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# EVALUATION OF HORIZONTAL CURVE DESIGN

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## FOREWORD

This report documents results from a program of research in which observational and analytical evaluations of horizontal curve design criteria were made. Observational data were collected for three categories of vehicles traversing three separate horizontal curves in order to obtain actual path and speed information. Analyses of both transient and steady-state dynamics of three categories of vehicles traversing idealized curves were made with the use of the Highway-Vehicle-Object Simulation Model (HVOSM). The report will be of interest to traffic and highway design engineers concerned with highway geometrics and the effects of geometrics on traffic operations.

This research program was conducted by the Advanced Technology Center of Calspan Corporation for the U.S. Department of Transportation, Federal Highway Administration, as part of the Federally Coordinated Program (FCP) of Research and Development. The Federal Highway Administration project manager was Mr. George B. Pilkington, II.

The authors would like to acknowledge the efforts of Mr. Timothy S. Johnson, whose aid in collection of the observational data was invaluable, and the efforts of Ms. Maureen E. Ball and Ms. Janice E. Mulartrick for preparation of the manuscript.

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Director, Office of Research
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16. Abstract

This report documents an initial evaluation of horizontal curve design criteria which involved two phases: an observational study and an analytical evaluation. Three classes of vehicles (automobiles, school buses and tractor semi-trailers) and three selected curves (8, 31 and 38) were utilized in the study in order to determine vehicle path and speed. The analytical evaluation using the HVOSM was conducted to relate the vehicle dynamics during curve traversal to horizontal curve design criteria. Horizontal curve parameters were curve radius, vehicle class, speed, curve transition type and super-elevation rate. The report suggests that the use of spiral transition curves in horizontal alignment would improve traffic operations and recommends further research to confirm the change in steady-state steer characteristics on superelevated curves.



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# 1. INTRODUCTION

The objective of the work reported herein has been to provide an initial evaluation of the applicability of existing horizontal curve design criteria to real world operating conditions. The geometric design of horizontal curves for highways has historically been based on empiricism and point-mass, steady-state kinematic theory. Effects that this design philosophy have had on the transient and steady-state dynamics of the widely varying types and sizes of vehicles using the highway system have been largely unexplored. Conversely, the role, if any, that vehicle dynamics should have in establishing horizontal curve design criteria has not been established.

While it must be recognized that existing highway curves are successfully negotiated by the vast majority of vehicles traversing them, very little is known about how drivers actually guide their vehicles around the curve or the extent of the burden that the curve imposes on the driver. Recent, widely publicized accidents involving loss-of-control on curves have prompted this study with the intent of identifying whether any aspect of existing design criteria may contribute to the difficulties that various classes of vehicles experience in negotiating curves.

This study was organized into three tasks. The first task involved a search of the literature to determine which vehicle simulation models were applicable for use in a subsequent task. This effort concentrated on finding an articulated vehicle simulation model that contained provisions for automatic guidance and non-uniform terrain. The second task was undertaken in order to determine how various vehicle classes negotiate curves. This task involved the unobtrusive observation of automobiles, school buses and articulated vehicles (tractor/semi-trailers) traversing three different horizontal curves for the purpose of acquiring information to establish the paths used by the driver/vehicle combination and the speeds at which the curves were negotiated. The third task involved computer simulation of different vehicles traversing idealized curves. In this task the Highway-Vehicle-Object Simulation Model

(HVOSM), described in Reference 1, was used to study the transient and steady-state dynamics of three vehicles on curves of different radius, transition and superelevation rate.

A description of the methodology employed in both the observation and simulation of vehicles traversing curves is contained in Section 2 of this report. The results obtained in both the field observation and simulation tasks are presented and discussed in Section 3. Conclusions and Recommendations resulting from the study are contained in Section 4.

## 2. METHODOLOGY

The study reported herein consisted of two basic efforts to aid in the evaluation of existing design criteria for horizontal curves. Computer simulation techniques were employed to evaluate the effects of different curve design elements - degree of curve, superelevation and transition type - on the performance of various vehicle classes. In addition, observations and measurements of vehicles traversing three selected curves were made to aid in evaluating the results obtained from the computer simulation study. This effort was judged to be necessary due to the inherent limitiations of the computer simulation used - in particular the limitations of the automatic guidance (driver) algorithm to accurately predict driver behavior. The object was to provide an experimental data base by which the idealized results from the simulation could be extrapolated to real world situations. While a methodology for making this extrapolation was not successfully developed during this effort, it must be noted that both the simulation and observational tasks produced results that are valuable - the simulation results are valid for making relative comparisons between curve designs and the observational results provide a start at understanding the relationships between curve design and driver/vehicle behavior. The general methodology employed in performing these two tasks is described in the two subsequent sections. Additional detail is given in Appendices A, B and C.

### 2.1 Collection of Observational Data

Constraints on the simulation task required study of 10°, 30° and 36° curves. It was therefore necessary to select observational sites with about the same degrees-of-curvature. However, additional criteria were also employed in the selection process based on practical considerations of traffic volume, mix and flow, as well as geometrical considerations such as approach to the curve and grade throughout.