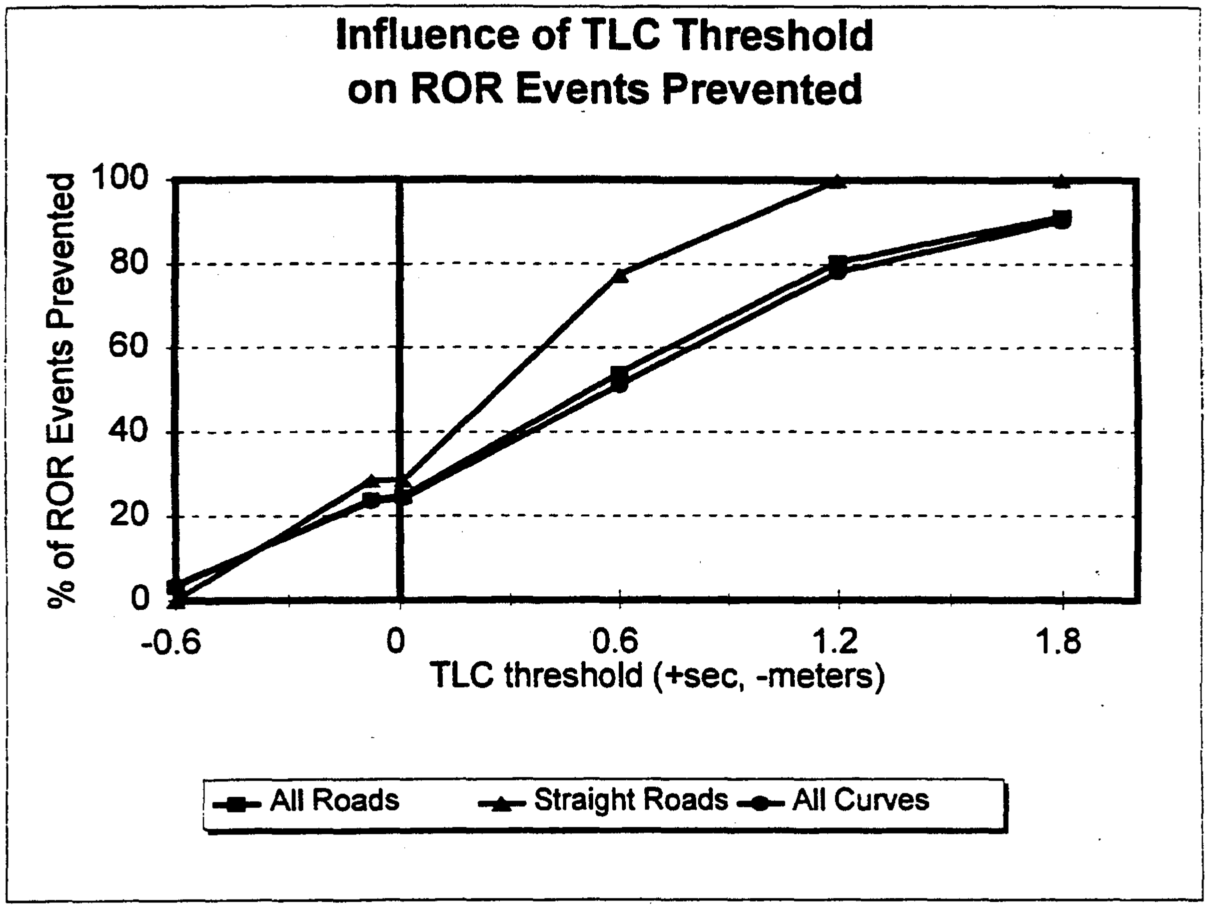


Figure 3-16. Study 3 results: effect of TLC threshold on percentage of ROR events prevented on different roadway segments.

Referring back to Figure 3-14, RORSIM predicts that SNAP would prevent about 65 percent of the ROR events in Study 2. This performance is similar to the 70 percent ROR reduction rate reported by the PTC, and thus is a good indication of the validity of RORSIM.

The results of the simulation studies comparing the CMS with SNAP are summarized in Figures 3-17 and 3-18. In Figure 3-17, CFDs of maximum lateral excursion are shown for no CMS, for a CMS with different TLC threshold levels, and for the SNAP system for all the roads considered in the study. Figure 3-18 compares the performance of the TLC based CMS with a SNAP system for straight roads only. As indicated in the figures, both the SNAP system and all configurations of the CMS provide substantial reductions in both maximum lateral excursions and ROR events. Further, as expected, the CMS performance exceeds that of the SNAP for TLC threshold values above zero. This is because the SNAP is equivalent to a perfectly accurate CMS system with an effective TLC threshold of slightly less than zero. Consequently, the CMS performance is not as good as that of the SNAP for TLC threshold values below the effective value for SNAP (-3 inches or -0.076 m for this study.)

Since SNAP has shown to improve highway safety by the reduction in recorded ROR events, by implication a properly configured CMS of the type modeled in these studies potentially can further improve ROR safety over that obtainable with SNAP.

3.3.4 Influence of CMS Accuracy

Several thousand simulations were run to evaluate the influence of CMS accuracy on CMS effectiveness. For this evaluation, the inattentive driver cases were run for each of six values of bias error in the lane position measurement (+/- 0.25 ft, +/- 0.50 ft and +/- 1 ft). This error would be manifested in an error between the calculated and actual values of TLC, because lane position is a dominant term in the TLC equation.

The results of this evaluation are summarized in Figure 3-19, which shows CFD plots of maximum lane excursion for the CMS with and without bias error, as well as for the case of no CMS.

The most significant result of these error studies is that the types of bias errors considered have a relatively minor effect on CMS effectiveness. For example, the CFD plots in Figure 3-19 indicate very little change with bias error for a TLC threshold of 1.2. Thus, lane position sensors with errors in the range of +/- 6 inches probably would be adequate for use in a CMS.

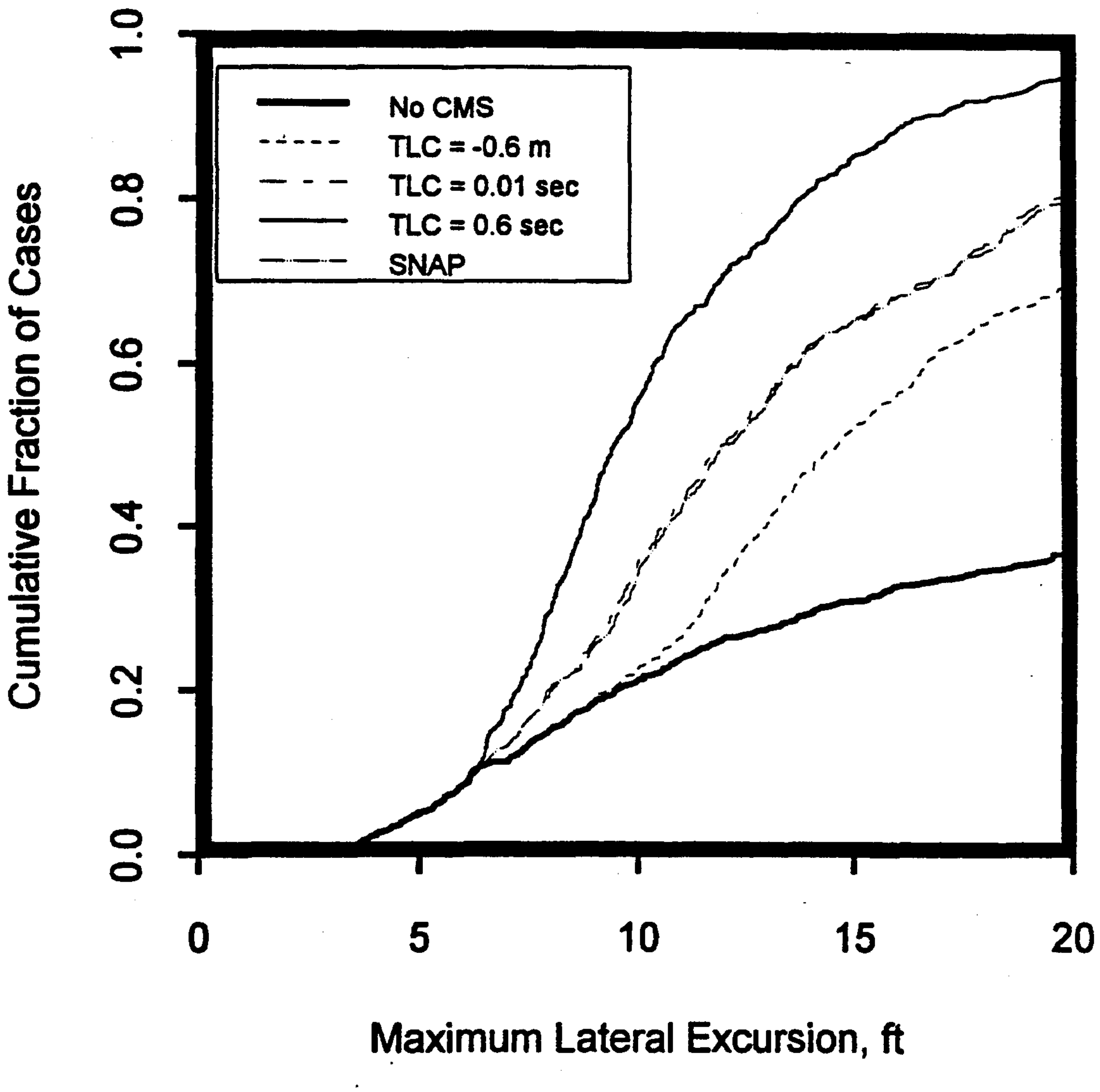


Figure 3-17. CFDs of maximum lateral excursion: comparison of electronic CMS with SNAP for all road types.

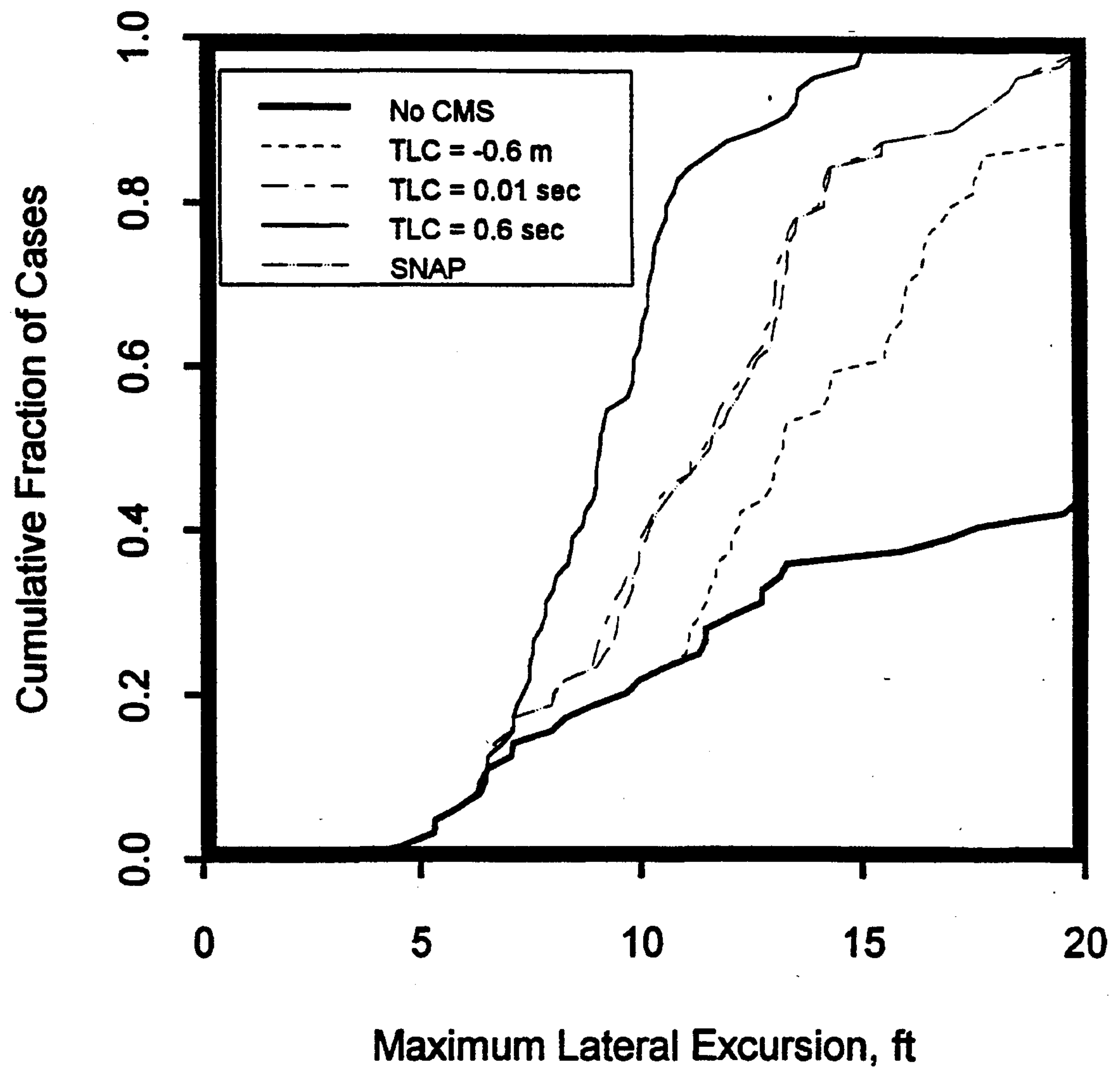


Figure 3-18. CFDs of maximum lateral excursion: comparison of electronic CMS with SNAP for straight roads.

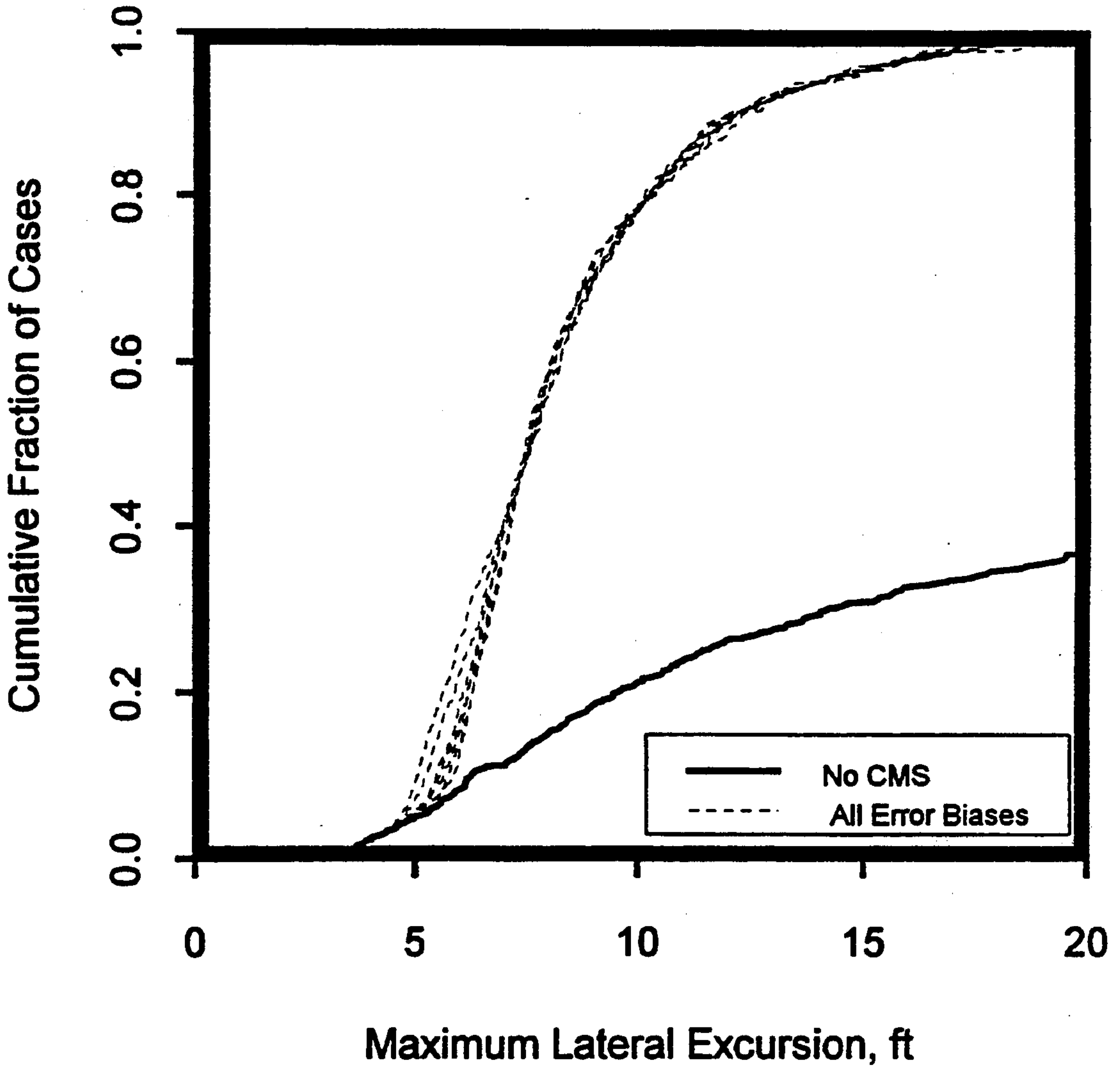


Figure 3-19. Study 3 results: influence of CMS error on CMS performance - CFDs of maximum lateral excursion for different lane position measurement bias errors.

4.0 Summary

Two of the most important measures of overall CMS effectiveness are the number of ROR events prevented and the false alarm rate: a perfect CMS would prevent all ROR events and issue no false alarms. As indicated by the results of the simulation study, there exists a tradeoff between ROR prevention and false alarm rate for the type of electronic CMS evaluated. This tradeoff is evident in the summary data provided in Figures 4-1 to 4-3 for straight roads, curved roads and all roads, respectively, using the 2-Tire ROR Criterion[1].

As shown in the figures, the CMS performance on straight roads is significantly better than that on curved roads from the standpoint of ROR events prevented, but is slightly worse from the standpoint of false alarm rates. For example, for a TLC threshold of 0.6 sec, about 78 percent of ROR events were prevented on straight roads, compared to about 55 percent on curved roads, with no false alarms issued for both road types. In contrast, for a TLC threshold of 1.2 sec, nearly 100 percent of ROR events were prevented on straight roads, compared to about 82 percent on curved roads; however, the false alarm rate on straight roads was about 21 percent, compared to about 13 percent on curves.

The data for all roads (Figure 4-3) are similar to those for curved roads (Figure 4-2), primarily because a disproportionately large percentage of curved roads (about 89 percent) was used in the distribution of roadway curvatures.

The data shown in these figures illustrate the strong potential for reducing ROR accidents by implementing an electronic in-vehicle CMS.

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[1] In these figures, false alarm rate was determined by a method other than that used in the results reported previously. The minimum TLC was calculated during each of the 541 normal driving (Study 1) simulation cases where the vehicle stayed in the lane, and a case where the TLC minimum fell below a specified TLC threshold value was defined as a false alarm. Using the 541 Study 1 cases rather than the non-ROR cases from Study 2 provides a larger sample size from which to calculate false alarm rate. However, a comparison of Figures 4-1 to 4-3 with Figures 3-10 to 3-11 indicates that the false alarm rates are similar for both methods.

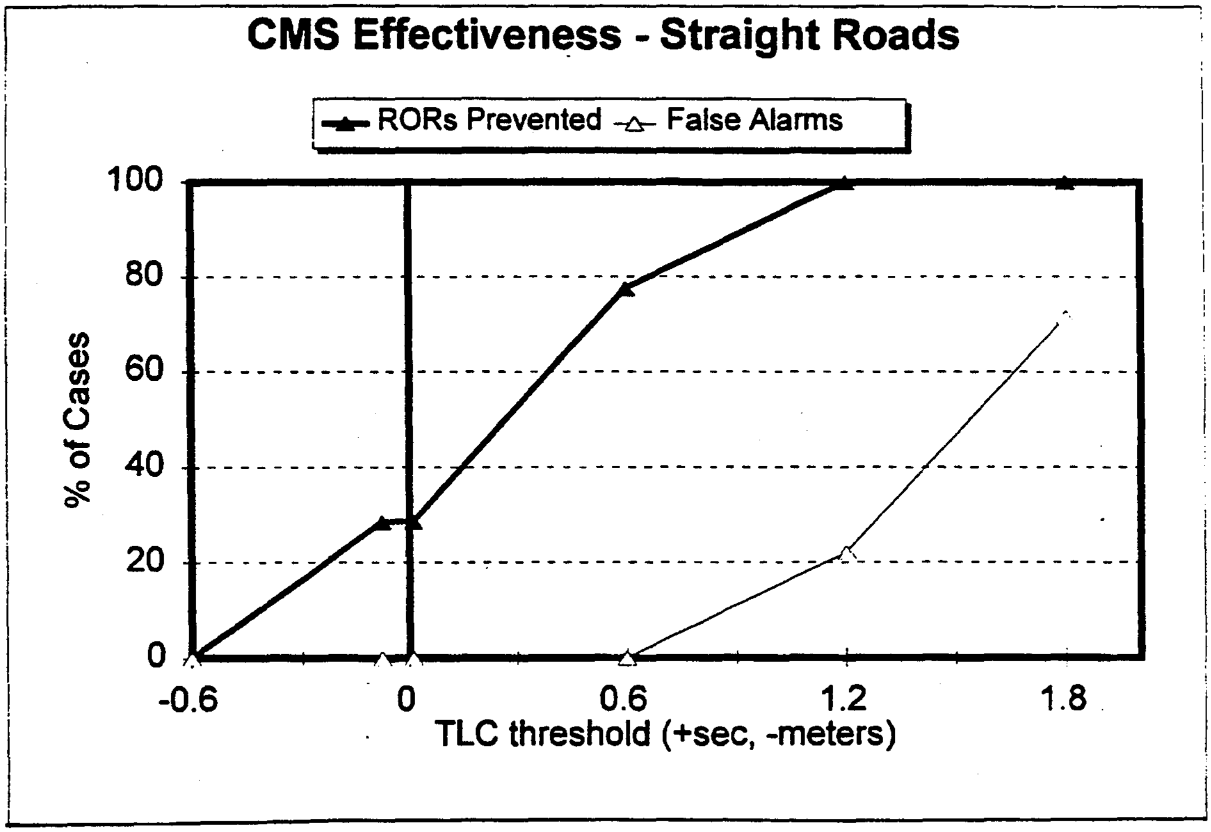

Figure 4-1. Summary of simulation studies: CMS effectiveness on straight roads using 2-Tire ROR Criterion.

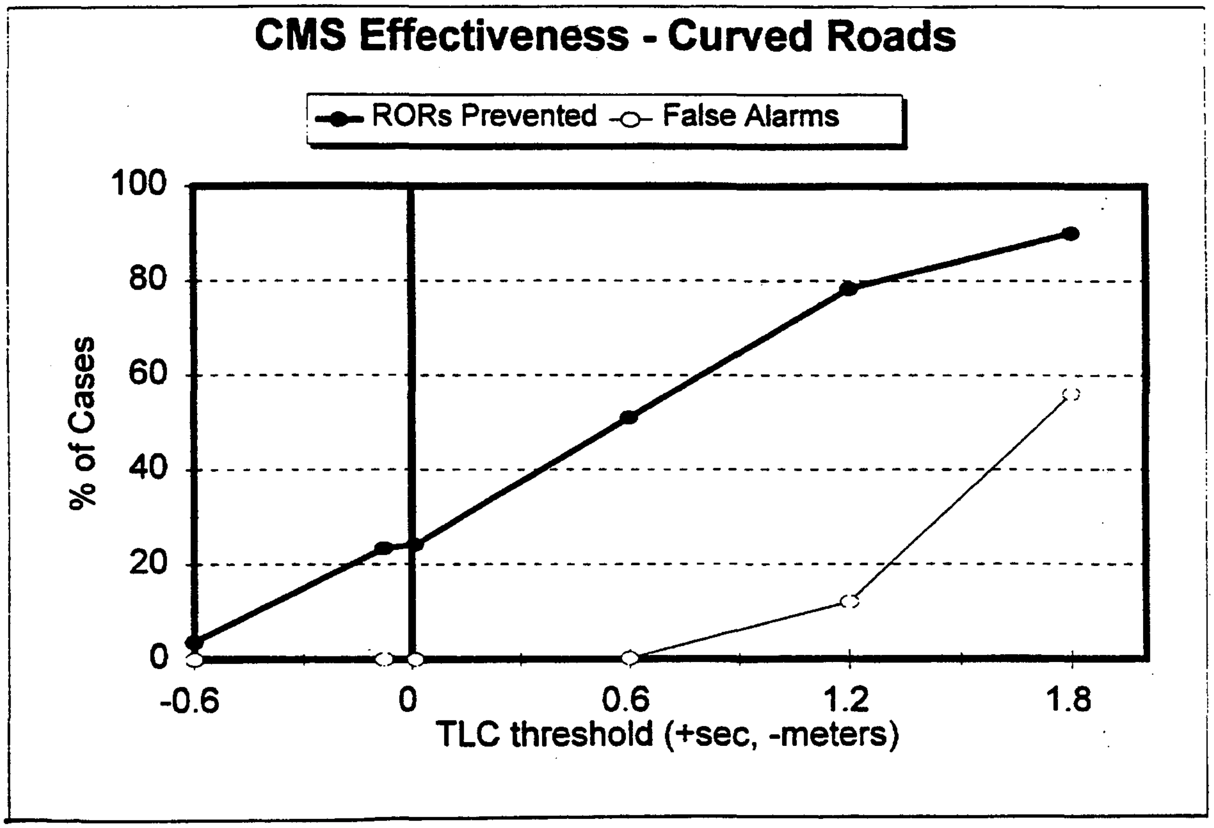

Figure 4-2. Summary of simulation studies: CMS effectiveness on curves using 2-Tire ROR Criterion.

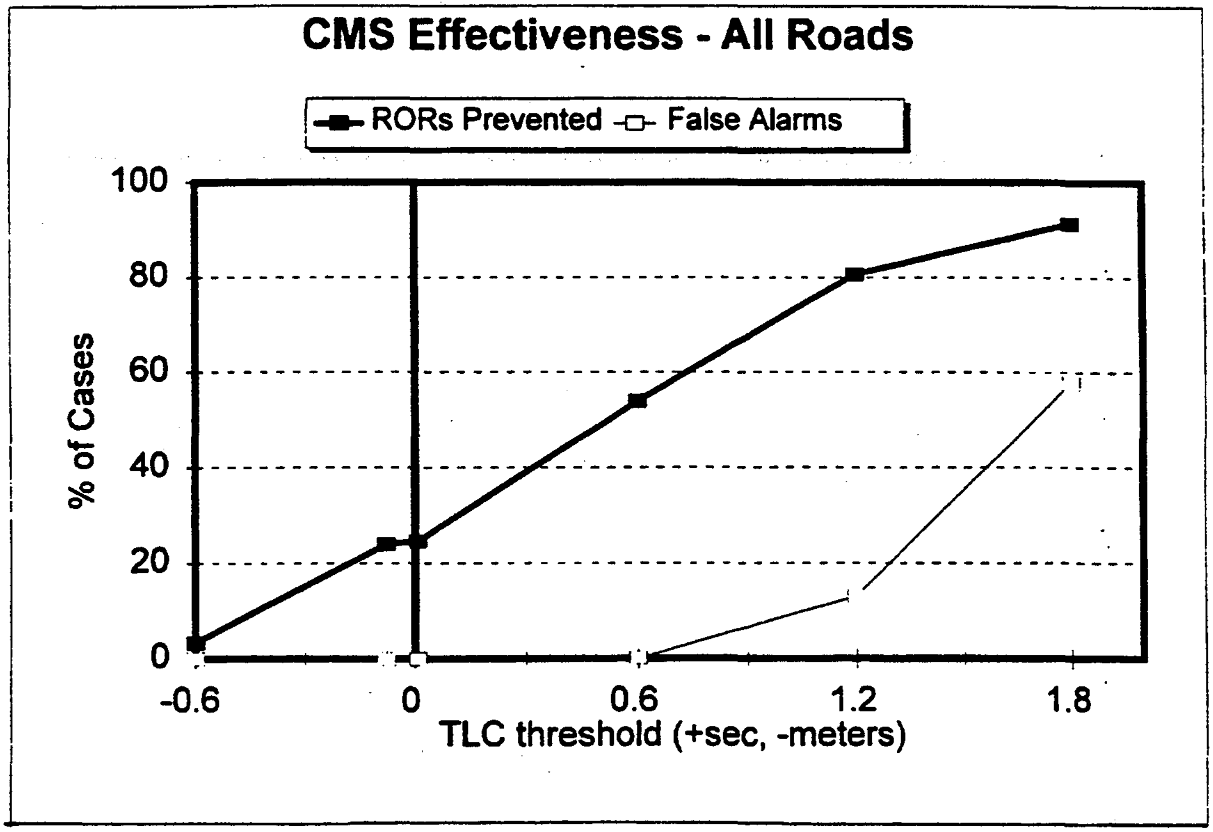

Figure 4-3. Summary of simulation studies: CMS effectiveness on all roadway types using 2-Tire ROR Criterion.

5.0 Conclusions

The following conclusions have been drawn from the results of the foregoing simulation studies:

1. RORSIM has been demonstrated to be a valuable analytical tool for evaluating CMS performance over a wide range of driving conditions and driver characteristics. The enhancements developed in this phase of the ROR program enable RORSIM to be used conveniently to implement Monte Carlo-type techniques to generate literally thousands of driving scenarios per day on a desktop computer. Thus, it is possible to perform an effectiveness assessment of a CMS in a few days. This capability is a powerful supplement to over-the-road and test track testing, which can be time-consuming, costly, and limited in the range of conditions that can be evaluated.

2. The CMS configuration evaluated in the studies showed considerable potential for effectively reducing a vehicle's probability of a ROR crash over a vehicle not equipped with a CMS as well as over a passive roadside system such as shoulder rumble strips ("SNAP").

3. There exist inherent trade-offs between correct ROR detection rate, false alarm rate, and non-detection rate. An effective CMS must account for these trade-offs and should be optimized to provide the best overall performance. The studies presented in this report have provided insight into these CMS performance issues and helped to quantify some of the trade-offs. These simulations suggest that under the conditions tested, a TLC warning threshold in the vicinity of 0.6 seconds best satisfies the goal of maximizing effectiveness while keeping the false alarm rate near zero. These results are supported by in-vehicle experiments conducted during Phase I of this program.

4. A potential safety issue is the nature of an disengaged driver's response to a ROR warning. Depending on the "aggressiveness" of the driver in his response (i.e., the warning "startle factor"), a warning actually could cause a subsequent ROR event.

5. The TLC method for warning of incipient ROR conditions is effective and is relatively insensitive to errors in lane position measurement (bias) error.

6. The effectiveness of a CMS depends strongly on the amount of clear shoulder available for maneuvering. Therefore, the reported effectiveness depends on the criterion used to define a ROR event. The results of this study indicate that the CMS is much more successful (on the basis of crash prevented) if instances of the vehicle riding partly on the shoulder are not considered as a ROR event. That is, if the driver is allowed to use some of the shoulder to maneuver the vehicle back into the lane, the success of the CMS is quite good. This strongly suggests the need for information on available shoulder widths, the presence of culverts and overpasses, etc., in order to ensure that proper ROR warnings are issued to the driver on a sitespecific basis, as was suggested in the Preliminary Performance Specifications of the Phase 1, Task 4 report.

6.0 Recommendations

The following recommendations are made based on the results of this study:

1. The results of the simulations in this study should be analyzed in greater detail to determine the effect of the various input parameters on the CMS effectiveness. Important questions that could be answered include, "Does the CMS performance differ between wet and dry conditions?" and "Should the threshold be varied according to the vehicle's current speed?" Improvements to the CMS can be proposed when the factors limiting the recovery maneuver have been identified.

2. Further simulation studies should be performed to evaluate the influence of several additional factors on CMS performance. These include vehicle type, and a wider range of driver behavior also should be employed. This should include driver "curve-cutting" behavior, avoidance maneuvers involving braking and steering.

3. Another focus of additional studies should be on differences in driver responsiveness (aggressiveness) before and after the disengagement period in situations where no CMS warning has been issued. This assumption may have biased the results to indicate only marginal improvements in ROR performance with SNAP and low TLC threshold values, because for the "NO CMS" (Study 2) cases, the driver "calmly" regained attentiveness. Data evaluated in Tasks 1 and 2 of this program indicate that a driver may be more likely to under-react when suddenly regaining attention. Thus, additional work should involve characterizing the changes in driver responsiveness before and after becoming disengaged, and evaluating the influence of these characteristics on the ability to maneuver to avoid ROR events.

4. More human factors information is necessary concerning how the driver and CMS will perform together. Specifically, studies should be performed to determine the range of driver reactions to a warning and how warnings might be "tuned out" if false alarms become too persistent. Controlled simulator studies would complement research with naive drivers in actual vehicles.

5. Further studies should be performed to explore the use of other detection schemes, including combinations of the three CMS methodologies developed in Phase I of this project. The ability of the expanded model to quickly simulate thousands of cases will permit researchers to identify classes of situations where one type of countermeasure system is preferable to another.

6. Additional simulation studies also should focus on different roadway types (e.g., multi-lane highways) and use a distribution of roadway curvatures that are more representative of U.S. roadways (e.g., a greater percentage of straight and nearly straight segments). Further, the roadway models should be modified to represent as realistically as possible the friction and geometry characteristics of the shoulders and off-road regions.

7.0 References

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[11] Pape, D., Narendran, V.K., Hadden, J., Everson, J., Koenig, M., and Pomerleau, D., (1995), "Run-Off-Road Collision Avoidance Using IVHS Countermeasures: Task 4--Volume I." Contract No. DTNH22-93-C-07023.

Appendix A

RORSIM Version 2.0

Appendix A: RORSIM Version 2.0

The scope of the RORSIM simulation studies under Phase II is to conduct extensive parameter studies using a Monte Carlo (MC) approach in an effort to provide a more comprehensive characterization of the effectiveness of collision avoidance systems (CAS) in incipient ROR events. The goal is to demonstrate the effectiveness of one or more proposed countermeasure systems in preventing ROR crashes in a variety of circumstances. A more fundamental objective is to develop and exercise a methodology for evaluating the effectiveness of a proposed countermeasure system.

To implement this approach, the simulation program RORSIM (Version 1.0), which was developed in Phase I of this project, was modified and expanded in the following manner:

A.1 Upgraded Vehicle Dynamics Model

RORSIM is an enhancement of the VDANL program, which is a commercial, general purpose, rubber tired vehicle simulation program owned by Systems Technology, Inc. RORSIM, Version 2.0 is based on the latest version of VDANL - Version 5.02. This version incorporates improved tire force estimation methods as well as advanced open loop speed control features.

A.2 New RORSIM Capabilities

Several new features have been introduced in Version 2.0. Two new features have been added to extend the driver model developed for Phase I studies, namely, driver lane keeping performance and driver aggressiveness of response to an alarm. In order to reduce the amount of post-processing required to generate counter measure system effectiveness estimates, algorithms were added to determine countermeasure system performance indicators such as number of correct detections, missed detections and false alarms issued by the CAS.

Driver Lane Keeping Performance. Human drivers usually do not control the vehicle to track the center of the lane perfectly and vehicle lane keeping behavior is characterized by a driver specific "meandering" or weaving tendency. In RORSIM (Version 2.0) a lateral wind gust forcing function was created to generate various levels of vehicle lane weaving or "meandering," which is associated with driver lane-keeping behavior. For ROR studies, the magnitude of lateral wind gust is provided as an input parameter that can be varied depending on the type of driver we want to model.

Driver Aggressiveness of Response. Driver aggressiveness of response models The driver's immediate reaction to an alarm issued by the CMS is captured by the driver aggressiveness of response factor. This is a multiplicative factor on the nominal driver response gain when an alarm sounds. In reality, the driver will revert to his nominal driving response a few seconds after he has reacted to the alarm. Therefore, the multiplicative factor exponentially converges to 1 with a fixed time constant. This time constant can also be varied. At this time, this feature comes into effect only when an alarm sounds during driver disengagement.

Counter Measure System Effectiveness. RORSIM has also been modified to automatically log countermeasure system effectiveness parameters such as maximum excursions of the tires and maximum vehicle heading angles (relative to the road) before, during and after driver disengagement, number of warnings issued by the CMS and total time the alarm is operational. Algorithms have been included to detect false alarms, correct detections and missed detections.

A.3 Input Parameters

RORSIM version 2.0 includes an expanded list of input parameters that can be varied automatically by RORMCRUN. They are:

1. Roadway curvature
2. Lane width
3. Tire/road friction coefficient
4. Tire/shoulder friction coefficient
5. Shoulder rolling resistance
6. Vehicle speed
7. Driver lane-keeping performance
8. Driver reaction time
9. Driver aggressiveness of response to an alarm
10. Initiation time of driver inattentiveness
11. Time duration of driver inattentiveness
12. CMS type (TTD or TLC) and threshold
13. CMS accuracy.

Nine roadway designs have been provided with road radius of curvature varying from 250 ft to a straight road. This feature is similar to that provided in Version 1.0 in that additional road designs must be created if they are required for the study. RORSIM Version 2.0 does not provide an automatic feature that creates the complete road design based on user input of road radius of curvature. In RORSTAT, the distribution of vehicle speed is curvature dependent but the user can specify the curvature-vehicle speed interdependence. This interdependence would then apply to all roadway designs.

The lane widths for rural and urban roadways usually vary from 9-12 ft. In this particular study, only the 12 feet lanes were considered. The tire/road and tire shoulder friction coefficients allow the user to simulate a wide range of road conditions varying from absolutely dry to icy road surface conditions. The shoulder rolling resistance is a useful parameter especially for vehicle excursions on to the shoulder of the road.

In addition to driver steering reaction time, the user now has the option of specifying nominal driver lane keeping behavior as well as the aggressiveness of response to issued alarms. A well-characterized driver model is important for studying run-off-the-road situations.

The addition of onset time of driver inattentiveness and time duration of driver inattentiveness gives the user greater flexibility in trying to create a potential ROR situations for study. These two parameters were fixed in Version 1.0.

A.4 Multiple Simulation Runs

The software was modified so that it could execute multiple runs autonomously. For example, in the study described in this report, over 4,000 simulation runs were made using RORSIM with the desktop computer unattended.

A shell program called RORMCRUN allows the user to perform multiple simulation runs by specifying three input files. In each file, each line of data constitutes the input stream for executing one run. The three files are described below.

1. **Baseline Parameter File** - The first file contains values for parameters 1-9, described in the previous section. The parameters define the baseline parameters required for simulation and include road geometry, vehicle speed and driver characteristics input parameters. These parameters must be specified for any run.

2. **Driver Disengagement Parameter File** - The second file contains driver disengagement time parameters (parameters 10-11) and include time of onset of driver disengagement and duration of driver disengagement. This data file is optional. When specified along with the Baseline Parameter File, driver disengagement cases are simulated.

3. **Countermeasure System Parameter File** - The third file consists of CMS specific parameters (parameters 12-13) such as the CMS threshold for warning and CMS sensor accuracy. This data file is optional. When included, the Baseline Parameter and Driver Disengagement Parameter Files must also be specified. This allows the user to simulate the effects of an active countermeasure system.

These files can be generated using RORSTAT. Appendix B has an example of an input file generated by RORSTAT. Please note that the last two columns are the Driver Disengagement Parameter Inputs.

A.5 Input files generation

The user can exercise RORSIM version 2.0 in two ways:

1. Use RORMENU, specify the necessary input parameters and execute a single run.

2. Use RORSTAT to develop the three input files from the predefined set of distributions for each parameter (described in the Section 2.3) and use RORMCRUN with RORSIM to execute multiple runs.

RORSTAT uses the Latin Hypercube approach to generate input files for multiple runs.

The program RORSTAT for generating the random Latin hypercube vectors was written in Splus. Splus is a statistical programming environment and a product of StatSci, a division of MathSoft, Inc., Seattle, Washington. Splus is available on a variety of computer platforms, including Windows 95 on a personal computer.

At this time the user has the freedom to vary distribution variables such as mean, variance or range of any of the defined input parameters but cannot change the distribution itself. The parameters of the input variable distributions are well documented in the program and can be modified by a user familiar with the Splus environment. Each line of the input file represents a particular combination of the input parameters and the entire file will be representative of the distributions defined for all the parameters.

Appendix B

Input Parameters for Studies 1 and 2

INPUT FOR STUDIES 1 AND 2

Description of Input parameters

Icase - Study1 case number
Rdnum - the road file being used varies from 1-9 (+/- 250ft Curature - straight)
LL - lane width
MUR - road coefficient of friction
MUB - shoulder coefficient of friction
RRB - shoulder rolling resistance
RtdSpd - the speed for the run
LKeepAmp - Lane keeping amplitude parameter (equivalent to magnitude of wind gust)
LKeepSeed - Seed for generating wind gust file
SteerReacTime - Driver steering reaction time
KPanic - gain for driver reaction to warning
DNS - Time driver inattention begins
Dur.NoSteer - Duration of driver inattentiveness

Input Stream for Phase II Studies

ICase	rd num	LL	MUR	MUB	RRB	Rtd Spd	LKeep Amp	LKeep Seed	Steer Reac Time	KPanic	DNS	Dur. No Steer
1	1	12	0.56	0.56	-0.035	42	0.25	50641	0.74	0.54	6.65	5.68
2	1	12	0.85	0.85	-0.047	51	0.12	29300	1.72	1.03	15.65	8.1
3	1	12	0.59	0.59	-0.017	49	0.2	37147	0.85	1.56	10.32	11.18
4	1	12	0.62	0.62	-0.044	49	0.17	5499	0.88	1.89	3.79	11.96
5	1	12	0.88	0.88	-0.036	46	0.11	22035	0.62	1.49	9.55	8.64
6	1	12	0.9	0.9	-0.065	44	0.24	57878	0.7	2.15	8.36	6.98
7	1	12	0.46	0.46	-0.025	47	0.15	7372	0.76	0.44	9.3	4.16
8	1	12	0.72	0.72	-0.079	46	0.16	61588	0.77	1.98	7.85	10.58
9	1	12	0.94	0.94	-0.016	50	0.18	9972	0.59	0.74	4.9	11.44
10	1	12	0.75	0.75	-0.019	51	0.32	42203	0.41	1.82	12.9	6.48
11	1	12	0.65	0.65	-0.023	47	0.28	12368	1	1.16	15.03	4.54
12	1	12	0.85	0.85	-0.179	48	0.13	20275	0.93	0.88	16.47	3.02
13	1	12	0.78	0.78	-0.029	56	0.21	54989	0.68	2.03	5.96	7.28
14	1	12	0.52	0.52	-0.026	50	0.26	17400	0.56	1.67	7.08	9.22
15	1	12	0.77	0.77	-0.017	45	0.34	46655	0.83	2.32	5.47	3.64
16	1	12	0.69	0.69	-0.106	49	0.27	44188	1.13	1.39	10.81	5.8
17	1	12	0.81	0.81	-0.021	49	0.35	38047	0.97	2.25	3.03	13
18	1	12	0.63	0.63	-0.021	45	0.22	28075	1.21	1.24	14.24	9.14
19	1	12	0.8	0.8	-0.27	47	0.14	24523	0.64	0.85	13.56	9.72
20	1	12	0.7	0.7	-0.054	48	0.31	32907	1.06	2.48	12.39	5.2
21	1	12	0.34	0.34	-0.018	52	0.3	2801	0.79	1.32	11.72	2.36
22	1	12	0.92	0.92	-0.032	53	0.23	61083	0.51	0.67	16.26	12.4
23	1	12	0.37	0.37	-0.019	50	0.34	39270	0.88	0.73	10.74	3.86
24	1	12	0.46	0.46	-0.051	53	0.3	4691	0.95	1.74	11.6	9.48
25	1	12	0.8	0.8	-0.061	47	0.26	30716	0.46	1.38	3.32	7.74
26	1	12	0.69	0.69	-0.039	46	0.11	11822	0.63	0.92	13.72	5.58
27	1	12	0.66	0.66	-0.02	47	0.16	23648	0.65	1.5	14.56	12.64
28	1	12	0.64	0.64	-0.021	51	0.2	8457	0.56	0.97	5.22	2.24
29	1	12	0.95	0.95	-0.033	54	0.35	871	0.84	1.97	4.28	10.62
30	1	12	0.78	0.78	-0.36	47	0.19	40995	1	0.42	14.37	13.08
31	1	12	0.7	0.7	-0.017	50	0.14	16770	0.79	1.56	5.65	6
32	1	12	0.84	0.84	-0.031	51	0.24	45806	0.72	2.32	10.04	7.32
33	1	12	0.77	0.77	-0.077	44	0.28	28196	0.93	2.43	12.45	10.8
34	1	12	0.49	0.49	-0.041	49	0.12	34210	0.77	0.68	16.09	8.42
35	1	12	0.73	0.73	-0.029	47	0.13	51339	1.03	2.15	8.3	9.86
36	1	12	0.62	0.62	-0.016	45	0.22	60570	1.16	1.14	16.49	4.54
37	1	12	0.87	0.87	-0.097	52	0.3	47144	0.5	1.92	9.66	8.92
38	1	12	0.57	0.57	-0.204	48	0.17	35355	0.75	2.07	7.61	3.38
39	1	12	0.91	0.91	-0.025	49	0.26	19974	1.14	1.19	9.17	5.02
40	1	12	0.82	0.82	-0.019	49	0.18	10688	0.84	0.59	3.98	6.98
41	1	12	0.86	0.86	-0.026	48	0.23	55262	0.71	2.28	6.66	6.64
42	1	12	0.91	0.91	-0.024	41	0.29	63553	1.28	0.81	7.04	11.52
43	1	12	0.75	0.75	-0.018	51	0.15	21395	0.66	1.29	15.71	3.1
44	1	12	0.56	0.56	-0.063	44	0.33	56159	0.59	1.8	12.96	12.12
45	1	12	0.83	0.83	-0.029	45	0.11	55060	0.96	1.92	8.16	4.86
46	1	12	0.63	0.63	-0.039	53	0.19	44814	1.34	1.64	13.75	10.88
47	1	12	0.66	0.66	-0.025	50	0.21	7390	0.76	1.47	3.45	9.42
48	1	12	0.62	0.62	-0.047	50	0.1	29391	0.74	1.24	11.35	8.36
49	1	12	0.97	0.97	-0.019	48	0.16	40860	1	0.78	9.89	5.46
50	1	12	0.43	0.43	-0.023	49	0.34	32728	0.84	1.98	13.03	6.7
51	1	12	0.77	0.77	-0.026	51	0.32	39487	0.85	0.57	5.88	10.4
52	1	12	0.72	0.72	-0.02	52	0.26	26965	0.67	0.85	15.3	6.08
53	1	12	0.71	0.71	-0.031	51	0.17	16880	0.59	2.35	4.94	10.16
54	1	12	0.93	0.93	-0.034	43	0.29	49580	1.06	0.88	7.38	12.9
55	1	12	0.86	0.86	-0.016	43	0.3	58104	0.45	1.79	6.75	8.78
56	1	12	0.32	0.32	-0.044	47	0.23	12760	0.69	1.4	14.23	4.6
57	1	12	0.78	0.78	-0.018	47	0.19	18250	1.1	2.28	10.15	3.74
58	1	12	0.5	0.5	-0.152	47	0.28	24305	0.62	1.07	4.59	8
59	1	12	0.8	0.8	-0.309	45	0.22	36575	0.55	2.13	9.19	11.94
60	1	12	0.89	0.89	-0.021	46	0.15	10667	0.65	1.28	4.16	6.96
61	1	12	0.91	0.91	-0.018	49	0.13	20577	0.93	1.09	10.8	11.52
62	1	12	0.82	0.82	-0.078	48	0.27	63963	0.88	2.49	14.5	3.34
63	1	12	0.67	0.67	-0.017	54	0.34	1885	1.21	2.11	12.48	2.38
64	1	12	0.75	0.75	-0.113	48	0.14	59537	0.8	0.43	16.84	3
65	1	12	0.58	0.58	-0.058	48	0.31	4641	0.49	1.65	16.05	7.3
66	1	12	0.56	0.56	-0.068	50	0.24	48309	0.77	0.63	7.74	12.42
67	2	12	0.43	0.43	-0.02	43	0.16	11198	0.65	1.96	14.08	8.84
68	2	12	0.86	0.86	-0.667	47	0.29	40264	0.38	0.74	4.08	5.8
69	2	12	0.73	0.73	-0.016	51	0.27	56317	0.55	2.04	7.64	12.7
70	2	12	0.69	0.69	-0.049	44	0.25	4844	1.14	1.92	14.82	12.06
71	2	12	0.83	0.83	-0.027	53	0.18	27277	0.67	2.36	5.27	10.36
72	2	12	0.93	0.93	-0.02	48	0.24	41188	0.79	1.04	11.59	8.56
73	2	12	0.62	0.62	-0.025	45	0.11	63750	0.53	0.96	8.69	7.32
74	2	12	0.89	0.89	-0.129	47	0.34	12289	0.88	1.22	12.98	4.7
75	2	12	0.82	0.82	-0.018	50	0.27	45381	1.54	1.1	6.59	2.22
76	2	12	0.97	0.97	-0.018	49	0.3	53110	1.24	1.53	10.57	2.9
77	2	12	0.67	0.67	-0.016	44	0.33	15071	1	0.84	13.2	10.7
78	2	12	0.89	0.89	-0.072	48	0.21	21524	0.83	1.71	16.86	7.78
79	2	12	0.63	0.63	-0.032	52	0.33	36358	0.59	2.17	10.99	6.44
80	2	12	0.81	0.81	-0.028	55	0.14	30389	0.79	0.62	9.27	3.8
81	2	12	0.59	0.59	-0.105	47	0.13	6306	0.93	1.35	6.96	6.9
82	2	12	0.74	0.74	-0.038	46	0.32	34602	0.63	0.58	15.6	4.82
83	2	12	0.31	0.31	-0.022	51	0.19	52302	0.87	1.78	5.66	5.38
84	2	12	0.51	0.51	-0.042	49	0.11	18427	1.07	1.38	16.2	9.28
85	2	12	0.79	0.79	-0.033	51	0.16	47388	0.94	1.62	9.63	12.34
86	2	12	0.7	0.7	-0.083	49	0.23	59264	0.72	2.23	12.15	10.14
87	2	12	0.54	0.54	-0.055	50	0.22	24179	0.75	2.49	4.58	3.5
88	2	12	0.76	0.76	-0.023	47	0.19	2484	0.7	0.42	3.38	11.28
89	2	12	0.75	0.75	-0.131	46	0.29	19667	0.73	2.17	13	10.36
90	2	12	0.37	0.37	-0.034	45	0.11	31655	0.48	1.76	3.63	5.1
91	2	12	0.42	0.42	-0.044	50	0.25	13204	0.94	1.06	10.04	8.74
92	2	12	0.6	0.6	-0.431	49	0.29	16815	0.91	1.2	7.69	5.28
93	2	12	0.86	0.86	-0.062	49	0.34	42918	0.77	0.65	11.09	7.12
94	2	12	0.85	0.85	-0.02	42	0.22	48369	1.18	0.96	14.84	4.38
95	2	12	0.64	0.64	-0.019	50	0.33	5176	0.8	1.85	5.36	9.54
96	2	12	0.7	0.7	-0.027	53	0.27	44544	0.59	0.88	13.18	11.1
97	2	12	0.8	0.8	-0.025	45	0.12	36746	0.69	1.1	9.18	12.58
98	2	12	0.91	0.91	-0.092	50	0.23	37933	0.98	2.28	9.53	3.32
99	2	12	0.59	0.59	-0.018	56	0.28	50231	0.53	0.58	5.63	12.2
100	2	12	0.88	0.88	-0.058	51	0.18	58869	0.63	2.08	4.79	2.4
101	2	12	0.76	0.76	-0.028	48	0.16	63916	0.75	1.57	14.42	6.1
102	2	12	0.78	0.78	-0.125	48	0.2	55250	0.81	2.33	6.74	12.88
103	2	12	0.94	0.94	-0.03	48	0.17	25375	0.88	0.44	16.49	8.56
104	2	12	0.66	0.66	-0.022	46	0.14	10154	1.02	1.46	15.8	6.34
105	2	12	0.53	0.53	-0.04	47	0.31	33574	0.87	2.45	4.13	9.9
106	2	12	0.94	0.94	-0.017	47	0.32	57937	0.64	1.28	12.48	7.24
107	2	12	0.73	0.73	-0.017	49	0.15	6333	0.55	0.7	11.31	11.42
108	2	12	0.52	0.52	-0.016	44	0.13	23208	1.13	2	7.11	7.94
109	2	12	0.68	0.68	-0.023	52	0.24	1244	0.67	1.44	15.71	3.06
110	2	12	0.83	0.83	-0.049	51	0.19	27900	1.31	1.67	8.31	4.14
111	2	12	0.8	0.8	-0.059	47	0.15	59611	1.47	0.96	13.17	9.68
112	2	12	0.77	0.77	-0.033	43	0.19	38566	0.89	1.34	8.2	5.26
113	2	12	0.57	0.57	-0.017	48	0.1	13560	0.43	1.18	10.07	10.22
114	2	12	0.53	0.53	-0.08	53	0.22	53198	0.96	1.02	4.02	2.42
115	2	12	0.72	0.72	-0.103	47	0.29	25592	0.56	1.73	4.69	4.72
116	2	12	0.71	0.71	-0.019	49	0.25	49882	0.82	1.39	16.18	6.2
117	2	12	0.86	0.86	-0.018	46	0.14	31699	0.99	0.82	10.85	4.52
118	2	12	0.79	0.79	-0.038	50	0.3	21625	0.62	0.66	7.99	6.3
119	2	12	0.65	0.65	-0.027	52	0.13	19722	0.81	1.15	15.53	7.3
120	2	12	0.64	0.64	-0.02	44	0.12	27299	0.74	2.19	14.59	11.06
121	2	12	0.87	0.87	-0.025	48	0.23	5772	0.87	0.49	16.56	12.8
122	2	12	0.75	0.75	-0.066	49	0.34	62389	1.03	2.26	6.25	8.8
123	2	12	0.3	0.3	-0.043	52	0.16	10431	0.66	0.78	12.45	6.76
124	2	12	0.82	0.82	-0.048	45	0.18	56591	0.91	1.51	7.45	9.94

125	2	12	0.92	0.92	-0.016	49	0.25	37706	0.7	1.63	3.2	11.84
126	2	12	0.85	0.85	-0.016	46	0.19	17021	0.78	2.4	11.7	11.7
127	2	12	0.53	0.53	-0.023	51	0.2	8395	0.75	1.86	5.12	7.94
128	2	12	0.41	0.41	-0.033	46	0.34	47376	1.19	2.1	9.51	4.14
129	2	12	0.89	0.89	-0.147	55	0.31	41399	1.14	1.75	14.28	3.12
130	2	12	0.6	0.6	-0.503	50	0.26	2446	0.58	1.99	8.8	12.46
131	2	12	0.68	0.68	-0.029	50	0.27	46279	0.49	0.52	13.18	8.34
132	2	12	0.96	0.96	-0.021	47	0.33	32678	0.68	2.42	6.08	3.38
133	3	12	0.94	0.94	-0.02	64	0.34	43847	0.99	1.59	5.41	7.5
134	3	12	0.78	0.78	-0.022	65	0.29	54278	0.68	1.08	9.13	12.26
135	3	12	0.73	0.73	-0.024	72	0.26	46961	0.92	1.32	11.01	4.92
136	3	12	0.68	0.68	-0.043	65	0.16	33524	0.59	0.64	11.52	10.56
137	3	12	0.74	0.74	-0.017	63	0.21	14698	0.76	2.01	8.49	9.32
138	3	12	0.57	0.57	-0.13	62	0.24	58549	0.49	0.55	16.94	6.9
139	3	12	0.24	0.24	-0.016	67	0.18	56936	0.42	2.09	13.11	2.52
140	3	12	0.84	0.84	-0.101	69	0.22	50866	1.18	1.23	7.61	11.28
141	3	12	0.55	0.55	-0.027	62	0.3	62095	0.86	0.74	5.58	5.22
142	3	12	0.64	0.64	-0.034	61	0.15	18010	1.11	2.45	3.43	12.14
143	3	12	0.86	0.86	-0.019	66	0.26	9944	0.64	0.79	15.14	6.4
144	3	12	0.88	0.88	-0.069	60	0.34	24428	0.9	2.35	14.78	7.88
145	3	12	0.52	0.52	-0.015	68	0.2	2147	0.94	1.64	10.62	8.46
146	3	12	0.8	0.8	-0.048	69	0.32	8142	0.73	1.47	6.86	13.02
147	3	12	0.67	0.67	-0.023	68	0.14	29185	0.83	0.42	3.95	4.02
148	3	12	0.71	0.71	-0.077	59	0.11	37564	1.03	2.26	6.61	5.78
149	3	12	0.77	0.77	-0.217	63	0.24	38670	0.79	1.92	13.69	4.68
150	3	12	0.9	0.9	-0.029	65	0.32	22084	0.61	1.03	15.88	3.08
151	3	12	0.62	0.62	-0.04	64	0.18	4329	1.84	0.89	12.51	10.1
152	3	12	0.81	0.81	-0.018	64	0.13	27136	0.55	2.2	9.82	11.12
153	3	12	0.92	0.92	-0.031	67	0.12	14291	0.7	1.4	4.58	3.66
154	3	12	0.45	0.45	-0.057	66	0.28	41505	0.74	1.76	14.15	8.74
155	3	12	0.57	0.57	-0.021	71	0.16	13567	0.77	0.51	16.43	7.14
156	3	12	0.64	0.64	-0.016	60	0.33	56567	0.71	1.8	11.86	11.52
157	3	12	0.77	0.77	-0.036	66	0.27	52824	0.79	2.2	3.24	4.26
158	3	12	0.82	0.82	-0.033	64	0.22	42852	0.67	2.25	5.59	10.18
159	3	12	0.38	0.38	-0.51	66	0.1	32122	0.55	1.63	14.91	6.62
160	3	12	0.41	0.41	-0.107	66	0.19	62594	0.49	0.79	13.05	5.1
161	3	12	0.69	0.69	-0.048	65	0.14	25103	0.63	0.61	4.22	8.42
162	3	12	0.72	0.72	-0.057	60	0.24	30378	0.9	2.08	10.05	10.74
163	3	12	0.87	0.87	-0.03	63	0.15	44996	0.92	1.94	7.31	2.6
164	3	12	0.98	0.98	-0.063	67	0.19	3118	0.96	0.72	14.34	7.48
165	3	12	0.91	0.91	-0.016	61	0.31	60043	0.69	1.16	16.33	3.5
166	3	12	0.89	0.89	-0.026	64	0.29	20594	1.72	0.99	5.13	7.74
167	3	12	0.77	0.77	-0.032	69	0.12	49759	0.76	1.71	15.47	12.22
168	3	12	0.61	0.61	-0.019	62	0.28	2746	1.21	0.91	7.66	10.36
169	3	12	0.52	0.52	-0.022	63	0.33	18960	0.82	1.91	9.87	3.14
170	3	12	0.92	0.92	-0.018	65	0.25	37907	0.66	2.41	13.59	9.34
171	3	12	0.85	0.85	-0.025	62	0.17	35942	0.6	1.31	4.67	8.86
172	3	12	0.71	0.71	-0.08	68	0.21	15984	0.41	1.5	9.01	13.08
173	3	12	0.75	0.75	-0.023	66	0.13	26597	0.99	2.38	10.66	3.94
174	3	12	0.53	0.53	-0.045	69	0.34	8916	1.05	1.25	12.02	5.38
175	3	12	0.8	0.8	-0.018	64	0.29	47609	1.11	0.44	6.22	12
176	3	12	0.67	0.67	-0.181	67	0.23	6557	0.85	1.36	8.48	5.98
177	3	12	0.85	0.85	-0.047	66	0.14	47263	0.55	1.36	10.09	7.28
178	3	12	0.51	0.51	-0.065	64	0.29	58927	0.6	0.43	13.4	12.86
179	3	12	0.71	0.71	-0.02	62	0.12	25800	0.75	0.75	5.14	5.8
180	3	12	0.68	0.68	-0.016	70	0.27	38302	0.98	0.85	14.03	9.78
181	3	12	0.62	0.62	-0.017	65	0.22	8479	0.91	2.38	7.73	8.44
182	3	12	0.9	0.9	-0.039	69	0.2	33230	1.03	1.19	11.2	4.76
183	3	12	0.66	0.66	-0.029	65	0.35	41867	0.84	1.12	8.12	10.36
184	3	12	0.53	0.53	-0.026	63	0.31	22422	0.64	2.26	15.21	5.42
185	3	12	0.88	0.88	-0.043	68	0.2	3253	0.87	1.27	14.59	4.56
186	3	12	0.86	0.86	-0.055	58	0.3	35406	0.45	0.62	16.76	12.26
187	3	12	0.57	0.57	-0.074	68	0.19	52670	0.68	2.02	4.79	11.84
188	3	12	0.77	0.77	-0.02	60	0.26	19358	1.15	1.7	6.59	3.12
189	3	12	0.74	0.74	-0.282	65	0.24	271	1.17	1.84	3.83	4.02
190	3	12	0.73	0.73	-0.035	66	0.23	50510	0.96	1.64	9.12	8
191	3	12	0.45	0.45	-0.017	64	0.15	9818	0.73	1.74	11.42	9.48
192	3	12	0.97	0.97	-0.166	67	0.1	27610	0.77	2.02	11.94	3.7
193	3	12	0.82	0.82	-0.019	63	0.32	63741	0.84	2.46	12.87	6.38
194	3	12	0.93	0.93	-0.022	62	0.34	12016	0.8	1.53	3.13	10.98
195	3	12	0.32	0.32	-0.104	66	0.17	57245	1.29	0.56	9.9	7.02
196	3	12	0.8	0.8	-0.026	64	0.27	30469	0.71	0.95	5.77	11.36
197	3	12	0.78	0.78	-0.023	69	0.13	45743	0.5	2.14	7.12	8.78
198	3	12	0.65	0.65	-0.032	61	0.17	16508	0.62	1.05	15.75	2.7
199	4	12	0.87	0.87	-0.022	69	0.13	34645	0.86	0.91	9.55	8.3
200	4	12	0.71	0.71	-0.017	67	0.21	59119	0.83	1.72	14.81	3.36
201	4	12	0.79	0.79	-0.016	62	0.25	49842	0.57	0.99	8.86	9.64

202	4	12	0.68	0.68	-0.092	70	0.18	40091	0.54	2.17	12.41	4.4
203	4	12	0.67	0.67	-0.02	63	0.3	28764	0.91	2.28	6.24	2.46
204	4	12	0.62	0.62	-0.096	64	0.31	15173	0.76	1.07	11.22	12.58
205	4	12	0.82	0.82	-0.069	65	0.26	18548	0.77	0.62	11.58	5.3
206	4	12	0.57	0.57	-0.029	65	0.33	36136	0.97	2.1	15.34	6.64
207	4	12	0.9	0.9	-0.038	63	0.23	53675	1.09	2.4	13.32	7.86
208	4	12	0.85	0.85	-0.018	62	0.21	31838	0.88	1.34	5.1	8.86
209	4	12	0.39	0.39	-0.017	66	0.27	61993	0.5	1.58	16.35	13.1
210	4	12	0.84	0.84	-0.025	67	0.15	5634	1.02	2.44	5.65	11.32
211	4	12	0.74	0.74	-0.04	60	0.2	46368	0.71	0.82	8.04	10.12
212	4	12	0.64	0.64	-0.185	59	0.11	7659	0.68	0.51	13.03	7.24
213	4	12	0.52	0.52	-0.056	66	0.34	12184	0.71	1.24	8.62	10.48
214	4	12	0.72	0.72	-0.019	74	0.14	1161	1.51	0.45	4.43	6.76
215	4	12	0.81	0.81	-0.033	68	0.24	42372	1.16	1.53	13.96	5.14
216	4	12	0.76	0.76	-0.035	67	0.16	57204	0.81	0.69	16.49	2.96
217	4	12	0.96	0.96	-0.046	63	0.1	46598	1.01	1.43	7.05	3.78
218	4	12	0.54	0.54	-0.026	64	0.29	23012	0.62	1.89	10.41	11.76
219	4	12	0.94	0.94	-0.302	65	0.17	23310	0.65	2.02	3.62	5.72
220	4	12	0.47	0.47	-0.024	64	0.34	9788	0.44	1.75	3.95	11.2
221	4	12	0.71	0.71	-0.016	66	0.3	134	0.57	0.43	13.87	9.6
222	4	12	0.92	0.92	-0.025	64	0.29	23652	0.83	1.25	15.53	11.14
223	4	12	0.56	0.56	-0.023	66	0.28	55991	0.59	2.07	16.8	10.1
224	4	12	0.63	0.63	-0.017	65	0.2	43364	1.27	1.41	7.18	7.2
225	4	12	0.88	0.88	-0.02	69	0.15	12891	0.9	1.98	9.76	2.42
226	4	12	0.72	0.72	-0.143	61	0.21	15294	0.44	0.8	3.37	11.96
227	4	12	0.76	0.76	-0.06	62	0.34	26831	0.73	1.82	15.82	5.1
228	4	12	0.68	0.68	-0.11	66	0.25	53914	0.74	0.95	7.94	7.88
229	4	12	0.74	0.74	-0.026	65	0.32	11366	1.12	1.33	14.87	7.24
230	4	12	0.82	0.82	-0.018	64	0.13	3885	0.68	1.9	12.33	12.5
231	4	12	0.59	0.59	-0.039	67	0.23	37308	0.61	2.36	9.34	9.18
232	4	12	0.83	0.83	-0.028	62	0.12	61198	0.92	0.56	4.51	4.5
233	4	12	0.95	0.95	-0.044	65	0.24	48294	0.84	2.21	6.68	5.86
234	4	12	0.9	0.9	-0.368	63	0.17	17697	0.96	1.02	8.63	12.92
235	4	12	0.67	0.67	-0.021	68	0.21	30699	0.78	0.74	13.7	3.74
236	4	12	0.78	0.78	-0.084	61	0.34	59306	0.64	0.65	11.16	6.68
237	4	12	0.85	0.85	-0.031	69	0.31	38979	0.69	1.68	11.87	3.4
238	4	12	0.36	0.36	-0.02	65	0.17	34744	0.99	1.54	3.77	5.2
239	4	12	0.49	0.49	-0.073	70	0.19	8332	1.28	2.14	13.05	10.58
240	4	12	0.8	0.8	-0.035	67	0.14	51204	0.5	1.11	5.73	3.08
241	4	12	0.61	0.61	-0.017	63	0.26	45478	0.81	2.41	5.31	11.7
242	4	12	0.43	0.43	-0.047	60	0.11	20713	1.06	1.62	10.44	8.62
243	4	12	0.98	0.98	-0.034	64	0.14	5214	1.07	0.93	14.33	3.34
244	4	12	0.75	0.75	-0.18	64	0.3	328	0.59	1.8	16.66	6.34
245	4	12	0.82	0.82	-0.019	63	0.18	43664	0.51	2.17	7.87	8.48
246	4	12	0.54	0.54	-0.017	56	0.25	52136	0.92	2.36	3.4	7.46
247	4	12	0.61	0.61	-0.032	66	0.12	14933	0.78	1.35	6.55	10.18
248	4	12	0.86	0.86	-0.052	66	0.22	31231	0.57	1.6	13.38	8.76
249	4	12	0.71	0.71	-0.044	68	0.2	20555	0.48	1.05	9.33	4.38
250	4	12	0.59	0.59	-0.026	64	0.28	62549	0.81	1.98	3.73	10.6
251	4	12	0.63	0.63	-0.039	67	0.25	10053	0.66	0.85	11.39	5.02
252	4	12	0.78	0.78	-0.118	62	0.32	28730	0.89	0.71	10.34	3.82
253	4	12	0.35	0.35	-0.024	65	0.18	7327	1.25	2.41	5.69	10.96
254	4	12	0.77	0.77	-0.224	70	0.23	58270	0.95	1.49	8.47	3.12
255	4	12	0.91	0.91	-0.025	63	0.11	32040	0.71	0.63	12.82	12.94
256	4	12	0.69	0.69	-0.064	66	0.15	39998	0.75	1.84	9.67	9.28
257	4	12	0.72	0.72	-0.02	65	0.16	12359	0.67	0.49	10.96	5.82
258	4	12	0.66	0.66	-0.017	69	0.34	49108	0.87	1.68	15.94	2.24
259	4	12	0.81	0.81	-0.02	62	0.21	53330	0.79	2.27	4.46	12.3
260	4	12	0.92	0.92	-0.016	67	0.26	36666	0.62	1.16	12.22	8
261	4	12	0.87	0.87	-0.055	62	0.31	17757	0.7	1.4	5.22	5.48
262	4	12	0.5	0.5	-0.03	65	0.27	25448	1.09	2.04	7.13	11.52
263	4	12	0.85	0.85	-0.08	69	0.11	40916	1.01	1.18	14.95	7.06
264	4	12	0.43	0.43	-0.022	60	0.34	56566	1.49	0.52	15.24	12.1
265	5	12	0.77	0.77	-0.066	84	0.15	5858	1.25	1.89	10.38	9.26
266	5	12	0.71	0.71	-0.032	76	0.16	17791	0.78	0.63	16.8	8.32
267	5	12	0.67	0.67	-0.026	83	0.13	9642	0.74	0.81	12.39	6.92
268	5	12	0.91	0.91	-0.15	82	0.11	25257	0.97	1.14	8	8
269	5	12	0.64	0.64	-0.209	81	0.34	37968	0.51	1.3	15.04	13.18
270	5	12	0.68	0.68	-0.055	84	0.21	55383	0.8	1.74	12.6	3.72
271	5	12	0.77	0.77	-0.025	86	0.25	49322	0.65	2.13	6.52	10.26
272	5	12	0.62	0.62	-0.039	81	0.14	29089	0.98	2.1	10.93	6.06
273	5	12	0.95	0.95	-0.021	79	0.3	4618	0.46	0.88	14.13	5.36
274	5	12	0.37	0.37	-0.049	83	0.35	32100	1.07	1.03	13.19	3.48
275	5	12	0.59	0.59	-0.016	78	0.29	44088	0.93	2.24	7.28	11.4
276	5	12	0.85	0.85	-0.035	78	0.19	41816	0.61	0.45	8.86	4.84
277	5	12	0.83	0.83	-0.018	80	0.11	61407	0.83	1.36	6.11	6.3
278	5	12	0.51	0.51	-0.043	81	0.26	60851	0.6	2.49	15.24	12.08

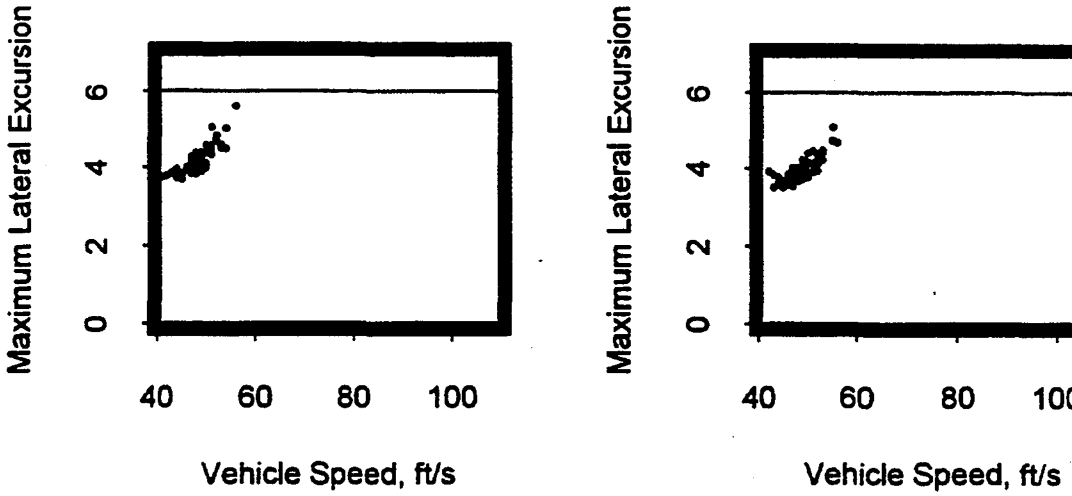
279	5	12	0.47	0.47	-0.093	80	0.24	839	0.9	1.56	3.45	10.04
280	5	12	0.75	0.75	-0.018	78	0.31	55067	1.6	0.71	5.32	12.5
281	5	12	0.81	0.81	-0.024	75	0.2	15557	0.72	1.26	4.73	10.76
282	5	12	0.9	0.9	-0.022	81	0.32	51047	1.13	2.35	8.64	8.92
283	5	12	0.85	0.85	-0.028	76	0.18	13181	0.67	0.56	9.63	2.8
284	5	12	0.73	0.73	-0.076	79	0.22	29606	0.7	1.5	4.13	4.28
285	5	12	0.87	0.87	-0.017	77	0.28	21875	0.54	1.95	16.27	2.68
286	5	12	0.56	0.56	-0.02	80	0.23	36661	0.86	1.67	11.82	7.38
287	5	12	0.41	0.41	-0.016	80	0.21	32935	0.62	1.79	16.68	2.58
288	5	12	0.85	0.85	-0.076	83	0.28	21240	0.9	0.45	10.61	4.5
289	5	12	0.74	0.74	-0.034	81	0.26	47134	0.93	1.37	12.65	9.86
290	5	12	0.7	0.7	-0.021	86	0.25	42655	0.65	0.69	3.32	4.14
291	5	12	0.62	0.62	-0.121	77	0.17	6365	0.76	0.81	8.1	7.36
292	5	12	0.64	0.64	-0.053	81	0.15	5079	0.72	1.21	4.19	12.92
293	5	12	0.9	0.9	-0.022	79	0.32	9736	0.6	1.94	14.63	10.38
294	5	12	0.57	0.57	-0.021	78	0.22	23976	0.95	1.32	9.49	7.98
295	5	12	0.56	0.56	-0.211	82	0.19	62324	0.49	2.34	5.28	6.86
296	5	12	0.66	0.66	-0.027	80	0.13	54324	0.83	2.3	16.35	8.7
297	5	12	0.78	0.78	-0.019	83	0.2	15731	1.03	0.94	12.19	8.92
298	5	12	0.96	0.96	-0.038	79	0.12	59093	0.74	0.68	14.32	2.96
299	5	12	0.77	0.77	-0.032	81	0.3	27935	0.44	2.04	11.45	6.22
300	5	12	0.85	0.85	-0.017	83	0.17	37992	0.56	1.54	7.29	5.86
301	5	12	0.88	0.88	-0.017	78	0.24	50375	1.55	1.12	11.16	4.96
302	5	12	0.68	0.68	-0.071	76	0.35	31903	0.81	2.48	13.79	10.86
303	5	12	0.52	0.52	-0.02	80	0.31	11924	1.27	1.91	9.33	11.38
304	5	12	0.91	0.91	-0.046	79	0.1	44299	1.01	1.56	6.32	11.74
305	5	12	0.46	0.46	-0.025	77	0.23	36279	0.69	0.53	15.45	9.6
306	5	12	0.73	0.73	-0.143	78	0.15	1176	0.86	1.01	7.92	3.34
307	5	12	0.8	0.8	-0.04	85	0.28	18066	0.68	1.73	5.9	12.54
308	5	12	0.81	0.81	-0.028	74	0.33	56064	1.1	2.14	4.84	5.46
309	5	12	0.89	0.89	-0.046	76	0.26	10721	0.74	0.64	12.56	2.82
310	5	12	0.5	0.5	-0.082	83	0.16	16034	0.5	1.97	4.4	11.44
311	5	12	0.87	0.87	-0.042	80	0.31	4182	0.64	0.49	9.4	8.7
312	5	12	0.66	0.66	-0.257	83	0.35	19158	0.87	0.79	6.19	3.26
313	5	12	0.75	0.75	-0.02	81	0.24	38728	0.71	0.51	4.91	4.96
314	5	12	0.68	0.68	-0.107	78	0.32	34886	1.21	1.69	3.66	7.64
315	5	12	0.95	0.95	-0.072	84	0.22	52632	0.69	0.89	15.72	12.72
316	5	12	0.62	0.62	-0.023	77	0.14	43026	0.61	2.18	16.21	9.42
317	5	12	0.78	0.78	-0.016	81	0.25	22514	1.32	1.6	5.68	9.1
318	5	12	0.77	0.77	-0.02	79	0.33	8203	0.87	1.91	11.99	4.66
319	5	12	0.64	0.64	-0.018	82	0.15	26655	1.13	1.24	8.41	2.26
320	5	12	0.82	0.82	-0.032	71	0.2	553	0.43	1.8	11.39	6.9
321	5	12	0.41	0.41	-0.154	78	0.3	48614	0.94	0.98	7.02	11.78
322	5	12	0.81	0.81	-0.017	75	0.29	35990	1	1.16	10.77	10.92
323	5	12	0.84	0.84	-0.027	84	0.17	12190	0.81	2.48	7.87	6
324	5	12	0.53	0.53	-0.025	79	0.23	25262	0.79	2.31	10.53	5.26
325	5	12	0.71	0.71	-0.053	85	0.27	59524	0.54	2.34	16.78	9.74
326	5	12	0.73	0.73	-0.033	77	0.11	55652	0.69	1.46	13.87	3.72
327	5	12	0.46	0.46	-0.018	79	0.12	31764	1.05	1.26	13.76	10.48
328	5	12	0.56	0.56	-0.029	82	0.19	63919	0.84	0.74	14.97	7.86
329	5	12	0.92	0.92	-0.039	81	0.12	49685	0.92	2.1	8.83	12.46
330	5	12	0.91	0.91	-0.021	80	0.21	45770	0.59	1.39	3.51	6.22
331	6	12	0.5	0.5	-0.026	82	0.18	38096	0.52	1.04	4.75	12.9
332	6	12	0.84	0.84	-0.065	83	0.16	53102	1.03	2.07	6.36	7.1
333	6	12	0.68	0.68	-0.047	77	0.34	47222	0.67	1.93	14.32	11.8
334	6	12	0.73	0.73	-0.169	80	0.35	62523	1.23	0.62	15.31	10
335	6	12	0.8	0.8	-0.03	77	0.2	8645	0.97	2.4	10.62	10.4
336	6	12	0.89	0.89	-0.034	82	0.3	55822	1.09	0.57	8.89	9.44
337	6	12	0.81	0.81	-0.024	80	0.25	35332	0.87	1.73	16.65	3.6
338	6	12	0.76	0.76	-0.015	83	0.13	2947	0.39	1.95	12.64	12.48
339	6	12	0.78	0.78	-0.037	78	0.1	59195	0.92	1.5	11.24	8.54
340	6	12	0.58	0.58	-0.04	78	0.15	17546	0.7	2.44	7.2	3.88
341	6	12	0.55	0.55	-0.123	85	0.29	10215	0.74	0.85	3.38	4.34
342	6	12	0.48	0.48	-0.017	81	0.12	26275	0.79	1.83	4.14	6.14
343	6	12	0.72	0.72	-0.021	76	0.32	32106	0.99	0.92	5.49	2.86
344	6	12	0.65	0.65	-0.029	79	0.23	1687	0.83	2.14	7.71	9.06
345	6	12	0.62	0.62	-0.538	86	0.15	45634	0.56	1.35	15.95	2.26
346	6	12	0.97	0.97	-0.024	81	0.18	16636	0.76	0.75	12.32	10.74
347	6	12	0.66	0.66	-0.018	82	0.24	42831	0.72	1.16	8.48	7.54
348	6	12	0.91	0.91	-0.02	79	0.31	51408	0.6	0.47	5.71	8
349	6	12	0.86	0.86	-0.018	79	0.28	24111	0.64	1.37	9.8	11.3
350	6	12	0.93	0.93	-0.055	74	0.26	31848	0.61	1.61	11.71	4.92
351	6	12	0.4	0.4	-0.022	80	0.2	12544	1.35	1.26	13.59	5.52
352	6	12	0.74	0.74	-0.081	76	0.21	21395	0.88	2.31	14.81	6.62
353	6	12	0.87	0.87	-0.099	76	0.1	41432	0.96	1.03	4.11	2.78
354	6	12	0.79	0.79	-0.028	73	0.12	19595	0.69	1.7	10.75	9.34
355	6	12	0.6	0.6	-0.016	81	0.16	45009	0.54	2.2	4.82	6.84
356	6	12	0.92	0.92	-0.017	84	0.2	9802	1.37	0.77	14.39	12
357	6	12	0.68	0.68	-0.044	77	0.17	34916	0.82	2.35	11.36	5.58
358	6	12	0.85	0.85	-0.047	77	0.24	1707	0.74	0.56	15.16	4.9
359	6	12	0.26	0.26	-0.063	78	0.27	12105	0.61	0.68	5.75	11.16
360	6	12	0.84	0.84	-0.034	80	0.35	29236	1.24	2.28	5.3	4.34
361	6	12	0.9	0.9	-0.022	78	0.23	49031	0.68	1.31	13.01	12.5
362	6	12	0.76	0.76	-0.057	83	0.27	6141	0.8	0.92	8.33	7.5
363	6	12	0.79	0.79	-0.024	81	0.25	23119	0.65	1.91	6.19	8.08
364	6	12	0.58	0.58	-0.027	87	0.33	4801	0.85	1.51	8.77	4.08
365	6	12	0.71	0.71	-0.032	79	0.22	59800	0.46	2	7.47	9.8
366	6	12	0.97	0.97	-0.02	82	0.3	33368	0.52	2.05	14.71	3.54
367	6	12	0.75	0.75	-0.022	79	0.31	49646	0.58	1.2	16.01	12.94
368	6	12	0.43	0.43	-0.018	82	0.14	57039	0.73	1.39	16.93	10.52
369	6	12	0.48	0.48	-0.016	82	0.32	63696	0.99	0.82	7.08	6.58
370	6	12	0.82	0.82	-0.152	81	0.13	16733	1.02	2.47	9.65	8.42
371	6	12	0.65	0.65	-0.037	84	0.15	39032	0.77	1.1	12.39	2.6
372	6	12	0.54	0.54	-0.604	79	0.2	25830	0.9	1.75	10.27	11.7
373	6	12	0.72	0.72	-0.019	80	0.18	26239	1.14	0.49	3.51	8.78
374	6	12	0.64	0.64	-0.079	80	0.28	54887	0.88	1.62	13.53	6.16
375	6	12	0.97	0.97	-0.019	75	0.12	24173	0.78	2.08	13.37	6.02
376	6	12	0.55	0.55	-0.029	80	0.25	4967	1.01	1.3	11.7	5.08
377	6	12	0.71	0.71	-0.024	78	0.21	55162	1.08	1.67	16.64	7.76
378	6	12	0.9	0.9	-0.059	81	0.34	2630	0.86	2.19	4.26	7.26
379	6	12	0.6	0.6	-0.03	83	0.24	13940	0.57	1.47	7.48	6.46
380	6	12	0.73	0.73	-0.045	84	0.1	50991	0.92	1.86	8.67	8.64
381	6	12	0.52	0.52	-0.02	79	0.13	56890	0.42	0.93	15.35	12.32
382	6	12	0.77	0.77	-0.019	82	0.18	15286	0.55	0.59	12.35	11.52
383	6	12	0.87	0.87	-0.348	82	0.19	27095	0.66	0.78	4.72	12.02
384	6	12	0.94	0.94	-0.022	73	0.16	11002	0.89	1.78	7.31	9.42
385	6	12	0.25	0.25	-0.024	76	0.35	38344	1.28	2.45	3.61	9.94
386	6	12	0.81	0.81	-0.052	84	0.32	46604	0.96	1.93	9.01	11.14
387	6	12	0.46	0.46	-0.087	79	0.23	45266	0.8	0.66	10.94	3.88
388	6	12	0.69	0.69	-0.017	81	0.28	62016	1.32	2.4	12.57	4.34
389	6	12	0.67	0.67	-0.026	81	0.29	32267	0.49	1.22	5.61	10.66
390	6	12	0.84	0.84	-0.07	78	0.14	31862	0.72	2.23	14.42	6.8
391	6	12	0.74	0.74	-0.016	77	0.21	20423	0.68	1.04	14.96	3.36
392	6	12	0.87	0.87	-0.036	86	0.2	41277	0.74	1.15	16.03	2.68
393	6	12	0.78	0.78	-0.04	80	0.26	35306	0.69	1.59	9.83	13.02
394	6	12	0.58	0.58	-0.122	77	0.31	17457	0.82	0.8	10.55	8.82
395	6	12	0.64	0.64	-0.137	80	0.15	58971	0.61	1.4	5.13	5.38
396	6	12	0.8	0.8	-0.016	83	0.28	8273	1.05	0.49	6.54	2.92
397	7	12	0.74	0.74	-0.018	93	0.33	49741	1.03	0.8	15.56	2.8
398	7	12	0.86	0.86	-0.063	97	0.31	48998	0.93	1.68	12.3	3.96
399	7	12	0.6	0.6	-0.019	96	0.3	40094	0.7	2.2	3.67	9.74
400	7	12	0.98	0.98	-0.052	91	0.16	59286	0.77	1.91	16.87	6.58
401	7	12	0.9	0.9	-0.016	90	0.35	25664	0.41	1.78	9.09	3.24
402	7	12	0.93	0.93	-0.025	94	0.25	55467	0.54	1.23	8.6	8.54
403	7	12	0.5	0.5	-0.022	90	0.24	43179	0.62	2.01	9.99	4.52
404	7	12	0.78	0.78	-0.381	88	0.29	55002	0.86	2.4	11.05	9.2
405	7	12	0.72	0.72	-0.034	89	0.18	14106	1.33	1.44	12.75	2.62
406	7	12	0.71	0.71	-0.022	92	0.12	4286	0.94	1.5	5.33	10.48
407	7	12	0.69	0.69	-0.124	90	0.1	9740	0.6	0.4	16.2	12.56
408	7	12	0.58	0.58	-0.016	95	0.2	30814	0.75	0.52	14.45	8
409	7	12	0.43	0.43	-0.029	83	0.32	33743	0.66	1.08	4.28	8.96
410	7	12	0.87	0.87	-0.133	92	0.28	22221	1.17	1.34	11.49	7.56
411	7	12	0.81	0.81	-0.076	94	0.15	16561	0.5	2.24	14.75	12.7
412	7	12	0.79	0.79	-0.042	91	0.26	61919	0.72	0.66	3.14	4.94
413	7	12	0.77	0.77	-0.026	93	0.17	19334	1.11	1.03	10.26	7.14
414	7	12	0.65	0.65	-0.038	93	0.14	44688	0.82	2.45	6.72	5.62
415	7	12	0.55	0.55	-0.03	95	0.24	8208	0.99	0.69	7.9	5.86
416	7	12	0.63	0.63	-0.057	92	0.2	37	0.64	2.11	13.43	11.54
417	7	12	0.4	0.4	-0.02	95	0.22	27888	0.87	0.97	7.28	11.04
418	7	12	0.84	0.84	-0.018	99	0.11	37471	0.81	1.55	6.14	12.14
419	7	12	0.59	0.59	-0.063	93	0.23	16958	0.88	1.5	14.71	11.3
420	7	12	0.77	0.77	-0.09	91	0.19	22460	1.05	2.38	11.71	5.74
421	7	12	0.75	0.75	-0.03	100	0.16	39194	0.56	2.14	7.47	2.84
422	7	12	0.68	0.68	-0.108	96	0.31	31670	0.98	0.98	4.94	6.8
423	7	12	0.89	0.89	-0.048	93	0.26	24919	1.18	0.62	9.33	8.4
424	7	12	0.64	0.64	-0.042	86	0.13	52812	0.79	1.16	3.94	11.76
425	7	12	0.71	0.71	-0.022	91	0.25	55281	0.92	0.75	10.99	10.18
426	7	12	0.79	0.79	-0.027	89	0.3	41756	0.72	1.39	8.41	4.3
427	7	12	0.35	0.35	-0.019	92	0.12	1248	0.75	1.94	15.68	11.16
428	7	12	0.65	0.65	-0.036	90	0.16	28392	0.58	0.85	4.9	8.96
429	7	12	0.52	0.52	-0.017	94	0.32	5635	0.44	1.82	5.95	6.4
430	7	12	0.9	0.9	-0.039	89	0.18	37056	0.97	1.57	16.18	3.58
431	7	12	0.73	0.73	-0.021	92	0.12	46081	0.64	1.34	12.24	12.2
432	7	12	0.82	0.82	-0.056	93	0.28	19939	0.84	2.43	13.84	9.28

433	7	12	0.92	0.92	-0.023	92	0.22	59178	1.65	0.5	10.07	5.44
434	7	12	0.53	0.53	-0.03	95	0.17	50024	0.67	1.9	6.68	4.76
435	7	12	0.83	0.83	-0.019	95	0.11	32218	1.1	1.67	16.9	2.48
436	7	12	0.6	0.6	-0.154	94	0.29	11183	0.7	1.2	3.31	10.34
437	7	12	0.98	0.98	-0.016	97	0.26	13053	0.53	0.42	12.9	13.04
438	7	12	0.85	0.85	-0.025	90	0.33	63145	0.78	2.23	13.77	4.06
439	7	12	0.8	0.8	-0.018	95	0.21	49386	0.87	2.1	7.07	7.26
440	7	12	0.73	0.73	-0.037	92	0.32	26772	0.88	0.99	4.92	5.38
441	7	12	0.57	0.57	-0.114	92	0.11	38569	0.75	1.88	5.8	7.66
442	7	12	0.83	0.83	-0.056	94	0.24	18252	0.86	2.43	3.83	10.92
443	7	12	0.43	0.43	-0.152	96	0.34	3004	1.13	2.17	15.26	11.58
444	7	12	0.75	0.75	-0.042	91	0.3	7809	1.07	0.93	3.46	4.12
445	7	12	0.48	0.48	-0.017	94	0.3	44775	1.59	0.69	6.25	9.78
446	7	12	0.9	0.9	-0.232	97	0.18	34753	0.8	1.25	11.33	6.5
447	7	12	0.86	0.86	-0.027	91	0.14	9713	0.73	1.58	8	6.94
448	7	12	0.97	0.97	-0.017	92	0.11	14079	0.62	1.31	14.47	8.78
449	7	12	0.71	0.71	-0.064	94	0.23	56680	0.65	0.8	4.52	3.02
450	7	12	0.62	0.62	-0.015	95	0.17	58258	0.66	1.94	8.39	11.8
451	7	12	0.76	0.76	-0.051	90	0.28	50596	1.16	1.14	9.44	8.44
452	7	12	0.88	0.88	-0.02	89	0.15	29899	0.99	2.1	16.82	13.04
453	7	12	0.83	0.83	-0.034	85	0.25	24578	0.96	1.68	13.77	5.96
454	7	12	0.55	0.55	-0.09	90	0.21	35917	0.52	0.48	12.99	2.36
455	7	12	0.66	0.66	-0.03	93	0.33	1965	0.78	1.36	15.81	7.96
456	7	12	0.69	0.69	-0.018	93	0.16	46840	0.55	0.52	11.91	9.36
457	7	12	0.4	0.4	-0.023	93	0.13	43596	0.69	2.24	10.77	3.22
458	7	12	0.93	0.93	-0.024	101	0.26	16197	0.58	2.38	10.6	5.18
459	7	12	0.63	0.63	-0.022	96	0.2	53721	0.44	0.67	14.14	4.64
460	7	12	0.81	0.81	-0.03	91	0.22	62741	0.92	1.52	7.1	12.24
461	7	12	0.79	0.79	-0.02	88	0.27	21311	0.84	1.8	8.94	10.64
462	8	12	0.75	0.75	-0.047	89	0.16	43852	0.49	0.93	13.81	7.86
463	8	12	0.88	0.88	-0.017	88	0.29	24273	1.05	1.71	16.02	10.58
464	8	12	0.77	0.77	-0.018	90	0.3	51513	0.75	2.26	9.49	11.54
465	8	12	0.85	0.85	-0.026	92	0.28	42688	0.69	0.44	4.69	3.74
466	8	12	0.9	0.9	-0.072	90	0.31	9838	0.97	0.83	13.16	12.06
467	8	12	0.95	0.95	-0.025	91	0.18	53975	0.92	0.78	9.12	13.06
468	8	12	0.47	0.47	-0.094	94	0.21	56248	0.48	0.52	12.44	9.88
469	8	12	0.93	0.93	-0.017	93	0.11	38838	0.57	1.49	11.19	7.08
470	8	12	0.78	0.78	-0.024	95	0.13	844	0.62	1.02	14.4	6.38
471	8	12	0.69	0.69	-0.042	92	0.27	33700	0.84	2.37	6.1	4.62
472	8	12	0.64	0.64	-0.02	91	0.15	20846	0.64	2.06	16.93	12.58
473	8	12	0.55	0.55	-0.039	93	0.11	11794	0.6	1.96	6.65	8.84
474	8	12	0.48	0.48	-0.061	94	0.32	46931	0.7	2.19	10.34	5.02
475	8	12	0.59	0.59	-0.14	93	0.19	27032	0.8	1.44	15.71	7.56
476	8	12	0.73	0.73	-0.093	90	0.33	6387	1.76	1.16	7.93	3.52
477	8	12	0.33	0.33	-0.02	96	0.14	30934	1.12	1.18	11.55	9.5
478	8	12	0.7	0.7	-0.028	97	0.23	63472	0.99	1.63	3.57	2.92
479	8	12	0.82	0.82	-0.016	87	0.34	20101	0.73	1.87	5.32	8.22
480	8	12	0.81	0.81	-0.034	92	0.25	5138	1.16	2.47	4.16	2.66
481	8	12	0.84	0.84	-0.022	99	0.22	16436	0.82	0.68	8.18	6.16
482	8	12	0.6	0.6	-0.693	94	0.24	59743	0.77	1.83	6.95	11.08
483	8	12	0.66	0.66	-0.031	95	0.18	37682	0.89	1.32	14.89	5.54
484	8	12	0.55	0.55	-0.049	91	0.25	49512	0.62	1.31	5.27	12.22
485	8	12	0.91	0.91	-0.016	89	0.33	53924	0.64	1.09	10.24	4.88
486	8	12	0.69	0.69	-0.043	98	0.26	25161	0.68	0.73	14.98	7.78
487	8	12	0.5	0.5	-0.02	92	0.12	58013	0.59	1.04	6.05	9.18
488	8	12	0.73	0.73	-0.085	93	0.11	19680	0.76	1.59	15.51	7.22
489	8	12	0.57	0.57	-0.053	88	0.33	10585	0.76	0.81	8.34	8.38
490	8	12	0.86	0.86	-0.03	95	0.31	37184	0.81	2.4	4.25	12.74
491	8	12	0.6	0.6	-0.065	92	0.23	27739	0.94	1.91	6.74	10.26
492	8	12	0.67	0.67	-0.176	86	0.27	8198	0.96	1.18	11.71	4.54
493	8	12	0.82	0.82	-0.016	89	0.18	31668	0.53	0.4	4.51	11.24
494	8	12	0.88	0.88	-0.022	94	0.19	4877	1.16	1.95	14.29	3.12
495	8	12	0.93	0.93	-0.039	91	0.14	38569	1.15	2.41	16.04	11.14
496	8	12	0.64	0.64	-0.023	90	0.2	60777	0.69	2.07	8.88	5.24
497	8	12	0.43	0.43	-0.035	93	0.3	47951	0.72	1.78	10.66	9.26
498	8	12	0.24	0.24	-0.017	92	0.29	34528	0.55	0.59	13.16	9.98
499	8	12	0.77	0.77	-0.21	93	0.12	63211	1.06	1.47	16.87	5.84
500	8	12	0.76	0.76	-0.018	96	0.34	40982	0.81	2.12	12.2	6.66
501	8	12	0.75	0.75	-0.031	90	0.22	1417	0.48	1.4	7.74	3.68
502	8	12	0.7	0.7	-0.019	96	0.15	12275	0.87	0.93	7.32	2.3
503	8	12	0.84	0.84	-0.093	95	0.27	44092	1.68	0.68	3.1	11.98
504	8	12	0.94	0.94	-0.026	94	0.21	22899	0.9	1.65	9.93	7.18
505	8	12	0.8	0.8	-0.025	97	0.16	14614	0.99	2.21	13.63	4
506	8	12	0.93	0.93	-0.025	91	0.33	62001	1.01	1.37	7.05	11.7
507	8	12	0.96	0.96	-0.04	96	0.16	54709	0.72	1.09	6.39	10.62
508	8	12	0.46	0.46	-0.019	92	0.34	11086	0.95	0.57	11.82	3.02
509	8	12	0.83	0.83	-0.193	88	0.31	6713	1.02	1.75	4.19	9.42
510	8	12	0.83	0.83	-0.017	99	0.29	17460	0.61	0.92	9.96	7.64
511	8	12	0.6	0.6	-0.03	91	0.23	15129	1.13	0.43	10.97	10.08
512	8	12	0.74	0.74	-0.099	89	0.24	14171	0.8	2.22	5.82	6.3
513	8	12	0.71	0.71	-0.018	90	0.3	30057	0.66	2.36	4.72	12.34
514	8	12	0.6	0.6	-0.016	95	0.15	4777	1.21	2.46	16.94	12.06
515	8	12	0.81	0.81	-0.051	92	0.1	44418	0.54	2.19	9	4.4
516	8	12	0.65	0.65	-0.035	95	0.11	25388	0.91	1.67	5.45	8.94
517	8	12	0.87	0.87	-0.017	95	0.22	41947	0.84	1.33	10.27	3.7
518	8	12	0.88	0.88	-0.04	93	0.21	56645	0.76	1.22	12.91	8.26
519	8	12	0.69	0.69	-0.023	94	0.14	27234	0.67	2.03	16.17	7.84
520	8	12	0.73	0.73	-0.021	93	0.19	49119	0.49	0.78	7.9	2.64
521	8	12	0.89	0.89	-0.083	90	0.13	50506	1.31	1.86	12.09	11.2
522	8	12	0.48	0.48	-0.063	93	0.19	60446	0.87	1.55	14.87	13.04
523	8	12	0.78	0.78	-0.057	87	0.26	21783	0.83	0.67	13.96	5.58
524	8	12	0.65	0.65	-0.021	90	0.27	34059	0.58	0.98	8.21	4.88
525	8	12	0.25	0.25	-0.026	92	0.28	38191	0.78	0.83	13.39	6.02
526	8	12	0.53	0.53	-0.032	97	0.32	37105	0.37	1.98	3.53	7.1
527	9	12	0.75	0.75	-0.017	103	0.14	5455	0.56	2.1	4.72	8.98
528	9	12	0.71	0.71	-0.038	105	0.12	24679	1.09	0.49	8.74	6.88
529	9	12	0.42	0.42	-0.17	106	0.13	21972	0.9	1.79	10.78	6.42
530	9	12	0.22	0.22	-0.02	107	0.22	659	1.05	1.48	16.16	12.16
531	9	12	0.73	0.73	-0.036	101	0.24	51931	0.72	1.37	15.48	4.14
532	9	12	0.9	0.9	-0.016	103	0.17	57520	0.95	1.65	3.71	8.58
533	9	12	0.86	0.86	-0.023	102	0.26	41533	0.87	0.89	13.06	5.2
534	9	12	0.52	0.52	-0.021	96	0.2	10928	0.69	1.61	9.59	7.5
535	9	12	0.56	0.56	-0.027	100	0.23	60554	1.65	1.1	14.57	11.5
536	9	12	0.62	0.62	-0.062	104	0.32	27498	0.62	1.91	5.37	2.24
537	9	12	0.76	0.76	-0.021	97	0.1	7709	0.6	1.97	10.6	3.58
538	9	12	0.95	0.95	-0.277	100	0.35	18058	0.81	2.3	8	2.72
539	9	12	0.84	0.84	-0.019	101	0.29	32972	0.83	0.83	13.76	4.52
540	9	12	0.81	0.81	-0.031	109	0.28	38749	0.76	2.18	11.68	12.44
541	9	12	0.93	0.93	-0.058	101	0.27	45442	0.66	1.06	3.37	8.2
542	9	12	0.87	0.87	-0.099	103	0.28	61609	0.47	0.72	6.74	12.9
543	9	12	0.81	0.81	-0.052	98	0.21	48292	1.24	0.53	7.43	5.48
544	9	12	0.78	0.78	-0.029	104	0.33	13389	0.49	0.6	16.77	6.16
545	9	12	0.58	0.58	-0.025	99	0.31	37654	0.76	2.41	5.89	9.24
546	9	12	0.68	0.68	-0.017	100	0.16	31594	1.02	1.21	14.03	10.48
547	9	12	0.65	0.65	-0.088	102	0.19	53492	0.67	2.32	11.99	10.8
548	9	12	0.66	0.66	-0.043	104	0.16	17409	0.88	1.31	8.11	10.18
549	9	12	0.84	0.84	-0.033	104	0.32	16917	0.94	1.92	11.61	9.3
550	9	12	0.7	0.7	-0.019	100	0.15	37978	0.82	2.1	4.45	13.16
551	9	12	0.74	0.74	-0.066	104	0.21	4478	0.69	2.02	6.6	9.02
552	9	12	0.91	0.91	-0.654	99	0.2	9125	0.42	0.89	12.76	11.18
553	9	12	0.76	0.76	-0.043	101	0.19	58894	0.71	0.7	14.96	4.96
554	9	12	0.85	0.85	-0.149	93	0.27	29297	0.62	1.45	15.77	3.98
555	9	12	0.45	0.45	-0.11	102	0.13	42187	0.86	1.48	5.28	9.84
556	9	12	0.69	0.69	-0.016	108	0.23	35307	1.06	1.12	15.27	12.6
557	9	12	0.74	0.74	-0.016	106	0.16	63989	0.67	1.79	7.3	5.82
558	9	12	0.62	0.62	-0.037	103	0.11	24049	0.79	0.83	13.82	10.38
559	9	12	0.57	0.57	-0.032	105	0.35	18403	1	2.19	10.85	5.22
560	9	12	0.82	0.82	-0.029	100	0.27	46428	0.59	2.5	8.02	2.58
561	9	12	0.96	0.96	-0.02	97	0.14	55452	1.3	1.62	9.35	6.9
562	9	12	0.79	0.79	-0.081	98	0.31	27558	1.2	1.72	9.77	3.06
563	9	12	0.92	0.92	-0.053	102	0.3	50695	1.15	0.58	10.6	6.68
564	9	12	0.63	0.63	-0.024	104	0.25	2760	0.55	1.26	12.28	3.7
565	9	12	0.26	0.26	-0.023	101	0.22	8661	0.74	2.25	8.48	7.94
566	9	12	0.88	0.88	-0.022	105	0.11	11701	0.78	1.02	16.85	7.66
567	9	12	0.48	0.48	-0.05	103	0.25	53785	0.91	0.6	3.87	11.86
568	9	12	0.65	0.65	-0.018	102	0.33	47222	0.65	0.44	13.6	11.32
569	9	12	0.8	0.8	-0.028	100	0.17	21592	0.53	2.34	3.17	8.24
570	9	12	0.56	0.56	-0.018	102	0.28	33637	0.87	1.32	5.81	4.64
571	9	12	0.61	0.61	-0.047	108	0.16	16245	0.81	2.16	12.64	8.12
572	9	12	0.75	0.75	-0.063	103	0.21	37185	0.92	1.16	14.4	6.34
573	9	12	0.67	0.67	-0.023	100	0.27	21454	0.5	0.75	16	9.3
574	9	12	0.95	0.95	-0.018	106	0.24	4012	0.88	1.02	13.48	12.96
575	9	12	0.64	0.64	-0.039	101	0.3	52118	0.46	1.45	7.58	6.72
576	9	12	0.91	0.91	-0.031	96	0.32	58776	0.69	1.24	4.81	2.76
577	9	12	0.49	0.49	-0.296	103	0.27	62099	0.57	0.62	15.23	10.62
578	9	12	0.69	0.69	-0.04	104	0.31	49123	0.6	0.41	12.26	10.06
579	9	12	0.73	0.73	-0.026	105	0.28	44291	0.77	1.41	5.01	8.92
580	9	12	0.78	0.78	-0.123	100	0.23	31764	0.74	2.42	6.17	10.76
581	9	12	0.7	0.7	-0.015	105	0.33	58015	0.65	1.64	11.83	7.52
582	9	12	0.82	0.82	-0.061	104	0.17	42701	0.85	1.77	9.26	5.78
583	9	12	0.59	0.59	-0.033	102	0.11	6095	1.08	1.71	9.82	12.02
584	9	12	0.38	0.38	-0.02	100	0.35	40068	0.82	0.56	10.97	4.98
585	9	12	0.88	0.88	-0.016	99	0.2	18840	1.43	0.83	10.01	12.22
586	9	12	0.81	0.81	-0.017	103	0.25	23566	0.63	2.25	3.52	3.36

587	9	12	0.46	0.46	-0.019	98	0.22	34234	0.66	1.34	6.41	3.76
588	9	12	0.85	0.85	-0.084	101	0.13	13420	0.72	2.1	7.39	11.7
589	9	12	0.76	0.76	-0.022	98	0.12	970	0.94	2.34	16.63	5.28
590	9	12	0.56	0.56	-0.029	101	0.19	54236	1.16	1.89	14.81	8.2
591	9	12	0.83	0.83	-0.152	102	0.13	9116	0.99	0.97	8.39	2.48
592	9	12	0.93	0.93	-0.025	105	0.15	28748	1.08	1.93	3.92	4.48

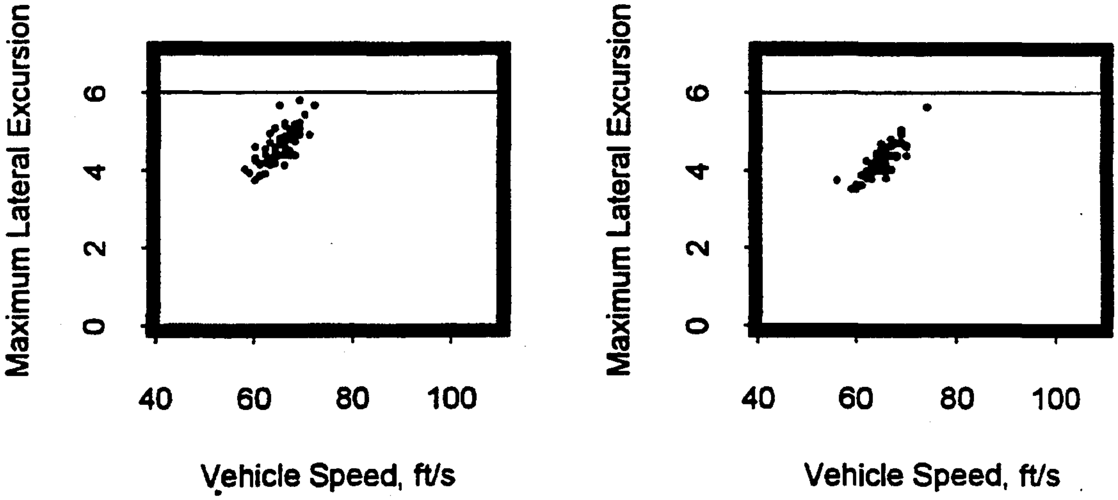
Appendix C

Distributions of Maximum Lateral Excursion for Studies 1 and 2



a) Right-Hand Curve - R=250 ft

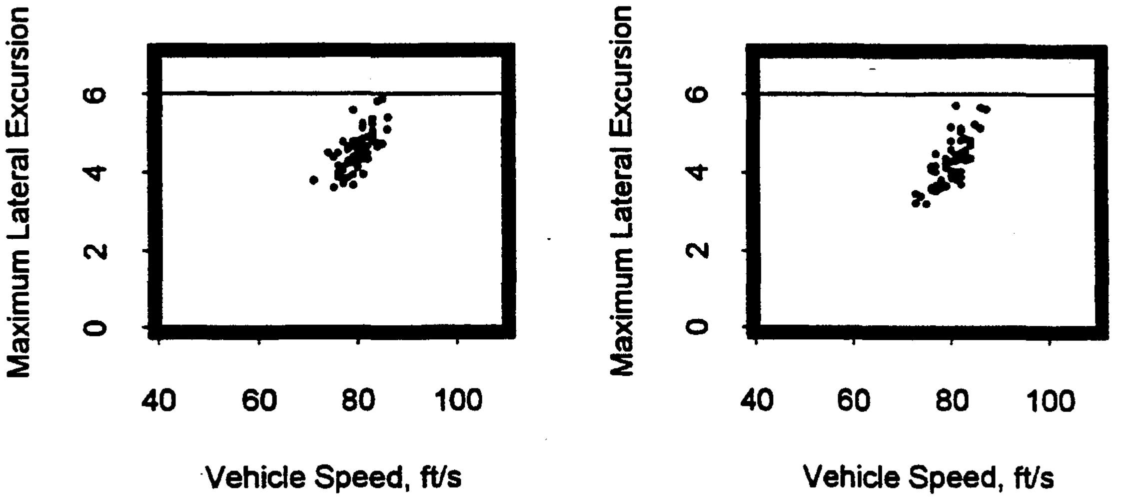
b) Left-Hand Curve - R=250 ft



c) Right-Hand Curve - R=500 ft

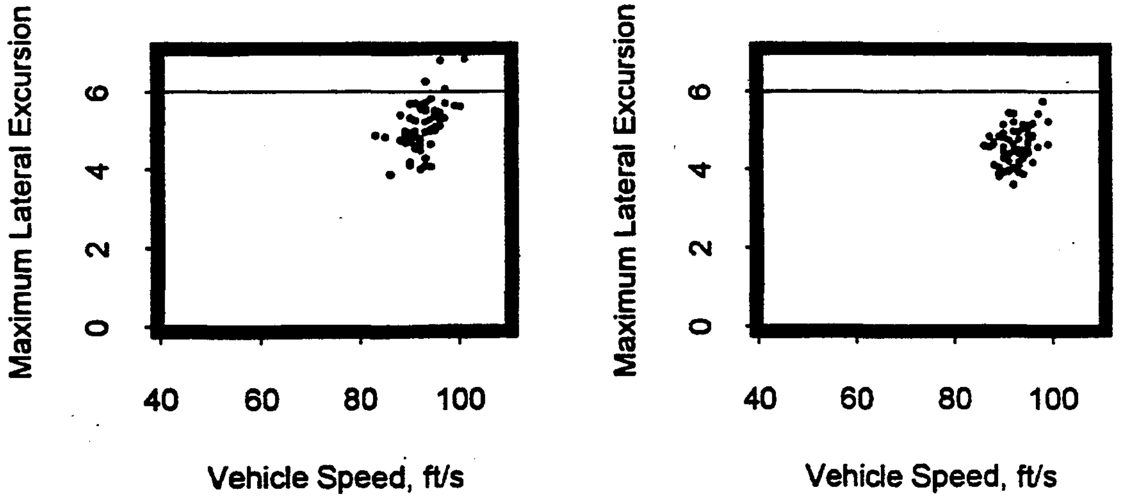
d) Left-Hand Curve - R=500 ft

Figure C-1. Study 1 results: distributions of maximum tire excursion as a function of vehicle speed for nine road segments - normal driving.



e) Right-Hand Curve - R=1000 ft

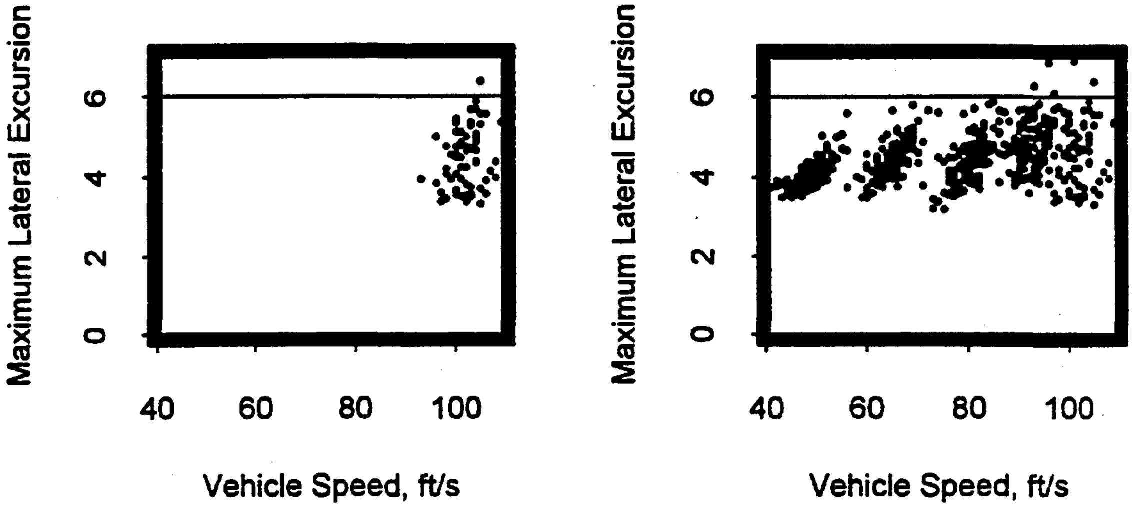
f) Left-Hand Curve - R=1000 ft



g) Right-Hand Curve - R=2000 ft

h) Left-Hand Curve - R=2000 ft

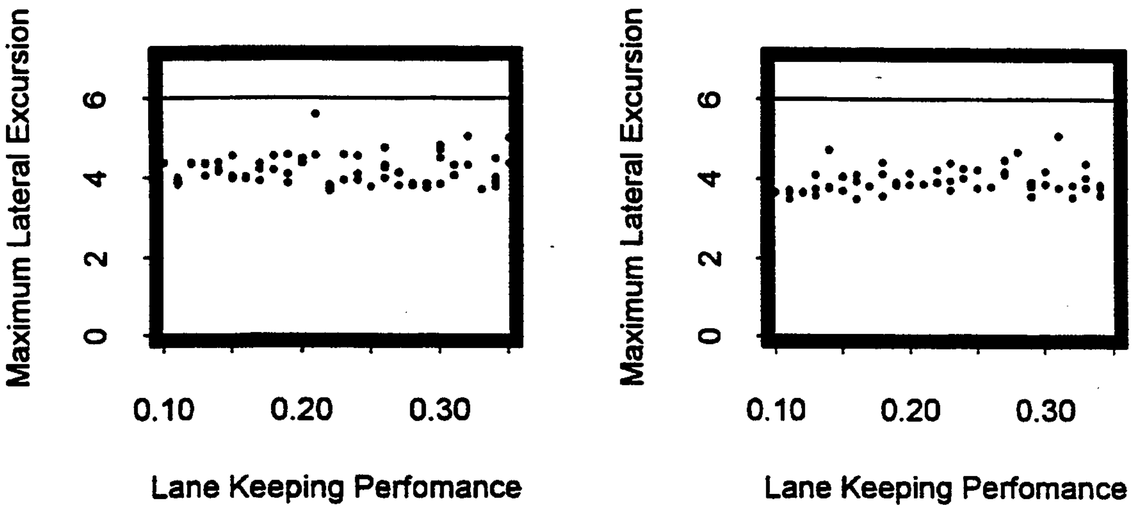
Figure C-1. (Continued) Study 1 results: distributions of maximum tire excursion a function of vehicle speed for nine road segments - normal driving.



i) Straight Road

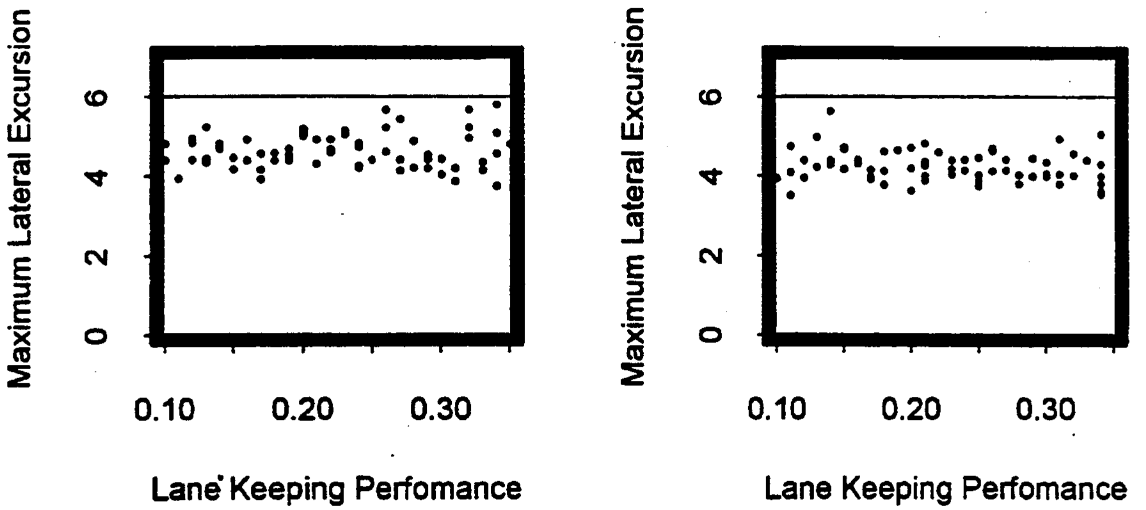
j) All Road Segments

Figure C-1. (Continued) Study 1 results: distributions of maximum tire excursion as a function of vehicle speed for nine road segments - normal driving.



a) Right-Hand Curve - R=250 ft

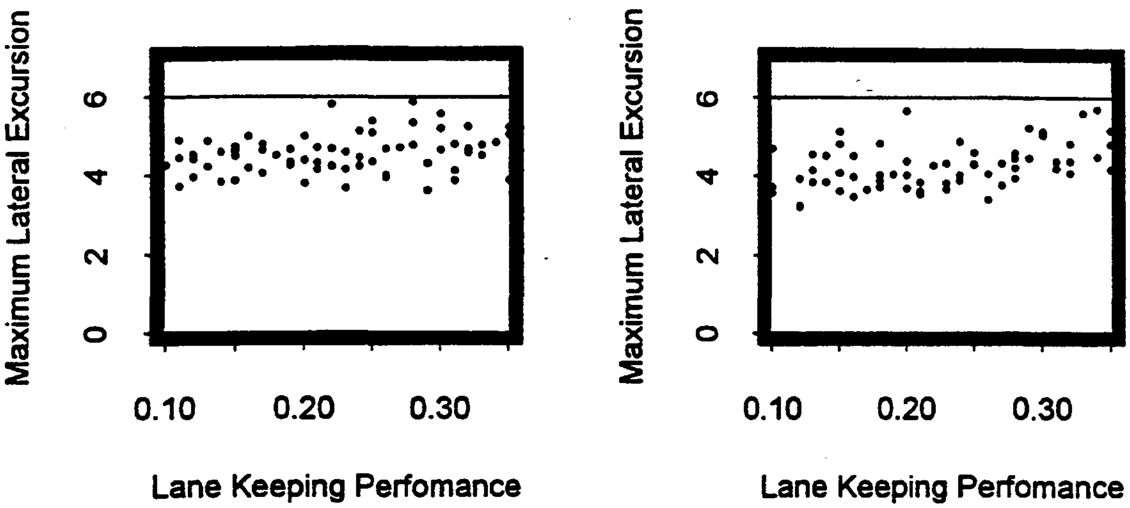
b) Left-Hand Curve - R=250 ft



c) Right-Hand Curve - R=500 ft

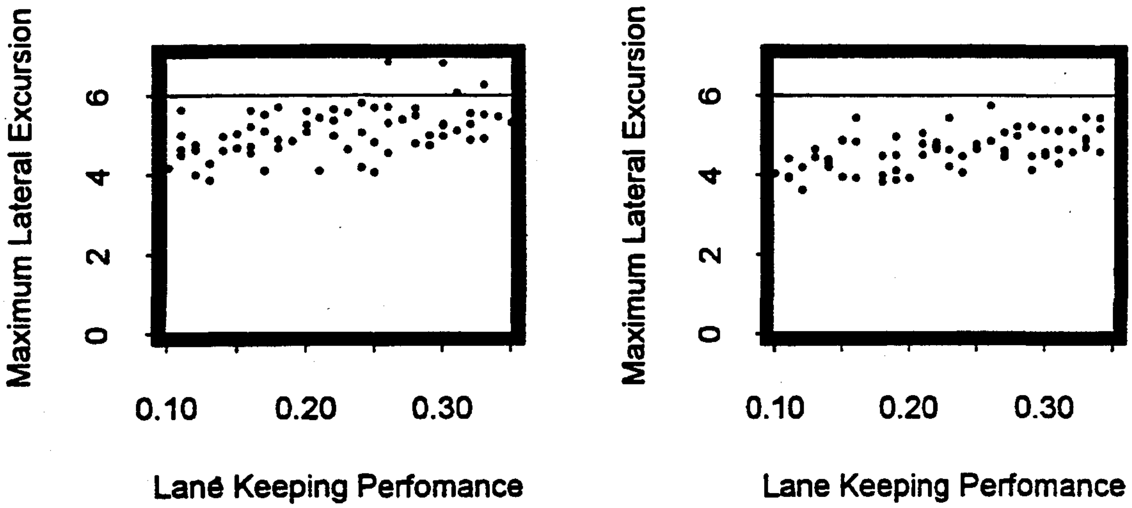
d) Left-Hand Curve - R=500 ft

Figure C-2. Study 1 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - normal driving.



e) Right-Hand Curve - R=1000 ft

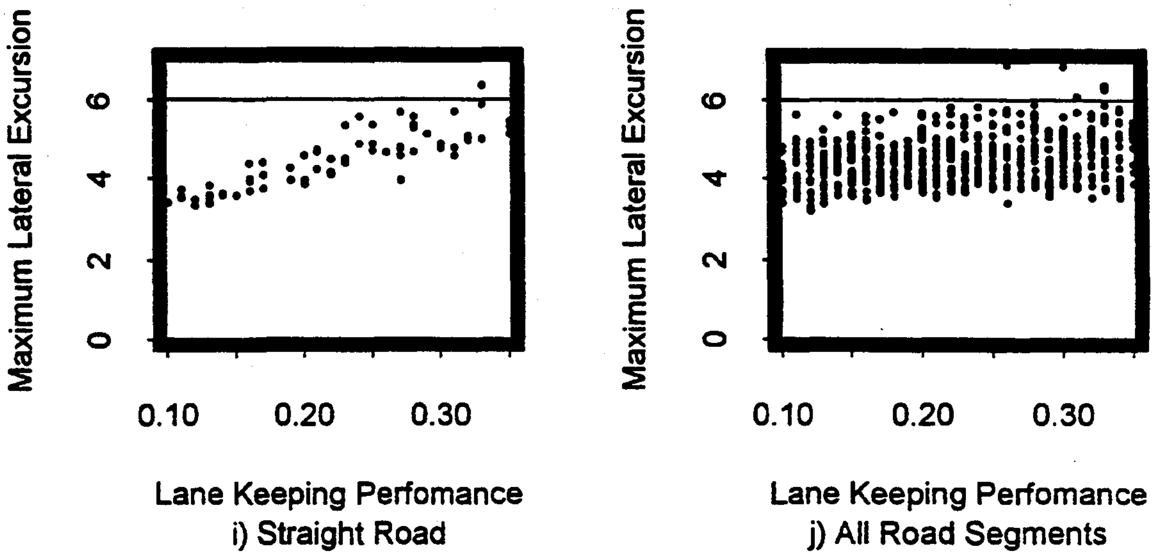
f) Left-Hand Curve - R=1000 ft



g) Right-Hand Curve - R=2000 ft

h) Left-Hand Curve - R=2000 ft

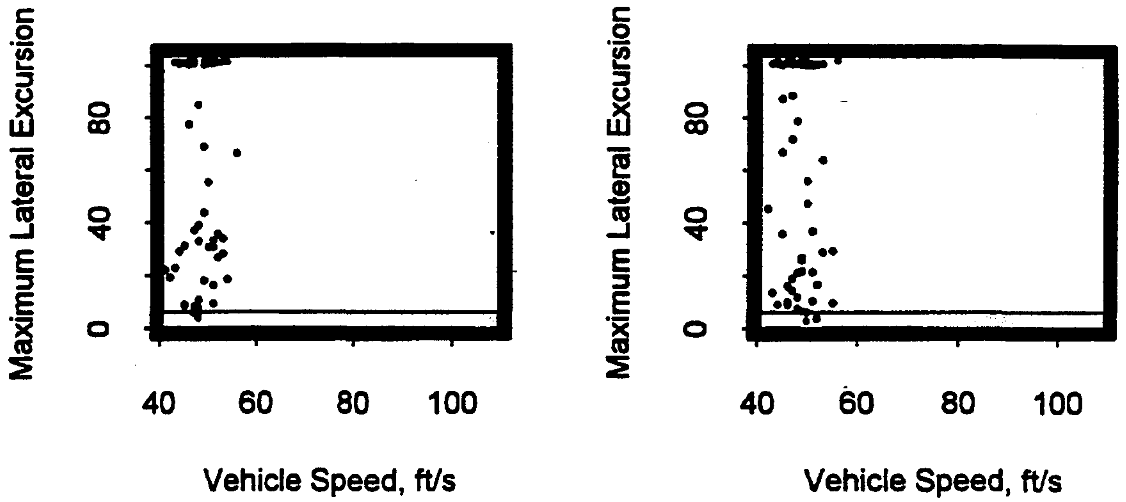
Figure C-2. (Continued) Study 1 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - normal driving.



i) Straight Road

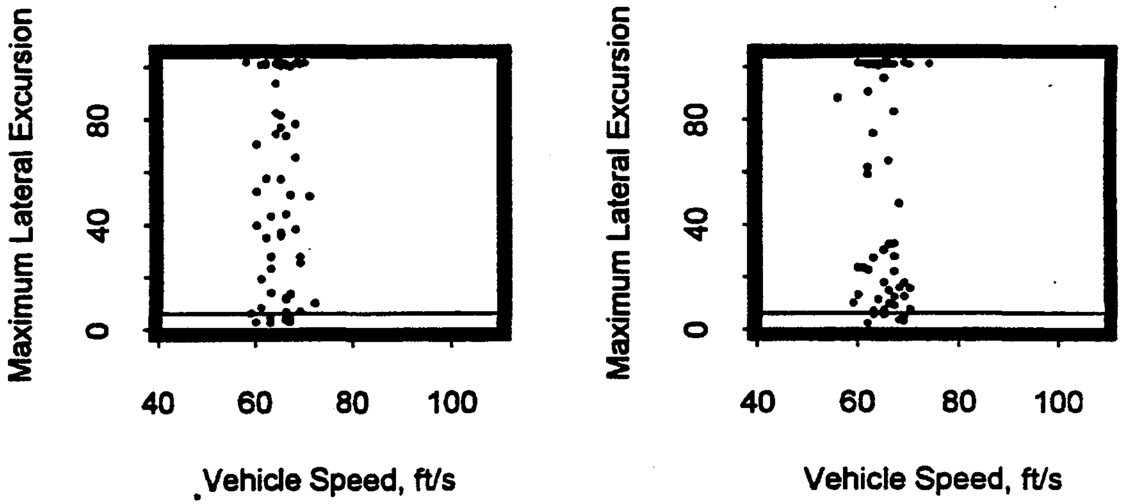
j) All Road Segments

Figure C-2. (Continued) Study 1 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - normal driving.



a) Right-Hand Curve - R=250 ft

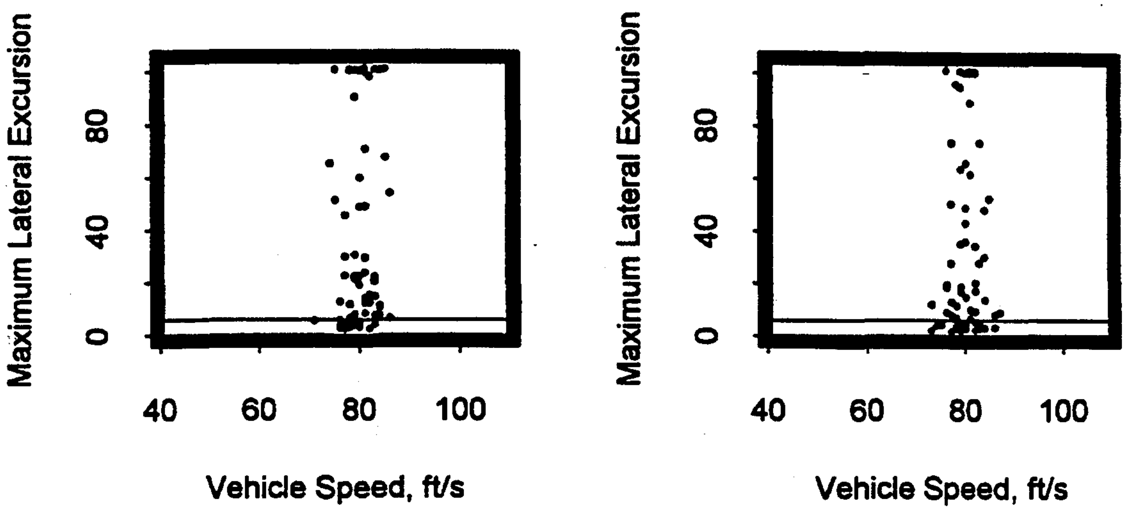
b) Left-Hand Curve - R=250 ft



c) Right-Hand Curve - R=500 ft

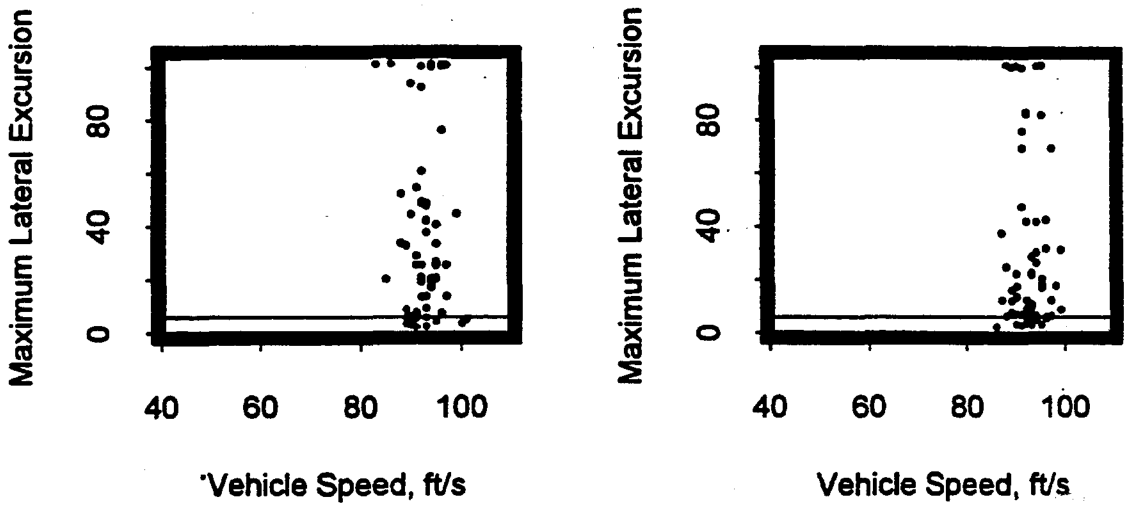
d) Left-Hand Curve - R=500 ft

Figure C-3. Study 2 results: distributions of maximum tire excursion as a function of vehicle speed for nine road segments - inattentive driving without a CMS.



e) Right-Hand Curve - R=1000 ft

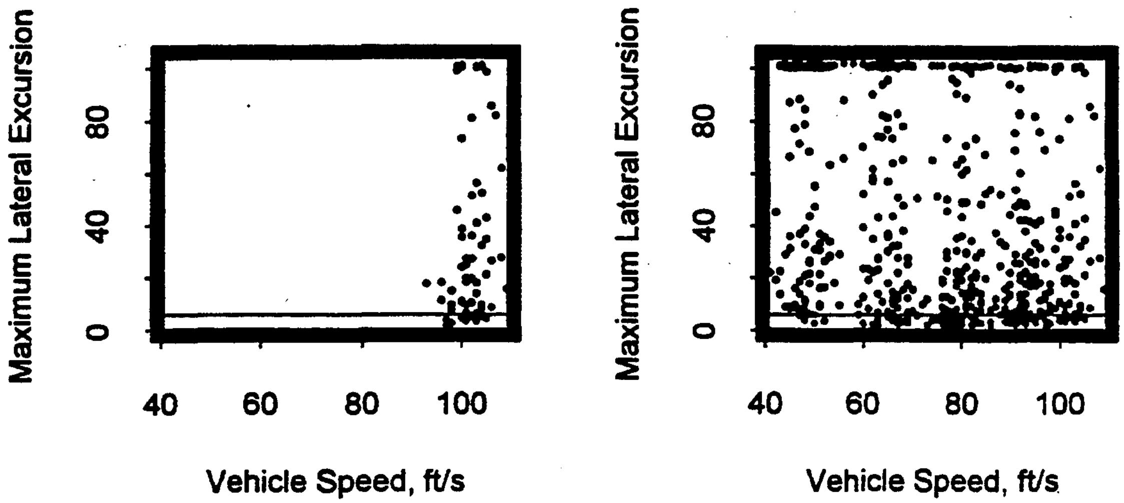
f) Left-Hand Curve - R=1000 ft



g) Right-Hand Curve - R=2000 ft

h) Left-Hand Curve - R=2000 ft

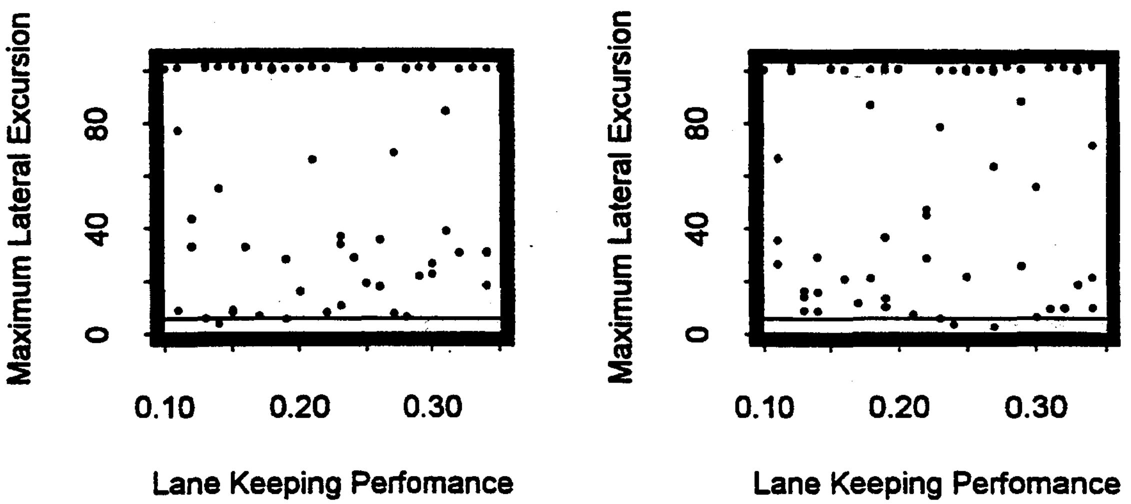
Figure C-3. (Continued) Study 2 results: distributions of maximum tire excursion as a function of vehicle speed for nine road segments - inattentive driving without a CMS.



i) Straight Road

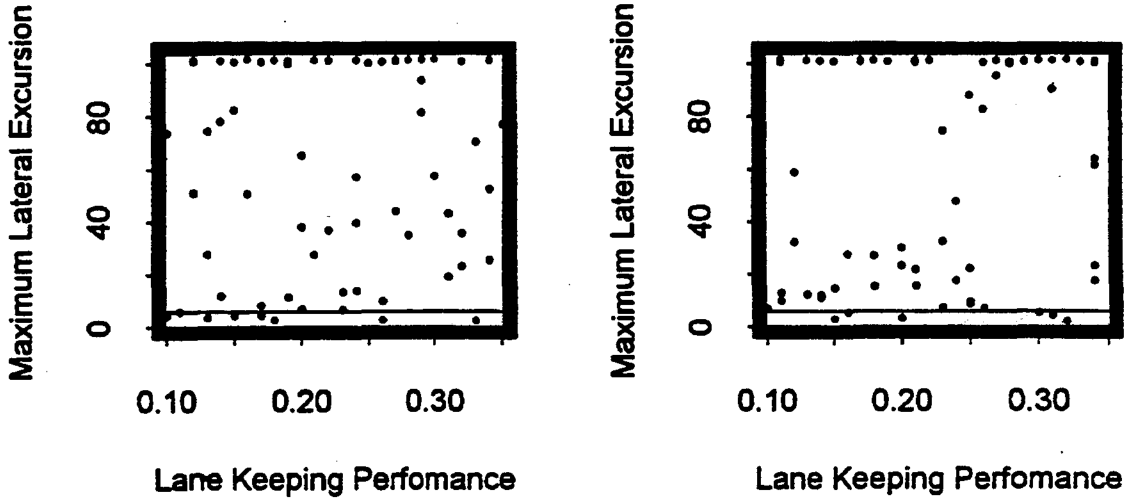
j) All Road Segments

Figure C-3. (Continued) Study 2 results: distributions of maximum tire excursion as a function of vehicle speed for nine road segments - inattentive driving without a CMS.



a) Right-Hand Curve - R=250 ft

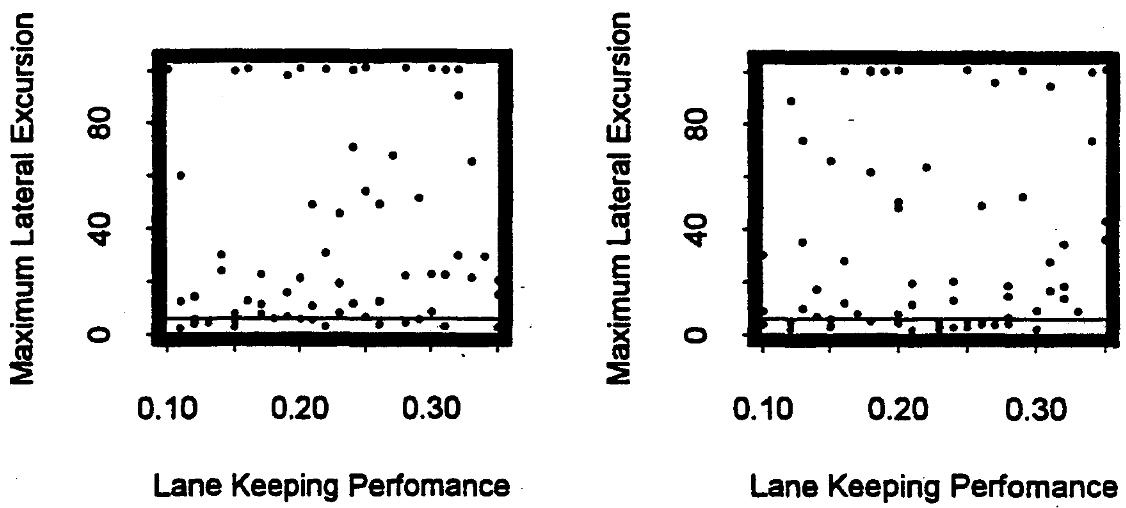
b) Left-Hand Curve - R=250 ft



c) Right-Hand Curve - R=500 ft

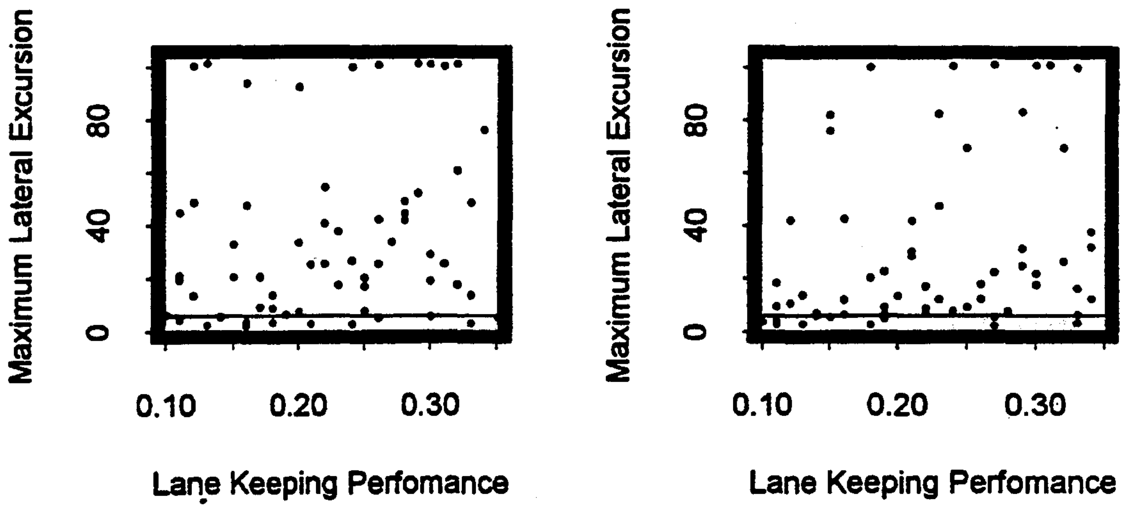
d) Left-Hand Curve - R=500 ft

Figure C-4. Study 2 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - inattentive driving without a CMS.



e) Right-Hand Curve - R=1000 ft

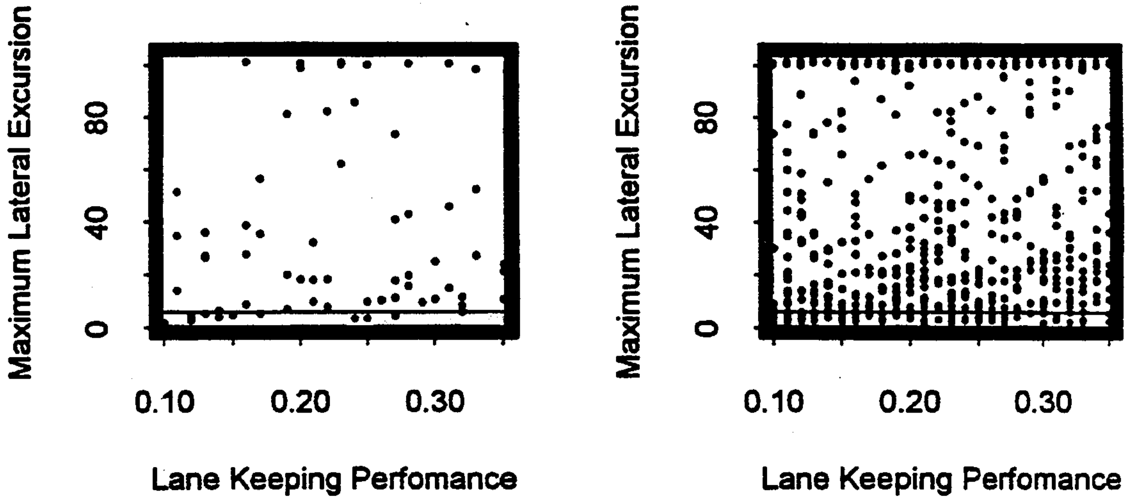
f) Left-Hand Curve - R=1000 ft



g) Right-Hand Curve - R=2000 ft

h) Left-Hand Curve - R=2000 ft

Figure C-4. (Continued) Study 2 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - inattentive driving without a CMS.



i) Straight Road

j) All Road Segments

Figure C-4. (Continued) Study 2 results: distributions of maximum tire excursion as a function of lane-keeping performance for nine road segments - inattentive driving without a CMS.