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16. Abstract <p>This research was performed to study the operational characteristics of variable pavement cross slopes. Computer simulation of vehicles conducting passing maneuvers on high-speed two-lane highways was the methodology employed. The objective was to determine the effects of cross slope and centerline crossover break on lateral tire acceleration, vehicle roll angle and driver comfort.</p> <p>The research utilized two simulation models of vehicle dynamics--the Highway Vehicle Object Simulation Model (HVOSM), and the Highway Safety Research Institute/Motor Vehicle Manufacturers Association Phase 4 Model (HSRI/MVMA). Vehicle simulations were performed for a range of vehicle types, and various combinations of design speed and cross slope design.</p> <p>The research demonstrates the potential severity of the passing maneuver on high-speed highways with even minimum cross slopes. On high-speed highways, cross slopes no greater than 2 percent are desirable. A practical maximum of 4 percent on lower speed highways was indicated by the dynamic responses of tractor-trailer combinations. In general, the research stresses the need to provide a cross slope design that is the minimum consistent with drainage requirements.</p>			
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## FOREWORD

This report summarizes research on the operational characteristics of variable pavement cross slopes on high speed highways. Computer simulation of vehicle dynamics was the methodology employed. The dynamic responses were studied for a range of vehicle types performing high speed passing maneuvers. Research findings provide a basis for defining maximum tolerable pavement cross slopes on high speed, 2-lane highways.

The research should be of interest to highway design professionals.

Sufficient copies of the report are being distributed to provide a minimum of one copy to each regional office, one to each division office, and one copy to each State highway agency. Direct distribution is being made to the division offices.

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## Introduction

An important consideration in the design of a two-lane highway is the cross slope of each lane, and the manner in which these slopes join at the centerline of the highway. Frequently, the two plane cross slopes are joined to form a distinct break point or "crossover break." More often, the center portion of this crossover break is slightly rounded.

In the development of AASHTO Policy (1), pavement drainage, driver comfort, and general vehicle control were all considered in the process of selecting recommended values for pavement cross slope. The AASHTO discussion of pavement cross slope is as follows:

"...Since many highways are on tangent or flat curve alignment, the rate of cross slope for this condition is an important element in cross section design...A reasonably steep lateral slope is desirable to minimize water ponding of flat sections due to pavement imperfections and uneven settlement. On the other hand, pavements with steep cross slopes are objectionable in appearance and may be annoying and uncomfortable in operation. Hazard may attend driving on steep cross slopes on tangents due to the tendency of vehicles to veer toward the low edge of the pavement."

With these considerations in mind, AASHTO policy (1) recommends the following values for cross slope, which relate to the surface type.

<u>Surface Type</u>	<u>Cross Slope (Percent)</u>
High	1-2
Intermediate	1.5-3
Low	2-4

Recent research (2) recommends minimum cross slopes (1 percent for dense surfaces and 2 percent for open or permeable surfaces) on the basis of drainage requirements. The AASHTO values for maximum cross slope have never been scientifically substantiated. There remains the question, therefore, of just how high the cross slope can be designed for various vehicle speeds and still accommodate reasonable vehicle operations without producing undue hazard or discomfort to the motorist. The objective of this research, therefore, was to study the dynamic effects of pavement cross slope and crossover break on

expected vehicle maneuvers for the purpose of recommending maximum cross slope designs as a function of vehicle type and design speed. The basic form of research involved the use of computer simulation of nominally critical vehicle maneuvers that can be reasonably expected on high-speed, two-lane highways.

### Investigation of Design Maneuvers

Highways should be designed so that each of the design elements does not "cause" or promote loss of control. This philosophy of course must be interpreted within the bounds of reasonable extremes of driver behavior. And, application of this philosophy requires an understanding of how each highway element relates to vehicle operations.

There are three basic vehicle operations that could be affected by the design of the pavement cross slope and centerline crossover break:

- (1) Tracking - In steering down the highway, the driver must compensate for the cross slope to keep his vehicle on the designed path. On tangent highway, the driver must, in effect, steer toward the centerline. For steeper cross slopes, this task requires more of the driver's attention and effort to keep from veering off the edge of the traveled way.
- (2) Braking - The cross slope also is an important feature with regard to sudden or emergency stops performed by the driver. Very flat cross slopes can add to pavement water depth, thereby reducing skid resistance during periods of wet weather. Steep cross slopes increase the probability that a vehicle would run off the road under severe braking conditions.
- (3) Passing - Under normal passing operations on two-lane highways, the higher speed passing vehicle usually performs a reverse curve across the centerline while accelerating. Under this kind of operation, the dynamic effects of path curvature and acceleration conceivably could be heightened by the amount of centerline crossover break encountered as the vehicle crosses the centerline, and by the "negative" or adverse slope in relation to the vehicle path in the opposing lane. Recent research (3) suggests that a fairly large crossover break does not

itself contribute to loss of control or vehicular instability. However, the research does indicate that negative cross slopes (in relation to vehicle path curvature) can produce an incremental increase in lateral acceleration on the vehicle.

#### Selection of the Basic Design Maneuver

A search of the literature did not reveal definitive research regarding the effect of maximum cross slope on the potential for loss of control under either normal tracking or severe braking operations. Research by Glennon (4), however, does provide insight on both the severity of vehicle operations and the effect of cross slope for automobile passing maneuvers.

Although pavement cross slope design should attempt to reasonably accommodate all expected operations, it is not totally clear which of these three operations would be most dominant in governing the maximum cross slope. However, within reasonable bounds, steeper cross slopes (say 6 to 10 percent) could be expected to seriously degrade all three operations. Therefore, it may be reasonable to infer a maximum cross slope for all operations based on the study of vehicle dynamics of one of the three.

The passing maneuver was selected as the controlling operation for studying the critical dynamic effects of maximum cross slope for the following reasons:

- (1) It is the only one of the three basic operations affected by cross slope that is dimensionally described in the literature.
- (2) Passing is a relatively frequent maneuver performed on two-lane highways.
- (3) Not only does passing occur more often than severe braking, but the severe braking maneuver tends to produce loss of control irrespective of the amount of cross slope.
- (4) Because the passing maneuver involves acceleration, high speeds, and a distinctly non-tangent path, it represents a reasonably critical maneuver.



- (5) The maximum cross slopes dictated by the passing maneuver could be expected to provide reasonable cross slopes for normal vehicle tracking.

#### Dimensions of the Passing Maneuver

The only research found that directly measured the passing path of vehicles under normal highway operation was the work of Glennon and Weaver (4,5). This research, conducted on two-lane Texas highways, had two specific objectives: (1) to study the critical nature of time-distance requirements for the purpose of verifying AASHTO passing sight distance requirements; and (2) to study the functional demands of passing vehicles as a potential basis for minimum skid resistance requirements and/or wet weather speed limits.

For the purpose of determining the dimensions of a critical passing maneuver, one phase of the Glennon and Weaver work used photographic techniques to measure the curvature of the initial passing path for about 160 maneuvers at two passing zones. These measurements were distributed among experiments where impeding vehicle speeds were 50, 56, 62 and 68 mph (80, 90, 100 and 110 km/h). For average speeds ranging from 50 to 81 mph (80 to 130 km/h), these studies determined the distribution of minimum vehicle path radius during the initial "pull-out" portion of the passing maneuver. Also, the analysis showed that the severity of this minimum radius was independent of speed. Higher speed passing vehicles were therefore just as likely to undergo critical path maneuvers as other passing vehicles.

Table 1 shows the critical end of the distribution of minimum path radius for the two different lengths of passing zone. Analysis of the data also indicated average automobile acceleration of about 3.28 ft/s<sup>2</sup> (1.00 m/sec<sup>2</sup>).

The Glennon and Weaver analysis (5) provides a basis for determining the time-distance aspects of the passing maneuver. The duration of the initial passing maneuver is about 4 seconds. This maneuver includes, in sequence, an initial tangent path (L<sub>1</sub>), a curve to the left (L<sub>2</sub>), a connecting tangent (L<sub>3</sub>), and a curve to the right (L<sub>4</sub>) bringing the vehicle back parallel to the roadway.

Table 1  
Distribution of Minimum Path Radii For Automobiles  
in the Passing Maneuver

Percent of Vehicles with Smaller Radius	Minimum Radius of Initial Path Maneuver--ft (m)	
	Site A 984 ft(300 m) Passing Zone	Site B 1684 ft(500 m) Passing Zone
5%	1614 (492)	1132 (345)
10%	1650 (503)	1289 (393)
15%	2011 (613)	1430 (436)

Source: Reference (4)

Based on these parameters of the passing maneuver it is possible to generate a nominally critical automobile passing traversal (see Figure 1) with the following additional set of assumptions:

- (1) The nominally critical minimum path radius is best represented by the path severity exceeded only by 5 percent of all drivers on the longer passing zone. This value is an 1132 ft (345 m) radius, as given in Table 1.
- (2) The left tires of the passing vehicle are initially 2.3 ft (0.7 m) right of the centerline.
- (3) The total lateral movement of the vehicle is 11.5 ft (3.5 m), which corresponds to a full lane width.
- (4) The duration of the initial tangent portion,  $L_1$ , of the maneuver is 1 second. The vehicle begins the designated acceleration rate at the beginning of this tangent portion.

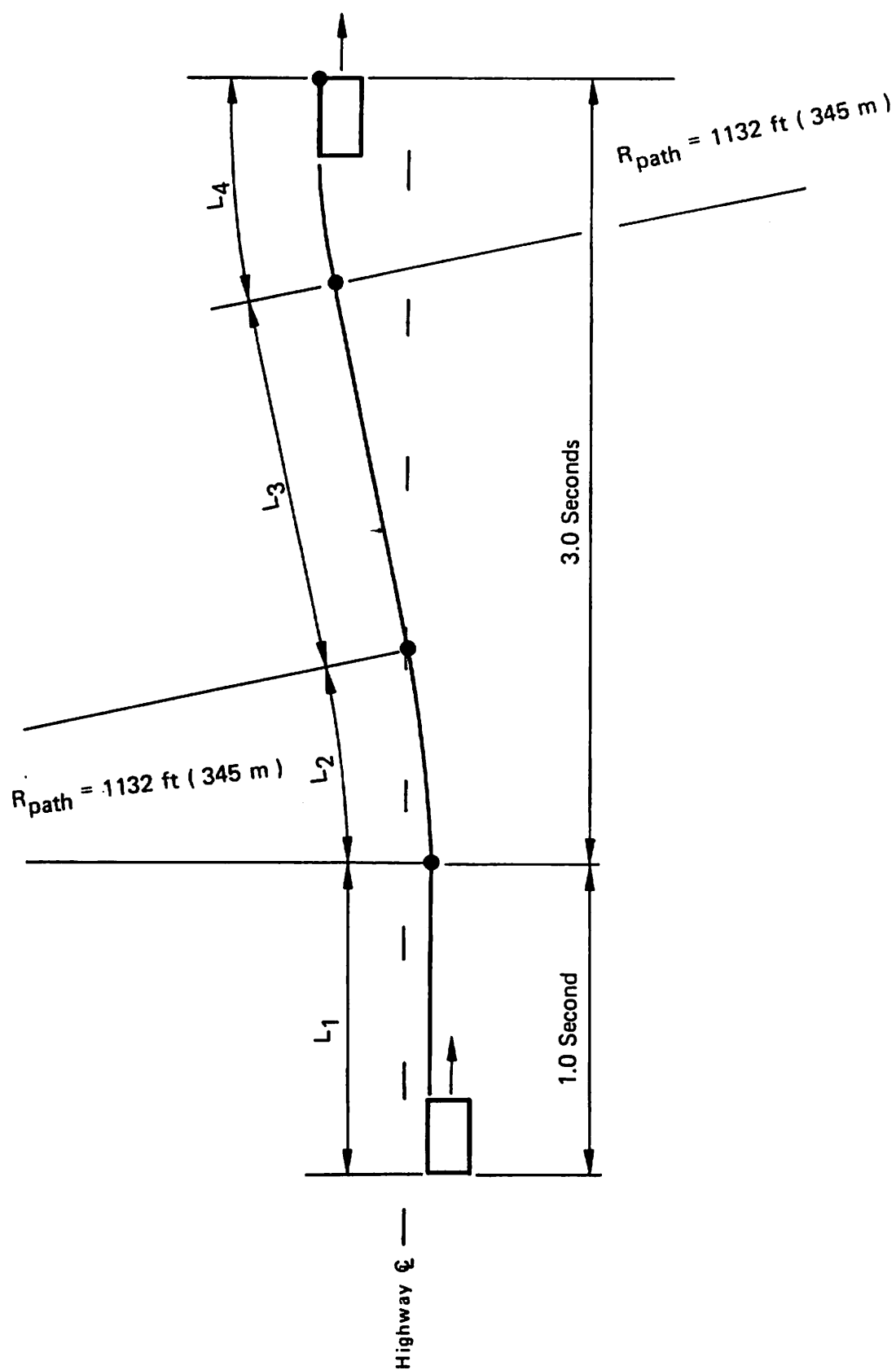


Figure 1. NOMINALLY CRITICAL INITIAL PASSING MANEUVER FOR AUTOMOBILES

- (5) A passing automobile accelerates from a starting speed that is 12 mph (20 km/h) slower than design speed.
- (6) The connecting tangent,  $L_3$ , between the reverse curves of the path is limited to not less than 66 ft (20 m). Under some lower design speed conditions, therefore, the duration of the initial maneuver is somewhat more than 4 seconds.

With these physical and operational parameters and constraints specified, it is possible to mathematically solve the complete geometric description of the initial automobile passing path for various design speeds. Table 2 shows these solutions.

Table 2  
Description of Derived Nominally Critical Initial  
Passing Maneuvers for Automobiles

Design Speed mph (km/h)	<u>Length of Initial Path Segments* ft (m)</u>			
	<u><math>L_1</math></u>	<u><math>L_2</math></u>	<u><math>L_3</math></u>	<u><math>L_4</math></u>
87 (140)	111 (33.8)	41 (12.6)	269 (82.1)	41 (12.6)
74 (120)	93 (28.3)	53 (16.2)	190 (58.0)	53 (16.2)
62 (100)	74 (22.7)	79 (24.1)	85 (25.9)	79 (24.1)
50 (80)	56 (17.2)	86 (26.2)	66 (20.0)	86 (26.2)

\*  $L_1$  -- Initial tangent path in proper lane

$L_2$  -- Initial "pull-out" maneuver to centerline

$L_3$  -- Tangent path to opposite lane

$L_4$  -- Curved, reversal path to correct vehicle path in opposite lane

Passing maneuvers undertaken by trucks are also of concern in design of the cross slope and crossover break. To generate the nominally critical initial paths for trucks the following additional assumptions were made:

- (1) Trucks initiating a passing maneuver would tend to utilize a rapid rate of acceleration (relative to vehicle type). For this study, loaded single-unit trucks and empty tractor-trailer combinations were assumed to accelerate at  $1.64 \text{ ft/s}^2$  ( $0.50 \text{ m/s}^2$ ). Fully loaded tractor-trailer combinations accelerate at  $0.66 \text{ ft/s}^2$  ( $0.20 \text{ m/s}^2$ ). These assumed rates compare with the assumed automobile acceleration rate of  $3.28 \text{ ft/s}^2$  ( $1.00 \text{ m/s}^2$ ).
- (2) In order to manage the passing maneuver with their lower acceleration capabilities, trucks start the initial passing maneuver at higher speeds than automobiles. For single-unit trucks and empty tractor-trailer combinations, the initial speed is 10 mph (16 km/h) below design speed. For loaded tractor-trailer combinations, the initial speed is 7.5 mph (12 km/h) below the design speed. These initial speed assumptions, in combination with the assumed truck acceleration rates, result in a final or critical truck passing speed identical to that of automobiles. This enables direct comparison of the effects of cross slope and crossover break on the full range of vehicle types studied.

With these additional assumptions, the dimensions for the critical initial path maneuvers for trucks are solved as shown in Table 3.

#### Description of Simulation Models

The dynamic effects of various cross slopes for the initial passing maneuver at various design speeds were studied using two different previously developed computer simulation models. The HVOSM and the HSRI/MVMA PHASE4 model were used to cover the full range of vehicle types on the highway. These two models and their modification for this research are described below.

##### HVOSM

The HVOSM (Highway-Vehicle-Object Simulation Model) is a computerized mathematical model originally developed at Cornell Aeronautical Laboratories (6) and

Table 3  
Description of Derived Nominally Critical  
Initial Passing Maneuver For Trucks

Loaded Single-Units and Empty Tractor-Trailers

Design Speed mph (km/h)	<u>Length of Initial Path Segments ft (m)*</u>			
	<u>L<sub>1</sub></u>	<u>L<sub>2</sub></u>	<u>L<sub>3</sub></u>	<u>L<sub>4</sub></u>
87 (140)	114 (34.7)	42 (12.8)	267 (81.5)	42 (12.8)
74 (120)	95 (29.1)	53 (16.2)	190 (58.0)	53 (16.2)
62 (100)	77 (23.6)	77 (23.5)	93 (28.5)	77 (23.5)
50 ( 80)	59 (18.0)	86 (26.2)	66 (20.0)	86 (26.2)

Loaded Tractor-Trailers

Design Speed mph (km/h)	<u>Length of Initial Path Segments ft (m)*</u>			
	<u>L<sub>1</sub></u>	<u>L<sub>2</sub></u>	<u>L<sub>3</sub></u>	<u>L<sub>4</sub></u>
87 (140)	117 (35.7)	41 (12.6)	269 (82.1)	41 (12.6)
74 (120)	99 (30.1)	53 (16.2)	192 (58.8)	53 (16.2)
62 (100)	80 (24.5)	79 (24.1)	87 (26.5)	79 (24.1)
50 ( 80)	62 (19.0)	86 (26.2)	66 (20.0)	86 (26.2)

- \* L<sub>1</sub> -- Initial tangent path in proper lane
- L<sub>2</sub> -- Initial "pull-out" maneuver to centerline
- L<sub>3</sub> -- Tangent path to opposite lane
- L<sub>4</sub> -- Curved, reversal path to correct vehicle path in opposite lane

subsequently refined by Calspan Corporation (7). The HVOSM is capable of simulating the dynamic response of a two-axle vehicle traversing a three-dimensional terrain configuration. The vehicle is composed of four rigid masses; viz., a sprung mass, unsprung masses of the left and right independent suspensions of the front wheels, and an unsprung mass representing a solid rear-axle assembly.

This study used the Roadside Design version of HVOSM that is currently available from FHWA. Certain modifications were necessary to perform the range of studies undertaken in this research. These modifications, described in Appendix A, included the following:

- (1) Driver discomfort factor output;
- (2) Friction demand output;
- (3) Driver model modifications;
- (4) Wagon-tongue path-following algorithm; and
- (5) Dual rear tire option.

For the centerline crossover break traversal studies, the important parameters of the driver simulation are the probe length, steer velocity and damping. The probe length represents the driver preview of the highway measured from the center of gravity of the vehicle. The steer velocity (PGAIN) is a steering correction factor that is multiplied by the lateral path error of the probe. The damping (QGAIN) is a term that smooths out the steer response.

A longer probe, slower steer response, and larger damping term simulate an attentive and non-aggressive driver by smoothing the path into a combination of sweeping spirals. A shorter probe length, quicker steer response, and smaller damping term simulate a very aggressive driver who turns sharply with a tendency to overshoot the intended path.

It is extremely important to carefully define the driver behavior being modeled. Highly variable dynamic results can be obtained using different driver simulation parameters on the same specified path at the speed. Guidance on appropriate driver behavior parameters was provided by previous simulation research (3).

#### HSRI/MVMA PHASE4 Model

The PHASE4 simulation program is a general purpose mathematical model for simulating the three-dimensional dynamic responses of trucks, tractor/trailers and triples combinations. The PHASE4 program was developed in 1980 by the Highway Safety Research Institute of the University of Michigan under the sponsorship of the Motor Vehicle Manufacturers Association and the Federal Highway Administration (8,9).

Modifications similar to those made for the HVOSM were made for the PHASE4 model. These modifications, described in Appendix B, included the following:

- (1) Driver discomfort factor output;
- (2) Friction demand output;
- (3) Driver model modifications;
- (4) Wagon-tongue path-following algorithm; and
- (5) Terrain option.

#### Comparison of Models

For the purpose of comparing the dynamic effects of cross slope design for various vehicles, it was necessary to obtain some degree of correlation between the HVOSM (2-axle) and the HSRI/MVMA PHASE4 models. Since both models can accommodate single-unit trucks with a single rear axle, a 1974 White Road Boss (4x2) was used for comparison simulations. Measured properties of this vehicle were reported in a study of truck tire properties performed by the Highway Safety Research Institute (10).

The documentation for the comparison of the two models is quite extensive and is reported in a separate project document (11). The conclusions from this effort were: (1) the two models give comparable dynamic responses for the types of maneuvers investigated in this research; and (2) the effects of the small-angle assumption of the PHASE4 model are negligible for the types of maneuvers investigated in this research.



### Simulation Experiments

Fourteen basic simulation runs were performed to test the dynamic effects of the centerline crossover break design for various vehicles and design speed. The range of test parameters is shown in Table 4.

Previous project research (3) on pavement/shoulder cross-slope break designs for highway curves had indicated that the centripetal force equation gave a reasonable estimate of tire friction demand. Table 5 shows the computation of the calculated range of lateral tire accelerations for various speeds and cross slopes using the 95th percentile passing automobile path radius described in Table 1. With regard to cross slope, the tentative conclusions that could be made from this analytical result are (1) the effect of cross slope appears reasonably minor; and (2) despite this apparently minor effect, minimal cross slopes are desirable for higher speeds because of the already marginal dynamics of the passing vehicle.

#### Determination of Driver Simulation Parameters

The results of Table 5 provide a basis for determining the driver simulation parameters to be used in the path-following algorithm. By using various combinations of parameters, preliminary simulations were run until dynamic results similar to Table 5 were produced. This kind of exercise was done using a standard passenger car, with the following parameters determined for testing the effects of pavement cross slope and crossover break:

$$\begin{aligned}L &= 0.25 V \\PGAIN &= 1/L \\QGAIN &= 1/(10L)\end{aligned}$$

Where

$$\begin{aligned}L &= \text{Probe Length ft (m)} \\V &= \text{Vehicle Speed ft/s (m/s)} \\PGAIN &= \text{Steer Velocity rad/ft (rad/m)} \\QGAIN &= \text{Steer Damping rad-s/ft (rad-s/m)}\end{aligned}$$

In attempting to use these same parameters for simulation of truck passing maneuvers, very severe and highly unstable dynamics were produced. These results indicated a threshold of dynamic instability related to very aggressive

Table 4  
Test Parameters For Simulation Experiments

Vehicles

Mid-Size Automobile (1971 Dodge Coronet)  
Compact Automobile (1971 Vega Sports Coupe)  
Loaded Single-Unit Truck (White Road Boss)  
Loaded Tractor Trailer (PHASE4 spec, 68,855 lbs. (31,298 kg))  
Empty Tractor Trailer (PHASE4 spec, 28,855 lbs. (13,116 kg))

Centerline Crossover Break Designs

2 percent each side (no rounding)  
4 percent each side (no rounding)

Test Speeds--mph (km/h)

87 (140)  
74 (120)  
62 (100)  
50 ( 80)

Test Paths

Radius = 1132 ft (345 m) (path segments L<sub>2</sub> and L<sub>4</sub>)  
Segment Lengths as per Tables 2 and 3

**Table 5**  
**Nominal Tire Friction Values Using 1132 Foot (345 Metre) Radius**  
**(From Table 1) in Centripetal Force Equation**

<u>Cross Slope (Percent)</u>	<u>Speed mph (km/h)</u>	<u>f Calculated at End of Initial Passing Maneuver*</u>
2	87 (140)	0.47
	74 ( 20)	0.35
	62 (100)	0.25
	50 ( 80)	0.17
4	87 (140)	0.49
	74 (120)	0.37
	62 (100)	0.27
	50 ( 80)	0.19
6	87 (140)	0.51
	74 (120)	0.39
	62 (100)	0.29
	50 ( 80)	0.21

\* See Figure 1 for description of Initial Passing Maneuver

sinusoidal steering (and not related to the cross slope or other highway geometrics). It was evident that the parameters selected for simulating nominally critical passenger car drivers were inappropriate for simulating truck driver behavior. It was therefore necessary to test various driver simulation parameters to determine a nominally critical level of operation appropriate for trucks. As always, the objective was to discover a reasonably critical threshold for which dynamic sensitivities associated with the vehicle, its speed and the cross slope could be observed. This exercise produced the following driver simulation parameters for trucks to test the effect of centerline crossover break:

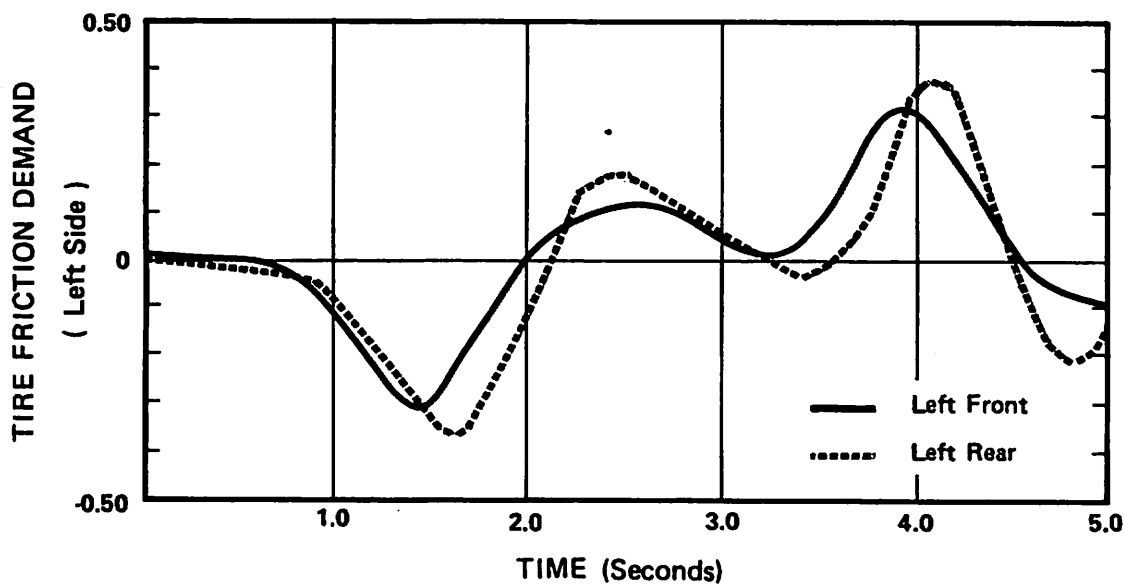
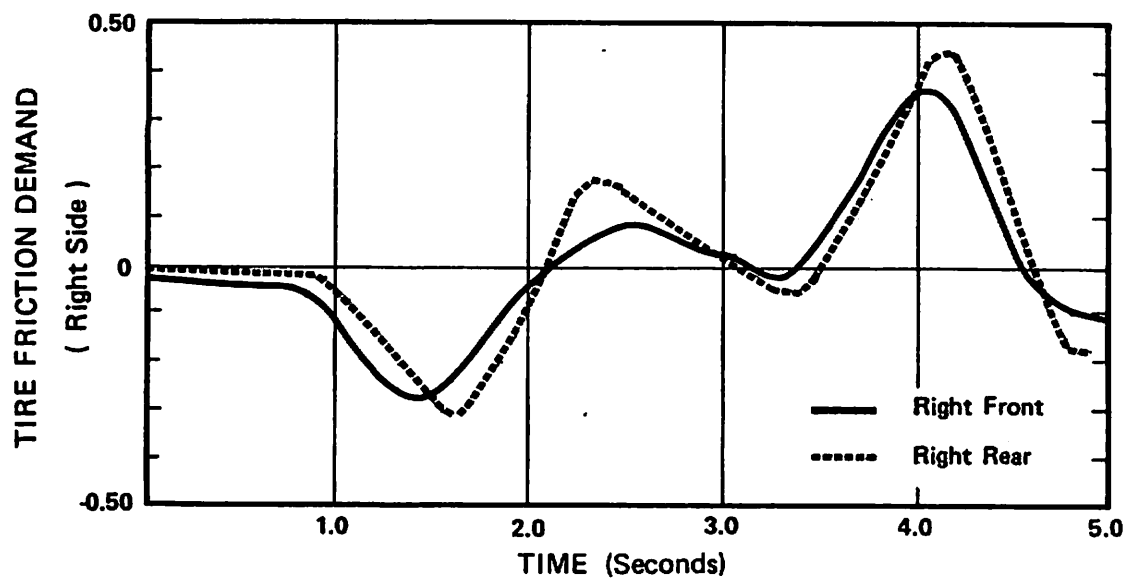
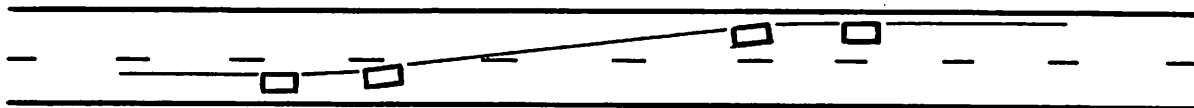
#### TRUCK DRIVER PARAMETERS

$$\begin{aligned}L &= 0.25 V \\PGAIN &= 1/(2L) \\QGAIN &= 1/(5L)\end{aligned}$$

Where L, V, PGAIN and QGAIN are as before

#### Results of Experiments

Figures 2 through 5 show sample results of the 14 simulation experiments. Summaries of the dynamic response for all experiments are shown in three comparison tables which report some of the experiments more than once. Table 6 provides a direct comparison of the dynamic responses of various vehicles for the same test speed and cross slope. Table 7 directly compares the dynamic effect of speed for the same vehicle and cross slope. Table 8 is a direct comparison of the dynamic effects of cross slope for a given vehicle and speed.



#### TEST CONDITIONS

Vehicle Type: Mid - size Auto

Cross Slope: 2 percent

Initial Speed: 100 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

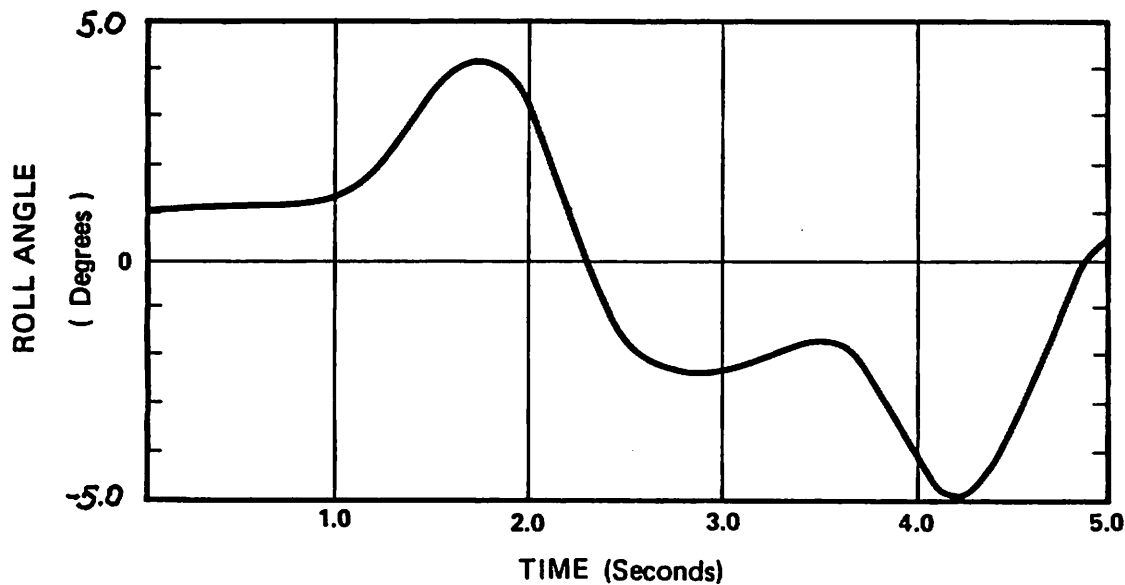
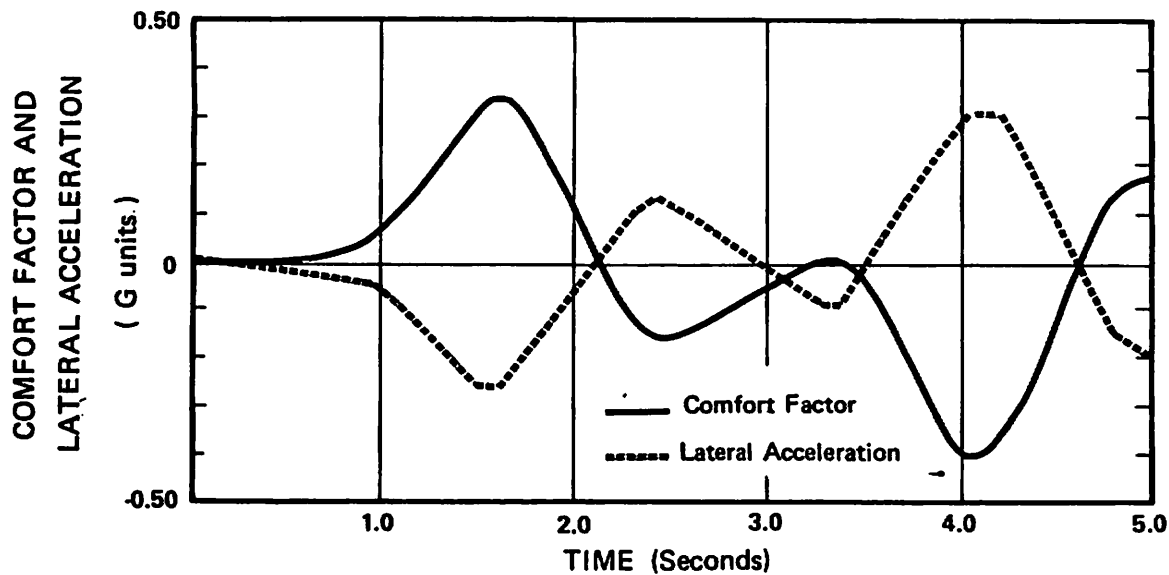
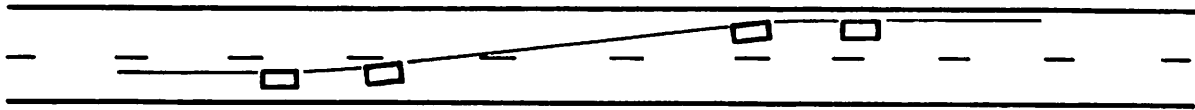
Probe Length: 6.94 m

P Gain:  $1.44 \times 10^{-1}$  rad / m

Q Gain:  $1.44 \times 10^{-2}$  rad - s / m

Acceleration:  $1.00 \text{ m} / \text{s}^2$

**Figure 2. SIMULATION RESULTS FOR MID - SIZE AUTOMOBILE USING HVOSM**



#### TEST CONDITIONS

Vehicle Type: Mid - size Auto

Cross Slope: 2 percent

Initial Speed: 100 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

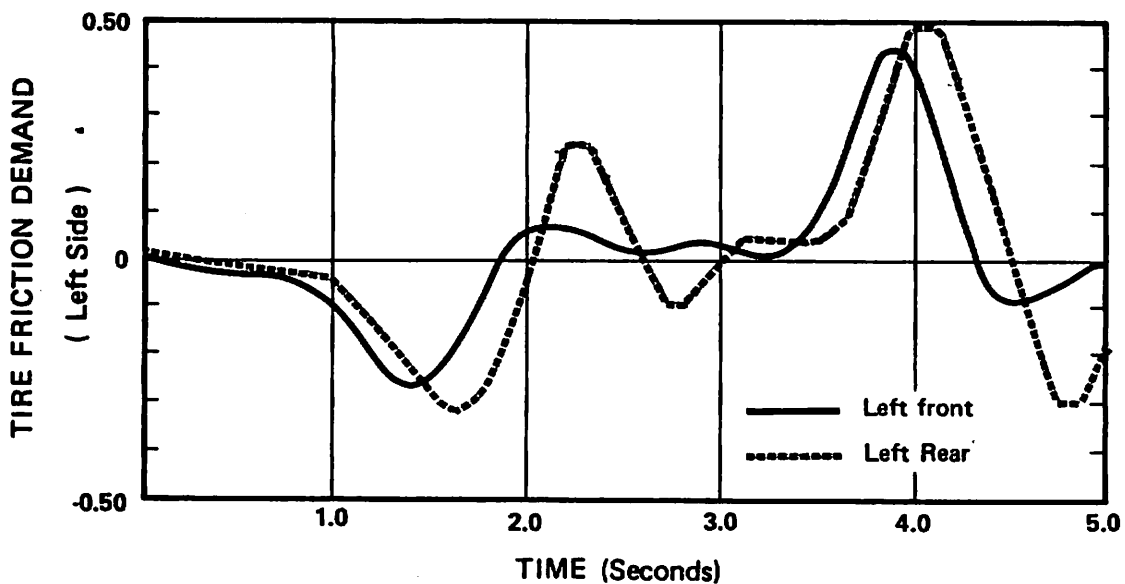
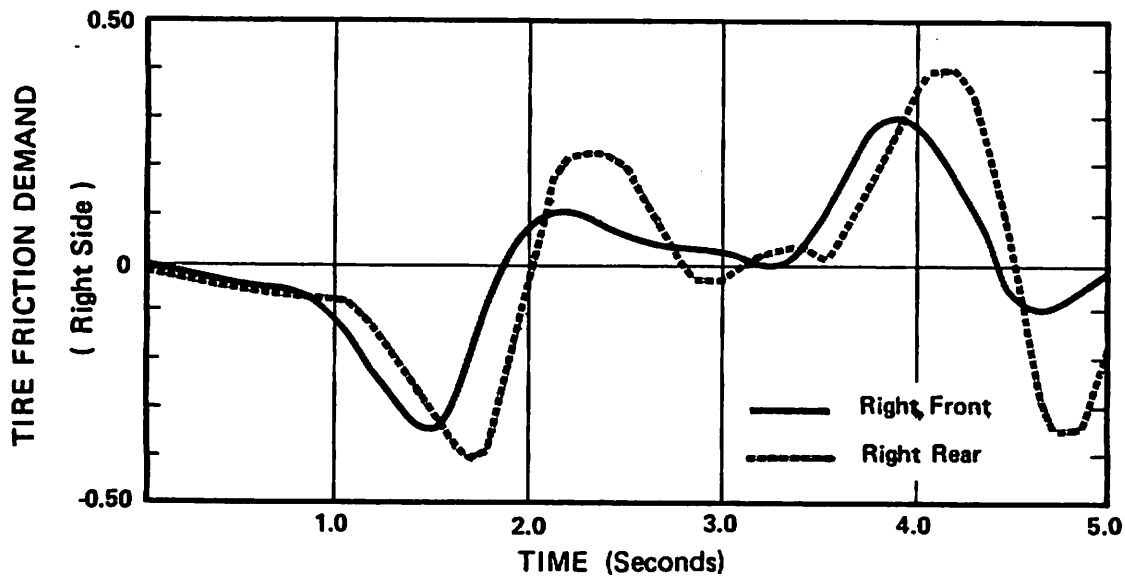
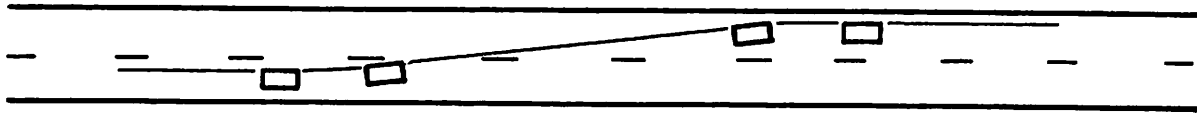
Probe Length: 6.94 m

P Gain:  $1.44 \times 10^{-1}$  rad / m

Q Gain:  $1.44 \times 10^{-2}$  rad - s / m

Acceleration:  $1.00 \text{ m} / \text{s}^2$

**Figure 2. SIMULATION RESULTS FOR MID - SIZE AUTOMOBILE USING HVOSM ( continued )**



#### TEST CONDITIONS

Vehicle Type: Compact Car

Cross Slope: 2 percent

Initial Speed: 100 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

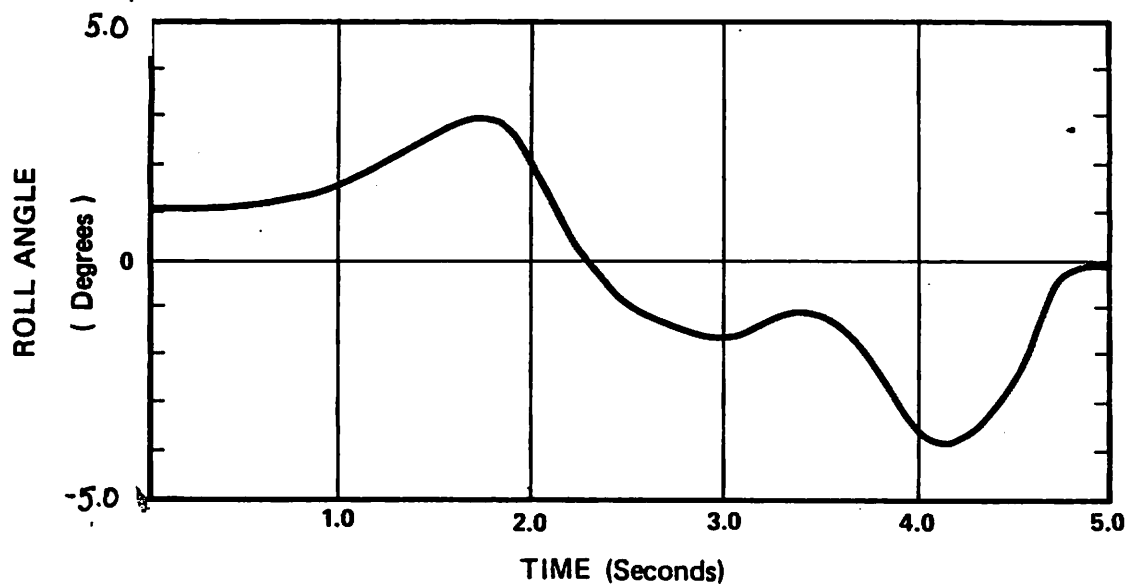
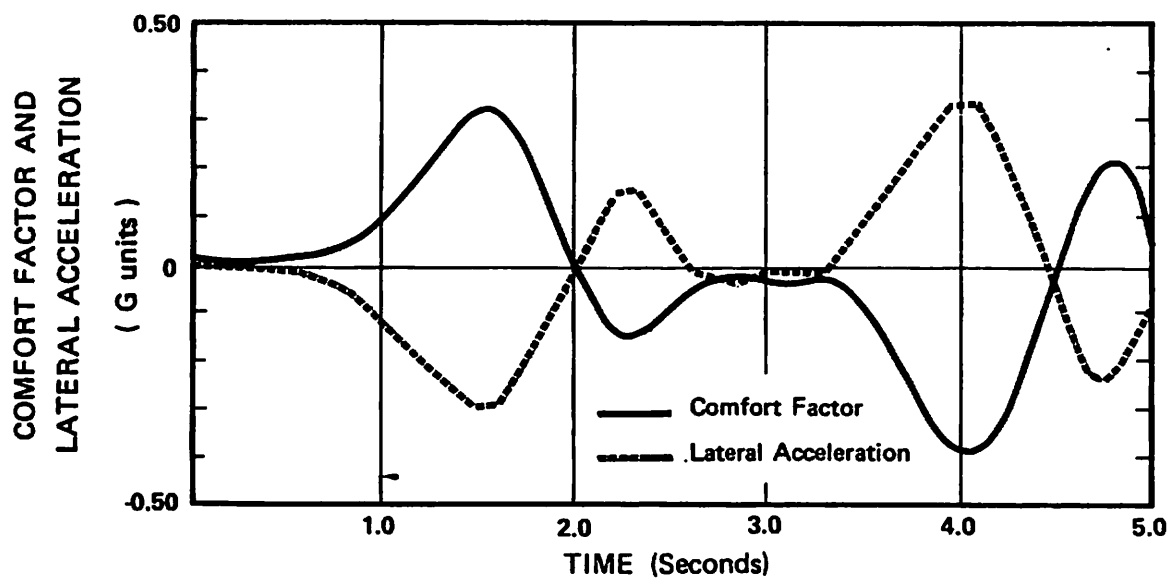
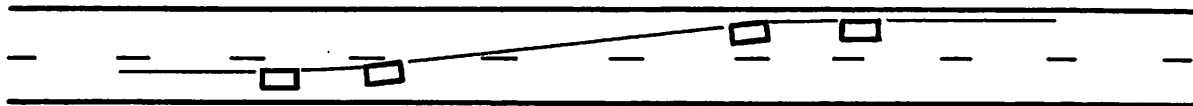
Probe Length: 6.93 m

P Gain:  $1.46 \times 10^{-1}$  rad / m

Q Gain:  $1.46 \times 10^{-2}$  rad - s / m

Acceleration:  $1.00 \text{ m} / \text{s}^2$

**Figure 3. SIMULATION RESULTS FOR COMPACT AUTOMOBILE USING HVOSM**



#### TEST CONDITIONS

Vehicle Type: Compact Car

Cross Slope: 2 percent

Initial Speed: 100 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

Probe Length: 6.93 m

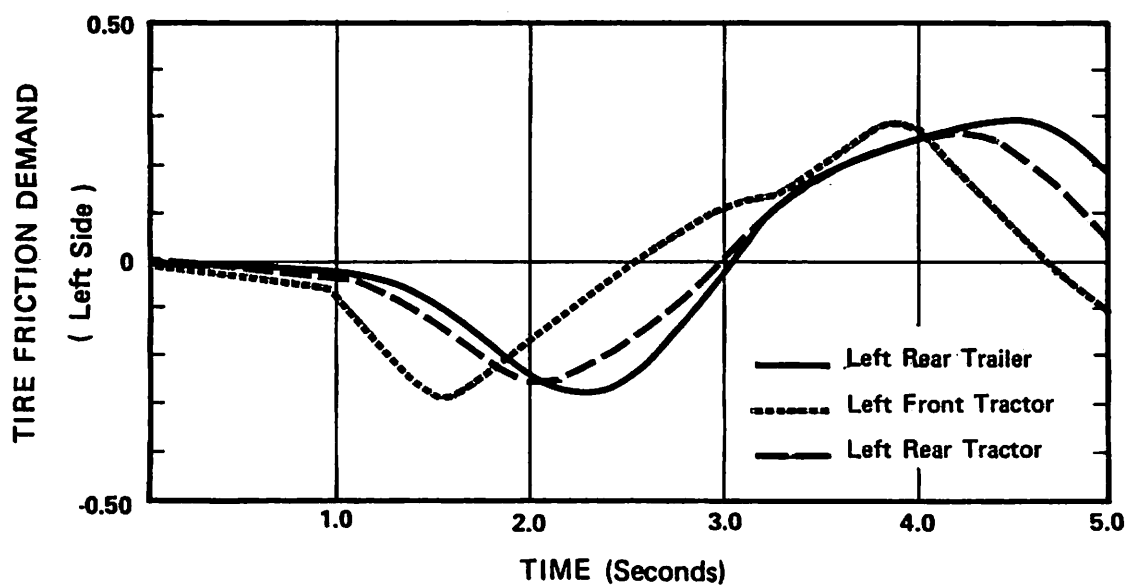
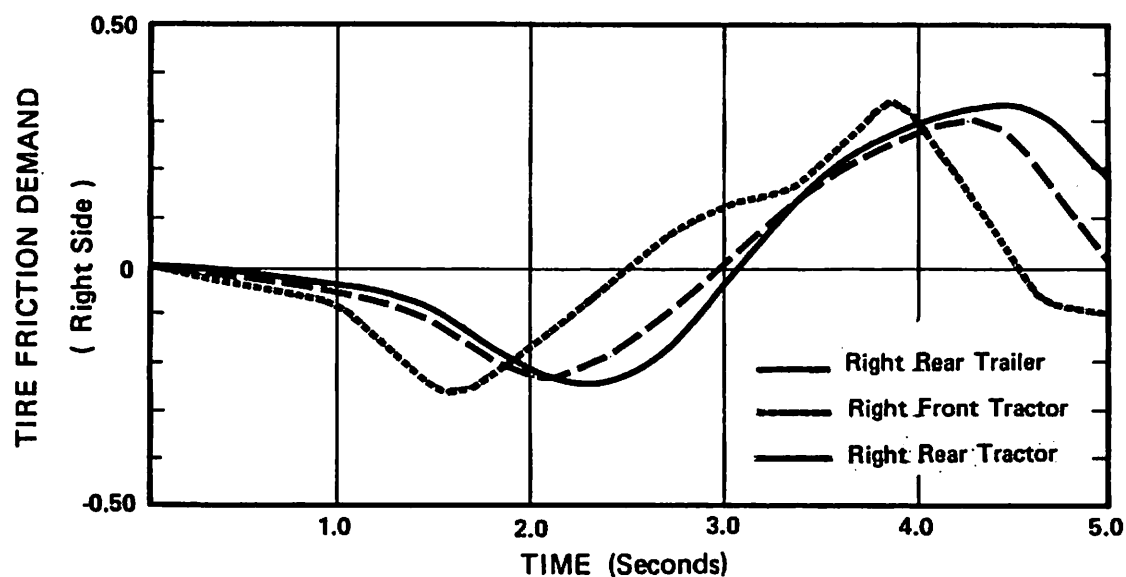
P Gain:  $1.46 \times 10^{-1}$  rad / m

Q Gain:  $1.46 \times 10^{-2}$  rad - s / m

Acceleration:  $1.00 \text{ m} / \text{s}^2$

Figure 3. SIMULATION RESULTS FOR COMPACT AUTOMOBILE USING HVOSM ( continued )





#### TEST CONDITIONS

Vehicle Type: Loaded Semi - trailer

Cross Slope: 2 percent

Initial Speed: 108 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

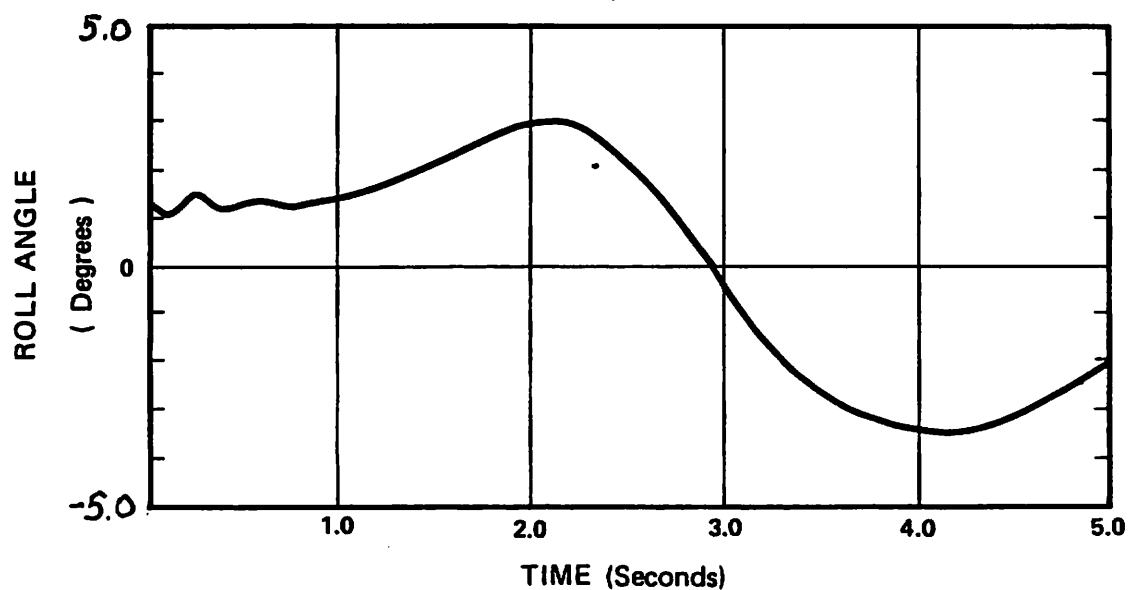
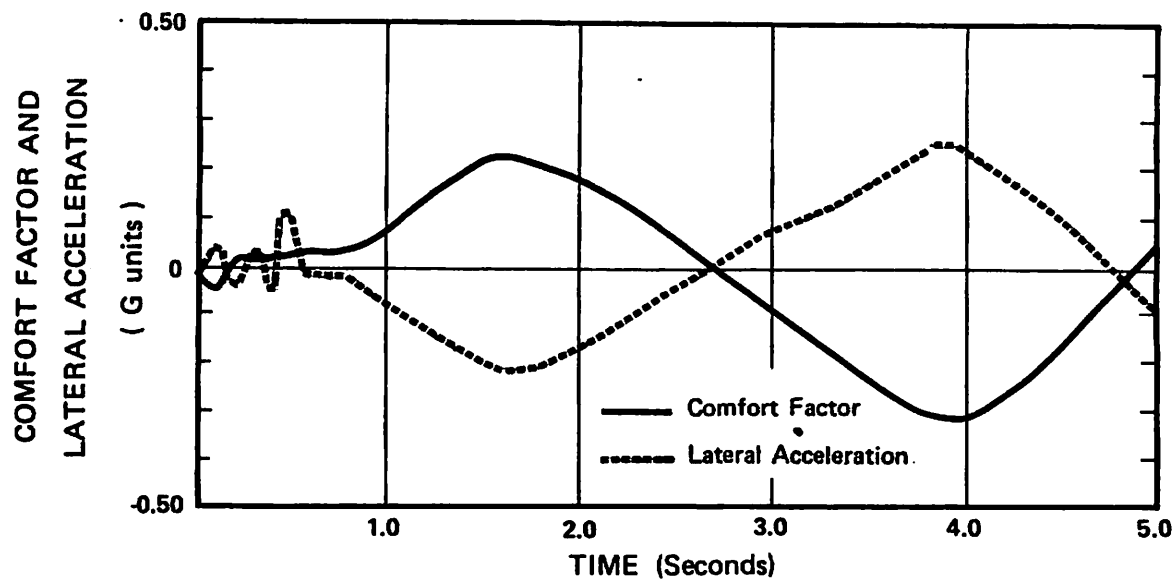
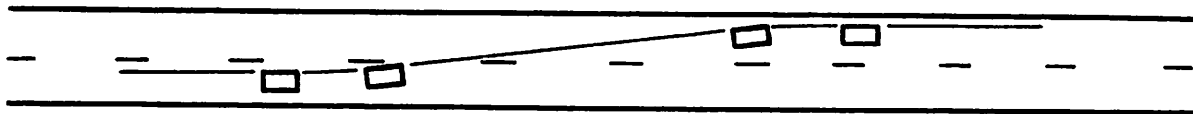
Probe Length: 7.21 m

P Gain:  $6.9 \times 10^{-2}$  rad / m

Q Gain:  $2.8 \times 10^{-2}$  rad · s / m

Acceleration:  $0.20 \text{ m} / \text{s}^2$

**Figure 4. SIMULATION RESULTS FOR LOADED SEMI - TRAILER TRUCK  
USING HSRI / MVM PHASE 4 MODEL**



#### TEST CONDITIONS

Vehicle Type: Loaded Semi - trailer

Cross Slope: 2 percent

Initial Speed: 108 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

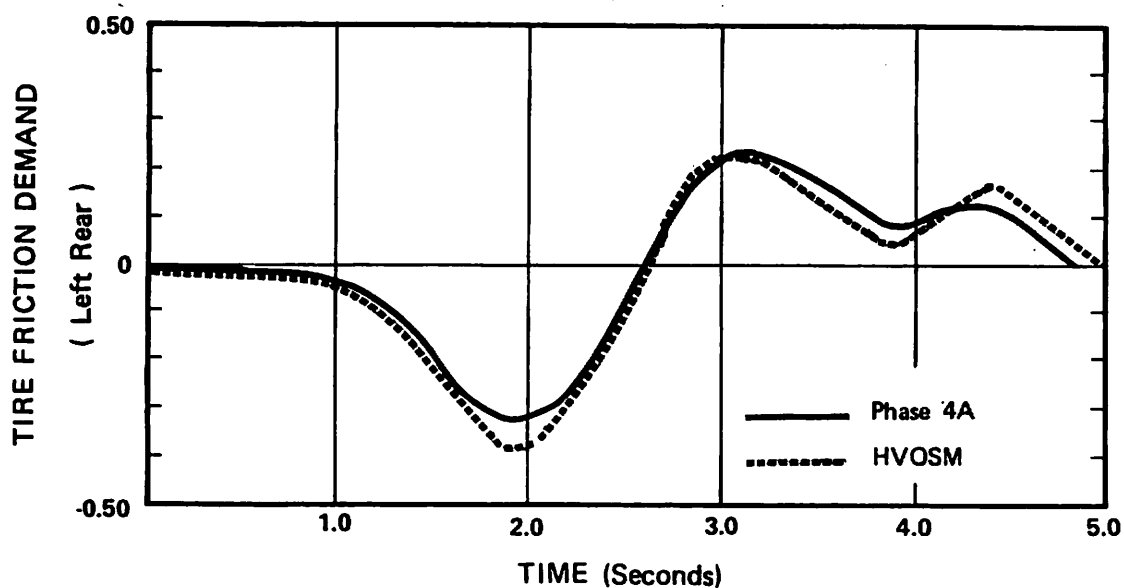
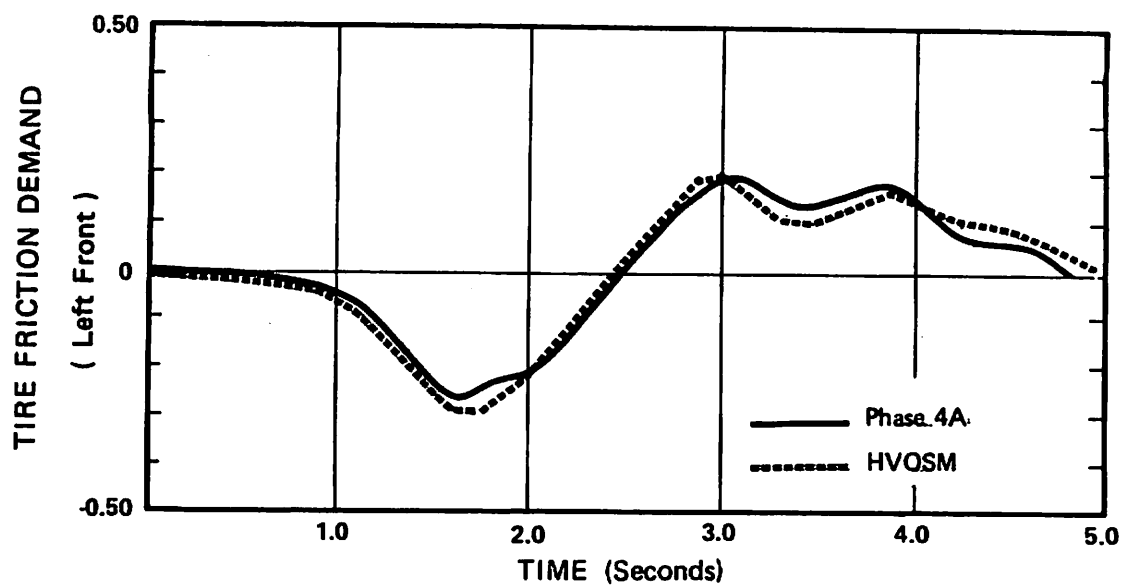
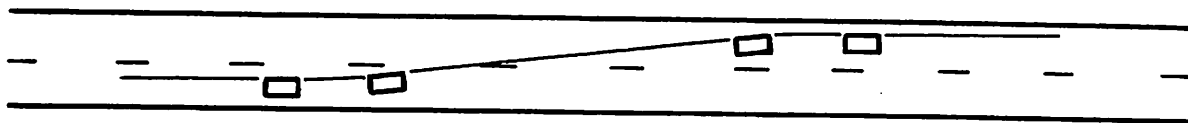
Probe Length: 7.21 m

P Gain:  $6.9 \times 10^{-2}$  rad / m

Q Gain:  $2.8 \times 10^{-2}$  rad - s / m

Acceleration:  $0.2 \text{ m} / \text{s}^2$

**Figure 4. SIMULATION RESULTS FOR LOADED SEMI - TRAILER TRUCK  
USING HSRI / MVM PHASE 4 MODEL ( continued )**



#### TEST CONDITIONS

Vehicle Type: Single - unit Truck

Cross Slope: 2 percent

Initial Speed: 104 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

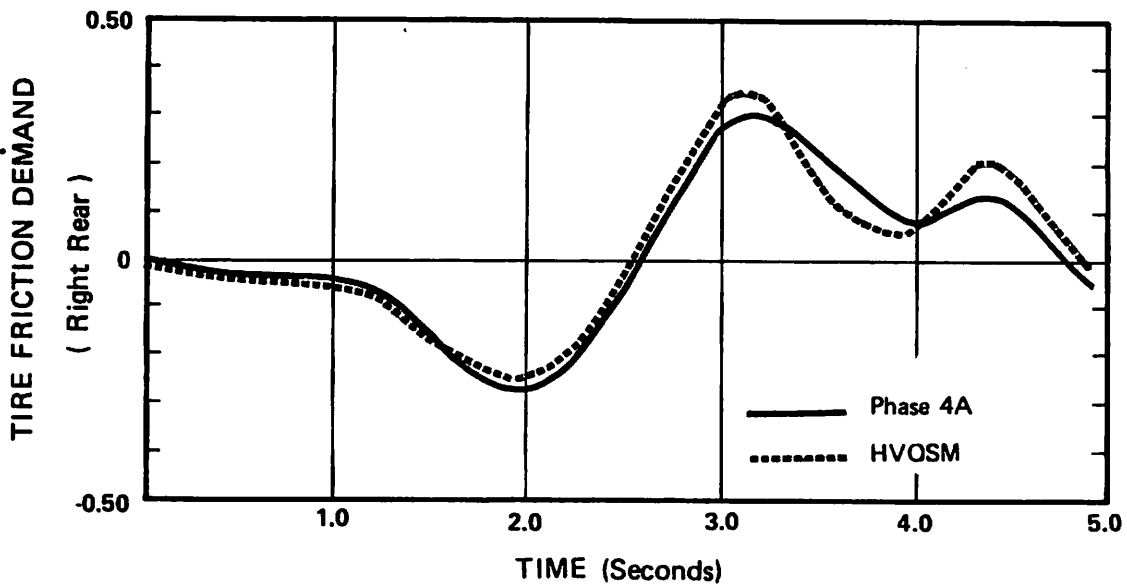
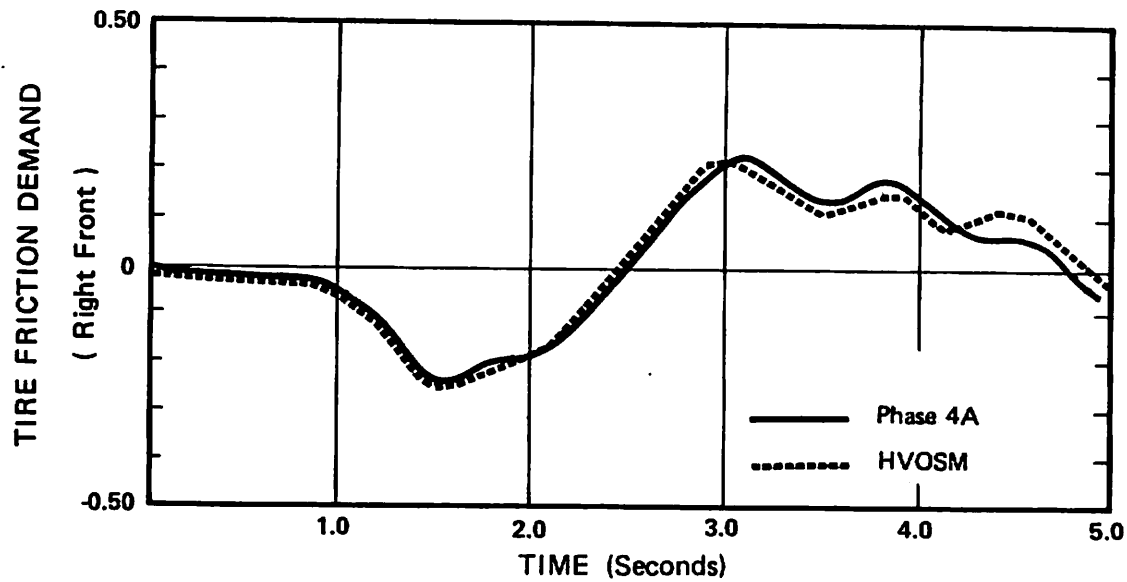
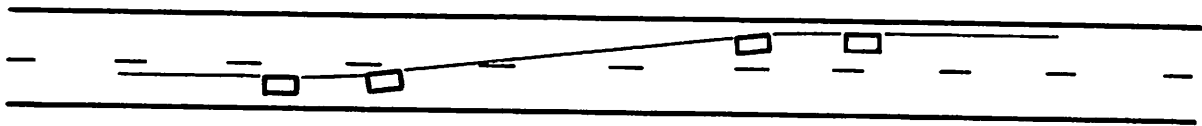
Probe Length: 7.21 m

P Gain:  $6.9 \times 10^{-2}$  rad / m

Q Gain:  $2.8 \times 10^{-2}$  rad - s / m

Acceleration:  $0.5 \text{ m} / \text{s}^2$

**Figure 5. SIMULATION RESULTS FOR SINGLE - UNIT TRUCK — COMPARISON BETWEEN HVOSM AND HSRI / MYM PHASE 4 MODEL**



#### TEST CONDITIONS

Vehicle Type: Single - unit Truck

Cross Slope: 2 percent

Initial Speed: 104 km / h

Design Speed: 120 km / h

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

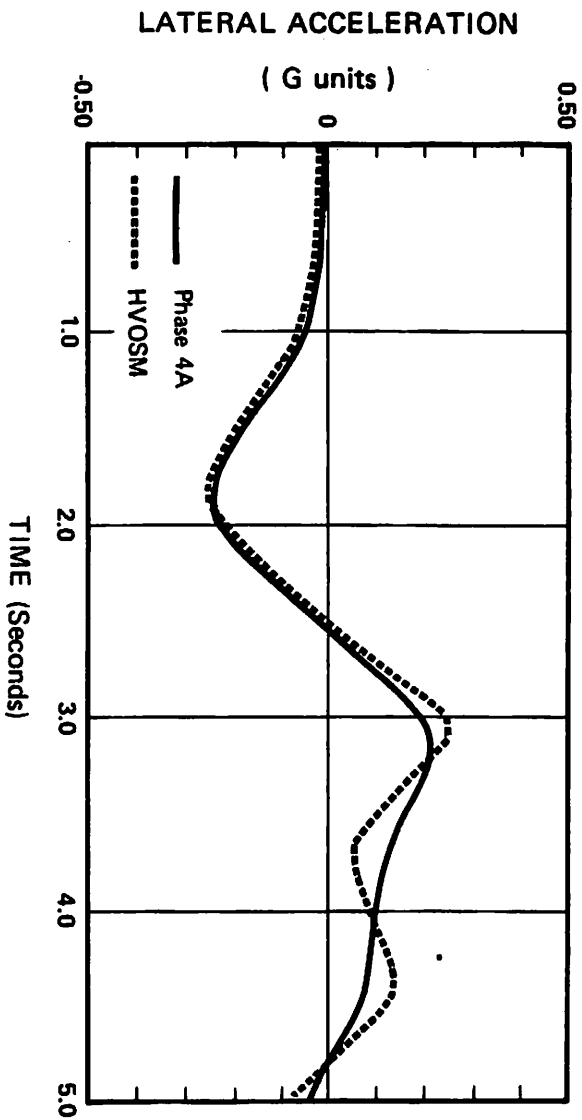
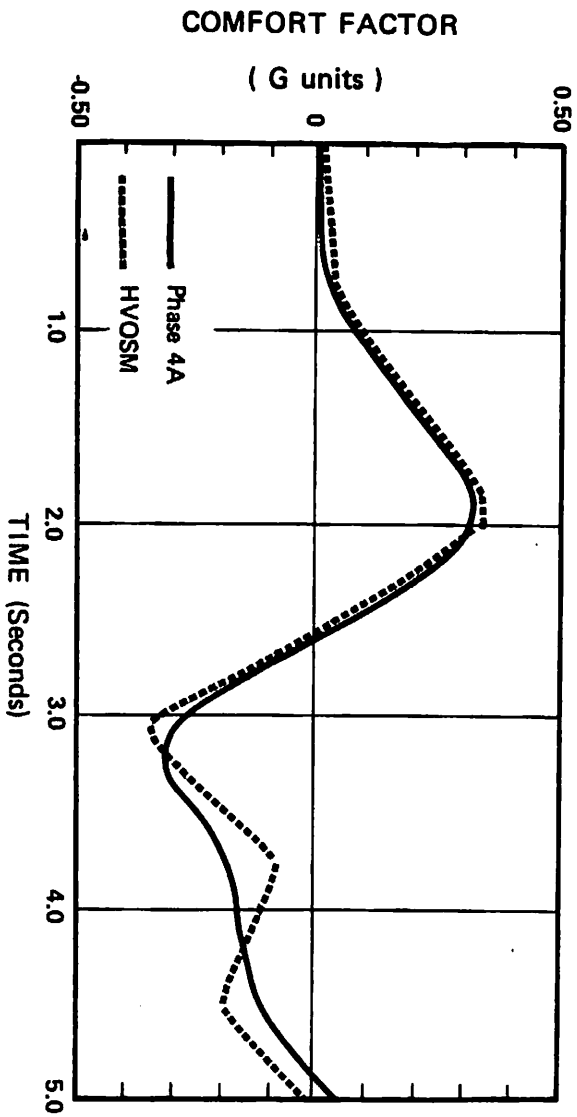
Probe Length: 7.21 m

P Gain:  $6.9 \times 10^{-2}$  rad / m

Q Gain:  $2.8 \times 10^{-2}$  rad - s / m

Acceleration:  $0.50 \text{ m} / \text{s}^2$

Figure 5. SIMULATION RESULTS FOR SINGLE - UNIT TRUCK — COMPARISON BETWEEN HVOSM AND HSRI / MVM PHASE 4 MODEL ( continued )

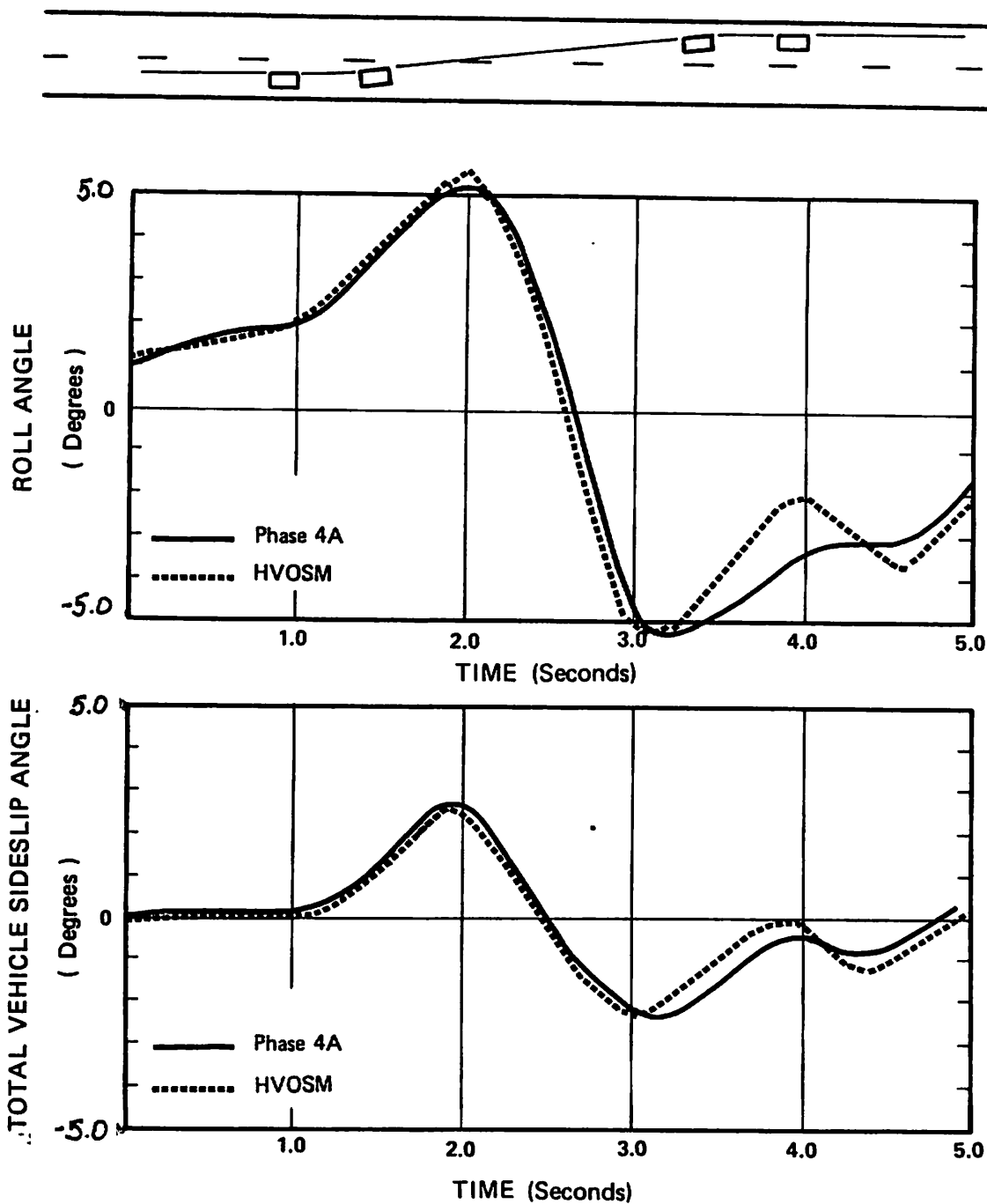


#### TEST CONDITIONS

Vehicle Type: Single - unit Truck	Probe Length: 7.21 m
Cross Slope: 2 percent	P Gain: $6.9 \times 10^{-2} \text{ rad} / \text{m}$
Initial Speed: 104 km / h	Q Gain: $2.8 \times 10^{-2} \text{ rad} \cdot \text{s} / \text{m}$
Design Speed: 120 km / h	Acceleration: $0.50 \text{ m} / \text{s}^2$

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

**Figure 5. SIMULATION RESULTS FOR SINGLE - UNIT TRUCK -- COMPARISON BETWEEN HVOSM AND HSRI / MVM PHASE 4 MODEL ( continued )**



#### TEST CONDITIONS

Vehicle Type: Single - unit Truck

Cross Slope: 2 percent

Initial Speed: 104 km / h

Design Speed: 120 km / h

Probe Length: 7.21 m

P Gain:  $6.9 \times 10^{-2}$  rad / m

Q Gain:  $2.8 \times 10^{-2}$  rad - s / m

Acceleration:  $0.50 \text{ m} / \text{s}^2$

Note : 1 km / h = 0.62 mph, 1 m = 3.28 ft.

Figure 5. SIMULATION RESULTS FOR SINGLE - UNIT TRUCK -- COMPARISON BETWEEN HVOSM AND HSRI / MVM PHASE 4 MODEL ( continued )

Table 6  
Comparison of Vehicle Effects  
on Dynamics of Passing Maneuvers

VEHICLE TYPE	TIRE FRICTION DEMAND (g's)	DRIVER DISCOMFORT (g's)	VEHICLE ROLL ANGLE (degrees)
Test Conditions: 74 mph (120 km/h) Design Speed, 2 percent Cross Slope			
Compact Auto	0.36	0.38	3.7
Mid-Size Auto	0.34	0.38	4.9
Tractor-Trailer (empty)	0.30	0.22	1.8
Tractor-Trailer (loaded)	0.29	0.30	3.3
Single-Unit Truck (HVOSM)	0.23	0.32	6.3
Single-Unit Truck (PHASE 4)	0.22	0.31	6.3
Test Conditions: 62 mph (100 km/h) Design Speed, 4 percent Cross Slope			
Tractor-Trailer (loaded)	0.38	0.42	5.3
Compact Auto	0.32	0.36	4.2
Mid-Size Auto	0.29	0.34	5.2

#### Summary of Vehicle Comparison

The following conclusions describe the effects of cross slope on the full range of vehicle types tested.

- (1) The compact automobile generates higher tire friction demands than the mid-size automobile.
- (2) The compact automobile generates the highest tire friction demand on a 2 percent cross slope.
- (3) The loaded tractor-trailer generates the highest tire friction demand on a 4 percent cross slope.
- (4) The empty tractor-trailer produces similar tire friction demands as a loaded tractor-trailer, but with significantly lower driver discomfort and roll angle.

Table 7  
Comparison of Speed Effects  
on Dynamics of Passing Maneuvers

Vehicle Type	Speed mph (km/h)		Cross-Slope (percent)	Tire Friction Demand (g's)	Driver Discomfort (g's)	Vehicle Roll Angle (degrees)
Mid-Size Auto	87	(140)	2	0.33	0.36	4.6
	74	(120)	2	0.34	0.38	4.9
	62	(100)	2	0.28	0.32	4.0
Mid-Size Auto	74	(120)	4	0.36	0.40	6.2
	62	(100)	4	0.29	0.34	5.2
	50	( 80)	4	0.22	0.26	4.4
Compact Auto	74	(120)	2	0.36	0.38	3.7
	62	(100)	2	0.31	0.34	3.0
Tractor-Trailer (Loaded)	74	(120)	2	0.29	0.30	3.3
	62	(100)	2	0.34	0.37	3.8

#### Summary of Speed Comparison

The results of comparisons across speeds are mixed. While the comparisons generally show an increase in tire friction demand with an increase in speed, two comparisons show the opposite. Although these discontinuities cannot be directly explained, it is believed they are partially an artifact of the total simulation process, which included varying the driver parameter values and passing path segment lengths with speed.



Table 8  
Comparison of Cross Slope Effects  
on Dynamics of Passing Maneuvers

Vehicle Type	Speed mph (km/h)		Cross-Slope (percent)	Tire Friction Demand (g's)	Driver Discomfort (g's)	Vehicle Roll Angle (degrees)
Mid-Size Auto	74	(120)	2	0.34	0.38	4.9
	74	(120)	4	0.36	0.40	6.2
Mid-Size Auto	62	(100)	2	0.28	0.32	4.0
	62	(100)	4	0.29	0.34	5.2
Compact Auto	62	(100)	2	0.31	0.34	3.0
	62	(100)	4	0.32	0.36	4.2
Tractor-Trailer (Loaded)	62	(100)	2	0.34	0.37	3.8
	62	(100)	4	0.38	0.42	5.3

#### Summary of Cross Slope Comparison

The dynamic effect of increasing cross slope from 2 to 4 percent is an increase in the tire friction ranging from 0.01 to 0.04 g's.

#### Conclusions

Although the simulation experiments only represent a small segment of real highway operations and did produce a few conflicting results with regard to speed effects, the implications with regard to pavement cross slope and centerline crossover break design are reasonably clear. These implications which are generally consistent with AASHTO requirements are as follows:

- (1) The passing maneuver on two-lane, high-speed (greater than 60 mph (100 km/h)) highways is potentially severe regardless of the cross slope. Simulation of nominally critical passing behavior produced vehicle dynamic responses on the order of 0.28 to 0.34 g's for cross slopes of 2 percent and a full range of vehicle types.

- (2) The dynamic effect of increased cross slopes (say, from 2 percent to 4 percent) is a marginal increase in driver discomfort and tire friction demand. Because of conclusion (1), any such increase is undesirable as it worsens an already critical situation. It is therefore clear that, to minimize the dynamic contribution of cross slope, cross-slope design should be kept to a minimum on high-speed highways.
- (3) Higher cross slopes may be permissible on highways with lower design speeds (say, 50 mph (80 km/h) or less). A practical maximum of 4 percent is indicated by the dynamic responses for tractor-trailer passing maneuvers on such highways.
- (4) In general, for all design speeds, the cross slope should be kept to the minimum consistent with drainage requirements for the type of surface and highway. It should be recognized that the establishment of a design cross slope affects other design elements. Greater cross slopes generally result in less design flexibility and a reduction in the safety effectiveness of the highway. They require longer super-elevation runout lengths, and affect the design of the shoulder slope. As shoulder slopes tend to be designed with greater slope than the cross slope to facilitate drainage of the traveled way, cross slopes of 4 to 6 percent would tend to be accompanied by shoulder slopes of 6 or 8 percent. Recent research on the dynamics of roadside traversals (3) points out the disadvantages of such steep shoulder slopes.

From the above four conclusions, it appears that current AASHTO criteria for maximum centerline cross slope, as shown on page 1, are appropriate. AASHTO policy should explicitly note the operational effects of pavement cross slope on the passing maneuver, and should encourage the use of minimal cross slopes on high speed highways.

## References

- (1) American Association of State Highway Officials, A Policy on Geometric Design of Rural Highways, 1965.
- (2) Gallaway, B.M., et al., Tentative Pavement and Geometric Criteria for Minimizing Hydroplaning, Research Report No. FHWA-RD-75-11, Washington, D.C., Federal Highway Administration, February 1975.
- (3) Glennon, J.C., et al., HVOSM Studies of Cross-Slope Breaks on Highway Curves, Research Report No. FHWA/RD-82/054, Federal Highway Administration, May 1982.
- (4) Glennon, J.C., Frictional Requirements for High-Speed Passing Maneuvers, Research Report No. 134-7, Texas Transportation Institute, July 1971.
- (5) Weaver, G.D., and Glennon J.C., Passing Performance Measurements Related to Sight Distance Design, Research Report No. 134-6, Texas Transportation Institute, June 1971.
- (6) McHenry, R.R., Deleys, N.J. Vehicle Dynamics in Single Vehicle Accidents - Validation and Extensions of a Computer Simulation, Research Report No. VJ-2251-V-3, Contract No. CPR-11-3988, Calspan Corporation, December 1968.
- (7) Segal, D.J., Highway-Vehicle Object Simulation Model - 1976
  - Vol. I - User's Manual, PB-267401
  - Vol. II - Programmer's Manual, PB-267402
  - Vol. III - Engineering Manual - Analysis, PB-267403
  - Vol. IV - Engineering Manual - Validation, PB-267404
- (8) MacAdam, C.C., et al. A Computerized Model for Simulating the Braking and Steering Dynamics of Trucks, Tractor-Semi-Trailers, Doubles, and Triples Combinations - User's Manual, Phase 4, Report No. PB80-227994.
- (9) Hu, G.T., et al. Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1 - Programmer's Manual, Report No. PB81-178360.
- (10) Ervin, R.D., et al. Effects of Tire Properties on Truck and Bus Handling,
  - Vol. I - Report No. PB-263-878
  - Vol. II - Report No. PB-263-879
  - Vol. III - Report No. PB-263-880
  - Vol. IV - Report No. PB-263-881
- (11) McHenry, B.G., Progress Report for Effectiveness of Design Criteria for Geometric Elements, FHWA Contract No. DOT-FH-11-9575, Modification No. 3, "Study of Centerline Crown," April 1, 1983.
- (12) Segal, D.J., and Raney, T.A., Evaluation of Horizontal Curve Requirements, Research Report No. FHWA-RD-79-48, Federal Highway Administration, October 1978.

## Appendix A - HVOSM Modifications

A number of refinements and revisions to the HVOSM program were required, including additional outputs of vehicle responses, revision of the path-following driver model, and input of dual rear tire specifications. These revisions are described below.

### Additional Outputs

Additional calculations and outputs of the existing HVOSM RD2 program were found to be required to enable the evaluation of the centerline crown. The revisions were as follows:

"Discomfort Factor".--The lateral acceleration output of HVOSM corresponds to measurements made with a "hard-mounted," or body-fixed accelerometer oriented laterally on the vehicle. During cornering, the lateral acceleration of the vehicle is directed toward the center of the turn. On a superelevated turn, the component of gravity that acts laterally on the vehicle is also directed toward the turn center. Thus, the lateral acceleration output is increased by superelevation.

Since the vehicle occupants respond to centrifugal force, their inertial reaction is toward the outside of the turn and therefore the component of gravity that acts laterally on them in a superelevated turn reduces the magnitude of the disturbance produced by cornering. A corresponding program output has been defined to evaluate occupant discomfort in turns.

The effects of a vehicle's roll angle and lateral acceleration on occupants are combined in a "discomfort factor" relationship which represents the net lateral disturbance felt by the occupants (i.e., the occupants' reaction to the combined effects of the lateral acceleration and roll angle).

The "discomfort factor" is coded in the following form:

$$\text{DISCOMFORT FACTOR} = - \text{YLAT} + 1.0 * \text{SIN } \theta$$

Where: DISCOMFORT FACTOR = G units

YLAT = Vehicle Lateral Acceleration in vehicle-fixed coordinate system, G units

$\theta$  = Vehicle roll angle, radians.

Calculations related to the discomfort factor and corresponding outputs were incorporated into the HVOSM.

Friction Demand.--The friction demand is defined to be the ratio of the side force to the normal load of an individual tire. It is indicative of the friction being utilized by each individual tire. The standard outputs of HVOSM include the side force and normal force for each tire. Coding changes were incorporated to calculate and print out the friction demand for each tire at each interval of time.

#### Driver Model

A recognized problem in the use of either simulation models or full-scale testing in relation to investigations of automobile dynamics is the manner of guiding and controlling the vehicle. Repeatability is essential, and the control inputs must be either representative of an average driver or optimized to achieve a selected maneuver without "hunting" or oscillation. In this investigation of geometric features of highways, the transient portions of the vehicle responses constituted justification for applying a complex computer simulation. The steady-state portions of the vehicle responses can be predicted by means of straightforward hand calculations. Thus, it is essential that the transient responses should not be contaminated by oscillatory steering control inputs.

The Driver model contained in the distributed version of the HVOSM Vehicle Dynamics program was intended to be incorporated into the HVOSM Roadside Design version, but it proved to be inadequate for the present research effort. Therefore, new routines were written for the HVOSM Roadside Design program as described below.

"Wagon-Tongue" Algorithm.--The "wagon-tongue" type of steering control incorporated into the HVOSM Roadside Design Version is one in which the front wheel steer angle is directly proportional to the error of a point on a forward extension of the vehicle X-axis relative to the desired path.

The basic inputs to the "wagon-tongue" algorithm are described in Table 9.

Table 9  
Inputs For "Wagon-tongue" Driver Model

<u>Input</u>	<u>Description</u>	<u>Units</u>
TPRB	Time at which driver model is to begin	sec
DPRB	Time between driver model samples	sec
PLGTH	Probe length measured from the center of gravity of the vehicle along the vehicle-fixed X axis	in
PMIN	Null band, minimum acceptable error	in
PMAX	Maximum allowable discomfort factor above which driver model will only reduce steer angle	g-units
PGAIN	Steer correction multiplier--error of probe from desired path multiplied by PGAIN to determine steer correction	rad/in

1 in = 25.4 mm

Desired Path Definition.--The revision to the HVOSM driver model included the incorporation of a "path generating" routine to create a desired path of X,Y data pairs from standard roadway geometric descriptors. Figure 6 lists the path generating routine.

```

C PATHG.FOR F12          30 DECEMBER 1980          J T FLECK
C PATH GENERATOR
C ROUTINE TO TEST PATH GENERATION SUBROUTINES SETD AND PATHG
C MAY BE USED TO GENERATE DATA SETS FOR TERRAIN GENERATOR
C OR HVOSM
C
C INPUTS:
C NPTS          NUMBER OF POINTS DESIRED
C XINIT         X COORDINATE OF FIRST POINT
C YINIT         Y COORDINATE OF FIRST POINT
C DELL         SPACING BETWEEN POINTS (ALONG STRAIGHT LINE)
C PSA          INITIAL HEADING (TANGENT TO PATH)
C KLI          NUMBER OF SECTIONS (CURVATURES)
C IF = 0       PROGRAM DEFAULTS TO POINTS IN DATA STATEMENT
C IF > 0       REQUIRES THE FOLLOWING INPUT L = 1, KLI
C DI(L)        CURVATURE > 0 RIGHT TURN
C              = 0 STRAIGHT
C              < 0 LEFT TURN
C RLI(L)       DISTANCE FROM INITIAL POINT WHERE DI(L)
C              IS EFFECTIVE.
C              DISTANCE IS MEASURED IN STRAIGHT LINE
C              SEGMENTS BETWEEN POINTS. IF DISTANCE
C              ALONG ARC IS REQUIRED SUBROUTINE SETD
C              MUST BE MODIFIED.
C NOTE: KLI MAY BE 1 OR GREATER
C E.G. TO GENERATE A STRAIGHT PATH N*DELL UNITS
C LONG AND THEN A RIGHT TURN WITH A CURVATURE OF 20
C INPUT KLI = 1, DI(1) = 20., RLI(1) = N*DELL
C THE ANGLE OF TURN IS GIVEN BY
C ANGLE = 2*ARCSIN[(DELL/2)*(PI/180)*(DI(L)/100)]
C
C OUTPUT
C X(I), Y(I)    COORDINATES OF POINT I I = 1 TO NPTS
C DX(I),DY(I)   TANGENT AT POINT I (DIRECTION OF PATH)
C D(I)          CURVATURE DEFINING PATH FROM POINT I TO POINT I+1
C
C THESE ARE WRITTEN ON A DATA SET (SY1:PTH.DAT) FOR USE BY OTHER
C ROUTINES
C
C INTEGER PLOT
C DIMENSION X(100),Y(100),DX(100),DY(100),D(100),DI(100),RLI(100)
C DIMENSION PLOT(70,70)
C DATA RAD/0.01745329/, D /10*0.0,9*20.0,9*-20.0,9*20.0,63*0.0/
C DATA KLI/0/, DI/100*0.0/, RLI/100*0.0/
C
C CALL OPEN(6,'SY1:PTH.DAT ')
C ENTER INITIAL DATA
C 1 WRITE(1,5)
C 5 FORMAT(1X,' ENTER NPTS,XINIT,YINIT,DELL,PSA '/')
C READ(1,6)NPTS,XINIT,YINIT,DELL,PSA
C 6 FORMAT(I4,4F9.0)
C IF(NPTS.LT.2)ENDFILE 6
C IF(NPTS.LT.2)STOP NPTS
C
C ENTER # OF CURVATURES (IF 0 ROUTINE USES D SET BY DATA STATEMENT)
C AND OUTPUT UNIT IOUT =0 DEFAULTS TO SCREEN, IOUT =2 FOR PRINTER
C WRITE(1,7)
C 7 FORMAT(' ENTER KLI,IOUT'/)
C READ(1,11)KLI,IOUT

```

Figure 6. PATH GENERATING ROUTINE

```

11  FORMAT(2I4)
C
      IF(IOUT.EQ.0)IOUT = 1
CHECK IF DI'S AND RLI' ARE TO BE INPUTTED
      IF(KLI.EQ.0)GO TO 17
      DO 15 I =1,KLI
      WRITE(1,14)
14  FORMAT(' ENTER DI, RLI'/)
15  READ(1,16)DI(I),RLI(I)
16  FORMAT(2F9.0)
C
CALL ROUTINE TO COMPUTE D'S FROM DI'S
      CALL SETD(KLI,DI,RLI,NPTS,DELL,D)
C
C INITIALIZE POINTS
17  X(1) = XINIT
      Y(1) = YINIT
C
C INITIALIZE TANGENT
      DX(1) = COS(PSA *RAD)
      DY(1) = SIN(PSA *RAD)
C
CALL ROUTINE TO SET PATH
      CALL PATHG(NPTS,DELL,X,Y,D,DX,DY)
C
      WRITE(6)NPTS,DELL,PSA ,X,Y,DX,DY,D
      WRITE(IOUT,23)NPTS,KLI,DELL,PSA
23  FORMAT(1X,'NPTS=',I4,', KLI=',I4,', DELL=',F10.4,', PSA =',F10.4/)
      IF(KLI.GT.0)WRITE(IOUT,24)(L,DI(L),RLI(L),L=1,KLI)
24  FORMAT(1X,I4,2F10.4)
      WRITE(IOUT,25)
25  FORMAT('/' POINT #          POSITION',19X,'TANGENT',10X,'CURVATURE')
      WRITE(IOUT,26)(I,X(I),Y(I),DX(I),DY(I),D(I),I=1,NPTS)
26  FORMAT(1X,I4,2F10.2,10X,2F10.5,F10.2)

```

Figure 6. PATH GENERATING ROUTINE ( continued )



```

C
C PRINTER PLOT: SPECIAL ROUTINE TO TEST ABOVE DATA
      M = NPTS
      XX = X(1)
      XM = X(1)
      YX = Y(1)
      YM = Y(1)
      DO 35 I =1,M
      IF(X(I).GT.XX)XX = X(I)
      IF(X(I).LT.XM)XM = X(I)
      IF(Y(I).GT.YX)YX = Y(I)
35    IF(Y(I).LT.YM)YM = Y(I)
      SC = XX-XM
      IF(YX-YM.GT.SC)SC = YX-YM
      SX = 60./SC
      SY = 0.6*SX
      DO 38 I=1,70
      DO 38 J=1,70
38    PLOT(I,J) = ' '
      IMAX = 1
      DO 40 K=1,M
      J = (X(K)-XM)*SX +1.
      I = (Y(K)-YM)*SY +1.
      IF(I.GT.IMAX)IMAX = I
40    PLOT(I,J) = '*'
      IF(IOUT.EQ.2)WRITE(2,41)

41    FORMAT(1H1)
C
      DO 50 I=1,IMAX
      LM = 61
      DO 44 J=1,60
      IF(PLOT(I,LM).NE.' ')GO TO 45
44    LM = LM-1
45    WRITE(IOUT,47)(PLOT(I,L),L=1,LM)
47    FORMAT(5X,71A1)
50    CONTINUE
      GO TO 1
      END

```

Figure 6. PATH GENERATING ROUTINE ( continued )

```

C SUBROUTINE PATH: PATH.FOR F12 30 DECEMBER 1980 J T FLECK
C PATH GENERATOR HVOSH RD-2
C ROUTINE USED IN HVOSH RD-2 TO GENERATE PATH DATA
C
C INPUTS:
C NPTS NUMBER OF POINTS DESIRED
C XINIT X COORDINATE OF FIRST POINT
C YINIT Y COORDINATE OF FIRST POINT
C DELL SPACING BETWEEN POINTS (ALONG STRAIGHT LINE)
C PSA INITIAL HEADING (TANGENT TO PATH)
C KLI NUMBER OF SECTIONS (CURVATURES)
C IF = 0 PROGRAM DEFAULTS TO POINTS IN DATA STATEMENT
C IF > 0 REQUIRES THE FOLLOWING INPUT L = 1, KLI
C DI(L) CURVATURE > 0 RIGHT TURN
C = 0 STRAIGHT
C < 0 LEFT TURN
C RLI(L) DISTANCE FROM INITIAL POINT WHERE DI(L)
C IS EFFECTIVE.
C DISTANCE IS MEASURED IN STRAIGHT LINE
C SEGMENTS BETWEEN POINTS. IF DISTANCE
C ALONG ARC IS REQUIRED SUBROUTINE SETD
C MUST BE MODIFIED.
C
C - NOTE: KLI MAY BE 1 OR GREATER
C E.G. TO GENERATE A STRAIGHT PATH N*DELL UNITS
C LONG AND THEN A RIGHT TURN WITH A CURVATURE OF 20
C INPUT KLI = 1, DI(1) = 20., RLI(1) = N*DELL
C THE ANGLE OF TURN IS GIVEN BY
C  $ANGLE = 2 * \arcsin[(DELL/2) * (PI/180) * (DI(L)/100)]$ 
C
C OUTPUT
C X(I), Y(I) COORDINATES OF POINT I I = 1 TO NPTS
C DX(I), DY(I) TANGENT AT POINT I (DIRECTION OF PATH)
C D(I) CURVATURE DEFINING PATH FROM POINT I TO POINT I+1
C
C
C SUBROUTINE PATH
C COMMON/PATHD/IPATH ,KLI ,DI(10),RLI(10).
C 1 NPTS,XINIT,YINIT,PSA,DELL.
C 2 X(100),Y(100),DX(100),DY(100),D(100)
C LIMIT ARRAY SIZES
C IF(KLI.GT.10)KLI = 10
C IF(NPTS.GT.100)NPTS = 100
C CALL SETD(KLI,DI,RLI,NPTS,DELL,D)
C SETD WAS MODIFIED ON 30 DEC 1980 TO PRODUCE SPIRAL
C INITIALIZE FIRST POINT AND TANGENT
C X(1) = XINIT
C Y(1) = YINIT
C DX(1) = COS(PSA)
C DY(1) = SIN(PSA)
C
C CALL PATHG(NPTS,DELL,X,Y,D,DX,DY)
C
C RETURN
C END

```

Figure 6. PATH GENERATING ROUTINE ( continued )

```

C PROBE.FOR F12
C SUBROUTINE PROBE: CALCULATES DISTANCE OF A POINT FROM CENTERLINE
C
C USED IN HVOSH RD-2 MOD'S
C
C INPUTS
C     XP,YP          GIVEN POINT
C     M              NUMBER OF REFERENCE POINTS (= NPTS)
C     X(I), Y(I)     REFERENCE POINTS OF PATH , I =1,NPTS
C     DX(I),DY(I)    TANGENT VECTOR AT REFERENCE POINT
C     D(I)           DEGREE OF CURVATURE AT BETWEEN POINT I AND I+1
C                   D > 0 RIGHT TURN
C                   D = 0 STRAIGHT LINE
C                   D < 0 LEFT TURN
C
C OUTPUTS
C     I              POINT IDENTIFYING SECTOR OF CLOSEST APPROACH
C     DIST           DISTANCE OF POINT FROM ARC
C                   POSITIVE IF POINT IS TO RIGHT OF ARC
C                   NEGATIVE IF POINT IS TO LEFT OF ARC
C     XX ,YY         POINT ON ARC NEAREST GIVEN POINT
C
C NOTE: ON FIRST ENTRY ROUTINE STARTS WITH I = 1, ON SUBSEQUENT
C       ENTRIES THE PREVIOUS VALUE OF I IS USED. THIS LOGIC SHOULD BE
C       ADEQUATE FOR THE PROPOSED USE OF THE ROUTINE.
C
C       CALCULATION OF XX AND YY MAY BE DELETED IF THIS POINT IS NOT NEEDED
C
C       SUBROUTINE PROBE(XP,YP,M,X,Y,DX,DY,D,I,DIST,XX,YY) :
C       DIMENSION X(1),Y(1),DX(1),DY(1),D(1)
C       DATA RAD/0.017453292519943296/,ILAST/1/
C INITIALIZE
C     I = ILAST
C     TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
C     TSAV = SIGN(1.0,TEST)
C     GO TO 15
C
C START SEARCH
C
C   7   I = I + 1
C       IF(I.LE.M)GO TO 10
C       IF(TSAV.LT.0.0)GO TO 20
C       I = M
C       GO TO 25
C  10   TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
C       IF(TEST*TSAV.LE.0.0)GO TO 25
C  15   IF(TEST)20,25,7
C  20   I = I - 1
C       IF(I.GE.1)GO TO 10
C       IF(TSAV.GT.0.0)GO TO 7
C       I = 1
C
C FINISH SEARCH
C   25  IF((TEST.LT.0.0).AND.(I.GT.1))I=I-1
C       ILAST = I
C FINISH OF DETERMINATION OF I

```

Figure 6. PATH GENERATING ROUTINE ( continued )

```

C
CALCULATE DISTANCE
  ZDN = -DY(I)*(XP-X(I))+DX(I)*(YP-Y(I))
  CONS = D(I)*RAD*0.005
  ZDZ = ((XP-X(I))**2+(YP-Y(I))**2)*CONS
  DIST = (ZDN-ZDZ)/(0.5+SQRT(0.25-CONS*(ZDN-ZDZ)))
C
CALCULATE POSITION OF CLOSEST APPROACH POINT ON ARC
C THE FOLLOWING CODE MAY BE DELETED AND THE REFERENCES TO XX AND YY TAKEN
C OUT OF THE CALL IF THE POINT OF CLOSEST APPROACH ON THE ARC IS NOT NEEDED
C
  DEN = 1.0-2.0*DIST*CONS
C
  IF(DEN.GT.0.0)GO TO 30
  WRITE(1,26)I,XP,YP,DIST,DEN
26  FORMAT(' SUBROUTINE PROBE HAS NEGATIVE OR ZERO DENOMINATOR'/
1    ' IN POSITION FORMULA; IMPLIES POINT NOT IN SECTOR'/I6,4F10.4)
  STOP PROBE
C THIS STOP SHOULD NEVER OCCUR IN NORMAL USAGE
C
30  XX = (XP-X(I)+DIST*DY(I))/DEN + X(I)
  YY = (YP-Y(I)-DIST*DX(I))/DEN + Y(I)
35  RETURN
  END
C
C
C*****
C  IF TANGENT VECTOR IS NOT AVAILABLE IT MAY BE REPLACED BY
C      DX = X(I+1)-X(I) , DY = Y(I+1)-Y(I) , I < M
C      DX = X(M) -X(M-1), DY = Y(M) -Y(M-1), I = M
C
C      USE DX FOR DX(I) AND DY FOR DY(I) IN CALCULATION OF TEST
C
C  RETURN CAN BE PUT AT END OF DETERMINATION OF I AND THE
C  DISTANCE AND CALCULATION OF XX,YY DONE BY ANOTHER ROUTINE.
C  (FORMULAS FOR DIST, XX AND YY ARE ONLY VALID FOR CIRCULAR ARCS
C  OR STRAIGHT LINES)

```

Figure 6. PATH GENERATING ROUTINE ( continued )

```

C PATHG.FOR F12          30 DECEMBER 1980          J T FLECK
C PATH GENERATOR, SUBROUTINE PATHG          HVOSH RD-2
C INPUTS
C      NPTS              NUMBER OF DESIRED POINTS ( > 1)
C      DELL              SPACING BETWEEN POINTS
C      X(1), Y(1)        INITIAL POSITION SET BY CALLING ROUTINE
C      DX(1), DY(1)      INITIAL TANGENT SET BY CALLING ROUTINE
C      D(I)              DEGREE OF CURVATURE, I = 1 TO NPTS
C                      D(I) > 0 TURN TO RIGHT
C                      D(I) = 0 STRAIGHT
C                      D(I) < 0 TURN TO LEFT
C      NOTE: RADIUS OF CURVATURE IS DEFINED AS
C              EQUAL TO  $(180/\pi) * (100/D) = (5729.6/D)$ 
C              (D HAS DIMENSION OF DEGREES PER 100 UNITS OF DELL)
C
C OUTPUTS                I = 1 TO NPTS
C      X(I), Y(I)        COORDINATES OF POINTS
C      DX(I), DY(I)      TANGENT VECTOR (DIRECTION OF PATH AT X,Y)
C
C NOTE: ROUTINE PRODUCES SMOOTH CURVE SUCH THAT TANGENTS ARE CONTINUOUS
C
C      SUBROUTINE PATHG(NPTS,DELL,X,Y,D,DX,DY)
C      DIMENSION X(1),Y(1),DX(1),DY(1),D(1)
C      DATA RAD/0.017453292519943296/
C INITIALIZE
C      CONS = DELL*RAD/200.0
C*
C      DXX = DELL*DX(1)
C      DYY = DELL*DY(1)
C*
C      DS1 = 0.0
C      DC1 = 1.0
C START LOOP
C      DO 20 I = 2, NPTS
C      COMPUTE SINE AND COSINE OF HALF SECTOR ANGLE
C      DS2 = CONS*D(I-1)
C      DC2 = SQRT((1.0-DS2)*(1.0+DS2))
C**
C      COMPUTE SINE AND COSINE OF SECTOR ANGLE
C      SP = 2.0*DS2*DC2
C      CP = 1.0 - 2.0*DS2**2
C UPDATE TANGENT VECTOR
C      DX(I) = CP*DX(I-1) - SP*DY(I-1)
C      DY(I) = SP*DX(I-1) + CP*DY(I-1)
C**
C      COMPUTE SINE AND COSINE OF AVERAGE SECTOR ANGLE
C      SP = DS1*DC2 + DC1*DS2
C      CP = DC1*DC2 - DS1*DS2
C      COMPUTE NEW INCREMENTS
C      DXS = DXX
C      DXX = DXS*CP - DYY*SP
C      DYY = DXS*SP + DYY*CP
C UPDATE POSITION
C      X(I) = X(I-1) + DXX
C      Y(I) = Y(I-1) + DYY
C SAVE SINE AND COSINE OF HALF SECTOR ANGLE FOR NEXT I
C      DS1 = DS2
C      DC1 = DC2
C      20 RETURN
C      END

```

Figure 6. PATH GENERATING ROUTINE ( continued )

Neuro-Muscular Filter.--The "neuro-muscular" filter from the HVOSM-Vehicle Dynamics Version (7) was incorporated into the HVOSM Roadside Design version. The filter structure corresponds to the first-order effects of the neurological and muscular systems of a human driver.

For the curve study, the following inputs were used for the filter for all runs:

TIL	Time lag of filter	0.05	seconds
TI	Time lead of filter	0.00905	seconds
TAUF	Time delay of filter	0.0	seconds

The related revisions to the Driver model were incorporated into the FHWA distributed Roadside Design version of the HVOSM. However, the revised path-following algorithm was found to produce sustained oscillations about a specified path under some operating conditions. Since the extent of oscillation is dependent on the guidance system parameters as well as the vehicle speed and path curvature, it is possible to obtain peak values of transient response predictions that reflect an artifact of the guidance system rather than a real effect of the highway geometrics under investigation. For example, in Reference (12), comparisons are made between peak transient and steady-state response values which are believed to be more reflective of effects of the guidance system than of the simulated roadway geometrics. Therefore, the following additional modifications were added to the Driver model:

(1) Damping

A damping term (QGAIN) was added to limit the extent of steering activity. Initial runs utilizing the damping term exhibited a reduction in the steering activity as expected. The value used in the curve study was  $QGAIN \text{ (rad-sec/m)} = PGAIN/10$ , where PGAIN is the steering velocity term described below.

(2) Steer Velocity

In addition to the damping term, an adjustable limit on the steering angle velocity was incorporated in the path-follower algorithm, enabling the user to limit the maximum instantaneous front wheel steer velocity to a selected value.

(3) Steer Initialization

For runs such as those being performed in relation to the cross-slope break study, the starting point must be relatively close to the cross-slope break to achieve an economical use of computer time. Thus, the input of an initial steer angle to approximate steady-state steer was

required. Previously, the path-follower algorithm was initialized to a steer angle of 0.0 degrees, regardless of the input value for the initial steer angle. Corresponding revisions were made to Subroutine DRIVER to enable input of an initial steer angle.

A revised listing of Subroutine DRIVER, including the cited modifications, is presented in Figure 7.

### Dual Tires

To permit the comparison simulation runs to be performed, the HVOSM program had to be modified to enable the simulation of dual rear tires such as are found in many single-unit trucks. The modification required to simulate dual rear tires consisted of a modification to subroutine TIRFRC to double the tire forces at the rear when the option is chosen. While a more elaborate definition of dual rear tires could be pursued, the selected approach was most efficient and equivalent to that used in the PHASE4 program.

```

05710 C SUBROUTINE DRIVER FOR HVOSM RD-2
05720 C
05730 SUBROUTINE DRIVER(PSI,DPSI,JJ,IFLAG,A,B,AMTI,CHCPS)
05740 DIMENSION AMTX(3,3),PPD(50),TPD(50)
05750 COMMON/PATHD/IPATH,KLI,DI(10),RLI(10),NPTS,XINIT,YINIT,
05760 I PSA,DELL,X(100),Y(100),DX(100),DY(100),D(100)
05770 COMMON/WAGON/IWAGN,TPRB,DPRB,PLGTH,PMIN,PMAX,PGAIN,QGAIN,PSIFD
05780 COMMON/FILT/IFILT,TIL,TI,THT,TAUF
05790 COMMON/INTG/NEQ,T,DT,VAR(50),DER(50)
05800 COMMON/ACC/CHFCG,CHFA1,CHFA2
05810 DATA NPDMAX/50/,NPD/0/,DPSL/0.0/,H/0/
05820 JJ = 0
05830 IF(IWAGN.EQ.0)GO TO 90
05840 JJ = 1
05850 PSIA = PSI
05860 DTP = DPRB
05870 DPS = 0.0
05880 DPSI = 0.0
05890 IF(IFLAG.EQ.0)GO TO 90
05900 IF(TPRB.GT.T + 0.1*DT)GO TO 10
05910 C COMPUTE NEW CHANGE IN STEER ANGLE
05920 TPRB = TPRB + DPRB
05930 XP = VAR(18) + AMTX(1,1)*PLGTH
05940 YP = VAR(19) + AMTX(2,1)*PLGTH
05950 CALL PRDCE(XP,YP,NPTS,X,Y,DX,DY,D,IPRB,DIST,XX,YY)
05960 C SELECTED POINT INDEX IPRB AND LOCATION OF CLOSEST POINT ON PATH XX,YY
05970 C ARE NOT CURRENTLY USED
05980 IF(DIST.EQ.0.0)GO TO 8
05990 SQND=DIST/ABS(DIST)
06000 IF(T.NE.TPRB) DDIST = (DIST-DISTA)/DPRB
06010 9 IF(ABS(DIST).GT.PMIN)DPS = -PGAIN*(ABS(DIST)-PMIN)*SQND
06020 1 -QGAIN*DDIST
06030 8 IF(ABS(DIST).LE.PMIN) DPS= -QGAIN*DDIST
06040 IF(IFILT.EQ.0)GO TO 55
06050 IF(NPD.EQ.NPDMAX)GO TO 10
06060 NPD = NPD + 1
06070 PPD(NPD) = DPS - PSIA
06080 TPD(NPD) = T + TAUF
06090 10 IF(IFILT.EQ.0)GO TO 55
06100 C
06110 C FILTER
06120 C
06130 IF(NPD.EQ.NPDMAX) GO TO 10
06140 TPDTHP = TPD(N)
06150 DO 20 NN = 1,NPD
06160 N = NPD + 1 - NN
06170 20 IF(T.GE.TPD(N))GO TO 30
06180 GO TO 90
06190 30 IF(TPDTHP.LT.TPD(N)) DPSL = 0.0
06200 DPSI = PPD(N)*THT*EXP(-(T - TPD(N))/TIL)/TIL
06210 DPSN = PPD(N) - TIL*DPSI
06220 DTP = 0.0
06230 DPS = DPSN - DPSL
06240 DPSL = DPSN
06250 IF(NPD.EQ.1)GO TO 50
06260 C
06270 C

```

Figure 7. SUBROUTINE DRIVER



```

06280 35 L = 1
06290 DO 40 MN = N,NPD
06300 PPD(L) = PPD(MN)
06310 TPD(L) = TPD(MN)
06320 40 L = L + 1
06330 NPD = L - 1
06340 C
06350 50 PSI = PSIA + DPS
06360 GO TO 59
06370 55 PSI = DPS
06380 58 CONTINUE
06390 C CHECK PREVIOUS TIME INTERVAL COMFORT FACTOR (SEE SUBROUTINE OUTPUT)
06400 C IF GREATER THAN PMAX ALLOW ONLY REDUCTION IN STEER ANGLE
06410 IF((PMAX.GT.0.0).AND.(ABS(CMFA1).LT.PMAX))GO TO 60
06420 IF(ABS(PSI).GT.ABS(PSIA)) PSI=PSIA
06430 60 CONTINUE
06440 C CHECK MAX STEER ANGLE
06450 IF((OMGPS.GT.0.0).AND.(ABS(PSI).GT. OMGPS))
06460 1 PSI = SIGN(OMGPS,PSI)
06470 IF(DTP.NE.0.0)DPSI = (PSI-PSIA)/DTP
- 06480 C+++ 1/16/81 MCI *****
06490 DPSO = DPS+57.2958
06500 PSIAO = PSIA+57.2958
06510 PSIO = PSI+57.2958
06520 DELPSI = PSIO- PSIAO
06530 XPFT = XP/12.0
06540 YPFT = YP/12.0
06550 XXFT = XX/12.0
06560 YYFT = YY/12.0
06570 C IF(FKD.EQ.1.0) GO TO 90
06580 IF(KPAGE.LE.50.AND.T.NE.0.0000) GO TO 110
06590 WRITE(50,100)
06600 100 FORMAT(
06610 A1H1,33X,37HPROBE COORDINATES PATH COORDINATES,5X,3#PSI,6X,
06620 B3HDPS,6X,4#PSIA,2X,7HDPSI ,2X,7HDPSN ,5HIFLAG,2X,4HIPRB/
06630 C3IH TIME DELTA PSIF ERROR ,6X,1HX,9X,1HY,10X,1HX,8X,1HY/
06640 D3IH (SEC) (DEG) (IN) ,4X,4H(FT),6X,4H(FT),7X,
06650 E4H(FT),5X,4H(FT)/)
06660 KPAGE = 0
06670 110 WRITE(50,120) T,DELPSI,DIST,XPFT,YPFT,XXFT,YYFT,PSIO,DPSO,
06680 A PSIAO,DPSI,DPSN,IFLAG,IPRB
06690 120 FORMAT(1H ,F7.3,2(4X,F7.3),2(3X,F7.1),2X,2(2X,F7.1),3(2X,F7.4),
06700 A 2X,F7.5,2X,F7.5,2X,13,2X,12)
06710 KPAGE = KPAGE + 1
06720 90 RETURN
06730 C*****
06740 END
06750 C*****

```

Figure 7. SUBROUTINE DRIVER ( continued )

## Appendix B - HSRI/MVMA PHASE4 Modifications

### New Routines Added to PHASE4 Program

Several new routines were added to the PHASE4 simulation program to permit the use of identical terrain definitions and/or driver model path-following in the PHASE4 and HVOSM simulation programs. The routines added to the PHASE4 program are essentially routines from either the HVOSM-76 (7) or the HVOSM-81 (routines previously added or modified within this contract).

The routines added to the PHASE4 program are as follows:

**INPUT2** Purpose:

- (1) Obtains card inputs from Fortran Unit 7 for terrain table and/or driver model option(s)
- (2) Prints card inputs.

Subroutine called from: INPUT

Subroutines called: BLK04, BLK05, PATH, IDOUT

Origin: Modified version\* of subroutine INPUT from HVOSM-76

**BLK04** Purpose: Assigns input values of simulation driver model data

Subroutine called from: INPUT2

Subroutine called: none

Origin: Modified version of subroutine BLK04 from HVOSM-76

**BLK05** Purpose: Assigns input values of simulation terrain table data

Subroutine called from: INPUT2

Subroutine called: TEREAD

Origin: Modified version of subroutine BLK05 from HVOSM-76

**TEREAD** Purpose: Reads terrain table input cards

Subroutine called from: BLK04

Subroutines called: none

Origin: Subroutine TEREAD from HVOSM-76

---

\* The modifications mentioned herein to the HVOSM routines consisted of the elimination of unnecessary codes and storage prior to their installation into the PHASE4 program.



DRIVE1 Purpose: Computes the front wheel steer angle from the driver model and path descriptor inputs  
Subroutine called from: FCT1  
Subroutines called: PROBE, CGERR  
Entry points: DRIVER, DRIVE2  
Origin: Modified version of subroutine DRIVER from HVOSM-81

PROBE PURPOSE: Calculates the error of an arbitrary point on the vehicle from the desired path  
Subroutines called from: DRIVE1  
Subroutines called: none  
Origin: Subroutine PROBE from HVOSM-81

CGERR Purpose: Calculates the error of the vehicle center of gravity from the desired path  
Subroutine called from: DRIVE1  
Subroutine called: none  
Origin: Subroutine CGERR from HVOSM-81

#### Modified Routines for the PHASE4

Two routines for the PHASE4 program required modification to enable their use with the program. The modified routines are as follows:

INPUT Purpose: Reads card inputs and echo's input parameters with units and headings and initializes variables

Modifications:

- (1) Print card inputs prior to echo
- (2) Call to INPUT2 to input and process terrain table and or driver model inputs

MAIN Purpose: Assign i/o devices, initialize variables, and act as program supervisor

Modifications:

- (1) Input and initialize initial heading angle
- (2) Permit the setting of initial conditions caused by road when terrain table option used

The program listings for the added and modified routines are shown in Figure 8.

```

0001 SUBROUTINE INPUT2(DZX,DZY,ROAD,ISTEER) 00000010
      C*** MODIFICATIONS PER FH-11-9575 "STUDY OF CENTERLINE CROWN" 00000020
      C*** INSTALLED IN HSRI/MVMA PHASE4 SIMULATION MODEL 00000030
      C*** NOVEMBER 1982 BY MCHENRY CONSULTANTS, INC. 00000040
      C*** UNDER SUBCONTRACT TO JACK E. LEISCH & ASSOC. 00000050
      C*** CONTRACT NO. D01-FH-11-9575 00000060
      C*** 00000070
      C*** INSTALLED ROUTINE TO ENABLE USE OF MVOSH TERRAIN TABLES 00000080
      C*** AND MVOSH DRIVER-PATH FOLLOWER ROUTINES IN PHASE4 00000090
      C*** ALL ROUTINES FROM MVOSH-76 AND MODIFICATIONS FROM HTIS CONTRACT 00000100
      C*** 00000110
      C*** INPUT2 ROUTINE FORMERLY SUBROUTINE INPUT FROM MVOSH-76 RD2 00000120
      C*** ROUTINE TO READ MVOSH CARD IMAGES INTO STORAGE FOR USE 00000130
      C*** WITH HSRI/MVMA TRACTOR TRAILOR SIMULATION PROGRAM 00000140
0002 COMMON/PAGE/NP,HEAD(20),R,W 00000150
0003 INTEGER R,W 00000160
0004 DIMENSION CARDIM(20),ICARD(300),DUM(18) 00000170
0005 DATA NBLKS/6/ 00000180
0006 WRITE(W,930) 00000190
0007 930 FORMAT('1 00000200
      41H ,5X, CARD INPUTS FROM UNIT 7 AS FOLLOWS: '//) 00000210
      C SET INPUT CARD COUNTER 00000220
0008 NC = 0 00000230
      C READ A CARD 00000240
0009 1 READ(7,5000) (CARDIM(K),K=1,18),NSEQ,NCARD 00000250
0010 5000 FORMAT(18A4,2I4) 00000260
      C OUTPUT CARD IMAGE 00000270
0011 WRITE(W,6000) (CARDIM(K),K=1,18),NSEQ,NCARD 00000280
0012 6000 FORMAT(1H,13X,18A4,2I4) 00000290
0013 IF(NCARD.GE.9999) GO TO 20 00000300
0014 IF(NCARD.LE.0) GO TO 90 00000310
0015 IF(NSEQ.GT.0) GO TO 1 00000320
0016 NC = NC+1 00000330
0017 ICARD(NC) = NCARD 00000340
0018 GO TO 1 00000350
0019 20 REWIND 7 00000360
      C TEST FOR AT LEAST ONE CARD OTHER THAN 9999 00000370
0020 IF(NC.LE.0) GO TO 91 00000380
      C SET COUNTER TO PROCESS ALL BLOCK NUMBERED CARDS 00000390
0021 IC = 1 00000400
      C DETERMINE CARD FORMAT AND TRANSFER TO PROPER CARD BLOCK 00000410
      C SUBROUTINE TO STORE DATA 00000420
0022 21 NBLK = ICARD(IC)/100 00000430
0023 NBCRD = ICARD(IC)-NBLK*100 00000440
      C FORMAT TEST 00000450
0024 IF(NBCRD.EQ.0) GO TO 22 00000460
      C NUMERIC INPUT 00000470
0025 READ(7,2000) (DUM(K),K=1,9),NSEQ,NCARD 00000480
0026 2000 FORMAT(9F8.0,2I4) 00000490
0027 GO TO 23 00000500
0028 22 CONTINUE 00000510
      C ALPHANUMERIC INPUT 00000520
0029 READ(7,2001) (DUM(K),K=1,18),NSEQ,NCARD 00000530
0030 2001 FORMAT(18A4,2I4) 00000540
      C BRANCH TO PROPER SUBROUTINE TO STORE INPUT 00000550
0031 23 IF(NBLK.LE.0) GO TO 92 00000560
0032 IF(NBLK.GT.NBLKS) GO TO 93 00000570
0033 GO TO(30,30,30,400,500,30),NBLK 00000580
      C PRINT ERROR MESSAGE HERE ? 00000590
0034 GOTO 94 00000600
0035 400 CALL BLK04(NBLK,NBCRD,NSEQ,NCARD,DUM,NERR) 00000610
0036 IF(NERR.EQ.0) GOTO 30 00000620
0037 GOTO 94 00000630
0038 500 NERR = 0 00000640
0039 CALL BLK05(NBLK,NBCRD,NSEQ,NCARD,DUM,NERR) 00000650
0040 IF(NERR.EQ.0) GO TO 30 00000660
0041 GO TO 94 00000670
0042 30 CONTINUE 00000680
      C TEST IF ALL CARDS ARE READ 00000690
0043 IC = IC+1 00000700
0044 IF(IC.GT.NC) GO TO 40 00000710
      C GET NEXT CARD FROM UNIT 7 00000720
0045 GO TO 21 00000730
0046 40 CONTINUE 00000740
      C SEARCH FOR END OF DATA 00000750
0047 READ(7,2001) (DUM(K),K=1,18),NSEQ,NCARD 00000760
0048 IF(NCARD.NE.9999) GO TO 95 00000770
0049 GO TO 50 00000780
0050 90 WRITE(W,6002) 00000790
0051 6002 FORMAT(56H A CARD NUMBERED LESS THAN OF EQUAL TO ZERO HAS ENCOUNTERED 00000800
      1 50HRED IN SUBROUTINE INPUT. CARD IMAGE PRINTED ABOVE ) 00000810
      C GO TO 49 00000820
0052 91 WRITE(W,6003) 00000830
0053 6003 FORMAT(33H THE NUMBER OF CARDS READ IS ZERO ) 00000840
      C GO TO 49 00000850
0054 92 WRITE(W,6004) 00000860
0055 6004 FORMAT(56H A BLOCK NUMBER OF LESS THAN OF EQUAL TO ZERO HAS BEEN 00000870
      1 7HBTAINED ) 00000880
      C GO TO 49 00000890
0056 93 WRITE(W,6005) 00000900
0057 6005 FORMAT(56H A BLOCK NUMBER LARGER THAN THE ALLOWED NUMBER HAS BEEN 00000910
      1 8HBTAINED ) 00000920
      C GO TO 49 00000930
0058 94 WRITE(W,6006) NBLK,NBCRD,NSEQ,NCARD,NERR 00000940
0059 6006 FORMAT(56H AN ERROR HAS OCCURRED IN STORING INPUT VALUES IN ONE OF 00000950
      1 23H THE BLKXX SUBROUTINES. 00000960
      2 39H THE CALLING ARGUMENTS FROM INPUT ARE : 00000970
      3 7H NBLK = ,14,2X,7HNBCRD = ,14,2X,6HNSEQ = ,14,2X,7HNCARD = , 00000980
      4 14,2X,6HNERR = ,14 ) 00000990
      C GO TO 49 00010000
0060 95 WRITE(W,6007) 00010010
0061 6007 FORMAT(56H AM EXPECTED 9999 CARD HAS NOT BEEN ENCOUNTERED AFTER ST 00010020
      1 20H HT NO. 40 IN INPUT. ) 00010030
      C 49 STOP 00010040
0062 50 IF(ROAD.LT.0)CALL ROAD(0,0,DZX,DZY) 00010050
0063 C CALL PATH TO SET UP PATH FOLLOWER TABLES 00010060
      C IF(ISTEER.LT.0) CALL PATH 00010070
      C CALL IDOUT TO ECHO INPUT PARAMETERS 00010080
0070 CALL IDOUT(ROAD,ISTEER) 00010090
0071 RETURN 00010100
0072 END 00010110

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL

```

0001      C
          C
          SUBROUTINE BLK04(NBLK,NBCRD,NSEQ,NCARD,DUM,NERR)
          C
          C*** MODIFICATIONS PER FH-11-9575, "STUDY OF CENTERLINE CROWN"
          C*** INSTALLED IN HSRI/MVMA PHASE 4 SIMULATION MODEL
          C*** NOVEMBER 1982 BY MCMENRY CONSULTANTS, INC.
          C*** UNDER SUBCONTRACT TO JACK E. LEISCH & ASSOC.
          C***
          C*** INSTALLED ROUTINE TO ENABLE USE OF HVOSH TERRAIN TABLES IN PHASE 4
          C*** ALL ROUTINES FROM HVOSH-76 RD2
          C***
          C*** BLK04 ROUTINE FROM HVOSH-76 RD2
          C*** HVOSH-RD2 VERSION
          C*** REVISED OCTOBER 1975 CALSPAN CORPORATION
0002      COMMON/PATHD/IPATH,KLI,DI(10),RLI(10),NPTS,XINIT,YINIT,
0003      1 PSA,DELL,X(100),Y(100),DX(100),DY(100),D(100),CHED(20),
          C*** COMMON/HAGON/IMAGN,TPRB,DPRB,PLGTH,PHIN,PHAX,PGAIN,QGAIN,PSIFD,
          C*** 1 TDOPT,TDPSI,TMAX
0004      COMMON/FILT/IFILT,TILT,TI,TMT,TAUF
0005      DIMENSION DUM(18)
0006      DATA NBS/5/
0007      NBT = NBCRD+1
0008      IF(NBT.LT.1.OR.NBT.GT.NBS+1) GO TO 98
0009      GO TO(400,98,402,403,404,405),NBT
0010      GO TO 98
0011      400 IF(NCARD.NE.400) GO TO 98
0012      DO 10 I=1,18
0013      10 CHED(I) = DUM(I)
0014      GO TO 99
0015      402 IF(NCARD.NE.402) GO TO 98
0016      IPATH = IFIX(DUM(1))
0017      IMAGN = IFIX(DUM(2))
0018      IFILT = IFIX(DUM(3))
0019      TILT = DUM(4)
0020      TI = DUM(5)
0021      IF(TILT.NE.0.0) TMT = (TILT-TI)/TILT
0022      TAUF = DUM(6)
0023      GO TO 99
0024      403 IF(NCARD.NE.403.OR.IPATH.NE.1) GO TO 98
0025      KLI = IFIX(DUM(1))
0026      NPTS = IFIX(DUM(2))
0027      XINIT = DUM(3)
0028      YINIT = DUM(4)
0029      PSA = DUM(5)
0030      DELL = DUM(6)
0031      GO TO 99
0032      404 IF(NCARD.NE.404.OR.KLI.EQ.0) GO TO 98
0033      N1 = 1
0034      N3 = N1+3
0035      4041 DO 4042 I = N1,N3
0036      H = (1 - N1)/2 + 1
0037      DI(I) = DUM(H)
0038      RLI(I) = DUM(H+1)
0039      4042 CONTINUE
0040      IF(KLI.LE.4.OR.NSEQ.EQ.1) GO TO 99
0041      READ(5000) (DUM(N),N=1,9), NSEQ,NCARD
0042      5000 FORMAT(9F8.0,2I4)
0043      IF(NSEQ.NE.1.OR.NCARD.NE.404) GO TO 98
0044      N1 = 5
0045      N3 = 9
0046      GO TO 4041
0047      405 IF(NCARD.NE.405.OR.IMAGN.EQ.0) GO TO 98
0048      TPRB = DUM(1)
0049      DPRB = DUM(2)
0050      PLGTH = DUM(3)
0051      PHIN = DUM(4)
0052      PHAX = DUM(5)
0053      PSIFD = DUM(6)
0054      PGAIN = DUM(7)
0055      QGAIN = DUM(8)
0056      TMAX = DUM(9)
0057      GO TO 99
0058      98 NERR = 1
0059      99 RETURN
0060      END

```

```

00001120
00001130
00001140
00001150
00001160
00001170
00001180
00001190
00001200
00001210
00001220
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00001500
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00001600
00001610
00001620
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00001790
00001800
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00001890
00001900

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

```

0001 SUBROUTINE BLK05(NBLK,NBCRD,NSEQ,NCARD,DUM,NERR) 00001910
C*** MODIFICATIONS PER FH-11-9575 "STUDY OF CENTERLINE CROWN" 00001920
C*** INSTALLED IN HSRI/MVMA PHASE 4 SIMULATION MODEL 00001930
C*** NOVEMBER 1982 BY MCHENRY CONSULTANTS, INC. 00001940
C*** UNDER SUBCONTRACT TO JACK E. LEISCH & ASSOC. 00001950
C*** 00001960
C*** INSTALLED ROUTINE TO ENABLE USE OF HVOSH TERRAIN TABLES IN PHASE 4 00001970
C*** ALL ROUTINES FROM HVOSH-76 RD2 00001980
C*** 00001990
C*** BLK05 ROUTINE FROM HVOSH-76 RD2 00002000
C*** HVOSH-RD2 VERSION 00002010
C*** REVISED OCTOBER 1975 CALSPAN CORPORATION 00002020
0002 COMMON/HVROAD/GHED(20),NZTAB,XB(5),XE(5),XINCR(5), 00002030
1 YB(5),YE(5),YINCR(5),NZ5,NX(5),NY(5) 00002040
2 XBERO(8,5),XEERO(8,5),YBERO(8,5),YEERO(8,5),IERABX,IERABY, 00002050
3 NNBX(5),NNBY(5),XBDRY(8,5),PSBDR(8,5),YBDRY(2,5), 00002060
4 ZGP(21,21,5),YYZGPS(21),XXZGPS(21) 00002070
0003 DIMENSION DUM(18) 00002080
0004 DATA NBS/15/ 00002090
0005 NBT = NBCRD+1 00002100
0006 IF(NBT.LT.1.OR.NBT.GT.NBS+1) GO TO 98 00002110
0007 GO TO (500,501,502,503,504,505, 00002120
1 514,515),NBT 00002130
0008 GO TO 98 00002140
0009 500 IF(NCARD.NE.500) GO TO 98 00002150
0010 DO 10 I=1,18 00002160
0011 10 GHED(I) = DUM(I) 00002170
0012 GO TO 99 00002180
0013 501 IF(NCARD.NE.501) GO TO 98 00002190
0014 IF(NZTAB.LT.1) NZTAB=1 00002200
0015 IERABX=0 00002210
0016 IERABY=0 00002220
0017 I = 1 00002230
0018 GO TO 20 00002240
0019 502 IF(NCARD.NE.502) GO TO 98 00002250
0020 IF(NZTAB.LT.2) NZTAB = 2 00002260
0021 I = 2 00002270
0022 GO TO 20 00002280
0023 503 IF(NCARD.NE.503) GO TO 98 00002290
0024 IF(NZTAB.LT.3) NZTAB = 3 00002300
0025 I = 3 00002310
0026 GO TO 20 00002320
0027 504 IF(NCARD.NE.504) GO TO 98 00002330
0028 IF(NZTAB.LT.4) NZTAB = 4 00002340
0029 I = 4 00002350
0030 GO TO 20 00002360
0031 505 IF(NCARD.NE.505) GO TO 98 00002370
0032 NZTAB = 5 00002380
0033 I = 5 00002390
C 20 NPAGE(15) = 1 00002400
20 XB(1) = DUM(1) 00002410
XB(2) = DUM(2) 00002420
XE(1) = DUM(3) 00002430
XINCR(1) = DUM(4) 00002440
YB(1) = DUM(5) 00002450
YE(1) = DUM(6) 00002460
YINCR(1) = DUM(7) 00002470
NNBX(1) = IFIX(DUM(8)) 00002480
NNBY(1) = IFIX(DUM(9)) 00002490
NZ5 = IFIX(DUM(10)) 00002500
NNBX = NNBX(1) 00002510
NNBY = NNBY(1) 00002520
IF(NZ5.GT.0) GO TO 21 00002530
NNX = IFIX((XB(1)-XB(2))/XINCR(1) + 1.2) 00002540
NNY = IFIX((YE(1)-YE(2))/YINCR(1) + 1.2) 00002550
NX(1) = NNX 00002560
NY(1) = NNY 00002570
CALL TEREAD(I,NNBX,NNBY,NNX,NNY,NZ5,NERR) 00002580
IF(NERR.NE.0) GO TO 98 00002590
GO TO 99 00002600
21 NNX = IFIX(DUM(3)) 00002610
NNY = IFIX(DUM(6)) 00002620
NX(1) = NNX 00002630
NY(1) = NNY 00002640
NZ5 = 1 00002650
CALL TEREAD(I,NNBX,NNBY,NNX,NNY,NZ5,NERR) 00002660
IF(NERR.NE.0) GO TO 98 00002670
GO TO 99 00002680
514 IF(NCARD.NE.514) GO TO 98 00002690
I = IFIX(DUM(9)) 00002700
DO 5141 J=1,4 00002710
J1 = (J-1)*2 + 1 00002720
J2 = J*2 00002730
XBERO(J,1) = DUM(J1) 00002740
XEERO(J,1) = DUM(J2) 00002750
5141 CONTINUE 00002760
IF(NBX(1).LE.4) GO TO 5144 00002770
READ(7,5142) (DUM(N),N=1,9),NSEQ,NCARD 00002780
FORMAT(9F8.0,2I4) 00002790
I = IFIX(DUM(9)) 00002800
IF(I.NE.1) GO TO 98 00002810
DO 5143 J=1,4 00002820
J1 = (J-1)*2 + 1 00002830
J2 = J*2 00002840
JJ = J+4 00002850
XBERO(JJ,1) = DUM(J1) 00002860
XEERO(JJ,1) = DUM(J2)

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

0080	5143 CONTINUE	00002870
0081	5144 IF(NZTAB.LE.1) GO TO 5145	00002880
0082	READ(7,5142) (DUM(N),N=1,9),NSEQ,NCARD	00002890
0083	GO TO 514	00002900
0084	5145 IERARX = 1	00002910
0085	GO TO 99	00002920
0086	515 IF(NCARD.NE.515) GO TO 98	00002930
0087	I = IFIX(DUM(9))	00002940
0088	DO 5151 J = 1,4	00002950
0089	J1 = (J-1)*2 + 1	00002960
0090	J2 = J*2	00002970
0091	YBERO(J,I) = DUM(J1)	00002980
0092	YEERO(J,I) = DUM(J2)	00002990
0093	5151 CONTINUE	00003000
0094	IF(NBX(I).LE.4) GO TO 5154	00003010
0095	READ(7,5142) (DUM(N),N=1,9), NSEQ,NCARD	00003020
0096	I1 = IFIX(DUM(9))	00003030
0097	IF(I1.NE.1) GO TO 98	00003040
0098	DO 5153 J = 1,4	00003050
0099	J1 = (J-1)*2 + 1	00003060
0100	J2 = J*2	00003070
0101	JJ = J*4	00003080
0102	YBERO(JJ,I) = DUM(J1)	00003090
0103	YEERO(JJ,I) = DUM(J2)	00003100
0104	5153 CONTINUE	00003110
0105	5154 IF(NZTAB.LE.1) GO TO 5155	00003120
0106	READ(7,5142) (DUM(N),N=1,9),NSEQ,NCARD	00003130
0107	GO TO 515	00003140
0108	5155 IERABY = 1	00003150
0109	GO TO 99	00003160
0110	98 NERR = 1	00003170
0111	99 RETURN	00003180
0112	END	00003190

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )



```

0001 SUBROUTINE TEREAD(I,NNBX,NNBY,NNX,NNY,NZST,NERR)
C*** MODIFICATIONS PER FH-11-9572 STUDY OF CENTERLINE CROWN"
C*** INSTALLED IN HSRI/MVMA PHASE 4 SIMULATION MODEL
C*** NOVEMBER 1982 BY MCMENRY CONSULTANTS INC.
C*** UNDER SUBCONTRACT TO JACK E. LEISCH & ASSOC.
C***
C*** INSTALLED ROUTINE TO ENABLE USE OF MVOSM TERRAIN TABLES IN PHASE 4
C*** ALL ROUTINES FROM MVOSM-76
0002 COMMON/HVROAD/GHED(20),NZTAB,XB(5),XE(5),XINCR(5),
1 YB(5),YE(5),YINCR(5),NZ5,NX(5),NY(5),
2 XBERO(8,5),XEERO(8,5),YBERO(8,5),YEERO(8,5),IERABX,IERABY,
3 NBX(5),NBY(5),XBDRY(8,5),PSBDRG(8,5),YBDRY(2,5),
4 ZGP(21,21,5),YYZGPS(21),XXZGPS(21)
0003 DIMENSION DUM(18)
0004 LSEQ = 0
0005 IF(NNBX.LE.0) GO TO 10
0006 READ(7,2000) (DUM(K),K=1,9),NSEQ,NCARD
0007 FORMAT(9F8.0,2I4)
0008 IF(NSEQ.LT.LSEQ) GO TO 98
0009 LSEQ = NSEQ
0010 IF(NNBX.GT.8) GOTO 98
0011 DO 11 K=1,NNBX
0012 11 XBDRY(K,1) = DUM(K)
0013 READ(7,2000) (DUM(K),K=1,9),NSEQ,NCARD
0014 IF(NSEQ.LT.LSEQ) GO TO 98
0015 LSEQ = NSEQ
0016 DO 12 K=1,NNBX
0017 12 PSBDRG(K,1) = DUM(K)
0018 IF(NNBY.LE.0) GO TO 20
0019 IF(NNBY.GT.2) GO TO 98
0020 READ(7,2000) (DUM(K),K=1,9),NSEQ,NCARD
0021 IF(NSEQ.LT.LSEQ) GO TO 98
0022 LSEQ = NSEQ
0023 DO 13 K=1,NNBY
0024 13 YBDRY(K,1) = DUM(K)
0025 20 NYCDS = (NNY-1)/9+1
0026 DO 30 J=1,NNX
0027 M = 0
0028 DO 40 K=1,NYCDS
0029 READ(7,2000) (DUM(N),N=1,9),NSEQ,NCARD
0030 IF(NSEQ.LT.LSEQ) GO TO 98
0031 LSEQ = NSEQ
0032 DO 50 N=1,9
0033 M = M+1
0034 ZGP(J,M,1) = DUM(N)
0035 IF(M.GE.NNY) GO TO 30
0036 50 CONTINUE

```

```

0037 40 CONTINUE
0038 30 CONTINUE
0039 IF(NZST.EQ.0) GO TO 99
0040 M = 0
0041 DO 60 K=1,NYCDS
0042 READ(7,2000) (DUM(N),N=1,9),NSEQ,NCARD
0043 IF(NSEQ.LT.LSEQ) GO TO 98
0044 LSEQ = NSEQ
0045 DO 61 N=1,9
0046 M = M+1
0047 YYZGPS(M) = DUM(N)
0048 IF(M.GE.NNY) GO TO 70
0049 61 CONTINUE
0050 60 CONTINUE
0051 M = 0
0052 M = M+1
0053 DO 71 K=1,MYCDS
0054 READ(7,2000) (DUM(N),N=1,9),NSEQ,NCARD
0055 IF(NSEQ.LT.LSEQ) GO TO 98
0056 LSEQ = NSEQ
0057 DO 72 N=1,9
0058 M = M+1
0059 XXZGPS(M) = DUM(N)
0060 IF(M.GE.NNX) GO TO 99
0061 72 CONTINUE
0062 71 CONTINUE
0063 98 NERR = 1
0064 99 RETURN
0065 END

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

```

C
C
0001      SUBROUTINE PATH
C
C
0002      COMMON/PATHD/IPATH, KLI, DI(10), RLI(10),
1          NPTS, XINIT, YINIT, PSA, DELL
2          X(100), Y(100), DX(100), DY(100), D(100), CHED(20)
C LIMIT ARRAY SIZES
0003      IF(KLI.GT.10) KLI = 10
0004      IF(NPTS.GT.100) NPTS = 100
0005      CALL SETD(KLI, DI, RLI, NPTS, DELL, D)
C SETD WAS MODIFIED ON 30 DEC 1980 TO PRODUCE SPIRAL
C INITIALIZE FIRST POINT AND TANGENT
0006      X(1) = XINIT
0007      Y(1) = YINIT
0008      DX(1) = COS(PSA)
0009      DY(1) = SIN(PSA)
C
0010      CALL PATHG(NPTS, DELL, X, Y, D, DX, DY)
C
0011      RETURN
0012      C=====
      END

```

```

00002170
00002180
00002190
00002200
00002210
00002220
00002230
00002240
00002250
00002260
00002270
00002280
00002290
00002300
00002310
00002320
00002330
00002340
00002350
00002360
00002370
00002380
00002390
00002400

```

```

C
C
0001      SUBROUTINE PATHG(NPTS, DELL, X, Y, D, DX, DY)
C
C
C***  PATHF MCI *****
C***  PATH GENERATOR ROUTINE
C***
0002      DIMENSION X(1), Y(1), DX(1), DY(1), D(1)
0003      DATA RAD/0.017453292519943296/
C INITIALIZE
0004      CONS = DELL/RAD/200.0
C
0005      DX1 = DELL*DX(1)
0006      DYC = DELL*DY(1)
C
0007      DS1 = 0.0
0008      DC1 = 1.0
C START LOOP
0009      DO 20 I = 2, NPTS
C COMPUTE SINE AND COSINE OF HALF SECTOR ANGLE
0010      DS2 = CONS*D(I-1)
0011      DC2 = SQRT((1.0-DS2)*(1.0+DS2))
C**
C COMPUTE SINE AND COSINE OF SECTOR ANGLE
0012      SP = 2.0*DS2*DC2
0013      CP = 1.0 - 2.0*DS2**2
C UPDATE TANGENT VECTOR
0014      DX(I) = CP*DX(I-1) - SP*DY(I-1)
0015      DY(I) = SP*DX(I-1) + CP*DY(I-1)
C**
C COMPUTE SINE AND COSINE OF AVERAGE SECTOR ANGLE
0016      SP = DS1*DC2 + DC1*DS2
0017      CP = DC1*DC2 - DS1*DS2
C COMPUTE NEW INCREMENTS
0018      DXS = DX1
0019      DXK = DXS*CP - DYC*SP
0020      DYC = DXS*SP + DYC*CP
C UPDATE POSITION
0021      X(I) = X(I-1) + DXK
0022      Y(I) = Y(I-1) + DYC
C SAVE SINE AND COSINE OF HALF SECTOR ANGLE FOR NEXT I
0023      DS1 = DS2
0024      DC1 = DC2
0025      RETURN
C
C
C=====
C CODE BETWEEN C**'S MAY BE DELETED IF TANGENT VECTORS
C ARE NOT REQUIRED: HOWEVER IN THE CODE BETWEEN THE C**'S
C DX(1) IS COS(PSI1) AND DY(1) IS SIN(PSI1), THESE WERE SET
C BY CALLING PROGRAM.
C POLYNOMIAL OR OTHER TYPE OF FITS TO THE X(I) AND Y(I) MAY
C BE DONE BY OTHER ROUTINES
C=====
0026      END

```

```

00002410
00002420
00002430
00002440
00002450
00002460
00002470
00002480
00002490
00002500
00002510
00002520
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00002800
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00002900
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00002960
00002970

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

```

0001      SUBROUTINE IDOUT(IROAD,ISTEER)
C***      MODIFICATIONS PER FM-11-9575 "STUDY OF CENTERLINE CROWN"
C***      INSTALLED IN HSRI/MVMA PHASE4 SIMULATION MODEL
C***      NOVEMBER 1982 BY MCENRY CONSULTANTS, INC.
C***      UNDER SUBCONTRACT TO JACK E. LEISCH & ASSOC.
C***      INSTALLED ROUTINE TO ENABLE USE OF MVOSH TERRAIN TABLES IN PHASE4
C***      ALL ROUTINES FROM MVOSH-76
C***
0002      INPUT ECHO ROUTINE FOR TERRAIN TABLE OPTION
0003      COMMON/PAGE/MP HEAD(20),R,M
      COMMON/HVROAD/GHED(20),NXTAB,XB(5),XE(5),XINCR(5),
1      YB(5),YE(5),YINCR(5),N25,NX(5),NY(5),
2      XBERO(8,5),KEERO(8,5),YBERO(8,5),YEERO(8,5),IERABX,IERABY,
3      NBX(5),NBV(5),YBDRY(8,5),PSBDRY(8,5),YBDRY(2,5),
4      ZGP(2),Z1(5),YXZGP5(2),XZGP5(2)
0004      COMMON/PATHD/PATH,KLI,D(100),DX(100),DY(100),D(100),CHED(20)
1      PSA,DELL,X(100),Y(100),NPTS,XINIT,YINIT,
0005      DIMENSION TTARG(50),NTARG(10)
0006      INTEGER R,M
0007      DIMENSION TXARG(21),TYARG(21)
0008      DIMENSION AMUG(5)
0009      DATA AMUG/5=1.0/
0010      DATA TTARG/50=0.0/,NTARG/10=0/
0011      DATA TXARG/21=0.0/,TYARG/21=0.0/
0012      DATA CON1/CONS/,VARI/VARI/
C
0013      RAD = 0.0174532925D0
0014      IF(NXTAB.EQ.0) GO TO 700
0015      930 FORMAT(1,2X,'HSRI/MVMA BRAKING AND HANDLING SIMULATION OF',
1      'TRUCKS, TRACTOR-SEMITRAILERS, DOUBLES, AND TRIPLES - PHASE4',
2      '4,1,1,36X,20A4',
3      '31H0,2X,'OPTIONAL INPUTS ADDED 9/82 BY MCI :',20A4/
4      '41H,38X,20A4/')
0016      DO 601 I=1,50
0017      601 TTARG(I) = 0.0
0018      DO 602 I=1,10
0019      602 NTARG(I) = 0
0020      DO 603 I=1,NXTAB
0021      TTARG(I) = XB(I)
0022      TTARG(5+I) = XE(I)
0023      TTARG(10+I) = XINCR(I)
0024      TTARG(15+I) = YB(I)
0025      TTARG(20+I) = YE(I)
0026      TTARG(25+I) = YINCR(I)
0027      TTARG(30+I) = AMUG(I)
0028      NTARG(I) = NBX(I)
0029      NTARG(5+I) = NBV(I)

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0030      603 CONTINUE
0031      WRITE(M,930) HEAD,GHED,CHED
0032      WRITE(M,6001)
0033      6001 FORMAT(//1H,26X,25H'TERRAIN TABLE ARGUMENTS' )
0034      WRITE(M,6002)
1      TTARG(1) = 1.5
2      TTARG(2) = 6.10
3      TTARG(3) = 11.14,ZERO,
4      TTARG(4) = 16.20,
5      TTARG(5) = 21.25,
6      TTARG(6) = 26.29,ZERO,
7      NTARG(1) = 1.5
8      NTARG(2) = 6.10
9      NTARG(3) = 11.14,ZERO,
10     TTARG(1) = 31.35,
11     NXTAB
0035      6002 FORMAT(1H0,25X,11H XB(BEGIN)=5F12.3,7H INCHES /
1      26X,11H X(END) =5F12.3,5H /
2      26X,11H X(INCR) =5F12.3,5H /
3      26X,11H Y(BEGIN)=5F12.3,5H /
4      26X,11H Y(END) =5F12.3,5H /
5      26X,11H Y(INCR) =5F12.3,5H /
6      25X,12HNO.X BOUNDS=18.4,112 /
7      25X,12HNO.Y BOUNDS=18.4,112 /
8      26X,11H AMUG =5F12.3 /
9      25X,18HNO.TERRAIN TABLES=,14 )
0036      IF(N25.EQ.0) GO TO 600
0037      WRITE(M,930) HEAD,GHEAD
0038      NX5 = NX(NXTAB)
0039      NY5 = NY(NXTAB)
0040      WRITE(M,6004) NX5,(XXZGP5(I) I=1,NX5)
0041      6004 FORMAT(66H0 ARGUMENTS FOR TERRAIN TABLE WITH VARYING INCREMENTS (LAST
1      TABLE) /10H NO.OF X = 13,2X,9H, X(ZGP)=,12F9.3/24X,9F9.3)
0042      WRITE(M,6003) NY5,(YYZGP5(I) I=1,NY5)
0043      6003 FORMAT(10HNO.OF Y = 13,2X,9H, Y(ZGP)=,12F9.3/24X, 9F9.3)
C
0044      600 IF(NXTAB) 604,700,604
0045      604 WRITE(M,930) HEAD,GHED,CHED
0046      LINES = 3
0047      DO 614 I=1,NXTAB
0048      NNBX = NBX(I)
0049      NNBY = NBV(I)
0050      NNX = NX(I)
0051      NNV = NY(I)
0052      LINES = LINES + 9 + (NNV+1)*(NNX/7 + 2)
0053      IF(I.EQ.1) GO TO 606
0054      IF(LINES.LT.55) GO TO 606
0055      WRITE(M,930) HEAD,GHED,CHED
0056      LINES = 3
0057      606 WRITE(M,6005) I,AMUG(I),(XBDRY(J,I),J=1,NNBX)

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Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

FORTRAN IV G1 RELEASE 2.0		IDOUT	DATE = 83073	21/40/29	PAGE 0003
0058	6005	FORMAT(19H0 TERRAIN TABLE NO. 13, 20X, 6H AMUG=, F13.5//			00000970
0059		X 1X,16H X BOUNDARIES=,8F13.5)			00000980
0060		WRITE(M,6006) (PSBDRO(J,I),J=1,MNBX)			00000990
0061	6006	FORMAT(1X,16H PSI BOUNDARIES=,8F13.5)			00001000
0062		IF(ITERABX.EQ.0) GO TO 9003			00001010
0063		WRITE(M,9000) (XBERO(J,I),J=1,MNBX)			00001020
0064	9000	FORMAT(1X,16H X RANGE : XMIN=,8F13.5)			00001030
0065		WRITE(M,9001) (XEERO(J,I),J=1,MNBX)			00001040
0066	9001	FORMAT(1X,11X,5HXMAX=,8F13.5)			00001050
0067	9003	IF(ITERABY.EQ.0) GO TO 9006			00001060
0068		WRITE(M,9004) (YBERO(J,I),J=1,MNBX)			00001070
0069	9004	FORMAT(1X,16H Y RANGE : YMIN=,8F13.5)			00001080
0070		WRITE(M,9005) (YEERO(J,I),J=1,MNBX)			00001090
0071	9005	FORMAT(1X,11X,5HYMAX=,8F13.5)			00001100
0072	9006	CONTINUE			00001110
0073		WRITE(M,6007) (YBDRO(J,I),J=1,MNBX)			00001120
0074	6007	FORMAT(1X,16H Y BOUNDARIES=,2F13.5)			00001130
0075		IF(1.EQ.NZTAB .AND. NZ5.NE.0) GO TO 607			00001140
0076		ANAME = COM1			00001150
0077		Y = XB(I)			00001160
0078		YYY = XINCR(I)			00001170
0079		DO 605 J=1,MNX			00001180
0080		TXARG(J) = Y			00001190
0081		Y = Y + YYY			00001200
0082	605	CONTINUE			00001210
0083		Y = YB(I)			00001220
0084		YYY = YINCR(I)			00001230
0085		DO 609 J=1,MNY			00001240
0086		TYARG(J) = Y			00001250
0087		Y = Y + YYY			00001260
0088	609	CONTINUE			00001270
0089		GO TO 610			00001280
0090	607	ANAME = VAR1			00001290
0091		DO 611 J=1,MNX			00001300
0092	611	TXARG(J) = XXZGP5(J)			00001310
0093		DO 612 J=1,MNY			00001320
0094	612	TYARG(J) = YYZGP5(J)			00001330
0095	610	WRITE(M,6008) ANAME, (TXARG(J),J=1,MNX)			00001340
	6008	FORMAT(1H0,A4,17H, INCREMENTS X=,2X,7F13.5/26X,7F13.5/28X,7F13.5/30X,7F13.5/32X,7F13.5/34X,7F13.5/36X,7F13.5/38X,7F13.5/40X,7F13.5/42X,7F13.5/44X,7F13.5/46X,7F13.5/48X,7F13.5/50X,7F13.5/52X,7F13.5/54X,7F13.5/56X,7F13.5/58X,7F13.5/60X,7F13.5/62X,7F13.5/64X,7F13.5/66X,7F13.5/68X,7F13.5/70X,7F13.5/72X,7F13.5/74X,7F13.5/76X,7F13.5/78X,7F13.5/80X,7F13.5/82X,7F13.5/84X,7F13.5/86X,7F13.5/88X,7F13.5/90X,7F13.5/92X,7F13.5/94X,7F13.5/96X,7F13.5/98X,7F13.5/100X,7F13.5/102X,7F13.5/104X,7F13.5/106X,7F13.5/108X,7F13.5/110X,7F13.5/112X,7F13.5/114X,7F13.5/116X,7F13.5/118X,7F13.5/120X,7F13.5/122X,7F13.5/124X,7F13.5/126X,7F13.5/128X,7F13.5/130X,7F13.5/132X,7F13.5/134X,7F13.5/136X,7F13.5/138X,7F13.5/140X,7F13.5/142X,7F13.5/144X,7F13.5/146X,7F13.5/148X,7F13.5/150X,7F13.5/152X,7F13.5/154X,7F13.5/156X,7F13.5/158X,7F13.5/160X,7F13.5/162X,7F13.5/164X,7F13.5/166X,7F13.5/168X,7F13.5/170X,7F13.5/172X,7F13.5/174X,7F13.5/176X,7F13.5/178X,7F13.5/180X,7F13.5/182X,7F13.5/184X,7F13.5/186X,7F13.5/188X,7F13.5/190X,7F13.5/192X,7F13.5/194X,7F13.5/196X,7F13.5/198X,7F13.5/200X,7F13.5/202X,7F13.5/204X,7F13.5/206X,7F13.5/208X,7F13.5/210X,7F13.5/212X,7F13.5/214X,7F13.5/216X,7F13.5/218X,7F13.5/220X,7F13.5/222X,7F13.5/224X,7F13.5/226X,7F13.5/228X,7F13.5/230X,7F13.5/232X,7F13.5/234X,7F13.5/236X,7F13.5/238X,7F13.5/240X,7F13.5/242X,7F13.5/244X,7F13.5/246X,7F13.5/248X,7F13.5/250X,7F13.5/252X,7F13.5/254X,7F13.5/256X,7F13.5/258X,7F13.5/260X,7F13.5/262X,7F13.5/264X,7F13.5/266X,7F13.5/268X,7F13.5/270X,7F13.5/272X,7F13.5/274X,7F13.5/276X,7F13.5/278X,7F13.5/280X,7F13.5/282X,7F13.5/284X,7F13.5/286X,7F13.5/288X,7F13.5/290X,7F13.5/292X,7F13.5/294X,7F13.5/296X,7F13.5/298X,7F13.5/300X,7F13.5/302X,7F13.5/304X,7F13.5/306X,7F13.5/308X,7F13.5/310X,7F13.5/312X,7F13.5/314X,7F13.5/316X,7F13.5/318X,7F13.5/320X,7F13.5/322X,7F13.5/324X,7F13.5/326X,7F13.5/328X,7F13.5/330X,7F13.5/332X,7F13.5/334X,7F13.5/336X,7F13.5/338X,7F13.5/340X,7F13.5/342X,7F13.5/344X,7F13.5/346X,7F13.5/348X,7F13.5/350X,7F13.5/352X,7F13.5/354X,7F13.5/356X,7F13.5/358X,7F13.5/360X,7F13.5/362X,7F13.5/364X,7F13.5/366X,7F13.5/368X,7F13.5/370X,7F13.5/372X,7F13.5/374X,7F13.5/376X,7F13.5/378X,7F13.5/380X,7F13.5/382X,7F13.5/384X,7F13.5/386X,7F13.5/388X,7F13.5/390X,7F13.5/392X,7F13.5/394X,7F13.5/396X,7F13.5/398X,7F13.5/400X,7F13.5/402X,7F13.5/404X,7F13.5/406X,7F13.5/408X,7F13.5/410X,7F13.5/412X,7F13.5/414X,7F13.5/416X,7F13.5/418X,7F13.5/420X,7F13.5/422X,7F13.5/424X,7F13.5/426X,7F13.5/428X,7F13.5/430X,7F13.5/432X,7F13.5/434X,7F13.5/436X,7F13.5/438X,7F13.5/440X,7F13.5/442X,7F13.5/444X,7F13.5/446X,7F13.5/448X,7F13.5/450X,7F13.5/452X,7F13.5/454X,7F13.5/456X,7F13.5/458X,7F13.5/460X,7F13.5/462X,7F13.5/464X,7F13.5/466X,7F13.5/468X,7F13.5/470X,7F13.5/472X,7F13.5/474X,7F13.5/476X,7F13.5/478X,7F13.5/480X,7F13.5/482X,7F13.5/484X,7F13.5/486X,7F13.5/488X,7F13.5/490X,7F13.5/492X,7F13.5/494X,7F13.5/496X,7F13.5/498X,7F13.5/500X,7F13.5/502X,7F13.5/504X,7F13.5/506X,7F13.5/508X,7F13.5/510X,7F13.5/512X,7F13.5/514X,7F13.5/516X,7F13.5/518X,7F13.5/520X,7F13.5/522X,7F13.5/524X,7F13.5/526X,7F13.5/528X,7F13.5/530X,7F13.5/532X,7F13.5/534X,7F13.5/536X,7F13.5/538X,7F13.5/540X,7F13.5/542X,7F13.5/544X,7F13.5/546X,7F13.5/548X,7F13.5/550X,7F13.5/552X,7F13.5/554X,7F13.5/556X,7F13.5/558X,7F13.5/560X,7F13.5/562X,7F13.5/564X,7F13.5/566X,7F13.5/568X,7F13.5/570X,7F13.5/572X,7F13.5/574X,7F13.5/576X,7F13.5/578X,7F13.5/580X,7F13.5/582X,7F13.5/584X,7F13.5/586X,7F13.5/588X,7F13.5/590X,7F13.5/592X,7F13.5/594X,7F13.5/596X,7F13.5/598X,7F13.5/600X,7F13.5/602X,7F13.5/604X,7F13.5/606X,7F13.5/608X,7F13.5/610X,7F13.5/612X,7F13.5/614X,7F13.5/616X,7F13.5/618X,7F13.5/620X,7F13.5/622X,7F13.5/624X,7F13.5/626X,7F13.5/628X,7F13.5/630X,7F13.5/632X,7F13.5/634X,7F13.5/636X,7F13.5/638X,7F13.5/640X,7F13.5/642X,7F13.5/644X,7F13.5/646X,7F13.5/648X,7F13.5/650X,7F13.5/652X,7F13.5/654X,7F13.5/656X,7F13.5/658X,7F13.5/660X,7F13.5/662X,7F13.5/664X,7F13.5/666X,7F13.5/668X,7F13.5/670X,7F13.5/672X,7F13.5/674X,7F13.5/676X,7F13.5/678X,7F13.5/680X,7F13.5/682X,7F13.5/684X,7F13.5/686X,7F13.5/688X,7F13.5/690X,7F13.5/692X,7F13.5/694X,7F13.5/696X,7F13.5/698X,7F13.5/700X,7F13.5/702X,7F13.5/704X,7F13.5/706X,7F13.5/708X,7F13.5/710X,7F13.5/712X,7F13.5/714X,7F13.5/716X,7F13.5/718X,7F13.5/720X,7F13.5/722X,7F13.5/724X,7F13.5/726X,7F13.5/728X,7F13.5/730X,7F13.5/732X,7F13.5/734X,7F13.5/736X,7F13.5/738X,7F13.5/740X,7F13.5/742X,7F13.5/744X,7F13.5/746X,7F13.5/748X,7F13.5/750X,7F13.5/752X,7F13.5/754X,7F13.5/756X,7F13.5/758X,7F13.5/760X,7F13.5/762X,7F13.5/764X,7F13.5/766X,7F13.5/768X,7F13.5/770X,7F13.5/772X,7F13.5/774X,7F13.5/776X,7F13.5/778X,7F13.5/780X,7F13.5/782X,7F13.5/784X,7F13.5/786X,7F13.5/788X,7F13.5/790X,7F13.5/792X,7F13.5/794X,7F13.5/796X,7F13.5/798X,7F13.5/800X,7F13.5/802X,7F13.5/804X,7F13.5/806X,7F13.5/808X,7F13.5/810X,7F13.5/812X,7F13.5/814X,7F13.5/816X,7F13.5/818X,7F13.5/820X,7F13.5/822X,7F13.5/824X,7F13.5/826X,7F13.5/828X,7F13.5/830X,7F13.5/832X,7F13.5/834X,7F13.5/836X,7F13.5/838X,7F13.5/840X,7F13.5/842X,7F13.5/844X,7F13.5/846X,7F13.5/848X,7F13.5/850X,7F13.5/852X,7F13.5/854X,7F13.5/856X,7F13.5/858X,7F13.5/860X,7F13.5/862X,7F1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0001      SUBROUTINE PTHOUT
COMMON/PAGE/NP,HEAD(20),R,M
INTEGER R,M
COMMON/HVROAD/GHED(20),N7TAB,XB(5),XE(5),XINCR(5),
1 YB(5),YE(5),YINCR(5),N25,NX(5),NY(5),
2 XBERO(8,5),KEERO(8,5),YBERO(8,5),YEEAO(8,5),IERABX,IERABY,
3 NBX(5),NBY(5),XBDY(8,5),PSBDAQ(8,5),YBDVAY(2,5),
4 ZGP(21,21,5),YZGPs(21),XZGPs(21)
0005 COMMON/PATMD/IPATH,KLI,DI(10),RLI(10),NPTS,XINIT,YINIT,
1 PSA,DELL,X(100),Y(100),DX(100),DY(100),D(100),CHED(20)
0006 COMMON/WAGON/IMAGN,TPRB,DPRB,PLGTH,PMIN,PMAX,PGAIN,QGAIN,PSIFD,
1 ITDOPT,TDPS1,TMAX
0007 COMMON/FILT/IFILT,TILT,TT,TAUF
0008 DIMENSION DIO(10),KO(100),YO(100),DXO(100),DYO(100),DO(100)
0009 PSAO = PSA*57.2958
0010 WRITE(M,930) HEAD,GHED,CHED
0011 930 FORMAT(1,2X,MSRI/MVMA BRAKING AND HANDLING SIMULATION OF',
1 4,' ',3X,20A4/,
2 1H0,2X,'OPTIONAL INPUTS ADDED 9/82 BY MCI :',20A4/,
3 1H 38X,20A4/)
0012 DO 10 I = 1,KLI
0013 DIO(I) = DI(I)*12.0
0014 WRITE(6,1010) IPATH,KLI,NPTS,DELL,XINIT,YINIT,PSAO
0015 1010 FORMAT(
1H0,9X,16HPATH DESCRIPTORS,18X,8HIPATH =,6X,I1/
B1H 10X,26HNUMBER OF PATH DESCRIPTORS,7X,8HKLI =,5X,I2/
C1H 10X,24HNUMBER OF POINTS ON PATH,9X,8HNPTS =,4X,I3/
D1H 10X,23HDISTANCE BETWEEN POINTS,10X,8HDELL =,3X,F8.3,
E7H INCHES/1H 10X,31HCOORDINATES OF 1ST PATH POINTS:,2X,
F8HXINIT =,4X,F8.3,7H INCHES/
G1H 43X,8HYINIT =,2X,F8.3,7H INCHES/1H 10X,
M23HINITIAL ROADWAY HEADING,10X,8HPSA =,3X,F7.2,9H DEGREES//)
0016 WRITE(6,1017)
0017 1017 FORMAT(1H0,9X,27HPATH CURVATURE DESCRIPTORS: //)
0018 DO 1015 I = 1,KLI
0019 DI(I) = DI(I)*12.0
0020 1015 WRITE(6,1020) I, DI(I),I,RLI(I)
0021 1020 FORMAT(
1H 10X,19HDEGREE OF CURVATURE,9X,'DI('',I1,'')' =,3X,F8.4,
B8H DEGREES/
C1H 10X,19HDISTANCE ALONG PATH,9X,'RLI('',I1,'')' =,
D3X,F8.2,7H INCHES//)
0022 IF(IITDOPT.EQ.1) GO TO 1035
0023 WRITE(6,1030) IMAGN,TPRB,DPRB,PLGTH,PMIN,PMAX,PGAIN,QGAIN,PSIFD
0024 1030 FORMAT(
1H0,9X,30HWAGON TONGUE STEER DESCRIPTORS,4X,8HIWAGN =,6X,I1/
B1H 10X,25HINITIAL PROBE SAMPLE TIME,8X,8HTPRB =,3X,F8.3,
C8H SECONDS/1H 10X,30HTIME INCREMENT BETWEEN SAMPLES,3X,
D8HDPTRB =,3X,F8.3,8H SECONDS/1H 10X,15HLENGTH OF PROBE,
E18X,8HPLGTH =,3X,F7.2,8H INCHES/1H 10X,
F24HMINIMUM ACCEPTABLE ERROR,9X,8HMPMIN =,3X,F8.2,8H INCHES/
G1H 10X,29HMAXIMUM OCCUPANT ACCELERATION,4X,8HPMAX =,3X,
HFB,3,8H G-UNITS/1H 10X,23HSTEER CORRECTION FACTOR,10X,8HPGAIN =,
I3X,F8.7,8H RAD/IN/
J1H 10X,31HSTEER CORRECTION DAMPING FACTOR,2X,8HQGAIN =,3X,F8.7,
K11H RAD-SEC/IN/1H 10X,27HMAXIMUM STEERING WHEEL RATE,6X,
L8HPSIFD =,3X,F8.3,8H DEG/SEC //)
0025 GO TO 1045
0026 1035 WRITE(6,1036) IMAGN,ITDOPT,TPRB,DPRB,PLGTH,PMIN,PMAX,PGAIN,QGAIN,
1 TMAX,PSIFD
0027 1036 FORMAT(
1H0,9X,30HWAGON TONGUE STEER DESCRIPTORS,4X,8HIWAGN =,6X,I1/
B1H 10X,29HTORQUE OPTION USED =,4X,8HITDOPT =,6X,I1/
C1H 10X,25HINITIAL PROBE SAMPLE TIME,8X,8HTPRB =,3X,F8.3,
D8HDPTRB =,3X,F8.3,8H SECONDS/1H 10X,15HLENGTH OF PROBE,
E18X,8HPLGTH =,3X,F7.2,8H INCHES/1H 10X,
F24HMINIMUM ACCEPTABLE ERROR,9X,8HMPMIN =,3X,F8.2,8H INCHES/
G1H 10X,29HMAXIMUM OCCUPANT ACCELERATION,4X,8HPMAX =,3X,
HFB,3,8H G-UNITS/1H 10X,24HTORQUE CORRECTION FACTOR,9X,8HKTQR1 =
I1,3X,F8.2,12H LB-IN/INCH/
J1H 10X,32HTORQUE CORRECTION DAMPING FACTOR,1X,8HKTQR2 =,3X,F8.2,
K15H LB-INCH-SEC/IN/1H 10X,33HMAXIMUM FRONT STEER TORQUE
L8HTMAX =,3X,F8.3,8H DEG/SEC / 1H 10X,
M29HINITIAL TORQUE =,4X,8HTDPSIO =,3X,F8.2,6H LB-IN//)
0028 WRITE(6,1040) IFILT,TILT,TT,TAUF
0029 1040 FORMAT(1H0,
1H0,18HFILTER DESCRIPTORS,16X,8HIFILT =,6X,I1/
B1H 10X,18HTIME LAG OF FILTER,15X,8HTILT =,3X,F8.6,8H SECONDS/
C1H 10X,19HTIME LEAD OF FILTER,14X,8HTI =,3X,F8.6,8H SECONDS/
D1H 10X,20HTIME DELAY OF FILTER,13X,8HTAUF =,3X,F8.6,
E8H SECONDS //)
0030 DO 20 N = 1,NPTS
0031 XO(N) = X(N)/12.0
0032 YO(N) = Y(N)/12.0
0033 DXO(N) = ARCOS(DX(N)) * 57.29578
0034 DYO(N) = ARSIN(DY(N)) * 57.29578
0035 DO 20 N = 1,NPTS
0036 WRITE(M,930) HEAD,GHED,CHED
0037 WRITE(6,1050)
0038 1050 FORMAT(1H0,13X,16HPATH COORDINATES,7X,15HTANGENT VECTORS,4X,
1A9HDEGREE OF 1H 56X,9H CURVATURE/
B1H 4H N,9X,4HX(N),7X,4HY(N),6X,5HDX(N),5X,5HDY(N),7X,4HDO(N)/
C1H 4X,2(8X,4H(FT)),2X,2(5X,5H(DEG)),7X,5H(DEG//)
J1 = NPTS
IF(JJ.GT.50) JJ = 50
DO 1055 I = 1,JJ
1055 WRITE(6,1060) I,XO(I),YO(I),DXO(I),DYO(I),DO(I)
1060 FORMAT(1H 1X,13X,5(2X,F9.3))
IF(NPTS.LE.50) RETURN
WRITE(M,930) HEAD,GHED,CHED
WRITE(6,1060)
DO 1065 I = 1,NPTS
1065 WRITE(6,1060) I,XO(I),YO(I),DXO(I),DYO(I),DO(I)
RETURN
END

```

**Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )**

```

0001      C      SUBROUTINE DRIVE1                                00000010
0002      C      ENTRY DRIVER(T,VAR,PSI)                          00000020
0003      C      SUBROUTINE DRIVER INSTALLED IN HSRI/MVMA PHASE4 PROGRAM 00000030
0004      C      BY MCHENRY CONSULTANTS, INC                      00000040
0005      C      UNDER SUBCONTRACT WITH JACK E. LEISCH & ASSOC. 00000050
0006      C      PER CONTRACT NO. DOT-FH-11-9575                  00000060
0007      C      NEW CALLING ARGUMENTS:                            00000070
0008      C      T = CURRENT TIME                                  00000080
0009      C      VAR = 5 MEMBER ARRAY:                             00000090
0010      C      VAR(1) = Y                                         00000100
0011      C      VAR(2) = YDOT                                     00000110
0012      C      VAR(3) = PSIDOT                                   00000120
0013      C      VAR(4) = VEHICLE HEADING ANGLE                   00000130
0014      C      VAR(5) = X                                         00000140
0015      C      PSI = FRONT WHEEL STEER ANGLE RETURNED BY DRIVER 00000150
0016      C      DIMENSION PPD(50),TPD(50),VAR(5)                 00000160
0017      C      COMMON/PATHD/IPATH,KLI,DI(10),RLI(10),NPTS,XINIT,YINIT, 00000170
0018      C      1 PSA,DELL,X(100),Y(100),DX(100),DY(100),D(100),CHED(20) 00000180
0019      C      COMMON/HAGON/IMAGN,TPRB,DPRB,PLGTH,PMIN,PMAX,PGAIN,CGAIN,PSIFD, 00000190
0020      C      1 ITDOPT,TDPSI,TMAX                                00000200
0021      C      COMMON/FILT/ IFILT,TIL,TT,TMT,TAUF               00000210
0022      C      COMMON/ACC/ ACLONG(4),ACLAT(4),CHFA1(4)          00000220
0023      C      DATA NPDMAX/50/,NPD/0/,DPSL/0.0/,N/0/           00000230
0024      C      DATA DISTA/0.0/,RAD/0.01745392/,FT/12.0/        00000240
0025      C      DATA OMGPS/.4363/,DT/0.005/,TPRNT/0.0/,IFLAG/0/ 00000250
0026      C      IF(IMAGN.EQ.0)GO TO 90                             00000260
0027      C      IFLAG = 0                                           00000270
0028      C      PSIA = PSI                                           00000280
0029      C      DTP = DPRB                                           00000290
0030      C      DPS = 0.0                                           00000300
0031      C      DPSI = 0.0                                           00000310
0032      C      DDIST = 0.0                                          00000320
0033      C      C* CHECK IF T > TLAST                                00000330
0034      C      IF(T.LT.TLAST) RETURN                               00000340
0035      C      C* CALCULATE CURRENT TIME INCREMENT                00000350
0036      C      IF(T-TLAST.GT.0) DT = T-TLAST                      00000360
0037      C      TLAST = T                                           00000370
0038      C      C* CHECK FOR PRINT INTERVAL HERE                  00000380
0039      C      IF(T.LT.TPRNT) GO TO 1                              00000390
0040      C      IFLAG = 1                                           00000400
0041      C      TPRNT = TPRNT + 0.010                               00000410
0042      C      C* CHECK IF THIS IS A SAMPLE TIME OF FILTER APPLICATION 00000420
0043      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000430
0044      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000440
0045      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000450
0046      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000460
0047      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000470
0048      C      1 IF(TPRB.GT.T + 0.0005)GO TO 10                   00000480

```

```

0025      C* COMPUTE NEW CHANGE IN STEER ANGLE                    **00000490
0026      C* TPRB = TPRB + DPRB                                    **00000500
0027      C* XP = VAR(5) + COS(VAR(4))*PLGTH                       **00000510
0028      C* YP = VAR(1) + SIN(VAR(4))*PLGTH                       **00000520
0029      C* CALL PROBE(XP,YP,NPTS,X,Y,DX,DY,D,IPRB,DIST,XX,YY)    **00000530
0030      C* SELECTED POINT INDEX: IPRB                             **00000540
0031      C* LOCATION OF CLOSEST POINT ON PATH : XX,YY             **00000550
0032      C* NOT CURRENTLY USED                                     **00000560
0033      C* IF(DIST.EQ.0.0)GO TO 8                                  **00000570
0034      C* SGND=DIST/ABS(DIST)                                     **00000580
0035      C* DDIST = (DIST-DISTA)/DPRB                              **00000590
0036      C* 9 IF(ABS(DIST).GT.PMIN)DPS = -PGAIN*(ABS(DIST)-PMIN)=SGND **00000600
0037      C* 1 IF(ABS(DIST).LE.PMIN) DPS= -GAIN*DDIST              **00000610
0038      C* DISTA = DIST                                           **00000620
0039      C* IF(IFILT.EQ.0)GO TO 55                                 **00000630
0040      C* IF(NPD.EQ.NPDMAX)GO TO 10                              **00000640
0041      C* NPD = NPD + 1                                           **00000650
0042      C* PPD(NPD) = DPS - PSIA                                   **00000660
0043      C* TPD(NPD) = T + TAUF                                     **00000670
0044      C* 10 IF(IFILT.EQ.0)GO TO 55                              **00000680
0045      C* MUERO-MUSCULAR FILTER                                  **00000690
0046      C* IF(NPD.EQ.NPDMAX) GO TO 10                             **00000700
0047      C* TPDTMP = TPD(N)                                       **00000710
0048      C* DO 20 NN = 1,NPD                                       **00000720
0049      C* N = NPD + 1 - NN                                       **00000730
0050      C* IF(T.GE.TPD(N))GO TO 30                                **00000740
0051      C* 20 CONTINUE                                           **00000750
0052      C* GO TO 50                                               **00000760
0053      C* 30 IF(TPTMP.LT.TPD(N)) DPSL = 0.0                    **00000770
0054      C* DPSI = PPD(N)*TMT*EXP(-(T - TPD(N))/TIL)/TIL          **00000780
0055      C* DPSM = PPD(N) - TIL*DPSI                               **00000790
0056      C* DTP = 0.0                                              **00000800
0057      C* DPS = DPSM - DPSL                                       **00000810
0058      C* DPSL = DPSM                                             **00000820
0059      C* IF(NPD.EQ.1)GO TO 50                                   **00000830
0060      C* 35 L = 1                                               **00000840
0061      C* DO 40 NN = N,NPD                                       **00000850
0062      C* PPD(L) = PPD(NN)                                       **00000860
0063      C* 40 CONTINUE                                           **00000870
0064      C* 50 CONTINUE                                           **00000880
0065      C* 55 CONTINUE                                           **00000890
0066      C* 60 CONTINUE                                           **00000900
0067      C* 65 CONTINUE                                           **00000910
0068      C* 70 CONTINUE                                           **00000920
0069      C* 75 CONTINUE                                           **00000930
0070      C* 80 CONTINUE                                           **00000940
0071      C* 85 CONTINUE                                           **00000950
0072      C* 90 CONTINUE                                           **00000960

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

FORTRAM IV G1 RELEASE 2.0 DRIVE1 DATE = 83074 08/52/02 PAGE 0003

```

0058      TPD(L) = TPD(NN)
0059      40 L = L + 1
0060      NPD = L - 1
0061      C
0062      50 PSI = PSIA + DPS
0063      GO TO 58
0064      55 PSI = DPS
0065      58 CONTINUE
0066      C=
0067      C= CHECK PREVIOUS TIME INTERVAL COMFORT FACTOR
0068      C= IF GREATER THAN PMAX, ALLOW ONLY REDUCTION IN STEER ANGLE
0069      C= IF TORQUE OPTION, ONLY ALLOW A REDUCTION OF TORQUE
0070      C=
0071      65 IF((PMAX.GT.0.0).AND.(ABS(CMFA1(1)).LT.PMAX)) GO TO 60
0072      IF(ABS(PSI).GT.ABS(PSIA)) PSI=PSIA
0073      60 CONTINUE
0074      C=
0075      C= CHECK MAX STEER ANGLE
0076      C=
0077      IF((OMGPS.GT.0.0).AND.(ABS(PSI).GT. OMGPS))
0078      1 PSI = SIGN(OMGPS,PSI)
0079      C=
0080      C= CHECK STEER VELOCITY
0081      C=
0082      IF(T.NE.0.0) DPSI = (PSI-PSIA)/DT
0083      IF(DPSI.GT.PSIFD/RAD) PSI=PSIA + PSIFD/RAD=DT
0084      75 DPSI = DPS/RAD
0085      PSIAO = PSIA/RAD
0086      PSIO = PSI/RAD
0087      DELPSI = PSIO- PSIAO
0088      XPFT = XP/FT
0089      YPFT = YP/FT
0090      XXFT = XX/FT
0091      YYFT = YY/FT
0092      XP = VAR(5)
0093      YP = VAR(1)
0094      CALL CGERR(XP,YP,NPTS,X,Y,DX,DY,D,IPRB,DIST2,XX,YY)
0095      RLO = SORT((XP-XINIT)**2 + (YP-YINIT)**2) / 12.0
0096      IF(KPAGE.LE.50.AND.T.NE.0.0000) GO TO 110
0097      WRITE(50,100)
0098      100 FORMAT(
0099      A1H1,'MVOSH VEHICLE PATH-FOLLOWING:SUBROUTINE DRIVER',
0100      B'DIAGNOSTIC DUMP, ROUTINE INSTALLED IN PHASE 1/83',
0101      C1M0,33X,37H'PROBE COORDINATES', PATH COORDINATES,5X,
0102      D'CG-ERROR',3X,CG DISTANCE,4X,'COMFORT',
0103      E31H TIME DELTA PSIF ERROR,6X,1HX,9X,1HY,10X,1HX,8X,1HY,
0104      F8X,'DIST',8X,'ALONG PATH',4X,'FACTOR',
0105      G31H (SEC) (DEG) (IN) .4X,4H(FT),6X,4H(FT),7X,

```

FORTRAM IV G1 RELEASE 2.0 DRIVE1 DATE = 83074 08/52/02 PAGE 0004

```

0086      H4H(FT),5X,4H(FT),7X,'(IN)',12X,'(FT)',6X,'(G-UNITS)')
0087      KPAGE = 0
0088      110 IF(IFLAG.NE.1) GO TO 90
0089      WRITE(50,120) T,DELPSI,DIST,XPFT,YPFT,XXFT,YYFT,DIST2,RLO,
0090      1 CMFA1(1)
0091      120 FORMAT(1H ,F7.3,2(4X,F7.3),2(3X,F7.1),2X,2(2X,F7.1),
0092      A 5X,F7.2,8X,F7.1,5X,F8.3)
0093      KPAGE = KPAGE + 1
0094      GO TO 90
0095      90 RETURN
0096      ENTRY DRIVE2(VEL)
0097      PSI = 0.0
0098      DISTA = 0.0
0099      TLAST = -1.0
0100      RETURN
0101      END

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )

```

0001      SUBROUTINE PROBE(XP,YP,M,X,Y,DX,DY,D,I,DIST,XX,YY)
C
C
C***  PATHF  MCI *****
C***  PROBE CALLED FROM DRIVER TO FIND ERROR OF PROBE FROM PATH
C
0002      DIMENSION X(1),Y(1),DX(1),DY(1),D(1)
0003      DATA RAD/0.017453292519943296/,ILAST/1/
C  INITIALIZE
0004      I = ILAST
0005      TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
0006      TSAV = SIGN(1.0,TEST)
0007      GO TO 15
C  START SEARCH
C
0008      7 I = I + 1
0009      IF(I.LE.M)GO TO 10
0010      IF(TSAV.LT.0.0)GO TO 20
0011      I = M
0012      GO TO 25
0013      10 TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
0014      IF(TEST.TSAV.LE.0.0)GO TO 25
0015      15 IF(TEST)20,25,7
0016      20 I = I - 1
0017      IF(I.GE.1)GO TO 10
0018      IF(TSAV.GT.0.0)GO TO 7
0019      I = 1
C  FINISH SEARCH
0020      25 IF((TEST.LT.0.0).AND.(I.GT.1))I=I-1
0021      ILAST = I
C  FINISH OF DETERMINATION OF I
C
C
C
C
C  CALCULATE DISTANCE
0022      ZDN = -DY(I)*(XP-X(I))+DX(I)*(YP-Y(I))
0023      CONS = D(I)*RAD*0.005
0024      ZDZ = ((XP-X(I))**2+(YP-Y(I))**2)*CONS
0025      DIST = (ZDN-ZDZ)/(0.5+SQRT(0.25-CONS*(ZDN-ZDZ)))
C  CALCULATE POSITION OF CLOSEST APPROACH POINT ON ARC
C  THE FOLLOWING CODE MAY BE DELETED AND THE REFERENCES TO XX AND YY TAKE
C  OUT OF THE CALL IF THE POINT OF CLOSEST APPROACH ON THE ARC IS NOT NEE
C

```

```

0026      DEN = 1.0-2.0*DIST*CONS
C
0027      IF(DEN.GT.0.0)GO TO 30
0028      WRITE(6,26)I,XP,YP,DIST,DEN
0029      26 FORMAT(' SUBROUTINE PROBE HAS NEGATIVE OR ZERO DENOMINATOR'/
X' IN POSITION FORMULA: IMPLIES POINT NOT IN SECTOR'/I6,4F10.4)
0030      STOP
C  THIS STOP SHOULD NEVER OCCUR IN NORMAL USAGE
C
0031      30 XX = (XP-X(I)+DIST*DY(I))/DEN + X(I)
0032      YY = (YP-Y(I)-DIST*DX(I))/DEN + Y(I)
0033      35 RETURN
C*****
0034      END

```

Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )



```

0001      SUBROUTINE CGERR(XP,YP,M,X,Y,DX,DY,D,I,DIST,XX,YY)
0002
0003      DIMENSION X(1),Y(1),DX(1),DY(1),D(1)
0004      DATA RAD/0.017453292519943296/,ILAST/1/
0005      C INITIALIZE
0006      I = ILAST
0007      TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
0008      TSAV = SIGN(1.0,TEST)
0009      GO TO 15
0010
0011      C START SEARCH
0012      I = I - 1
0013      IF(I.LE.M)GO TO 10
0014      IF(TSAV.LT.0.0)GO TO 20
0015      I = M
0016      GO TO 25
0017      10 TEST = DX(I)*(XP-X(I))+DY(I)*(YP-Y(I))
0018      IF(TEST=TSAV.LE.0.0)GO TO 25
0019      15 IF(TEST)20,25,7
0020      20 I = I - 1
0021      IF(I.GE.1)GO TO 10
0022      IF(TSAV.GT.0.0)GO TO 7
0023      I = 1
0024
0025      C FINISH SEARCH
0026      25 IF((TEST.LT.0.0).AND.(I.GT.1))I=I-1
0027      ILAST = I
0028      C FINISH OF DETERMINATION OF I
0029
0030      CALCULATE DISTANCE
0031      ZDN = -DY(I)*(XP-X(I))+DX(I)*(YP-Y(I))
0032      CONS = D(I)*RAD*0.005
0033      ZDZ = ((XP-X(I))**2+(YP-Y(I))**2)*CONS
0034      DIST = (ZDN-ZDZ)/(0.5+SQRT(0.25-CONS*(ZDN-ZDZ)))

```

```

00001990
00002000
00002010
00002020
00002030
00002040
00002050
00002060
00002070
00002080
00002090
00002100
00002110
00002120
00002130
00002140
00002150
00002160

C CALCULATE POSITION OF CLOSEST APPROACH POINT ON ARC
C THE FOLLOWING CODE MAY BE DELETED AND THE REFERENCES TO XX AND YY TAKEN
C OUT OF THE CALL IF THE POINT OF CLOSEST APPROACH ON THE ARC IS NOT NEEDED
0026 DEN = 1.0-2.0*DIST*CONS
C
0027 IF(DEN.GT.0.0)GO TO 30
0028 WRITE(6,26)I,XP,YP,DIST,DEN
0029 26 FORMAT(' SUBROUTINE PROBE HAS NEGATIVE OR ZERO DENOMINATOR'/
0030 X' IN POSITION FORMULA: IMPLIES POINT NOT IN SECTOR'/16,4F10.4)
C STOP
C THIS STOP SHOULD NEVER OCCUR IN NORMAL USAGE
0031 30 XX = {XP-X(I)+DIST*DY(I)}/DEN + X(I)
0032 YY = {YP-Y(I)-DIST*DX(I)}/DEN + Y(I)
0033 35 RETURN
0034 END

```

**Figure 8. NEW AND MODIFIED ROUTINES FOR HSRI / MVM PHASE 4 MODEL ( continued )**