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16. Abstract

The Surface Transportation Assistance Act (STAA) of 1982 provided for more uniformity in size and weight regulation on federal aid highways, particularly tractor-trailer combinations. Section 138/415 of that Act also called for a feasibility study of a National Intercity Truck Route Network for commercial vehicles up to 118 ft long and 8 ft 6 in. wide. The extra length and width allowed contribute significantly to the offtracking characteristics of these long combination vehicles (LCV's). The objective of the research in this report is to assess the operational impact of the LCV's on the geometry of diamond interchanges located along Interstate Highways in Texas. The assessment was done by randomly sampling diamond interchanges and simulating all possible turn measurements of LCV's at their terminals. The movements were simulated with the computer Truck Offtracking Model (TOM). Results include the data collected on all interchanges located along Interstate Highways in Texas and interval estimates of the proportion of diamonds with inadequate geometry, i.e., pavement widths at ramp terminals inadequate to accommodate the LCV's. Ninety-nine percent confidence intervals were also estimated for the extra pavement width required to prevent the LCV's from damaging pavement edges and other roadside appurtenances at the ramp terminals.

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AN ASSESSMENT OF THE OPERATIONAL IMPACT OF THE LONGER AND WIDER COMBINATION VEHICLES ON THE GEOMETRY OF DIAMOND INTERCHANGES

by

Bala M. Rajappan
and
C. Michael Walton

Research Report Number 447-1F
Research Project 3-18-85-447

"Longer and Wider Trucks on the Texas Highway System"

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
United States Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

August 1986

PREFACE

This is the final report on research project 3-18-85-447, "Longer and Wider Trucks on the Texas Highway System." This report represents an effort to assess the operational effects of an increase in truck size on the geometry of interchanges located along Interstate Highways in Texas.

The authors wish to express their appreciation to Harold D. Cooner, D-8 of the Texas State Department of Highways and Public Transportation (SDHPT), for his support and assistance with this study, and to Mac Q. Munn, D-10 of SDHPT, for his assistance with the data collection.

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Allen Hoffman, for his assistance with the data collection, and
Shekhar Govind, for his computer assistance during the initial phase of the study.

Bala M. Rajappan
C. Michael Walton

ABSTRACT

The Surface Transportation Assistance Act (STAA) of 1982 provided for more uniformity in size and weight regulation on federal aid highways, particularly tractor-trailer combinations. Section 138/415 of that Act also called for a feasibility study of a National Intercity Truck Route Network for commercial vehicles up to 118-ft long and 8 ft, 6 in. wide. The extra length and width allowed contribute significantly to the offtracking characteristics of these long combination vehicles (LCV's). The objective of the research in this report is to assess the operational impact of the LCV's on the geometry of diamond interchanges located along Interstate Highways in Texas. The assessment was done by randomly sampling diamond interchanges and simulating all possible turn measurements of LCV's at their terminals. The movements were simulated with the computer Truck Offtracking Model (TOM). Results include the data collected on all interchanges located along Interstate Highways in Texas and interval estimates of the proportion of diamonds with inadequate geometry, i.e., pavement widths at ramp terminals inadequate to accommodate the LCV's. Ninety-nine percent confidence intervals were also estimated for the extra pavement width required to prevent the LCV's from damaging pavement edges and other roadside appurtenances at the ramp terminals.

SUMMARY

With the increasing interest around the U.S. in longer combination vehicles (LCV's), a research effort was authorized to explore the relationships between the performance of longer and wider trucks and the geometric design of interchanges on Texas interstate highways.

The objectives of this study were:

(1) stratify the existing interstate highway interchanges by type, number, and location;

(2) determine the number of existing diamond interchanges with geometry inadequate for LCV turning maneuvers on ramps;

(3) identify the factors which influence the pavement area available for LCV turning maneuvers; and

(4) estimate, within a 99 percent confidence interval, the extra pavement width required at ramp terminals on all diamond interchanges.

The study reviewed all interstate highway interchanges in Texas and classified them by geometric design, e.g. diamonds, cloverleafs, directional. Since the diamond configuration represented 86 percent of the 1557 interchanges identified and surveyed, the study focused on these for analysis. For the analysis 85 diamond interchanges were randomly selected and each truck turning movement associated with the ramps were analyzed. The LCV type used in the analysis was defined as a 118 ft long, 8.5 ft wide Turnpike Double comprised of a 3 axle conventional tractor (CBE tractor), 48 ft semitrailer and a 48 ft trailer since it represented the "worst" case for a design vehicle. The analysis utilized a computerized truck offtracking model (TOM) to estimate the adequacy of available pavement area for turning movements.

The findings indicated that existing diamond interchanges on the Texas interstate highway system, whether located in urban or rural areas, did not possess adequate pavement area to accomodate LCV turning movements, right or left, at ramp terminals. Further, ninety-two or higher percent of diamonds located in urban areas were estimated to be incapable of accommodating right turn maneuvers by the LCV's and may require additional pavement widths of up to 25 ft, dependin^σ^ upon the radii and angles of turns. The proportion of urban diamonds which were estimated to have inadequate geometry to accommodate left turn maneuvers of similar vehicles ranges from 83 to 100 percent at 95 percent confidence level, and the extra pavement widths required at their ramp terminals may reach up to 20 ft. The rural diamonds are estimated to have higher proportions than the urban diamonds for right turns. Up to 30 ft of extra pavement width may be required at their ramp

terminals; and they are more critical than the urban diamonds. The proportion of rural diamonds with inadequate geometry for left turn maneuvers by the LCV's ranges from 81 to 98 percent confidence level and may require up to 24 ft of extra pavement width.

One of the final conclusions is that the proportion of diamonds that would experience damage to curbs and other roadside appurtenances is extremely high if the LCV's are allowed to traverse them. Furthermore, rural diamonds have a higher tendency to experience damage than those in the urban areas, due to the more confined pavement areas at the ramp terminals. The pavement areas available for right turns are more critical than those for left turns, because it is possible for drivers to make illegal left turns utilizing all the pavement area available. Thus, the modifications of pavement edges at the ramp terminals for right turns are more urgent than for left turns, and the rural diamonds require earlier attention than those located in the urban areas.

Recommendations

The truck type used for the assessment of the impact of LCV's on the geometry of diamond interchanges was a Turnpike Double, which produced the maximum offtracking. Thus, the conclusions make are applicable for all LCV's which are introduced in the Interstate Highway System. Any other LCV type wouyld produce a less severe impact on the geometry of diamonds due to its lower offtracking characteristics. However, Turnpike Doubles have been successfully used on restricted routes in some states and thus could be used successfully in Texas. If the LCV's are introduced in Texas, they might be allowed to operate only on restricted routes, as in other states; thus, restricting the assessment to the LCV route network would facilitate a cost study regarding improvements required at the interchanges in the future. Further research is recommended to assess the impact of LCV's on the geometry of interchanges on restricted routes.

IMPLEMENTATION STATEMENT

An initial benefit of the project was the transfer of the computerized Truck Offtracking Model (TOM) from CTR to the Highway Design Division of the Texas State Department of Highways and Public Transportation. The CTR staff obtaining the mainframe version from the California Department of Transportation which had improved on microcomputer versions developed by the University of Michigan Transportation Research Institute, and modified by the Federal Highway Administration. The SDHPT version made available in February 1987 is entitled "Vehicle Turning Characteristics for Use in Geometric Design". The implementation and availability of this program will provide highway engineers in the districts and divisions ready access to the latest computerized model procedure for use in design and evaluation where truck operations may be pertinent to operational efficiency and safety.

Further, the results of the study located and evaluated the interstate interchanges in the state with regard to their ability to accomodate LCV or other large vehicles. This information will provide the administration with readily available information on the impact of LCV's operating on a limited truck route network and the location of acceptable or unacceptable access points via diamond interchange ramp terminals.

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CHAPTER I. INTRODUCTION

Background

Due to interest in longer and wider truck combinations, Federal legislation and action taken in some states have called for the elimination or reduction of truck size restrictions. Changes in the legal limits will have impact on such diverse activities and practices as vehicle design, highway design, highway usage, and ultimately the economic vitality of the state.

The Texas State Department of Highways and Public Transportation (SDHPT) recognized the need to better understand impact of truck size and weight decisions, such as the introduction of longer and wider combination vehicles (LCV's) up to 118 ft long and 8.5 ft wide on the design of highways, on the upgrading of the roadway should changes be implemented, and on the management of the state's road network.

The research in this report originated from Project 447, entitled "Truck Use of Highways in Texas," which is an ongoing research effort that assists the SDHPT in the assessment process. The project is being conducted at the Center for Transportation Research of The University of Texas at Austin in cooperation with the Texas SDHPT. In this report, emphasis was placed on the assessment of the impact the LCV's would have on the geometric design of interchanges, especially diamonds, along the Interstate Highway System in Texas. It is based on sampling existing interchanges and simulating the movement of the LCV's on these interchanges using the computer Truck Offtracking Model (TOM).

Objectives

The objectives of this research included the following:

(1) to collect data on interchanges to determine the total number of existing interchanges, stratify them according to their types, and identify their precise locations in Texas;

(2) to determine the proportion of existing diamond interchanges with geometry inadequate to accommodate the turn maneuvers by LCV's at the ramp terminals;

(3) to identify the factors involved which significantly influence the pavement area available for turn maneuvers by LCV's at diamond interchange ramp terminals; and

(4) to develop 99 percent confidence intervals for the extra pavement width required at the ramp terminals for the entire population of diamond interchanges in Texas should the LCV's be allowed to operate on them.

Scope

The assessment of the impact of LCV's on the geometry of diamond interchanges was limited to the Interstate Highway System in Texas. The cross-road types analyzed at each diamond interchange were

(1) U.S. Highway,

(2) State Highway,

(3) Farm-to-Market Road, and

(4) Arterial.

Furthermore, the assessment was done with the largest LCV type, i.e., a 118-ft-long, 8.5-ft-wide Turnpike Double with a 3-axle conventional tractor (CBE tractor), 48-ft semitrailer and 48-ft trailer. The offtracking values for other LCV types are provided in Appendix D.

The remainder of the report is organized as follows

Chapter II provides an overview of the offtracking characteristics of LCV's plus the methods used by designers in the past to estimate offtracking of heavy trucks. It also includes a discussion of the actual over-the-road operational test conducted by CALTRANS (California Department of Transportation). Finally, this chapter describes the theoretical basis of TOM as it was originally developed at the University of Michigan Transportation Research Institute, and the characterization of input paths for this model.

Chapter III describes the LCV types chosen as representative of their population in use today and likely to be in the future. They are categorized into base and alternative scenarios. The base scenario includes a 48-ft conventional semitrailer, and the alternative scenario includes Turnpike Doubles, Rocky Mountain doubles, Triples (3 x 28), and Western Doubles (2 x 218). Their configurations are also provided.

Chapter IV covers the sources of data collected on interchanges along Interstate Highways in Texas, the limitations of the data collected, 1984 AASHTO definitions of interchange types used in the systematic identification, and categorization of all the interchanges. Finally, it provides a tabular summary of the data collected.

Chapter V explains the sample size determination for stratified random sampling of interchanges for statistical analysis, especially for urban and rural diamonds. A major part of this chapter is dedicated to describing the data collection representative of the amount of pavement width available for turn movements by LCV's on each interchange sampled.

Chapter VI describes the analysis of data collected from the sampled diamond interchanges using the analysis of variance (ANOVA) procedure as a "screening process" (Ref 26) to determine the significance of factors involved. It also includes a discussion of the factors and their various levels and provides a suitable linear model for use in the ANOVA procedure. Finally, it identifies the significant factors on which the analysis in Chapter VII is based and discards the insignificant ones with a confidence level of 99 percent.

Chapter VII describes the development of distributions of the extra pavement width required at the diamond interchange ramp terminals in order for them to accommodate the turn maneuvers by LCV's based on the factors found significant from the ANOVA procedure. Finally, it provides a 99 percent confidence interval for the extra pavement width required for the total population of diamond interchanges along the Interstate Highways in Texas.

Chapter VIII includes the summary of results, the conclusions, and recommendations for further research.

CHAPTER II. OFFTRACKING OF THE LONGER AND WIDER COMBINATION VEHICLES USING THE COMPUTER TRUCK OFFTRACKING MODEL

This chapter reviews the offtracking characteristics of the Longer and Wider Combination Vehicles (LCV's) and the methods previously used by highway designers to estimate the offtracking of heavy trucks. It then describes a computer method for graphing the complete swept path of an arbitrary vehicle making any type of turn at low speed and how the swept path is used for the analysis of the geometry of interchanges in this study. It also includes several example plots of a 118 ft long and 8.5 ft wide Turnpike Double (2 x 48 ft) negotiating turns on two conventional diamond interchanges.

Offtracking Review

When a vehicle negotiates a turn, its rear wheels track inward of the track traced by its front wheels, and this phenomenon is called offtracking. LCV's, especially, face critical problems during maneuvers in confined areas due to offtracking.

Offtracking can be defined as the difference in radii from the turning center to the vehicle center at the front steering axle and at the rearmost axle, during negotiation of a turn. Another term which is used almost as frequently as offtracking is swept path. Swept path can be defined as the radial distance between the turning paths of the outer front wheel and the outside of the rear wheel nearest to the center of the turn. Figure 1 illustrates the definitions of offtracking and swept path graphically.

Past research in offtracking and the factors which affect its magnitude have contributed to the following conclusions:

> The amount of offtracking is directly affected by the wheelbase length of a unit and inversely by the radius of the turn through which the vehicle travels. Other factors which affect the magnitude of offtracking are the number and location of articulation points, the number of radians (length of arc) involved in the turn, the type of curve (simple, compound, reverse) and the speed and turning ability of the vehicle. There are few other factors related to the physical characteristics of the vehicle such as inflation and condition of tires and heads on steering axle which are impossible to be taken into account when computing magnitude of offtracking mathematically. Variations in driver skills, the amount of the curve's super elevations, velocity and

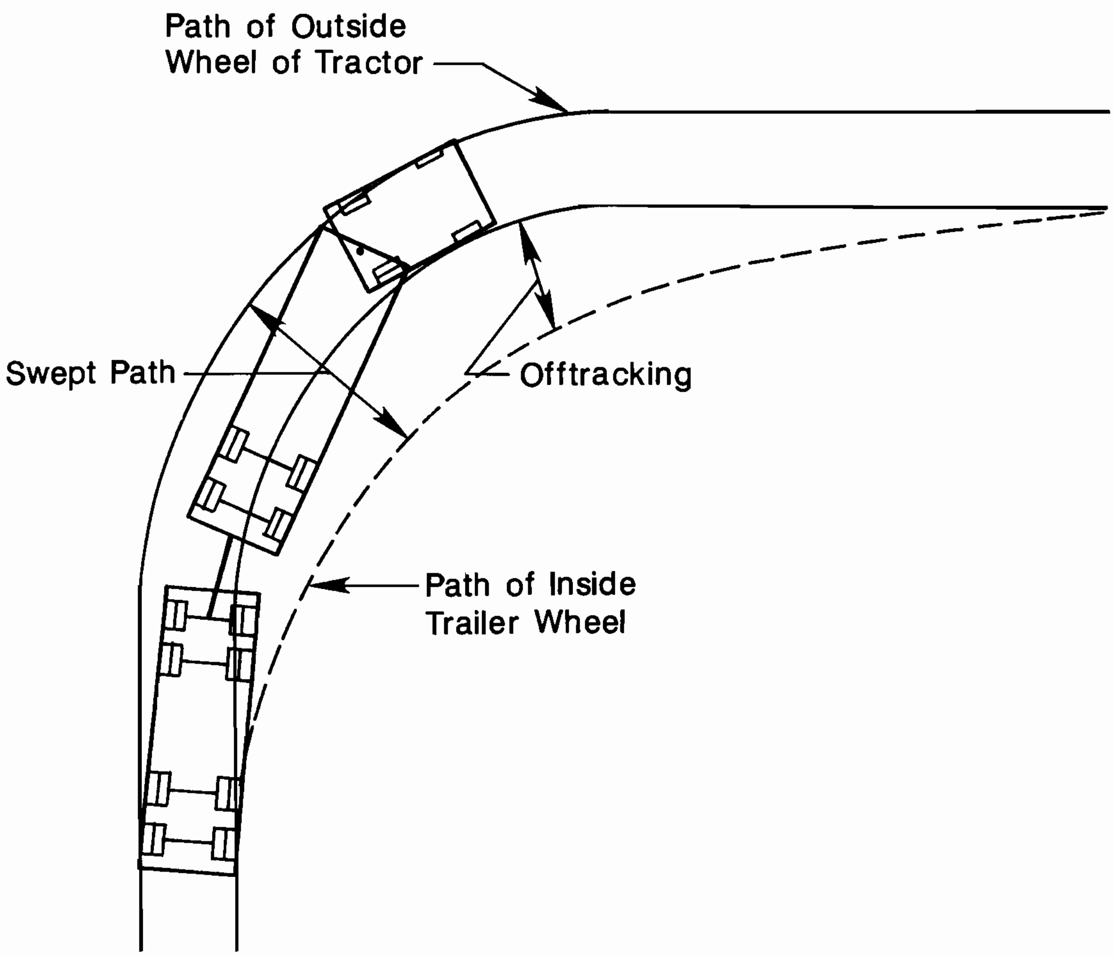


Fig 1. Offtracking and swept path of a long combination vehicle.

direction of wind, speed of vehicle at curve approach, conditions of the pavement and the physical characteristics mentioned above can be taken into account only through the testing of actual equipment. However, it is important to note that despite recognized differences in this matter of result-affecting factors being considered in the actual testing of equipment on one hand and the theoretical methods of determining offtracking for vehicles and turns of given measurements on the other, values obtained by way of the latter are consistently in approximate agreement with results derived from actual truth. (Ref 1)

Review of Methods Used to Estimate Offtracking

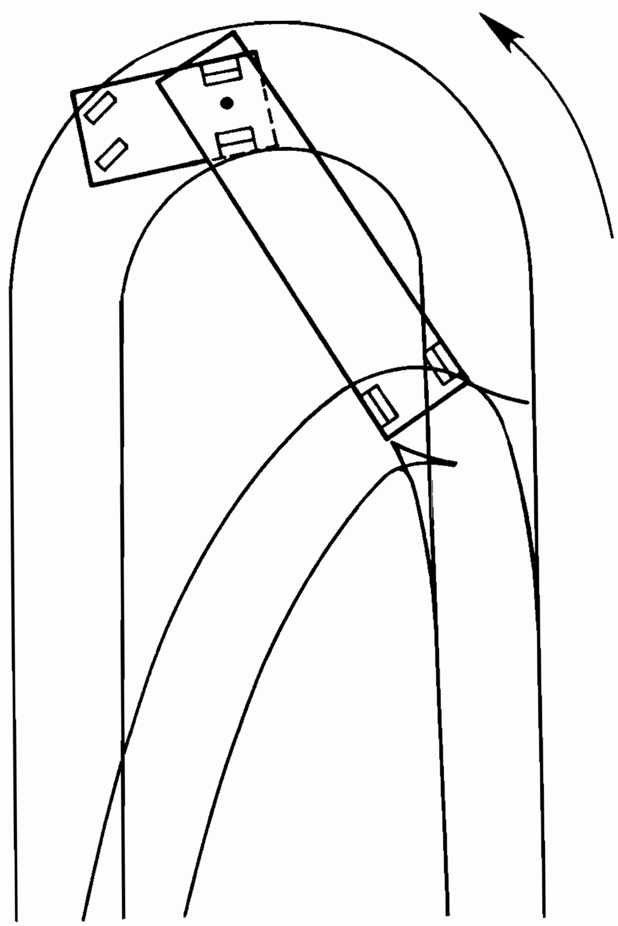
Several methods which have been used previously to estimate offtracking of vehicles are listed below:

(1) graphical representation,
(2) mathematical formulation,
(3) simulation with mechanical models, and
(4) observation of actual vehicles.

Graphical representation offers only the determination of a vehicle's maximum possible offtracking at a given radius of turn, and it requires more time than do the mathematical formulas in order to provide the same result. Thus, it is not as popular as the other methods.

Perhaps the best-known of the mathematical approaches to offtracking measurements is that of the Society of Automotive Engineers (SAE). The results that can be obtained through the use of the SAE equations are in terms of the maximum offtracking distance that will result when a vehicle of given wheelbase is driven into a turn of known radius. However, it does not provide information such as the point at which maximum offtracking is reached, and the distance duration around the curve. Also, the mathematical equation will not compute the maximum offtracking for those cases of turns made through short radius curves with centers between the path of the rearmost axle and the curves themselves. This limitation is shown in Fig 2.

Tractrix Integrator. Tractrix Integrator is a vehicle simulator which has been used successfully in the past in the measuring of offtracking of single unit and combination vehicles. It has a clear advantage over the other two methods since the amount of offtracking can be quickly scaled at any stage in the execution of the turn, once the paths of vehicles are traced on paper. The tractrix integrator is a single device with a scaled bar



Source: Ref 1.

Fig 2. A long wheelbase combination on a short radius turn, in which the semitrailer backs up and pivots behind the turning radius.

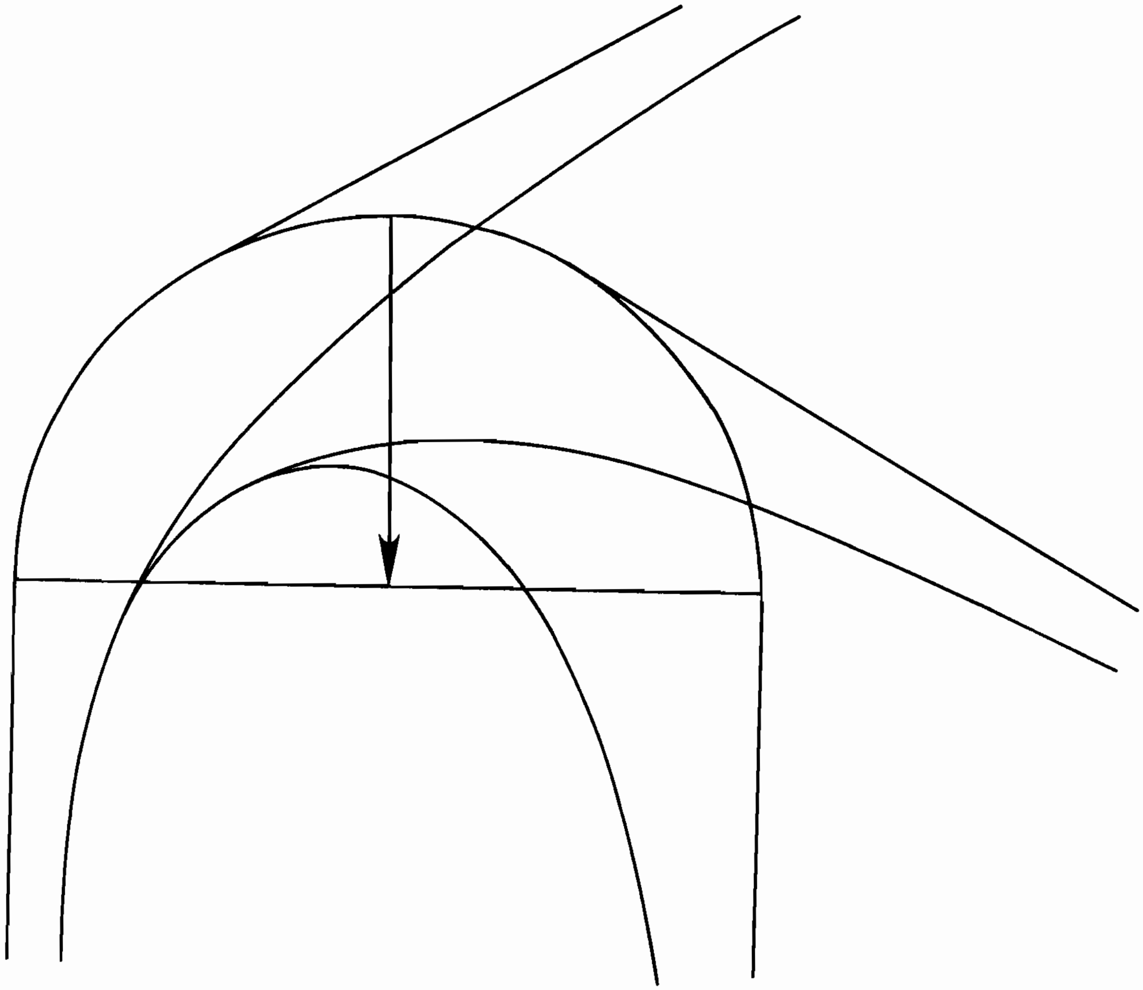
supported at one end by a pointer and steadying frame. It has an inked wheel attached at the other end between the bar, which makes a trail of ink as the bar is moved. With this model the maximum offtracking of a vehicle can be measured for any degree of turn and turn radius, as can the amount of offtracking at any point along the curve. Furthermore, it can be used in cases where the mathematical formulas are unusable, i.e., where the paths of the rear axle tracks are inside the center of the radius of curvature.

One of the main disadvantages inherent in using a tractrix integrator is that it is cumbersome to draw successive paths of each unit of a truck combination in order to obtain the swept path of a vehicle. Furthermore, user experience is needed to obtain a good approximation of the actual path of the vehicle, or significant variance between the output of different users can be expected. Millar and Walton (Ref 4) created templates using the tractrix integrator for various radii and angles of turn for examples of truck combinations. Figure 3 shows the swept path of a Turnpike Double combination negotiating 60, 120, and 180-degree turns with a 60-ft turning radius. Templates are useful tools for highway designers provided that the intersections have turn radii and angles in common with the templates. It would not be possible to design for any other angle and radius of turn or conduct analysis on existing intersections and diamond interchanges since the templates available are only for a particular radius and angle of turn and for limited truck combinations, which might not be representative of those in the future.

Observation of Actual Vehicles (Ref 7). The California Department of Transportation (CALTRANS) conducted an actual over-the-road, operational test of three LCV's: Triple Trailers, Rocky Mountain Doubles, and Turnpike Doubles.

Each combination was tested over the same 1,200-plus-mile route, which allowed for both observations of each combination and a direct comparison between the combinations. The observations of significance to this study are in the areas of freeway interchanges and other freeway facilities, such as rest areas and scales.

The triple trailer combination consisted of a 2-axle cab-over-engine (COE) tractor, a 28-ft semitrailer, and two 28-ft trailers, for an overall length of 100.2 ft. The combination also used a three-axled cab-behind-engine (CBE) conventional tractor, for an overall length of 107.4 ft. This combination had a maximum gross vehicle weight (GVW) of 111,000 lb. The triple trailer combination was found to be the most maneuverable of the three combinations, as witnessed by the offtracking tests and travel through numerous interchanges and intersections.



Source: Ref 4.

Fig 3. Template for 60°, 120°, and 180° turn with 60' turning radius for a turnpike double with 48' semitrailer and trailer.

The Rocky Mountain Double combination consisted of a three-axle conventional tractor (CBE) pulling a 48-ft semitrailer and a 28-ft trailer, and had an overall length of 93.2 ft. Its maximum GVW was 106,850 lb. With respect to maneuverability, this combination was the intermediate of the three test combinations used. It was observed to consistently place all four tires of the right rear set of duals onto the paved shoulders of loop ramps; however, it was found to have better maneuverability than the Turnpike Doubles when traversing other interchanges.

Turnpike Doubles were observed to be the least maneuverable of the three combinations tested. They had problems maneuvering through interchanges of the latest design located in rural areas. The CALTRANS study concluded that (1) the triple trailers could handle most of the interchanges traversed reasonably well, (2) the Rocky Mountain Doubles could handle most of the interchanges utilizing virtually all of the available space, and (3) the Turnpike Doubles had significant problems on existing interchanges and thus would require either substantial pavement edge maintenance work or new facilities with design standards far exceeding those existing today.

The observations made in the actual vehicle tests performed by CALTRANS were helpful in determining the critical elements of highways and interchanges to be further analyzed in this study.

Truck Offtracking Model (Ref 6)

The Truck Offtracking Model, or TOM, is a computer simulation model which has the capability to graph the complete swept path of an arbitrary vehicle making any type of low-speed turn. It was originally developed by M. Sayers at the University of Michigan Transportation Research Institute for the Apple II microcomputer, and was called Vehicle Offtracking Model (Ref 3). The Apple II version of the model is available to the public from the Federal Highway Administration (FHWA). When equipped with the appropriate plotting hardware, it produces high-quality scaled drawings of vehicle offtracking.

TOM is a simulation portion of the Vehicle Offtracking Model which is adopted by CALTRANS Division of Transportation Planning (DOTP) for implementation on the state's IBM mainframe computer (Ref 6). Although TOM is not as "user friendly" or flexible as its predecessor, its capacity is much larger. New TOM is also on the IBM mainframe computer of The University of Texas at Austin and is the basis of the analysis of the longer and wider combination vehicles' movements on interchanges.

Bicycle Model. The theoretical basis for the computer method is that it is essentially a numerical version of the tractrix integrator using the concept of "bicycle model" (Ref 3). The tractrix integrator can be termed as a physical bicycle model. The bicycle model assumes that all non-steered wheels that are rigidly connected can be represented by a single "equivalent wheel" located near the centroid of the actual position. The highway vehicles are modeled geometrically as a bicycle since they are symmetrical from right to left, with each wheel on the right-hand side of the vehicle having a corresponding wheel on the left-hand side. Multiple-axle suspensions are similarly modeled as a single effective axle, usually located at the geometric center of the non-steered axles. Figure 4 shows an eighteen-wheeled tractor semitrailer combination vehicle being represented by two linked bicycle models.

In Fig 4, the bicycle model for the tractor has the front point coinciding with a point midway between the two rear axles. The wheelbase, designated L_1, is the distance between these points. The wheelbase for the semitrailer, designated L_2, is the distance between the hitch and the center point of the two axles. The front point of the semitrailer does not necessarily coincide with the rear point of the tractor unit, and therefore the offset distance, designated λ_1, is also needed. The offset is positive in the figure because it is in front of the equivalent wheel position; when the hitch point is located behind the rear wheel, a negative value is used.

Characterization of Input Path. Designers are mainly interested in the case of the vehicle making circular turns for a given angle of interest and then exiting the turn in a straight line. Therefore, the input path is represented by a circular arc and a tangent line. In this model, the input path is characterized as a sequence of arcs. The end-point of one arc is also the beginning-point of the next, and the arcs are constrained to be tangent where they meet. Figures 5a, 5b, and 5c show three examples of input paths.

Figure 5a shows the simple curve with two arcs, where the second has zero curvature. Figure 5b shows a more complex type of turn which would be used to model where the driver first turned to the left in order to obtain more room for a right turn. It is composed of four arcs, with the fourth having zero curvature. Figure 5c shows a lane-change type of path, which could be used to model the maneuver taken by a bus pulling into a bus-stop lane and then leaving. Further discussion on the bicycle model and the details of numerical computation of offtracking in the computer method can be found in a paper by M. Sayers (Ref 3).

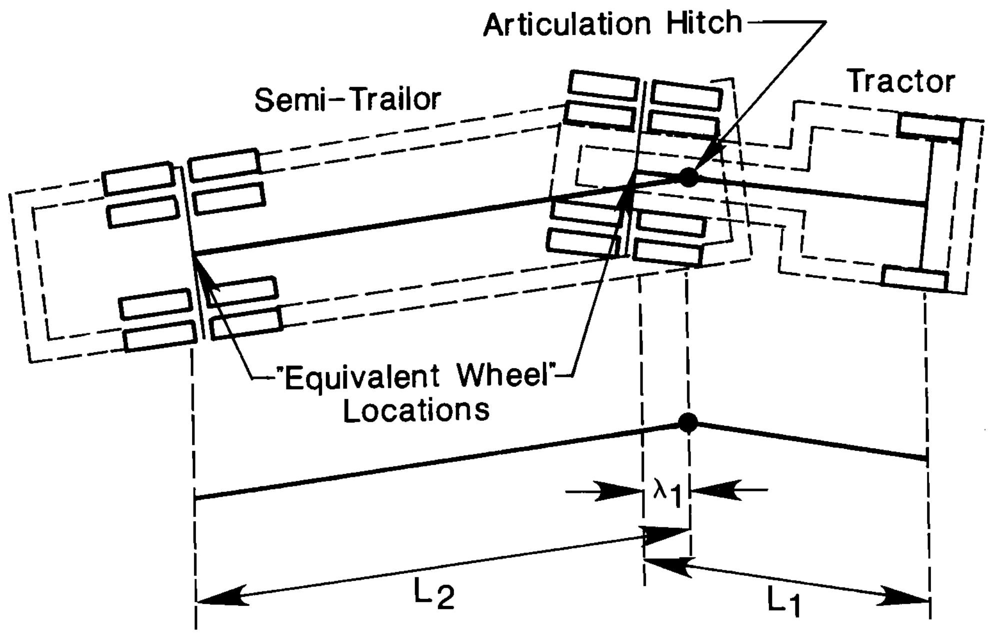


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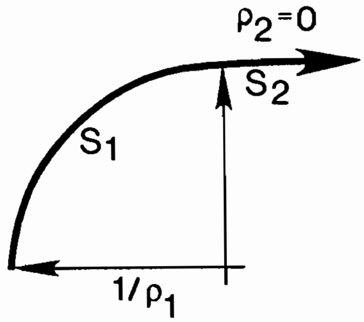
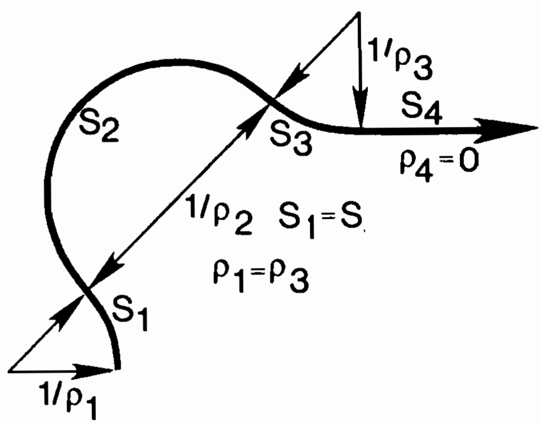
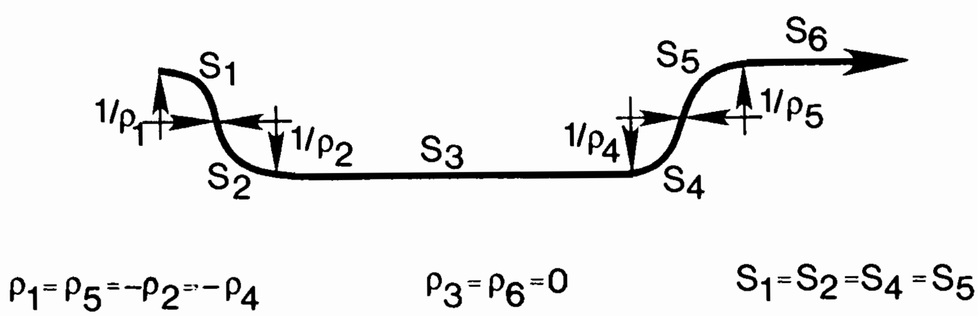
Fig 4. Two linked "bicycle" vehicle models.



a. Simple 90^{o} Turn



b. Complex 90^{o} Turn



c. Lane Change

Fig 5. Three maneuvers represented as a sequence of circular arcs.

CHAPTER III. REPRESENTATIVE TRUCK TYPES

This chapter presents more information on the types and configurations of LCV's used in this study as a framework for analyzing their impacts on the geometry of highway interchanges. The types and dimensions of trucks chosen play an important role in the analysis of the data collected, which is described in the later chapters.

Although the LCV's are not operational in Texas, they are operational on restricted routes in other parts of the United States. Their existence and operational characteristics facilitated obtaining their configurations and typical dimensions. The following truck combinations are at present classified as LCV's: (1) Turnpike Doubles, (2) Rocky Mountain Doubles, and (3) Triples, and these classifications are used in this study also.

History of LCV's

Past research studies have concluded that increasing need and demand for goods transported over highways may require a substantial increase in the number of commercial trucks within the next fifteen years unless more goods are carried per power unit. Fuel shortages and environmental factors may become more critical and require almost all transportation modes, including highways, to utilize more efficient and productive equipment and operational procedures.

More than 30 years of operation and development has produced highway truck combinations which can haul more goods while conserving fuel and reducing the effects on highway pavements and bridges. These more productive combinations are made by adding another trailer to present day conventional truck combinations. These combinations have been operated for many years on Eastern and Midwestern toll roads and in several Western States.

Turnpike Doubles (Ref 9). Turnpike Doubles, with a cubic capacity of 5,000 cubic ft, have been operated on some eastern toll roads for as long as 20 years. They generally consist of a 3-axle tandem drive CBE truck tractor, a 40 or 45-ft tandem axle semitrailer, and a 40 or 45-ft trailer. The gross weight is distributed over nine axles and an overall length of 105 to 110 ft. A COE truck tractor may be used,which generally reduces overall length in proportion to the difference in wheelbase. Turnpike Doubles are operated on the New York Thruway, Massachusetts Turnpike, Ohio Turnpike, Kansas Turnpike, Indiana Toll Road, and Florida Turnpike. They are also operated regularly on designated highways in the states of Idaho, Nevada, Utah, and Arizona and under demonstration test programs in South Dakota, New Mexico, and Montana and are awaiting approval in Oregon.

Rocky Mountain Doubles (Ref 9). This combination has two cargo units which are quite versatile and provide flexibility in scheduling the movement of freight, and is gaining popularity among operators hauling a mix of high and low density products. A three-axle tandem drive COE or CBE truck tractor generally is employed to pull a 40 or 45-ft semitrailer followed by a 27-ft semitrailer converted to a full trailer by a single axle converter gear, also called a dolly. With a 45-ft and a 27-ft semitrailer, it has a cubic capacity of 4,600 cubic ft and its weight is spread over seven axles. Overall length is generally restricted to 85 ft, which requires that the shorter wheel-base COE truck tractor be used with 45-ft semitrailer units. Rocky Mountain Doubles are operated in Washington, Montana, Wyoming, Idaho, Utah, and Oregon.

Triples (Ref 9). Generally, this combination consists of a two-axle COE truck-tractor pulling a 27-ft semitrailer followed by two 27-ft semi-trailers converted to full trailers by the use of single-axle converter dollies. This combination has a total length of around 95 ft, and its weight is distributed over seven axles. A three-axled tandem drive COE or CBE truck-tractor is sometimes used, which adds around 3 ft to the overall length depending on the truck tractor's wheelbase. This combination has a capacity of approximately 5,110 cubic ft. Triple trailer combinations are presently operated on the Kansas Turnpike and on designated highways in Idaho, Nevada, Oregon, Utah, Arizona, and the Province of Alberta. Operational test programs are underway in New Mexico and Montana.

Truck Scenarios

Two scenarios of truck types were developed as a framework for this study, a base scenario and an alternative scenario. The base scenario consists of truck types with a total length of 65 ft or less, which was the maximum legal length in Texas prior to the Surface Transportation Assistance Act (STAA) of 1982. The alternative scenario consists of all truck combinations classified as LCV's under the STAA 1982. Some of the truck combinations in the alternative scenario were selected from the configurations of LCV's used in past research studies on truck weights and LCV's route network at the Center for Transportation Research of The University of Texas at Austin (Ref 12). Some were also based on truck combination configurations and dimensions used for FHWA studies in the past (Ref 5). The dimensions represent the typical dimensions used by the LCV operators in various parts of the United States mentioned above. The axle spacings used satisfy the bridge formula limits and are typical of the truck combinations in use today.

Base Scenario. The base scenario (which consists of a tractor semitrailer combination) was created mainly for comparison of results with the alternative scenario. This combination consists of a three-axled COE tractor with wheelbase length of 11 ft, 10 in, attached to a 48-ft semitrailer with wheelbase length of 34 ft, 8 in. The overall length of this combination is 57 ft, 10 in. Figure 6 shows the configuration of the base scenario.

Alternative Scenario. This scenario is comprised of truck combinations which are classified as LCV's. The semitrailer and trailer width is 102 in. (8 ft, 6 in.) which is 6 in. wider than the semitrailers and trailers which existed before the 1982 STAA. The truck combination types, configurations, axle spacings and other dimensions are selected such that they are representative of truck combinations which may be used in the future in Texas.

There are four cases in this scenario. Case I is the Western Double, with double 28-ft semitrailer and trailer. The tractor is the COE type with two axles and wheelbase length of 10 ft. The wheelbase of the semitrailer is 19 ft, 6 in. and that of the trailer is 21 ft, 6 in. The overall length of this combination is 67 ft. The fifth wheel location is 8.5 in. in front of the rear axle of the tractor. Case I is illustrated in Fig 7a.

Case II is a Rocky Mountain Double combination with a 48-ft semitrailer and a 28-ft trailer. The combination is attached to a three-axled conventional CBE tractor with a wheelbase of 15 ft, 6 in. The semitrailer has a wheelbase of 37 ft, 4 in. and the trailer 22 ft 4, in. The total length of this combination is 93 ft, 2 in. The configuration of this combination is shown in Fig 7b.

Case III consists of a Triple Combination with a 28 ft semitrailer and trailers. A conventional, or CBE, tractor with two axles and a wheelbase of 13 ft, 6 in. is employed in this combination. The wheelbase of the semitrailer is 20 ft 8 in. and that of the trailers is 21 ft 7 in. The overall length of this combination is 102 ft. All the axles in this combination are single axles and the fifth wheel location is 0.7 ft in front of the rear axle of the tractor. The gap length is 3 ft between semitrailer and trailer. Fig 8a shows this Triple combination.

Case IV consists of a Turnpike Double combination which was developed by FHWA for offtracking calculations. It is believed to be a realistic

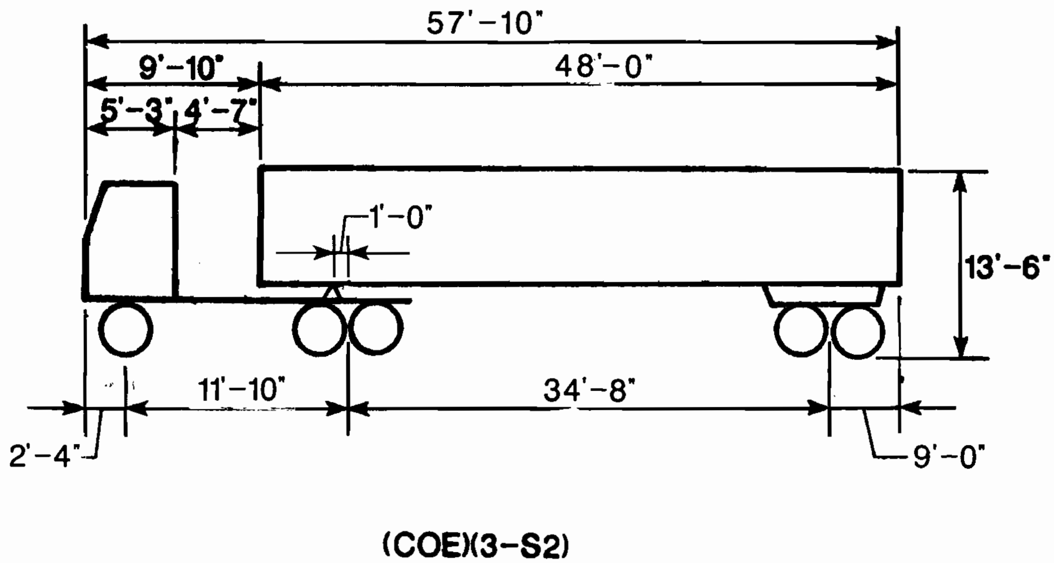


Fig 6. Base scenario: tractor semitrailer combinations.

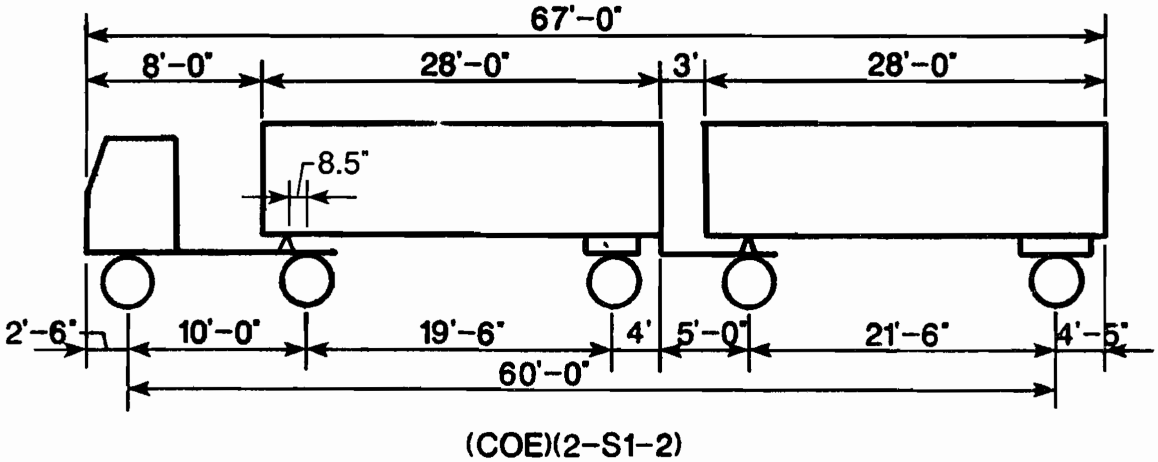


Fig 7a. Alternative scenario: western double (2 x 28).

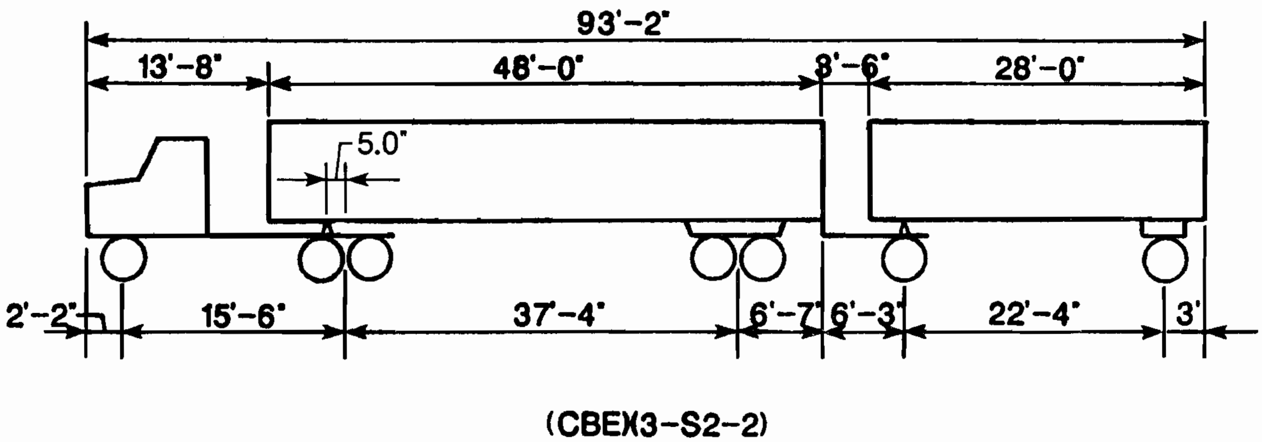


Fig 7b. Alternative scenario: Rocky Mountain Double (48 + 28).

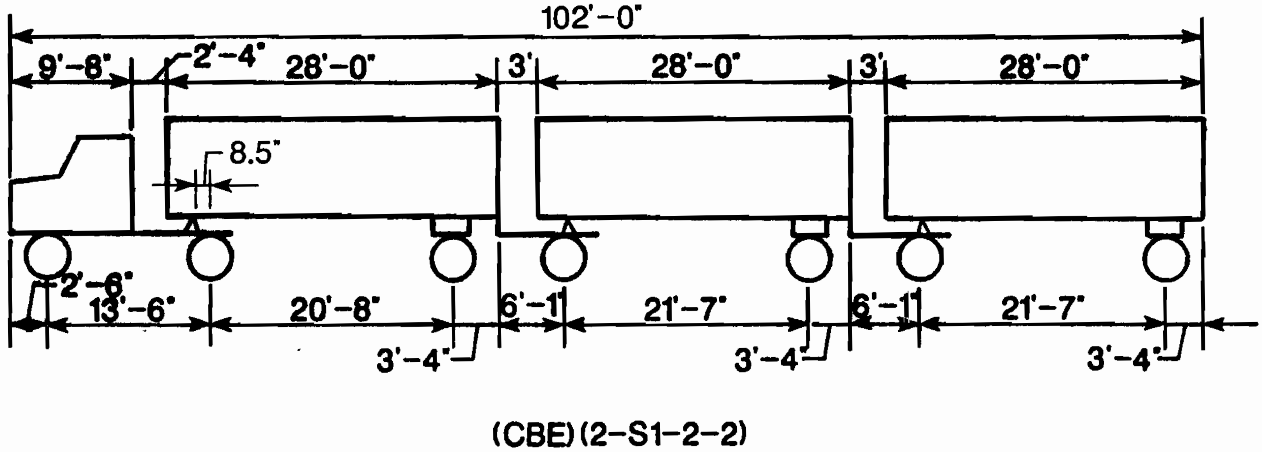


Fig 8a. Alternative scenario: triple (3 x 28).

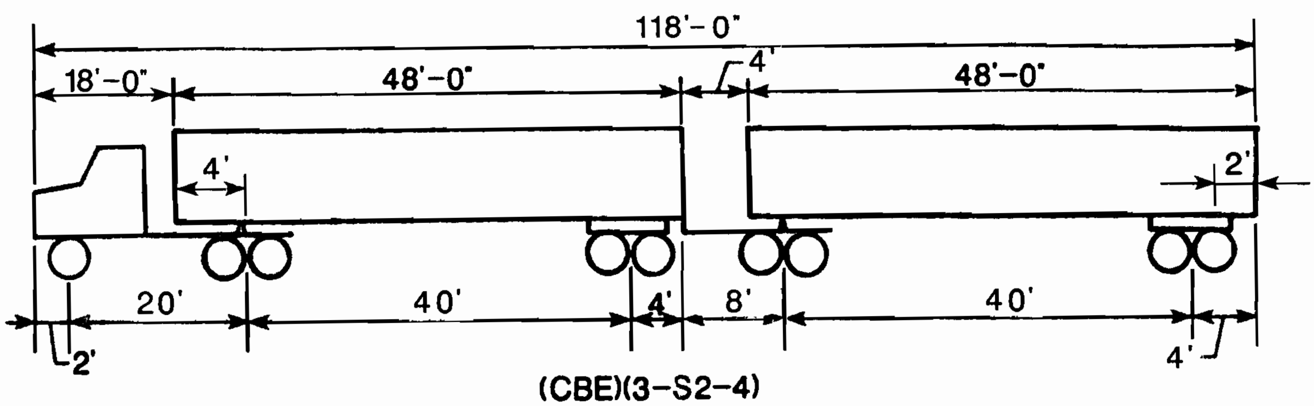


Fig 8b. Alternative scenario: turnpike double (2 x 48).

representation of Turnpike Doubles of the future, taking into consideration the steering axle load and tandem axle load limitations (Ref 5). This combination has a conventional or CBE, 3-axled tractor with a 48-ft semitrailer and a 48-ft trailer. Its overall length is 118 ft. Both the semitrailer and trailer have wheelbase lengths of 40 ft. The gap between the semitrailer and trailer is 4 ft. The fifth wheel offset is zero. The maximum gross combination weight (GCW) of this combination is 120,000 lb. This combination is shown in Fig 8b.

The truck combinations represented in the base and alternative scenarios will form the framework for the assessment of the impact of LCV's on the geometry of diamond interchanges in Texas.

CHAPTER IV. DATA COLLECTED ON INTERCHANGES

Over-the-road operational tests of LCV's have shown that these vehicles encountered critical problems while traversing highways of the latest design, including interchanges. An inexpensive and rather quick way of assessing the impact of LCV's on the geometry of existing interchanges is simulation of the turn movements of the LCV's on actual existing interchanges using a computer simulation model. The availability of plan drawings with configurations and dimensions of existing interchanges from the Texas State Department of Highways and Public Transportation (SDHPT) made possible the sampling of many interchanges of various types. The assessment of the impact of LCVs is limited to interchanges along Interstate Highways in Texas. The interchanges sampled and statistical results of the assessment are covered in later chapters of this report. This chapter describes the sources of data collected, the limitations of data collected, and 1984 AASHTO definitions of interchange types used in the systematic identification and categorization of all the interchanges along Interstate Highways in Texas. Finally, it provides a tabular summary of the data collected.

Sources of Data Collected

Almost all types of interchanges were identified along with the types of crossroads and their locations. Sources of data collected are the 1986 county and district maps obtained from the Texas SDHPT. The county maps displayed the configurations of the interchanges with an acceptable scale which enabled us to identify the interchange types, and also provided the types of crossroad at most of the interchanges, such as "U.S. Highway, State Highway, FM," etc. District maps had the control and section number of highways, and, by cross-referencing with county maps, complete information on all the interchanges was obtained. The information includes the type of interchange, the type of cross-road, and the location identifiers, which are the district numbers, county names, and control and section numbers. The job numbers of the the sampled interchanges were obtained from the Texas SDHPT Planning Department. Finally, the plan drawings were collected from the Texas SDHPT warehouse where all the Texas highway plan drawings are stored. These plan drawings provided all the information needed, such as number of lanes available in the crossroad, lane widths, curb radii, etc., to simulate the turn movements of LCV's using the Truck Offtracking Computer Model (TOM).

Limitations of Data Collected

Identification and categorization of the interchanges are restricted to those located along Interstate Highways in Texas only. The accuracy of the dimensions obtained from the plan drawings is limited to the accuracy of the plan drawings themselves. The plan drawings collected from the Texas SDHPT included the latest changes made to those interchanges after they were originally built.

Highway Interchange Types

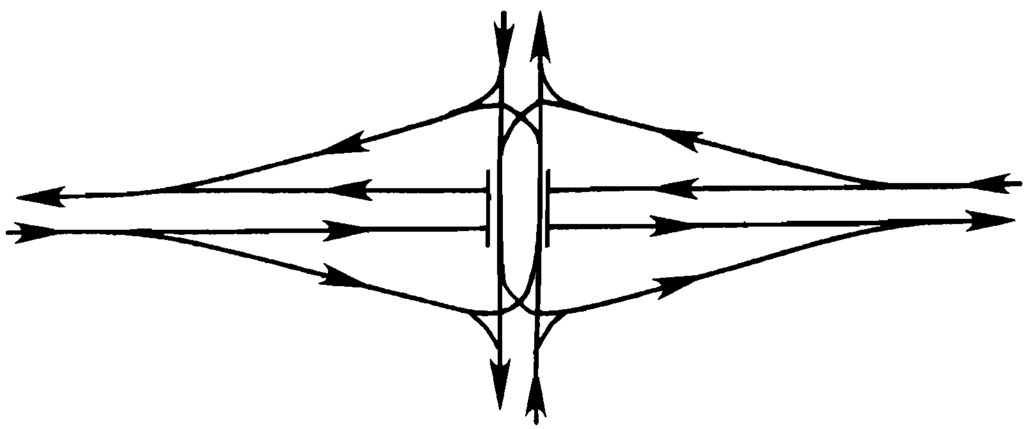
A total of five types of interchanges were identified in the data collected. Each type was further classified as a 3-leg, 4-leg, service, or system interchange. The following are the five major types of interchanges:

(1) Diamond,
(2) Cloverleaf,
(3) Directional,
(4) Semi-Directional, and
(5) Combination.

Before a detailed discussion of each of the above interchange types is presented, definitions of 3-leg, 4-leg, service, and system interchanges would be beneficial. An interchange at an intersection with three intersecting legs is termed a 3-leg interchange. It consists of one or more highway grade separations and one-way roadways for all traffic movements. An interchange with 4 intersecting legs is called a 4-leg interchange, and some of the types of interchanges which can be classified under 4-leg are ramps in one quadrant, diamond interchanges, cloverleaf interchanges, and interchanges with direct and semi-direct connections. An interchange where two Interstate Highways intersect is called a system interchange, and all other interchanges where Interstate Highways intersect with other types of cross-roads are called service interchanges (Ref 8).

Diamond Interchanges. The simplest and the most common type is the diamond interchange. A full diamond interchange is formed when a one-way diagonal type ramp is provided in each quadrant. The ramps are aligned with free-flow terminals on the major highways, and the left turns at grade are configured to the cross-road (Ref 8). Figure 9 shows the configuration of a full diamond interchange.

Diamond interchanges are further classified into conventional diamonds, conventional split diamonds, split diamonds with "jug-handle" ramps, diamonds



Source: Ref 8.

Fig 9. A full or conventional diamond interchange.

with turnarounds, and x-diamonds. A conventional diamond is a full diamond and is the most common among diamonds. Conventional split diamonds are conventional diamonds with each pair of ramps connected to a separate cross-road about a block apart.

X-diamonds are diamonds with entrance and exit ramps provided before and after the cross-road, respectively, forming an x-pattern. Diamonds of this design are common in some urban areas in Texas, such as Houston. Diamonds with turnarounds are the conventional or split diamonds with turnaround facility. A split diamond with "jug handle" ramps is the unique type of diamond commonly found in the rural areas of Texas. Fig 10 shows one of its configurations. It consists of a pair of "jug handle" ramps intersecting the cross-road and the frontage road at-grade and most of the time at right angles. Sometimes, both ramps are found on the same side of the cross-road. Most of the cross-roads at these interchanges are of low-type pavement such as soil, gravel, etc.

All the diamond interchanges identified are classified under the above-mentioned types of diamonds, and the analysis of their geometry is described in the next chapter.

Cloverleaf Interchanges. Cloverleafs are defined as

> four-leg interchanges that employ loop ramps to accommodate left-turning movements. Interchanges with loops in all quadrants are referred to as full cloverleafs and all others are partial cloverleafs. (Ref 8)

Figures 11 and 12 show the configuration of a typical full cloverleaf and a partial cloverleaf interchange, respectively.

Directional Interchanges. Directional interchanges are interchanges with direct connections, which are defined as "a one-way roadway that does not deviate greatly from the intended direction of travel" (Ref 8). Fig 13 shows the configuration of a semi-directional interchange. It is also a 3-leg T-type, or trumpet. Figure 14 shows a fully directional interchange.

Combination Interchanges. A Combination Interchange is a combination of two different interchanges, custom-designed to accommodate traffic demands on a location of interest. It could be a combination of a diamond with a semi-directional ramp to accommodate high-volume left turn traffic, a combination of a cloverleaf with a semi-direct connection, etc. Figure 15 shows an example of a combination interchange which is a four-leg diamond with a semi-direct connection.

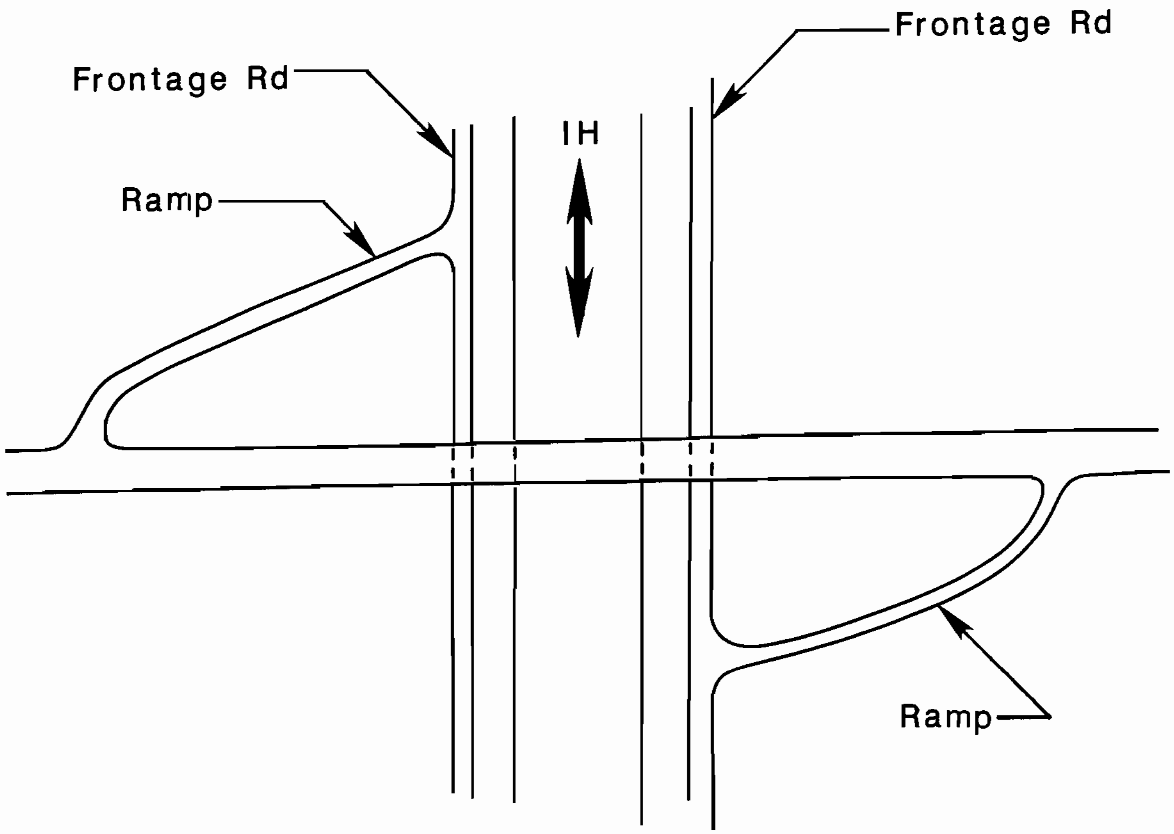
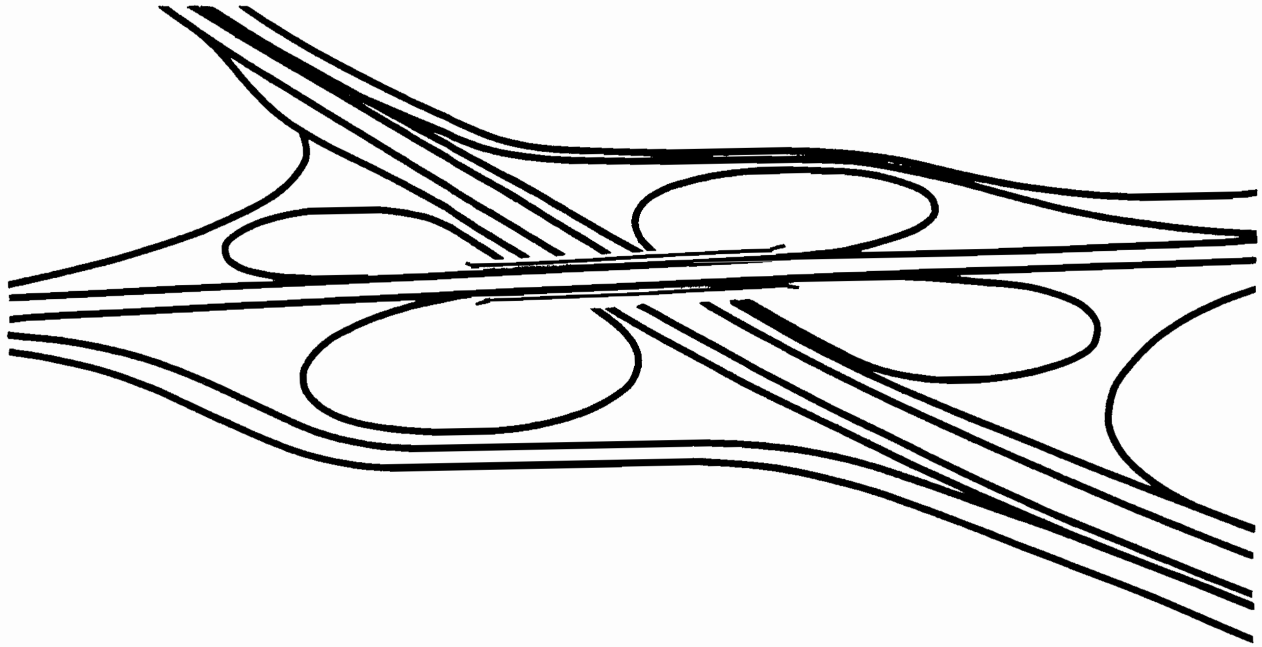
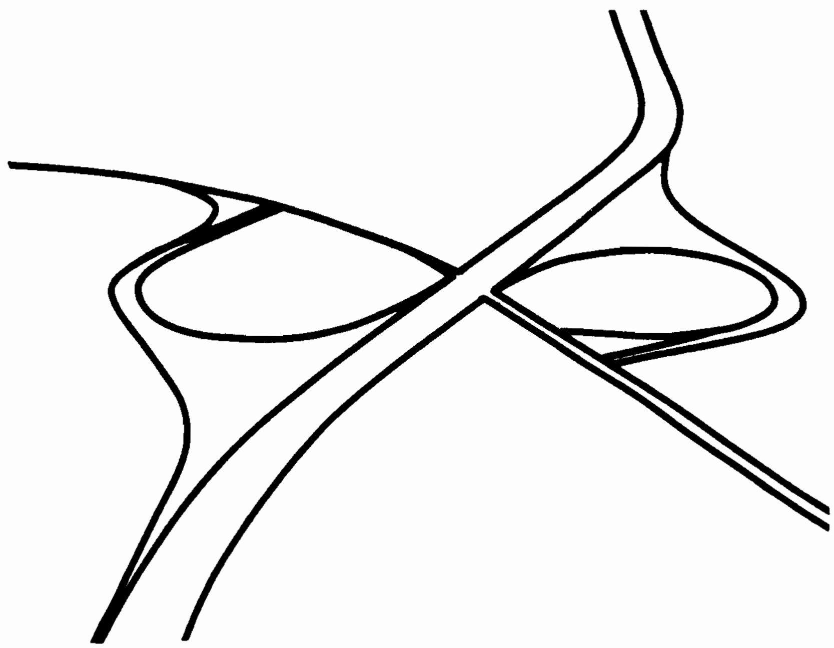


Fig 10. A split diamond interchange with "jug handle" ramps.



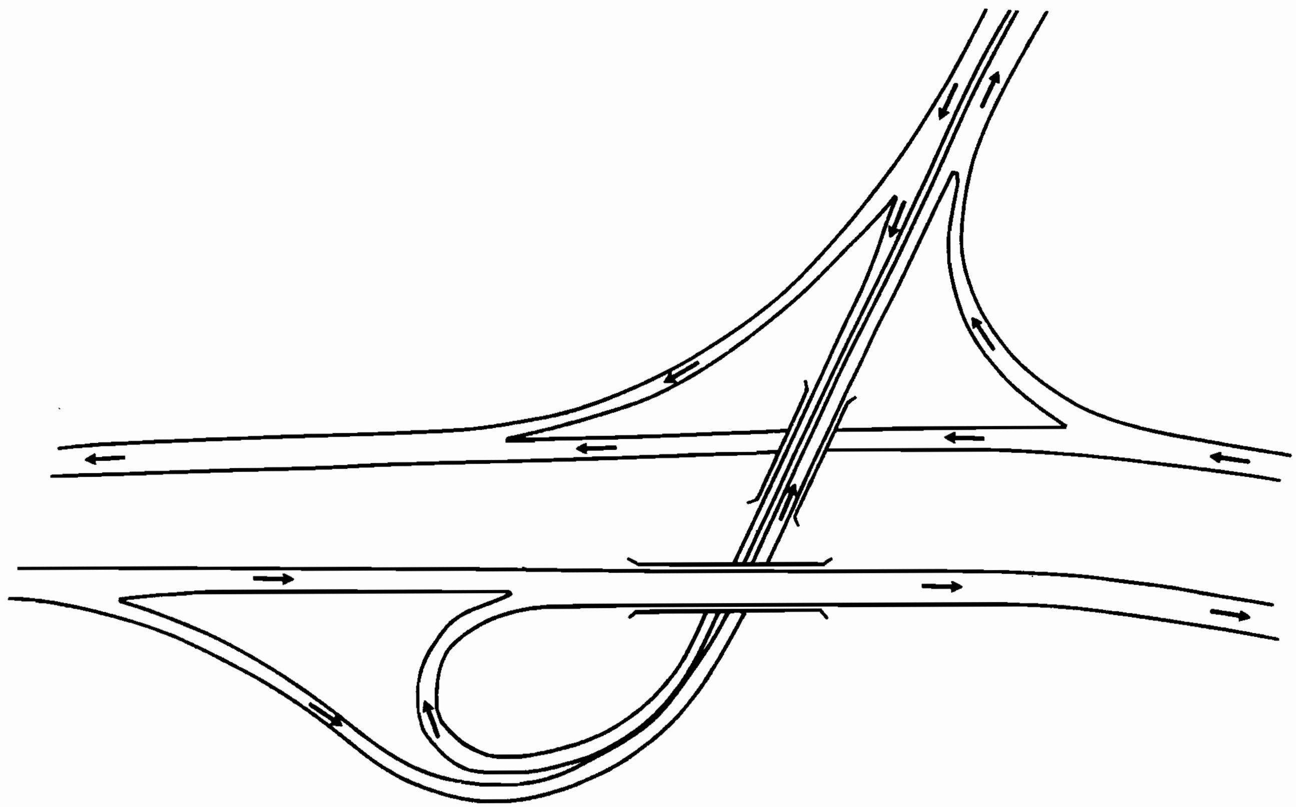
Source: Ref 8.

Fig 11. A full cloverleaf interchange.



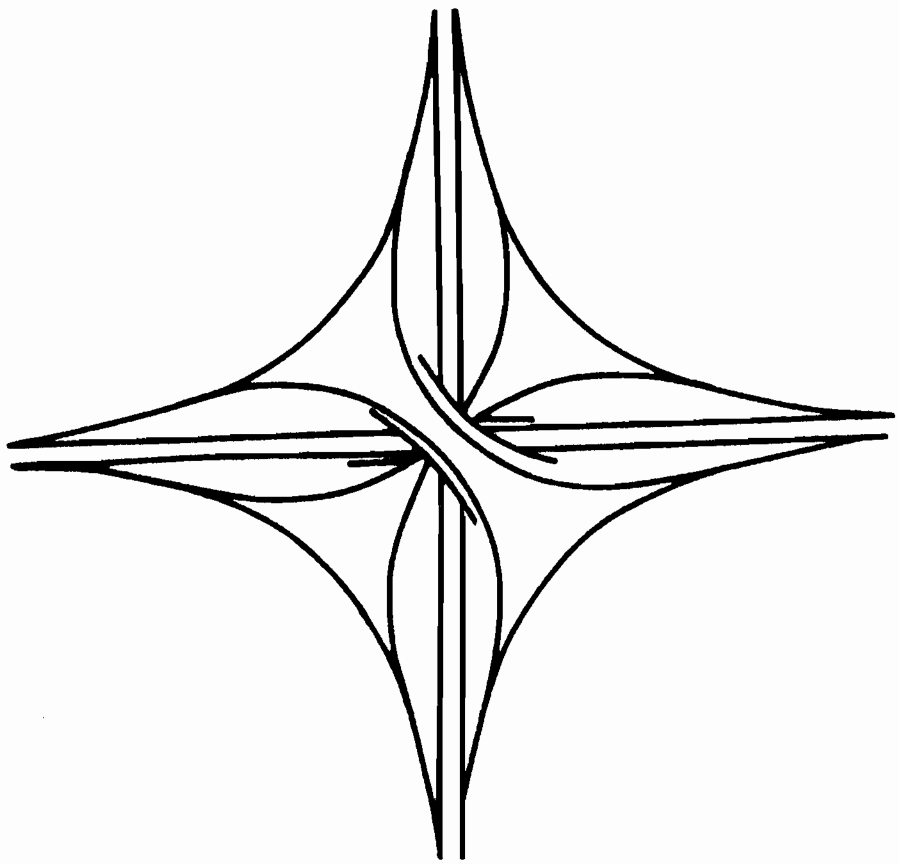
Source: Ref 8.

Fig 12. A partial cloverleaf interchange.



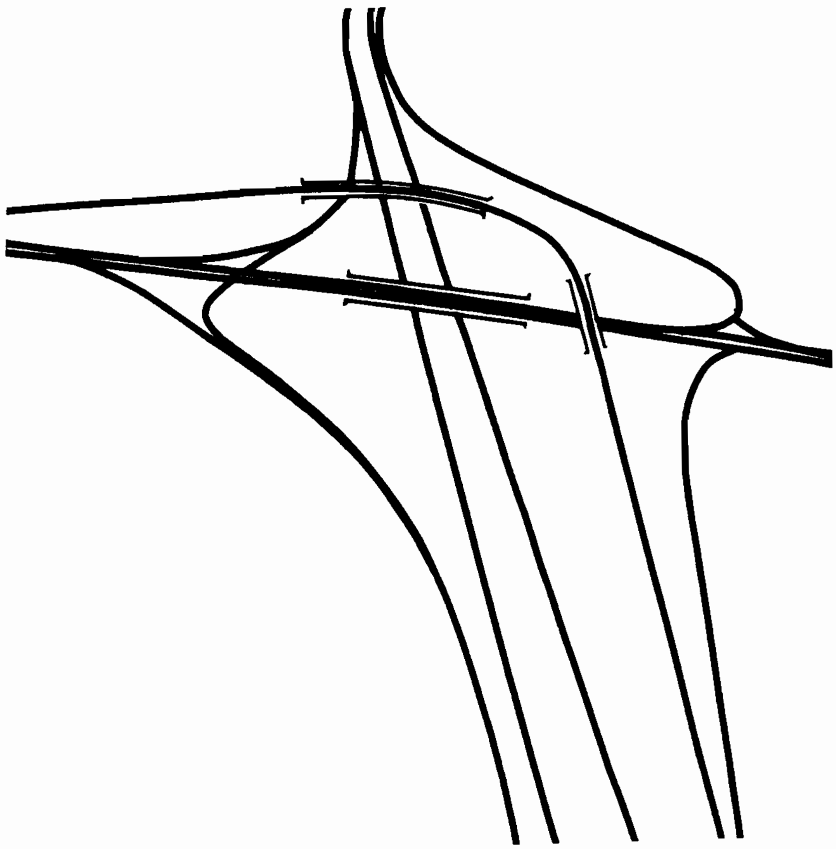
Source: Ref 8.

Fig 13. A t-type, or trumpet, interchange.



Source: Ref 8.

Fig 14. A full directional interchange.



Source: Ref 8.

Fig 15. A 4-leg diamond interchange with a semi-direct connection.

Offset Interchange. These interchanges have applications where there are major buildings or other developments in close proximity to the crossing of the freeways. It consists of a pair of trumpet interchanges, one in each highway, which are connected to each other with a ramp highway. The length of the connecting roadway depends on the distances between the trumpet interchanges and the crossing of the freeways. In this study, for simplicity of data collection, an offset interchange is classified as two 3-leg semi-directional interchanges since they are both T-type, or trumpets.

Identification and Categorization of Interchanges

Since the analysis in this study required random sampling from the total population of each major type of interchange, each type was numerically coded. A total of six separate numerical codes were utilized to identify all the interchanges. Diamonds, full directionals, semi-directionals, partial cloverleafs, full cloverleafs, and combinations were all coded separately and include those located in both urban and rural areas.

Appendix F lists all the interchanges identified along Interstate Highways in Texas. Two listings were provided for each type of interchange: one is for those located in urban areas and the other for those located in rural areas. Since diamonds can be further classified into conventional diamonds, conventional split diamonds, diamonds with turnarounds, split diamonds with "jug handle" ramps, and x-diamonds, they are all listed separately but under one numerical code system.

As shown in Appendix F, each interchange is identified with a three-part code. The first part is the cumulative numerical code. The middle part describes the type of cross-road and the last part identifies the location within a county as given in the 1986 Texas County Maps. A plus sign in-between the first and the second parts of the three-part code indicates that it is a three-leg interchange. The absence of a plus sign indicates a four-leg interchange. Each interchange is provided with four location identifiers: the Interstate Highway number along which it is located, the district number, the county number, and the control-and-section number of the highway. For example, the first interchange under "Diamond Interchange (Conventional) -- Urban" in Appendix F is coded as 7+ ART C. It means that it is the 7th diamond interchange identified and the cross-road is an urban arterial. The C identifies the location within El Paso County. Furthermore, it is a 3-leg interchange and is located along Interstate Highway 10 in District 14. The control-and-section number of the highway where this interchange is located is 2121-2.

The interchanges which were randomly sampled have an asterisk before the numerical part of the code and also their job numbers listed. Double asterisks indicate the interchanges which were subsampled for preliminary analysis.

A total of 7 types of crossroads were identified from the county maps: U.S. Highway, State Highway, Arterial, Farm-to-Market Road (F.M.), paved, gravel, and soil. The cross-roads type is indicated in the middle part of the 3-part code.

Results of Data Collected

The total number of interchanges of all types identified along the Interstate Highways in Texas is 1557. Fig 16 contains a summary of the data collected in this study. Diamond Interchanges, which include conventional diamonds, conventional split diamonds, split diamonds with "jug-handle" ramps, diamonds with turnarounds, and X-diamonds comprise 85.9 percent of the entire population of interchanges along Interstate Highways in Texas. Due to this high proportion of diamonds, the analysis in this study is concentrated on those interchanges. The results shown have two main categories, 4-leg and 3-leg. Each main category is further divided into system and service, where the former includes system interchanges and the latter includes the remaining service interchanges. Urban and rural include those located in urban and rural areas, respectively.

Eighty-one percent of the total population of interchanges are those with 4-legs. The proportion of interchanges located in urban areas, such as Houston, San Antonio, and Dallas Fort-Worth, etc., is 36.7 percent, which makes the number located in rural areas 956. Eighty-six point eight percent of the full directionals and 64.7 percent of the cloverleafs are located in urban areas. Sixty-five percent of the diamonds and 67.4 percent of the semi-directionals are located in rural areas. Furthermore, 80.7 percent of the semi-directionals are 3-leg interchanges.

Types Of Interchanges	4 - Leg				3 - Leg				
	Service		Systems		Service		Systems		
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	TOTAL
Conventional Diamond (CDI)	337	641	0	0	17	151	0	0	1146
Split Diamond (SDI)	22	6	0	0	1	0	0	0	29
Split Diamond W/ Jug Handle Ramps (SDJ)	4	60	0	0	0	0	0	0	64
Diamond with Turnaround (DIT)	64	11	0	0	5	0	0	0	80
X - Diamond (XDI)	18	0	0	0	0	0	0	0	18
Fully Directional (FD)	9	0	15	1	4	3	5	1	38
Semi-Directional (SD)	20	4	2	0	18	85	4	2	135
Full Cloverleaf (FC)	17	5	2	1	0	0	0	0	25
Partial Cloverleaf (PC)	3	9	0	0	0	0	0	0	9
Combination Interchange (CI)	4	9	0	0	0	0	0	0	13
TOTAL	498	742	19	2	45	239	9	3	1557

Fig 16. Summary of data collected on interchanges along interstate highways in Texas.

CHAPTER V. DATA COLLECTED ON THE GEOMETRY OF INTERCHANGES

The stratification of interchange types during initial data collection along Interstate Highways in Texas was done to facilitate stratified random sampling. The random sampling would then allow one to perform statistical analysis on the geometry of existing interchanges. The availability of the computer Truck Offtracking Model (TOM) and plan drawings of interchanges made possible the selection of large enough interchange sample sizes. This chapter describes the determination of sample sizes for urban and rural diamond interchanges. A major part of this chapter, however, is dedicated to describing the data collection methodology.

Sample Size of Diamond Interchanges

One of the objectives of random sampling of diamonds was to determine the proportion of existing diamonds with geometry inadequate to accommodate the turn maneuvers of the LCV's at the ramp terminals. Since no information was available on the population distribution of the proportion of inadequate diamond interchanges, the following equation was helpful in determining the sample sizes for the diamonds:

$$\pi = P \pm (Z\sigma_p) \qquad \text{Eq 1}$$

(Ref 27)

where

$$\sigma_p = \sqrt{\frac{P(1-P)}{n}}$$

and

P = the sample proportion of interchanges with inadequate geometry,
Z = normal deviate for acceptable confidence level,
σ_p = population standard deviation of proportion of diamonds with inadequate geometry,
π = population proportion of interchanges with inadequate geometry,

n = sample size.

At this stage, σ_p and π are unknown since they are both population parameters. However, the Central Limit Theorem allows one to infer population parameters from sample statistics without knowing the shape of the population distribution. The following adaptation of the Central Limit Theorem applies to this case. If P is the proportion of interest in a random sample taken from the population, and if the population values are not normally distributed, the sampling distribution of P nevertheless approaches a normal distribution provided $n(\pi)$ as well as $n(1-\pi)$ is greater than 5, where n is the sample size and π is the population proportion. A pilot sample of 16 diamonds revealed that 94 percent of the diamonds have adequate geometry. Setting P equal to 0.94, we obtain the following:

Eq 2

$$\sigma_p = \sqrt{\frac{P(1-P)}{n}}$$

$$= \sqrt{\frac{(0.94)(1-0.94)}{n}} = \sqrt{\frac{0.056}{n}}$$

(Ref 27)

Substituting Eq. 2 into Eq. 1, we get

Eq 3

$$\pi = P \pm Z\sqrt{\frac{0.056}{n}}$$

(Ref 27)

The quantity $Z\sqrt{\frac{0.056}{n}}$ is called the standard error. By varying the standard error values within acceptable limits and using the normal deviates Z for the confidence level of preference, it is possible to determine the most suitable sample size. Fig 17 shows the sample size distribution for various standard errors and confidence levels. For example, one needs to sample 148 interchanges to obtain results with a standard error of 0.05 and confidence level of 99 percent, or 103 interchanges for an error of 0.06 and similar confidence level. Unfortunately, sample sizes of this magnitude are

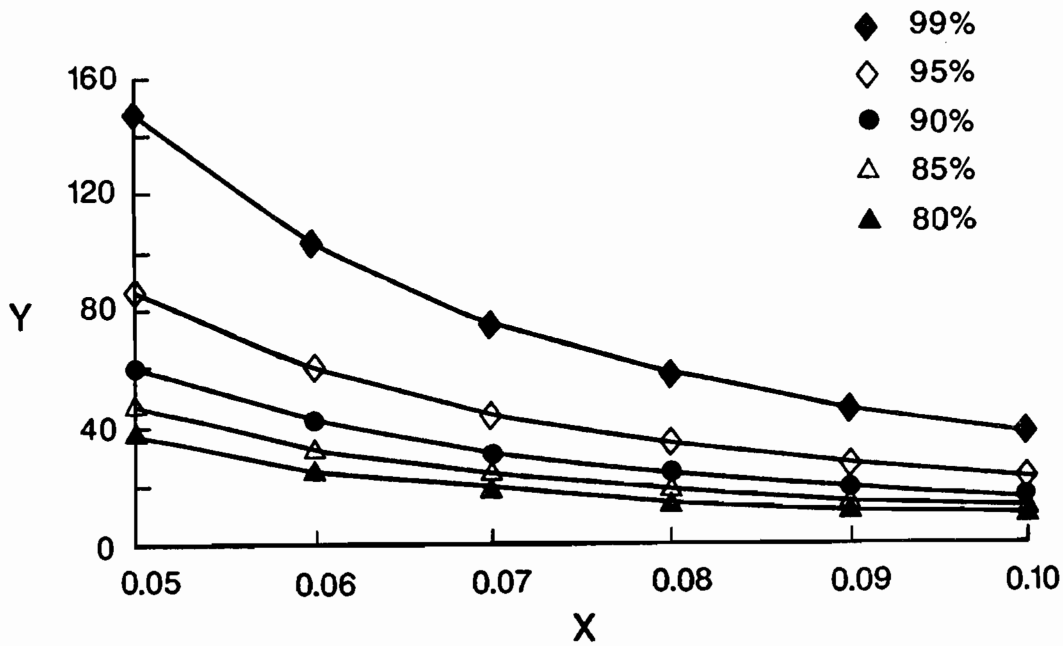


Fig 17. Sample size vs. acceptable standard error.

not feasible for extracting detailed data from each interchange. However, the feasible sample sizes were 40 urban and 50 rural diamonds, from a total population of 1337. The final sample sizes which were actually used for the analysis in the later chapter were 36 and 49 of urban and rural diamonds, respectively. Sample sizes of 36 and 49 would allow estimation of the proportion of diamonds with inadequate geometry at a confidence level of 95 percent for acceptable standard errors of 0.08 and 0.07, respectively.

The geographical locations of all the sampled interchanges are shown in Appendix A. It contains maps of North, West, South, and East Texas showing the Interstate Highways and the crossroads at the locations of the sampled interchanges. The maps of urban areas, such as Houston, San Antonio, etc., are shown in boxes.

Geometry of Ramp Terminals at Diamond Interchanges

Over-the-road operational tests of LCV's conducted in the past have shown that their rear wheels could cause severe damage to curbs at pavement edges and other roadside appurtenances at the diamond interchange ramp terminals. In order to examine the adequacy of a given diamond interchange to accommodate LCV's, all possible turn movements at the ramp terminals have to be analyzed. The three most common cases of ramp terminals were identified among the sample diamond interchanges. They are

(1) two-way crossroad - one lane each direction, one-way exit and entrance ramp - one-lane each direction; total number of turn movements possible - eight;

(2) two-way crossroad - two lanes each direction, one-way exit and entrance ramp - one lane each direction; total number of turn movements possible - eight;

(3) two-way crossroad - two lanes each direction, two-way frontage road - one lane each direction; total number of turn movements possible - sixteen.

Figures B1 and B6 in Appendix B show the configurations for Cases 1 and 2, respectively, and all possible turn movements are numbered for later reference (Case 3 is shown in Figs B11 and B12). The analysis is based on the computer Truck Offtracking Model (TOM), which requires an input path. It then simulates the movement of a given LCV along the given input path. The details of the model input are discussed in the next chapter. However, the data collected from each interchange is based on the input path for each turn movement possible. For example, the input path for a right turn would be the path the tractor's frontmost left wheel would follow. For a left turn, the input path would be the path taken by the frontmost right wheel of the tractor. These input paths had to be drawn manually for each turn on each interchange. The data collected for each turn are the distances between the input path and the pavement edge.

Assumptions for Input Path

Four assumptions were made for the input path. First, the drivers of LCV's follow simple curve turns. Second, the minimum radius of turns is 45 ft for the outermost front wheel. A simple curve turn was assumed to facilitate data collection and is a reasonable one to represent the pavement area available at a ramp terminal. The 45-ft minimum turn radius is in accordance with the AASHTO recommendation (Ref 8). Although some LCV's could make turns with lower turn radii, 45 ft in most cases will prevent the semitrailers and trailers from backing up and pivoting behind the turning radius center as shown in Fig 2. A 45-ft minimum turn radius for the outermost front wheel sets the turn radius for the center of the front axle at 40 ft, 9 in. for an 8 ft, 6 in. wide LCV. The third assumption, LCV's do not use the opposing traffic lanes during turn maneuvers. This assumption prevents LCV's from hindering the opposing traffic flow and thus reduces the potential for accidents, which means that the LCV's operate under "normal" conditions. Since the data collected are representative of the pavement area available, the LCV's are further assumed to use illegal left turn movements if extra lanes are available in the direction of travel.

Measurements of Pavement Area at Ramp Terminals

Three measurements were made for each turn movement: DB, DM, and DE; these measurements are illustrated in Fig B2 of Appendix B. DB and DE measure the perpendicular distances from the tangents at the beginning and end of the simple curve to the pavement edge, respectively. DM measures the maximum perpendicular distance from the tangent to the pavement edge. The location of the tangent on the curve for maximum distance between the curve and the pavement edge occurs in most cases between the middle and the end of the curve. These three measurements for each turn movement are the data for analysis in the next chapter.

Appendix B shows the example locations of DB, DM, and DE for Cases 1, 2, and 3 described earlier. Only four turn movements are shown for Cases 1 and 2, and the same locations apply to the ramp terminal on the other side of the interchange. Turns 1 and 2 are right turns, and 3 and 4 are left turns. Turns 5, 6, 7, and 8 occur on the other side of the interchange.

For Case 2, where two lanes are available for each direction on the crossroad, right turns 1 and 2 utilize both lanes in the direction of travel but not the opposing lanes.

Similar assumptions and turn numbers are adhered to in Case 3. However, four extra movements are possible in this ramp terminal due to the two-way frontage road facility. For example, turns 1, 2, 9, and 10 are right turns located on the right side of the interchange plus the left turns 3, 4, 11, and 12. The other turns are located on the left side of the interchange.

Data collected from the diamond interchanges as described in this chapter are used for the ANOVA (Analysis of Variance) procedure as a "screening process" to determine the significance of effects of the various factors involved and utilized in the data collection.

CHAPTER VI. PRELIMINARY ANALYSIS - ANOVA

This chapter discusses the preliminary analysis of the data collected from the diamond interchanges. The method used was the ANOVA (Analysis of Variance) procedure as a "screening process" to determine the significance of the factors involved in the data collected from each sampled diamond interchange (Ref 26). In the next chapter, the final analysis, using TOM, is based on the results from the analysis of variance.

The ANOVA procedure was done using the SAS (Statistical Analysis Software) computer program which runs on the IBM mainframe computer. In order to use this procedure, all factors had to be clearly defined and expressed as levels of factors. These factors could be either fixed or random. Fixed factors are factors with all levels of interest to this study included in the analysis. Random factors are those with fewer than the population levels of the factors that are included in the analysis (Ref 26).

Factors and Levels of Factors

The analysis included five fixed factors and one random factor. The fixed factors are location, type of crossroad, movement type, direction, and measured distances. Figure 18 shows the fixed factors and their levels. The random factor describes the random location occurrence of the interchanges sampled.

Since 65 percent of the total population of diamonds are located in rural areas and the remaining in urban areas, a location factor, L, was introduced. This factor can be used to test the significance of the effect of location on the pavement area available at the ramp terminals.

The factor T will test the effect of types of crossroads on the pavement area available. Although many types of crossroads were identified in the data collection, as shown in Appendix F, only four were used as levels of factor T. They includes U.S. Highway, State Highway, F. M. (Farm-to-Market) Road, and Arterial. Other types, i.e., paved, gravel, and soil, were ignored since they represent low level types of roads which may be used by LCV's only intermittently or not at all. Interstate Highways were not included as a crossroad type since the intersection of two Interstate Highways generally requires higher levels of interchanges, such as full directionals or semi-directionals.

FACTORS	LEVELS OF FACTORS
LOCATION, L	1 - Urban 2 - Rural
TYPE OF CROSSROAD, T	1 - U.S. Highway 2 - State Highway 3 - F.M. Road 4 - Arterial
MOVEMENT TYPE, M	1 - Right Turns 2 - Left Turns
DIRECTION, C	1 - Ramp to Crossroad on Right Frontage Rd 2 - Crossroad to Ramp on Right Frontage Rd 3 - Ramp to Crossroad on Left Frontage Rd 4 - Crossroad to Ramp on Left Frontage Rd
SPACE, D	1 - Distance Available (DB) at the Beginning of Turn 2 - Maximum Distance Available (DM) Between the Beginning and the End of Turn 3 - Distance Available (DE) at the End of Turn

Fig 18. Factors and Levels of Factors

One could easily conclude from careful observation of the figures in Appendix B that the measurements of DB, DM, and DE for right turns are shorter than those for left turns. Due to this difference, separate analyses might be needed for left and right turns. Thus, the effect of left and right turns can be tested for significance by using the next major factor, movement type, M, with two levels.

Factor C is introduced to test the effect of the various directions of movements. It has four different levels which describe the different movements on the right frontage road and the left, plus the movement from ramp to crossroad and vice versa. The right side of an interchange is defined as the west side of a North-South Interstate Highway, and as the south side of an East-West Interstate Highway. The final factor, D, has three levels representing DB, DM, and DE, as described in the preceding chapter. It will be used to test the significance of the differences between the three measurements.

ANOVA (Analysis of Variance) Procedure

In the analysis of variance, each interchange is treated as an experimental unit. A total of 16 interchanges were subsampled from the original sample of 85 diamonds, of which 36 are located in urban areas and 49 are located in rural areas. Factors L, T, M, C, and D are fixed factors and thus do not have any random variance components associated with them. However, an additional factor, O, is introduced; it is the random occurrence of interchanges nested within the crossroad type, T, and location, L. Two interchanges were randomly sub-sampled for each combination of location, L, and crossroad type, T. For example, two urban diamonds with U.S. Highways as crossroads will form two experimental units, shown as 1 and 2 of random factor O in Fig 19. Fifteen and sixteen represent two diamonds with arterials as crossroads; they are located in rural areas. Therefore, factor O represents the random occurrence of 16 interchanges along Interstate Highways in Texas, and thus the inference space for this analysis is all of Texas. The two random occurrences of interchanges or experimental units nested within crossroad type, T, and location, L, provide the errors needed to test the significance of the factors involved (Ref 26). Furthermore, factors M, C, and D represent fixed factors within an interchange, thus causing "splits" in the analysis (Ref 26). Fig 19 shows the input values for the sixteen interchanges.

The sixteen interchanges sub-sampled had the data needed to fill all the cells, as shown in Fig 19, thus allowing complete factorial split-split-split plot analysis (Ref 26). The dependent variable is the measurement made at

Direction, C	Distance, D	Movement Type, M	1								2							
		Crossroad Type, T	1		2		3		4		1		2		3		4	
		Interchange Occurrence, O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	24	24	24	32	40	19	26	33	24	18	18	15	18	20	22	24
		2	31	20	22	16	40	17	42	20	32	21	20	18	24	25	26	25
		3	26	28	22	30	32	35	32	26	25	12	18	12	12	10	12	22
	2	1	26	28	22	39	32	35	32	26	24	12	18	12	12	10	12	25
		2	31	20	22	20	40	17	42	20	35	21	20	18	24	25	26	30
		3	24	24	22	32	30	24	26	32	24	18	18	15	18	20	22	25
	3	1	24	24	24	32	33	48	26	33	24	18	20	14	18	20	22	25
		2	31	20	22	18	39	45	43	20	32	21	20	14	24	25	26	30
		3	26	28	22	22	36	35	32	26	25	13	14	17	12	10	12	25
	4	1	26	28	22	42	36	35	32	26	24	13	16	12	12	10	12	22
		2	31	20	22	47	40	18	43	20	36	21	20	12	24	25	26	25
		3	24	24	22	32	36	24	26	33	24	18	16	18	18	20	22	24
2	1	1	24	24	26	32	36	51	48	33	32	18	28	15	18	20	30	25
		2	43	41	54	60	40	77	42	66	49	27	32	20	32	28	45	30
		3	30	37	22	24	32	40	32	30	28	25	28	30	12	20	20	21
	2	1	30	37	62	24	41	40	34	30	28	25	32	28	12	20	20	24
		2	43	45	66	60	47	77	44	65	49	27	38	28	32	28	44	25
		3	24	24	26	32	24	52	48	32	32	18	30	30	18	20	30	24
	3	1	30	24	28	32	44	52	48	33	32	18	16	20	18	20	30	50
		2	43	42	62	53	48	78	43	66	50	27	16	30	32	28	44	25
		3	30	38	62	24	40	40	32	30	28	25	20	28	12	20	20	24
	4	1	24	38	62	24	32	40	34	31	28	25	24	27	12	20	20	21
		2	43	45	40	60	49	78	45	66	50	27	33	30	32	28	45	30
		3	24	24	28	32	48	52	47	33	32	18	24	20	18	20	30	25

Fig 19. Input data for ANOVA procedure.

DB, DM, and DE for each turn movement at each interchange sampled. A linear model for the preliminary analysis is shown in Appendix G.

Since the model is a complete factorial, it includes all the 2-factor, 3-factor, 4-factor, and 5-factor interaction effects. The interactions with the O factor or random occurrences are assumed to be normally and independently distributed with zero mean and variance σ^2. The remaining fixed factor interaction effects need to be tested using F-tests for significance. The F-tests are made under the null hypothesis of no factor or interaction effects. Normality for the data was assumed, since α is robust to non-normality. However, the data were found homogeneous using the Bartlett Test (Ref 26) at α of 5 percent. If the F-value computed is greater than some tabular value it is concluded that the tested effect is significant for a given significance level, i.e., α level. All tests will be made for α of 5 percent, which means the probability of rejecting a null hypothesis when it should be accepted is 5 percent.

Results of ANOVA

Figure 20 shows the results of the analysis of variance which includes sources of effects and corresponding degrees of freedom, sums of squares, MS (mean squares), and the F-values. The effects are all tested with the corresponding error terms. For example, the main effects of L,T, and interaction effect of L*T were tested with the first restriction error or whole plot error, i.e., with the MS of C(LT). The effects of M, L*M, T*M, and L*T*M were tested with the split plot error O(LT)*M. The total degrees of freedom for this model is 383.

Using the F-tests, the main effects, L, M, and D were found significant at alpha of 5 percent. Two 2-factor interaction effects, L*T and M*D, and one 3-factor effect, T*C*D, were also found significant at the same significance level. None of the 4-factor or 5-factor interaction effects was found significant. It can be concluded that the location, L, and the movement type, M, and the three different locations along the input path significantly affect the pavement area available at the ramp terminals of the diamond interchanges. Other main factors such as the crossroad type, T, and the direction of travel, C, do not have significant effects on the pavement area available.

However, further analysis was done on the interaction effects found significant using the Bonferroni means comparison test in order to investigate which pairs of the factors involved have differences of means significantly different at the chosen confidence level. Fig 21 shows the plots of the mean values of measurements, Y(mean), for every combination of geographic location, L, and crossroad type, T. The tests revealed at 95

SAS

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: Y

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	341	57863.71854093	
ERROR	42	1295.27104241	30.84
CORRECTED TOTAL	383	59158.98958333	

SOURCES	DF	ANOVA SS	MS	VALUE
L	1	13160.166	13160.167	45.12
T	3	791.629	263.876	< 1.00
L*T	3	3408.834	1136.278	3.90
O(LT)	9	2625.259	291.695	
M	1	9381.260	9381.260	33.66
L*M	1	852.041	852.041	3.06
T*M	3	379.648	126.549	< 1.00
L*T*M	3	774.296	258.099	< 1.00
O*M(LT)	8	2229.519	278.690	
C	3	84.802	28.600	1.06
L*C	3	105.937	35.312	1.31
T*C	9	287.302	31.922	1.19
L*T*C	9	246.666	27.407	1.02
O*C(LT)	26	698.390	26.861	
M*C	3	22.843	7.614	< 1.00
L*M*C	3	25.854	8.618	< 1.00
T*M*C	9	214.219	23.802	< 1.00
L*T*M*C	9	191.763	21.307	< 1.00
O*M*C(LT)	21	720.219	34.296	
D	2	6818.973	3409.487	53.90
L*D	2	44.223	22.112	< 1.00
T*D	6	196.485	32.748	< 1.00
L*T*D	6	253.067	43.845	< 1.00
O*D(LT)	18	1138.699	63.261	
M*D	2	2934.723	1467.362	6.83
L*M*D	2	1440.723	720.362	3.35
T*M*D	6	133.100	22.183	< 1.00
L*T*M*D	6	280.994	46.832	< 1.00
O*M*D(LT)	16	3435.840	214.740	
C*D	6	108.863	18.161	< 1.00
L*C*D	6	262.546	43.758	1.38
T*C*D	18	1241.765	68.987	2.17
L*T*C*D	18	159.973	8.887	< 1.00
O*C*D(LT)	52	1650.300	31.737	
M*C*D	6	116.796	19.466	< 1.00
L*M*C*D	6	160.880	26.813	< 1.00
T*M*C*D	18	689.124	38.285	1.24
L*T*M*C*D	18	594.877	33.04	1.07

Fig 20. Results of ANOVA procedure.

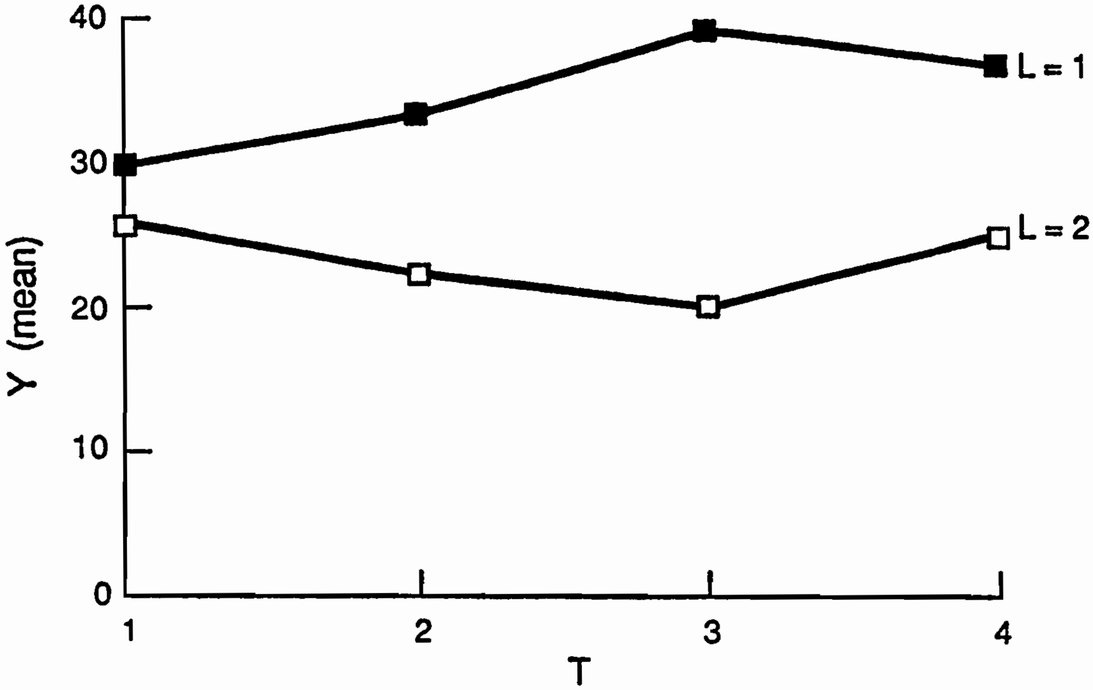


Fig 21. Plot of Y(mean) for 2-way classification of L and T.

percent confidence level that the difference between the pair of means at level 3 of crossroad type T, which is the Farm-to-Market (F.M.) road, was significant. This means that the compounded effect of the locations which are urban and rural, and the crossroad type on the pavement area available at the diamond interchange ramp terminal was significant only for the F.M. crossroad. However, the crossroad types do not directly influence the pavement area available.

Figure 22 shows the plots of the mean values of measurements, Y(mean), versus the locations of measurements on the input path, D, for various levels of movement type, M. The Bonferroni test for the interaction effect of M*D revealed at 95 percent confidence that the difference between the mean value of measurements for movement type, M, which is left and right turns, was significantly different only at the second level of factor D, which is the location along the input path where the maximum offtracking occurs. The difference between the left and right turns at the beginning and at the end of input path curves was found insignificant at alpha of 5 percent. The 3-factor interaction T*C*D was not analyzed because it has no practical significance to the assessment.

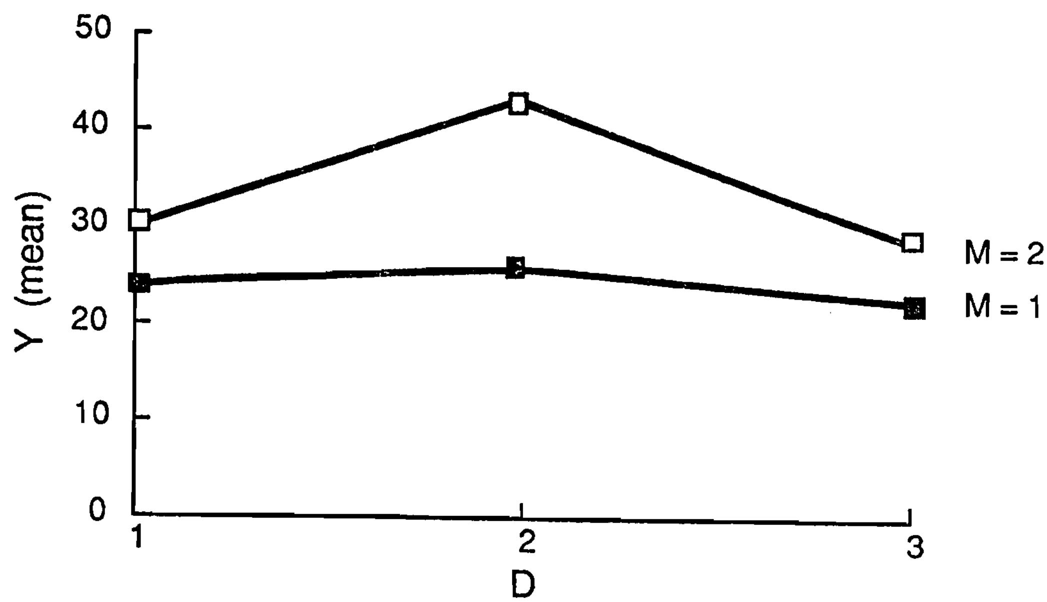


Fig 22. Plot of Y(mean) for 2-way classification of M and D.

CHAPTER VII. INTERVAL ESTIMATES FOR PROPORTION OF DIAMONDS WITH INADEQUATE GEOMETRY AND FOR EXTRA PAVEMENT WIDTH REQUIRED

This chapter focuses on the three main factors found significant and discusses the separate analysis for each case and includes the demonstration of the computer model TOM. It also includes the determination of confidence intervals for the proportion of interchanges with inadequate geometry, and the amount of extra pavement width required at diamond interchange ramp terminals along Interstate Highways in Texas in order for them to be able to accommodate the swept paths of LCV's.

Offtracking Plots of TOM

In order to demonstrate the simulation characteristics of TOM, two diamond interchange ramp terminals were selected. One of them is unchannelized while the other is channelized. Appendix C shows the swept path of an 118-ft-long and 8 ft, 6 in. wide Turnpike Double making right and left turn maneuvers at both interchanges. It also contains the configurations and dimensions of the interchanges. The turn radius and angle of turn are shown for each movement. Note that all four assumptions mentioned in the preceding chapter are met for each turn movement. The vehicle follows a simple curve turn with 45 ft as the minimum radius, stays within the lanes provided for a given direction of travel, and uses the illegal turn movements if extra lanes are available. At the unchannelized diamond interchange, the rear wheels of the LCV encroached on the pavement edges for all four turn movements. The maximum encroachment of 23.2 ft occurred for turn 4, which is a left turn from the crossroad into the exit ramp. In this turn, even the center of the semi-trailer axle encroached the pavement edge. However, the other turns encroached only 4.4 to 5.2 ft. The channelized interchange, on the other hand, has much more pavement area available than the former and thus there were no encroachments by the rear wheels of the 118-ft-long Turnpike Double for any of the four turn movements.

TOM Input Data

The computer model TOM needed five different input data cards. Card one contained the degree of turn, the radius of turn, and the tangent runoff distance from the end of the curve. The second had the information on the number of units in the vehicle combination, wheelbase of each unit, width of vehicle, location of fifth wheel or hitchpoint, and the distance between the rear axle and the hitchpoint which would be used to tow another unit. Fig 23 shows the data required to perform a simulation run using TOM. Card three contains information on the initial x and y coordinates for plotting purposes, and the offset distance between the center of the front axle and the front outer wheel; it also contains the simulation increment preferred by the user, which was set to a foot for this study. The fourth card describes the location of the reference points to be plotted, plot area, and scale factor. Finally, the fifth input data card contains the name of the vehicle.

Offtracking Values for Truck Scenarios

The second phase of data collection provided the values of the radii and degrees of turns for each movement analyzed. The radii of turns for all diamond interchanges sampled ranged from a minimum of 45 ft to a maximum of 450 ft. The angle of turn ranged from a low of 37 degrees to a high of 180 degrees and was used to analyze turnaround facilities at diamond interchanges. Maximum offtracking values for each truck type in the base and alternative scenarios, discussed in Chapter III, were obtained by making repetitive runs for each turn movement with a given radius and angle of turn. The results are given in Appendix D. The 118-ft-long Turnpike Double, however, has three columns of values associated with it since this truck type produced the highest offtracking values in comparison to the others and thus will be used for analysis later in this chapter. If one compares the MOT values between the truck types given in Appendix E, the ascending order for offtracking would be Western Double (2 x 28 ft), Conventional Semi (48 ft), Triples (3 x 28 ft), Rocky Mountain Doubles (48 + 28 ft), and Turnpike Double (2 x 48ft). The Western Doubles and Triples are more maneuverable with regard to offtracking than the existing Conventional Semis. The Turnpike Double, on the other hand, produces extremely high maximum offtracking values. BD and EC columns give the offtracking values for the Turnpike Double at the beginning and at the end of simple curves for each turn movement. The differences in offtracking between the truck types are lower at smaller angles of turn and increase with higher angles of turn.

```
FILE: 1   DATA       A

125.  45. 250.

FILE: 2   DATA       A

    4       8.5
    1      20.00       0     TRACTOR
    2      40.0     -4.00    SEMITRAILER
    3       8.00       0     TOWBAR1
    4      40.00    -4.00    TRAILER1

FILE: 3   DATA       A

    0.    0. 4.25 1.

FILE: 4   DATA       A

    7
    3
    1      20.00    -4.25    LEFT FRONT WHEEL
    4      -2.0      4.25    RIGHT REARMOST WHEEL
    1      20.00     4.25    RIGHT FRONT WHEEL
    -5.-120. 300. 105.

FILE: 5  DATA        A

TURNPIKE DOUBLES (TRACTOR, 48 FT S-TRAILER, 48 FT TRAILER) 118FT
```

Fig 23. Input cards for truck offtracking model (TOM).

Statistical Assessment of the Impact of LCV's on the Geometry of Diamond Interchanges

This section contains the assessment of the impact of LCV's on the geometry of diamond interchanges. First, the confidence interval for the proportion of interchanges with inadequate geometry will be determined. Second, this section includes the determination of extra pavement width required at the diamond interchange ramp terminals in order to accommodate the LCV's. Since the assessment is made to draw inferences about the total population of diamond interchanges along Texas Interstate Highways, and is based on the sample statistics, the results are interval estimates for chosen confidence levels.

The sample statistic will be estimated from the differences between the distances measured (DB, DM, and DE), and the swept path values computed by TOM (BC, MOT, and EC, respectively). Thus, the population for which interval estimates of extra pavement width are required is now the total number of movements instead of interchanges. Since the distances measured were subtracted from corresponding values of TOM, a positive value indicates that the swept path value is greater than the pavement width available and a negative value indicates the opposite. Thus, in order to classify the pavement width available for a given movement as adequate, all three differences have to be negative, which means the pavement width is greater than the swept path of the LCV. If one or more of the three differences are positive, then the pavement width available is classified as inadequate. An interchange is classified as inadequate if one or more turn movements involved are inadequate. In order for an interchange to be adequate, all turn movements involved have to be adequate. These rules are adhered to throughout the chapter.

Proportion of Diamond Interchanges with Inadequate Geometry. This proportion estimation is a continuation from the worst case analysis discussed in Chapter V. Note that the final sample sizes of 36 urban diamonds and 49 rural diamonds were obtained at standard errors of 0.08 and 0.07, respectively, with 95 percent confidence. The analysis of variance (ANOVA) in Chapter VI concluded that the effects of locations of interchanges and movement types on the pavement area available at the existing diamond interchange ramp terminals are significant. Thus, the proportions will be determined for urban right-turns, urban left-turns, rural right-turns, and rural left-turns. Table 1 shows the proportion of interchanges (with inadequate geometry) for given locations and movement types.

TABLE 1. INTERVAL ESTIMATES FOR PROPORTION OF DIAMOND INTERCHANGES WITH INADEQUATE GEOMETRY

Diamond Interchanges	Proportion Interval Estimates (Confidence Level of 95%)				
Urban right turns	35/36	0.053	0.92	p	1.00
Urban left turns	33/36	0.090	0.83	p	1.00
Rural right turns	48/49	0.040	0.94	p	1.00
Rural left turns	44/49	0.085	0.81	p	0.98

The estimate of the proportion of diamond interchanges located in urban areas with inadequate pavement width for right turn maneuvers by an 118-ft-long Turnpike Double is between 0.92 and 1.00. The proportion for similar interchanges but for left turn maneuvers is between 0.83 and 1.00. The minimum proportion for rural interchanges with inadequate pavement widths for right turn maneuvers is the highest (with a value of 0.94) among all the cases, indicating the worst case. However, the minimum value of the proportion estimate for left turns in rural diamonds is the lowest, with a value of 0.81. For both urban and rural diamonds, the proportion is lower for left turns than for right turns since more pavement area is available for left-turn maneuvers. It should be noted that these intervals were developed with a confidence level of only 95 percent, which means that the probability of rejecting the above estimates instead of accepting them is 50 percent which is alpha (α). Also, these proportions were determined for the largest LCV, i.e., 118 ft long and 8 ft, 6 in. wide Turnpike Double. The proportions of inadequate pavement widths would be lower if the assessment is made for other LCV's with lower offtracking characteristics, such as Triples (3 x 28) and Rocky Mountain Doubles (48 + 28), as exhibited in Appendix D. Thus, the assessment with 118-ft-long Turnpike Doubles is a worst-case.

<u>Interval Estimates for Extra Pavement Width Required.</u> In order to develop the confidence intervals for extra pavement width needed at diamond interchange ramp terminals with inadequate geometry, distributions of the available data were examined. A total of 8 cases were analyzed in accordance with the results of the analysis of variance in Chapter VI. The difference values at the beginning and at the end of input paths, i.e., (BC - DB) and (EC - DE) were not analyzed as different cases for the rural diamonds since

they were not significantly different from the urban diamonds, as shown by the Benferrani test previously. The cases are summarized in Table 2.

Thirty-six urban diamonds and 49 rural diamonds produced approximately 680 turn movements, which were divided between urban right, urban left, rural right and rural left. The total number of observations available for DB, DM, and DE ranged from 110 to 180. The dependent variable of interest is the difference between the actual pavement width available at the ramp terminal of an interchange and the swept path value produced by TOM at the same location of a movement.

TABLE 2. DESCRIPTION OF CASES WHICH REQUIRE EXTRA PAVEMENT WIDTH

Case #	Location, L	Movement Type, M	Extra Pavement Width Needed
1	Urban	Right	(BC - DB)
2	Urban	Right	(MOT - DM)
3	Urban	Right	(EC - DE)
4	Urban	Left	(BC - DB)
5	Urban	Left	(MOT - DM)
6	Urban	Left	(EC - DE)
7	Rural	Right	(MOT - DM)
8	Rural	Left	(MOT - DM)

Appendix D provides the offtracking values needed for each turn. Swept path values are obtained by adding the width of the Turnpike Double to the offtracking values. Frequency distributions were plotted for each case using the differences as data. Positive values indicate inadequate pavement width since the pavement widths measured were subtracted from the swept path values computed by TOM. Negative values indicate adequacy of space for a given turn movement or surplus width. The frequency distribution plots for all 8 cases are shown in Appendix E. The results are summarized in Table 3. The objective of this analysis is to develop interval estimates of extra pavement width required for a given confidence level, i.e., 95 percent. Since the data included both positive and negative vlues, two-tailed intervals were deemed more descriptive.

TABLE 3. DISTRIBUTION STATISTICS FOR CASES WHICH REQUIRE EXTRA PAVEMENT WIDTH

Case#	Sample Size, N	Mean	Standard Deviation	D Value
1	119	-2.2	12.9	0.083
2	119	2.5	9.2	0.085
3	119	2.9	11.5	0.0718
4	120	-3.5	10.8	0.092
5	120	-13.5	12.1	0.076
6	120	1.3	9.5	0.126
7	108	13.5	8.3	0.082
8	177	0.6	11.7	0.088

The lower tail describes the adequacy of the geometry of diamond interchanges, while the upper tail describes the inadequacy. Table 3 includes the mean, standard deviation, and D-value for each case. The D-value is a measure of maximum deviation and is used for the Kolmogorov-Smirnov test for normality. If, for a chosen significance level, the observed value of D is greater than or equal to the critical value tabulated, the null hypothesis of normality will be rejected. The twelve distributions were tested at significance levels of 5%, i.e., against D values (Ref 28). All of them were found to be normal. Table 4 shows the 95 percent intervals for all cases for the differences between the actual pavement width available at existing diamond interchange ramp terminals and the swept path computed by TOM.

The confidence interval for extra pavement width required at the beginning of a simple curve right turn at urban diamond interchanges is between -27.5 ft and 23.1 ft at 95 percent confidence. The physical interpretation of the above confidence interval is that, in order for a 118-ft-long Turnpike Double to maneuver a turn for a given radius and angle without its rear wheels climbing over the curbs, the extra pavement width needed at the beginning of a simple curve right turn at <u>any</u> diamond interchange located in an urban area will be between -27.5 and 23.1 ft 95 percent of the time. The inference space for this interval is along the Interstate Highways in Texas. The negative tail of the interval indicates interchanges with adequate geometry, since the width available is larger than the offtracking of the LCV plus its width of 8 ft, 6 in. The positive tail describes inadequacy, which means that there are interchanges within the total population of urban diamonds where the rear wheels of the LCV would encroach into neighboring land space up to 23 ft from the pavement edge. Encroachment of this magnitude, however, would occur only for a large angle of turn and small turning radius provided the turn were made at a highly confined ramp terminal.

A second example would be Case 8, where the interval between -22.3 and 23.5 ft describes the extra pavement width needed at the location where maximum offtracking occurs for left turns at rural diamond interchange at 95 percent confidence. This means that in 95 percent of occurrences the extra pavement width required at the location where maximum offtracking occurs for left turns at diamonds located in rural areas will be up to 23.5 ft.

Table 4 also reveals the differences in the intervals between the 8 cases as indicated by the ANOVA procedure in Chapter VI. For example, looking at only the lower limits of the 95 percent confidence interval, the limits are lower for left turns than for right turns at both urban and rural interchanges, indicating the extra pavement area available for left turns. Furthermore, the lower limits for left turns at urban diamonds are higher in

TABLE 4. INTERVAL ESTIMATES FOR CASES WHICH REQUIRE EXTRA PAVEMENT WIDTH

Case	Confidence Intervals for Extra Pavement Width, Ft	
	95%	
	Lower	Upper
1	-27.5	23.1
2	-15.5	20.5
3	-19.6	25.4
4	-24.7	17.8
5	-37.4	10.0
6	-17.3	19.9
7	-2.8	29.8
8	-22.3	23.5

magnitude than those of rural diamonds. This signifies higher design levels for diamond interchange ramp terminals in urban areas than those in rural areas. These observations can also be seen from the upper limits. The positive or upper limits are higher for right turns than for left turns at both urban and rural diamonds, indicating the inadequacy of geometry for right turns is more critical than for left turns. Furthermore, the differences between the swept paths of LCVs and pavement width available are higher for right turns.

The frequency distributions for all eight cases are given in Appendix E. The distributions for urban right and left turns are either centered around the difference value of zero or to the left of it. The distributions for rural diamonds, for most cases, are centered to the right of the zero value, especially for the right turns.

CHAPTER VIII. SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Summary of Results

The data collected on interchanges along Interstate Highways in Texas are for all the interchanges which can be identified from the 1986 Texas County maps. The data include the type of interchange, type of crossroad, county name, district number, and the control and section number of the Interstate Highway where the interchange is located. Appendix F presents the collected data, and the sampled and subsampled interchanges are also indicated. A total of 1557 interchanges were identified, and approximately 86 percent of them are diamonds. The remaining population of interchanges is divided between Directionals, Cloverleafs, and Combinations. Figure 16 summarizes the collected interchange data.

The analysis was concentrated on diamonds due to the high proportion of them within the total population of interchanges. A total of 85 diamonds were randomly sampled and analyzed for the adequacy of their geometry to accommodate the turn maneuvers by LCV's. Each possible turn movement was analyzed at each diamond ramp terminal.

Preliminary analysis using the ANOVA procedure revealed that at a 99 percent confidence level the locations of diamond interchanges, i.e., urban or rural, and the movement types, which are left and right turns, significantly affected the pavement area available at the diamond interchange ramp terminals. Furthermore, the pavement widths available between the input paths and the pavement edges at the beginning, middle, and end of the curves were significantly different. The middle measurements, however, were larger than those at the beginning and end of the curves for all types of turns and at all locations.

The final analysis was based on the factors found significant from the ANOVA procedure at the 5 percent significance level. Sample sizes of 36 urban diamonds and 49 rural diamonds were sufficient to determine the proportion of interchanges with geometry inadequate to accommodate the turn maneuvers by LCV's at the 95 percent confidence level. The proportion of urban diamonds with geometry inadequate to accommodate right turn maneuvers by LCV's ranges from 0.92 to 1.00. The proportion of urban left turns ranges between 0.83 and 1.00. Rural diamonds with geometry inadequate for right turns are greater in number and proportion than the urban diamonds. Rural diamonds with geometry inadequate for left turns, on the other hand, have lower proportions than other turns, with an interval between 0.81 and 0.98 at

95 percent confidence. It should be noted that an interchange is termed inadequate if the pavement width available for one or more turn movements is found inadequate. For example, if a diamond interchange with a possibility of eight turn movements had one movement that was inadequate and the remaining seven adequate, the interchange would still be classified as inadequate. The above-mentioned proportions are based on this rule.

A total of eight cases were analyzed to develop 95 percent confidence intervals for the extra pavement width required at diamond interchange ramp terminals. The extra pavement widths would allow the ramp terminals to accommodate the swept paths of the LCV's without experiencing damage to curbs and other roadside appurtenances. Table 4 shows the intervals for all eight cases. However, they can be combined into fewer cases with the same confidence. Figure 24 shows the 95 percent confidence intervals for right and left turns for both urban and rural diamonds. It also shows intervals for urban and rural diamonds and for diamonds overall.

For example, the differences between the swept path and the pavement width available for any right turn by the Turnpike Double at any urban diamond interchange will be between -28 and 25 ft 95 percent of the time and the differences for left turns will be between -37 and 20 ft at the same confidence level. Similar deductions can be made for left and right turns for rural diamonds. Furthermore, similar conclusions can be made with both types of turns combined. For example, the differences between the swept path of the Turnpike Double and the pavement width available for any diamond interchange located along Interstate Highways in an urban area in Texas will be between -45 and 25 ft with 95 percent confidence. Similar differences for any rural diamond interchange located along the interstate highway system in Texas will be between -28 and 30 ft with 95 percent confidence. The interval for diamond interchanges overall is between -37 and 30 ft.

Conclusions

The objective of this study was to make a statistical assessment of the impact of longer and wider combination vehicles on the geometry of existing diamond interchanges. The preceding final analysis made possible the determination of the proportion of diamonds with inadequate pavement width to accommodate the swept paths of the largest Long Combination Vehicle, i.e., a 118-ft-long and 8 ft, 6 in. wide Turnpike Double with cab-behind engine (CBE) tractor. The Turnpike Double produced the maximum offtracking relative to the other types in the Alternative Scenario discussed in Chapter IV, and the 48-ft conventional semi in the base scenario. Its use for the analysis made possible the conclusion on the worst possible impact the LCV's would have if they were introduced in the Interstate Highway System in Texas. All results

	Case	Lower Limit	Upper Limit
Urban Diamonds	Right Turn	-35	33
Urban Diamonds	Left Turn	-45	26
Rural Diamonds	Right Turn	-21	35
Rural Diamonds	Left Turn	-29	31
Urban Diamonds	Overall	-45	33
Rural Diamonds	Overall	-29	35
Diamonds	Overall	-45	35

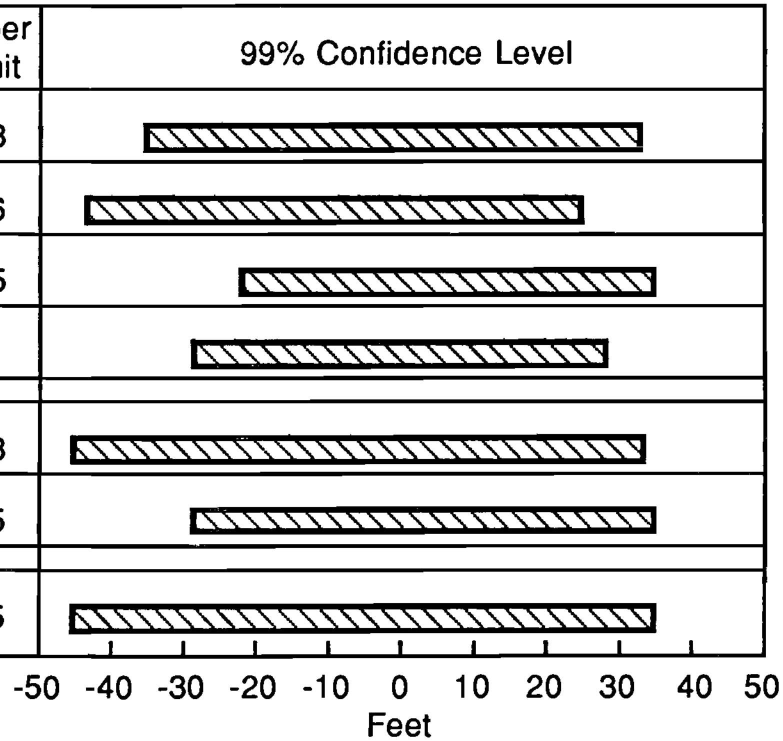


Fig 24. 99% confidence intervals for extra pavement width required for diamond interchanges, overall.

were obtained with the assumptions that truck drivers utilize only simple curve turn maneuvers, with 45 ft as the minimum turning radii, that they are allowed to make illegal left turns, and that they operate under normal conditions, i.e., they do not use the lanes provided for opposite traffic flow.

Ninety-two or higher percent of diamonds located in urban areas are estimated to be incapable of accommodating right turn maneuvers by the LCV's and may require additional pavement widths of up to 25 ft, depending upon the radii and angles of turns. This estimation is made at a confidence level of 95 percent. The proportion of urban diamonds which are estimated to have inadequate geometry to accommodate left turn maneuvers of similar vehicles ranges from 83 to 100 percent at 95 percent confidence level, and the extra pavement widths required at their ramp terminals may reach up to 20 ft. The rural diamonds are estimated to have higher proportions than the urban diamonds for right turns, i.e., 94 percent or higher; up to 30 ft of extra pavement width may be required at their ramp terminals; and they are more critical than the urban diamonds. The proportion of rural diamonds with inadequate geometry for left turn maneuvers by the LCV's ranges from 81 to 98 percent confidence level and may require up to 24 ft of extra pavement width. (These comparisons are summarized in Table 1 and 4).

One of the final conclusions is that the proportion of diamonds that would experience damage to curbs and other roadside appurtenances is extremely high if the LCV's are allowed to traverse them. Furthermore, rural diamonds have a higher tendency to experience damage than those in the urban areas, due to the more confined pavement areas at the ramp terminals. The pavement areas available for right turns are more critical than those for left turns, because it is possible for drivers to make illegal left turns utilizing all the pavement area available. Thus, the modifications of pavement edges at the ramp terminals for right turns are more urgent than for left turns, and the rural diamonds require earlier attention than those located in the urban areas.

Recommendations

The truck type used for the assessment of the impact of LCV's on the geometry of diamond interchanges was a Turnpike Double, which produced the maximum offtracking. Thus, the conclusions made are applicable for all LCV's which are introduced in the Interstate Highway System. Any other LCV type would produce a less severe impact on the geometry of diamonds due to its lower offtracking characteristics. However, Turnpike Doubles have been successfully used on restricted routes in some states and thus could be used successfully in Texas. If the LCV's are introduced in Texas, they might be allowed to operate only on restricted routes, as in other states; thus, restricting the assessment to the LCV route network would facilitate a cost study regarding improvements required at the interchanges in the future. Further research is recommended to assess the impact of LCV's on the geometry of interchanges on restricted routes.

Most professional drivers initially swerve to the left to make a right turn in order to utilize the maximum pavement area available, and to prevent the rear wheel from climbing over the curbs. A similar swerve is made to the right to make a left turn. The paths followed by the outermost front wheels of tractor for both types of turns are complex curves, unlike the simple curves assumed for this study. Although the assumption of simple curves was valid to determine the amount of pavement area available and the factors influencing them, further research is recommended to assess the impact of LCV's with complex curves.

APPENDIX A. GEOGRAPHIC LOCATIONS OF DIAMOND INTERCHANGES SAMPLED

● indicates locations of diamonds

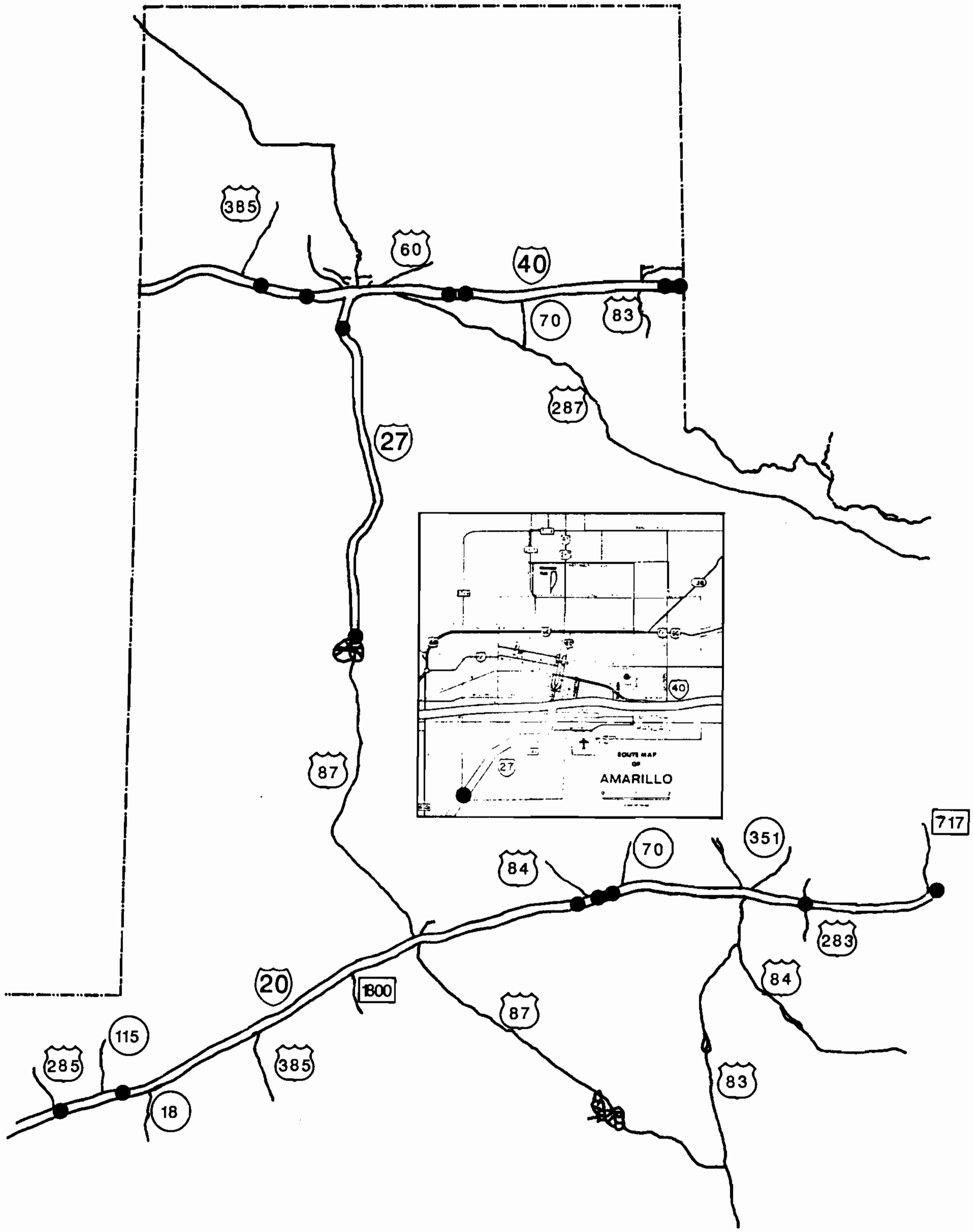


Fig A1. North Texas.

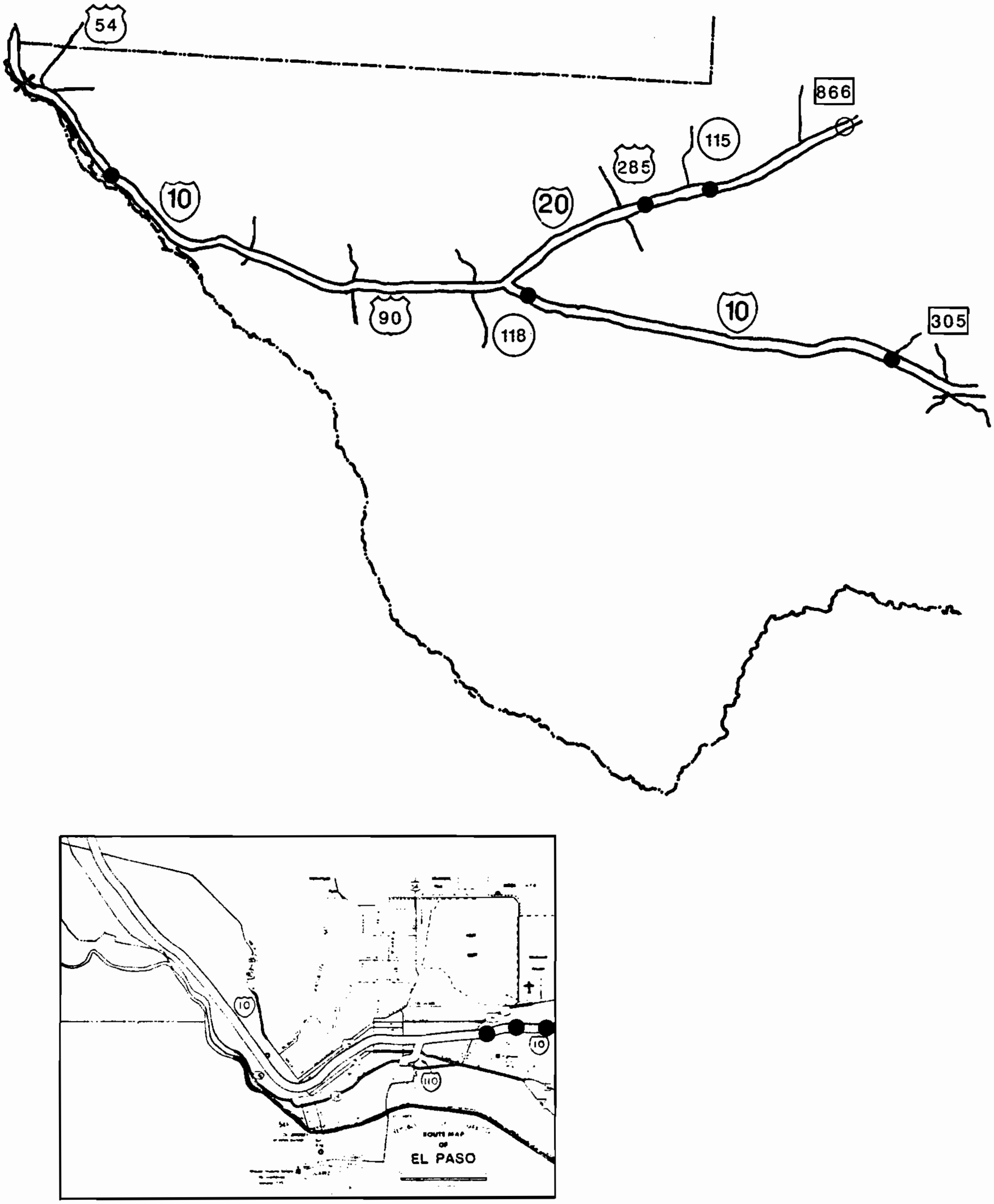


Fig A2. West Texas.

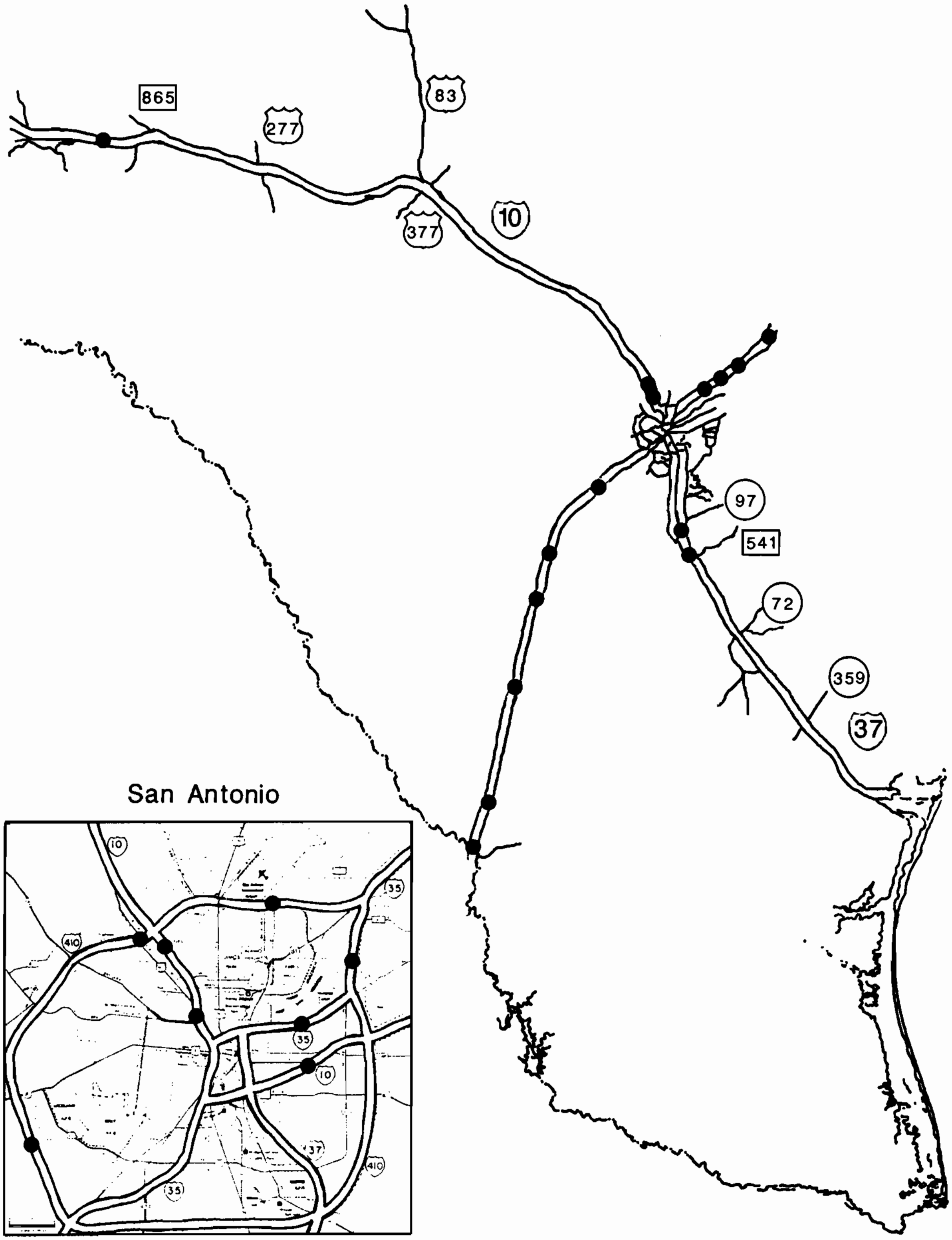


Fig A3. South Texas.

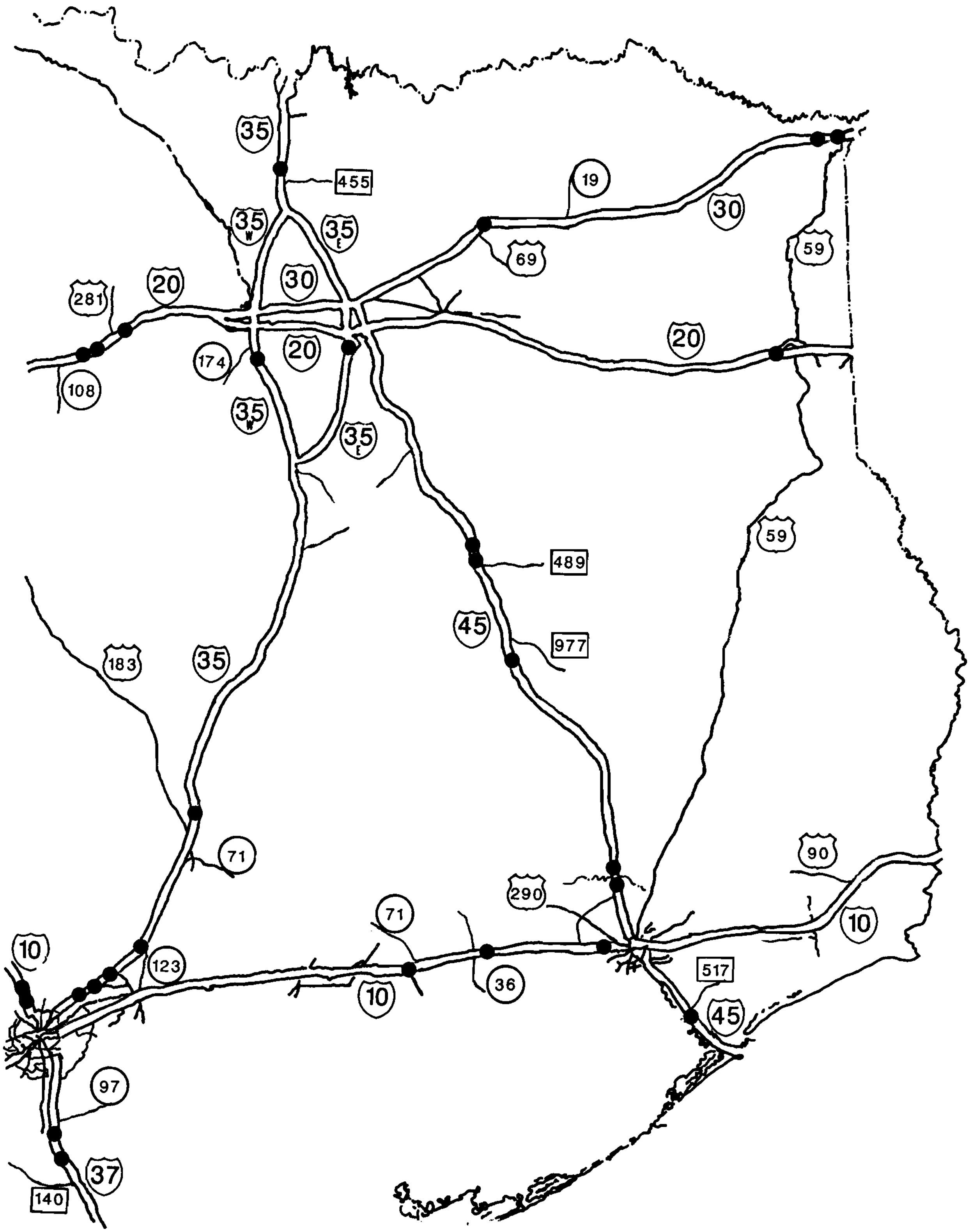


Fig A4. East Texas.

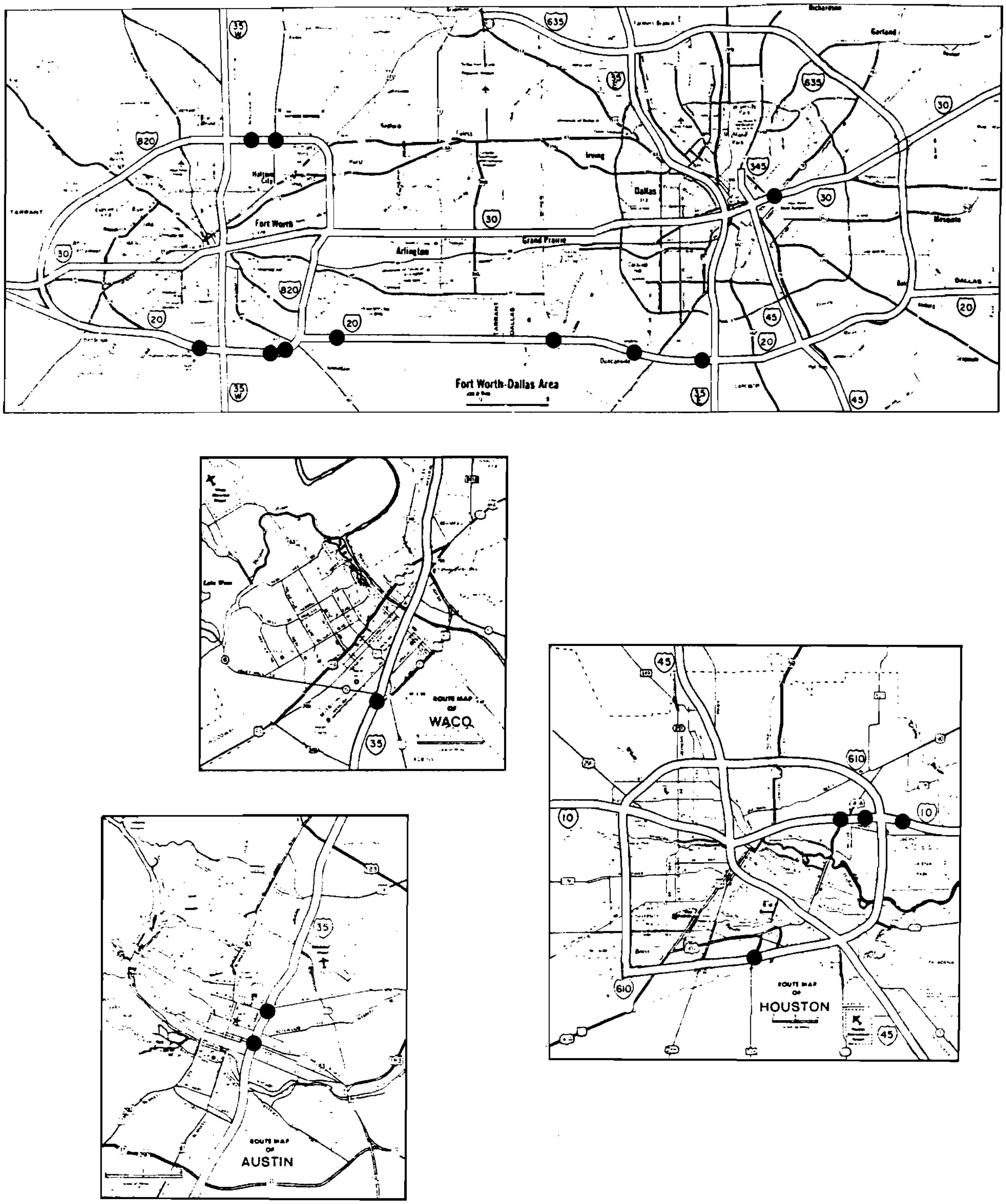


Fig A5. Major urban areas in Texas.

APPENDIX B. TURN MOVEMENTS ANALYZED AT THE THREE MOST COMMON CASES OF DIAMOND INTERCHANGE RAMP TERMINALS

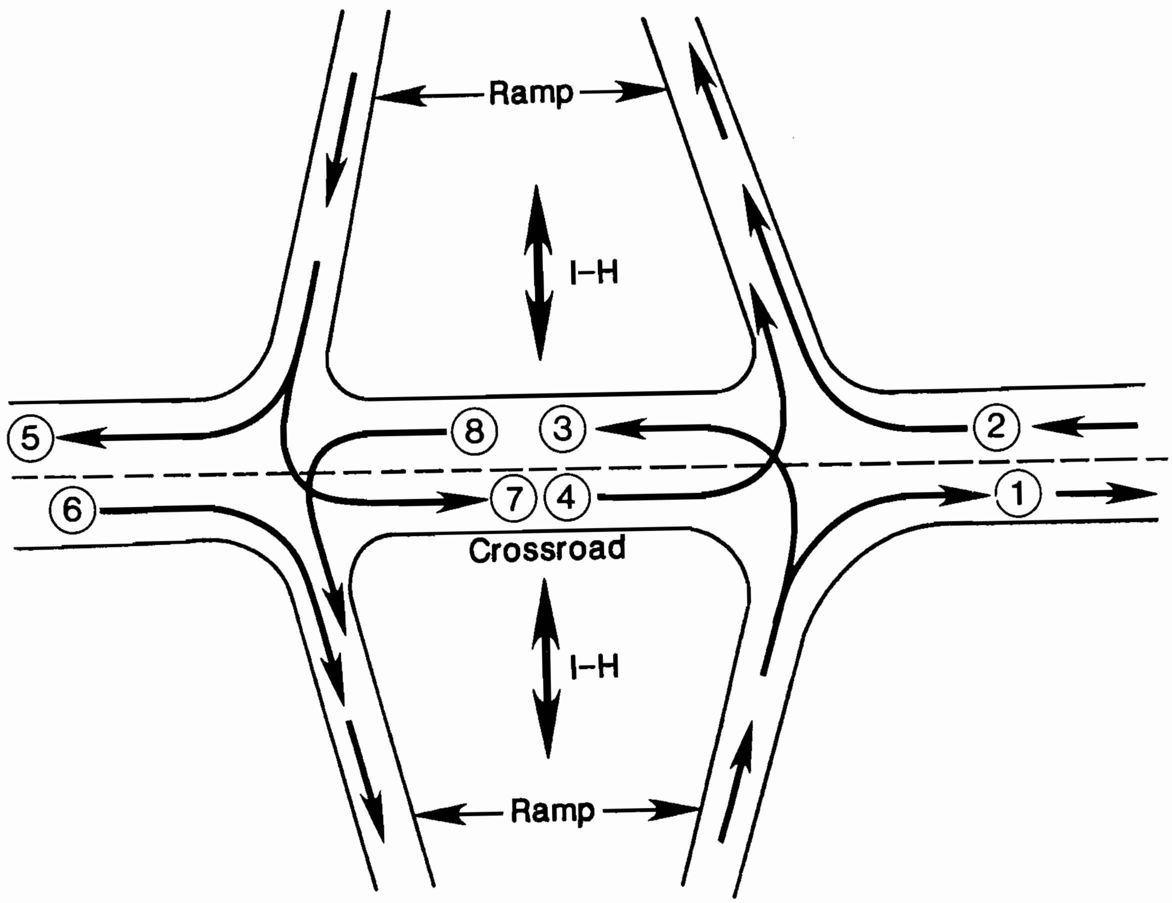


Fig B1. Case 1 - diamond interchange with two-way crossroad - one lane each direction with 8 turn movements.

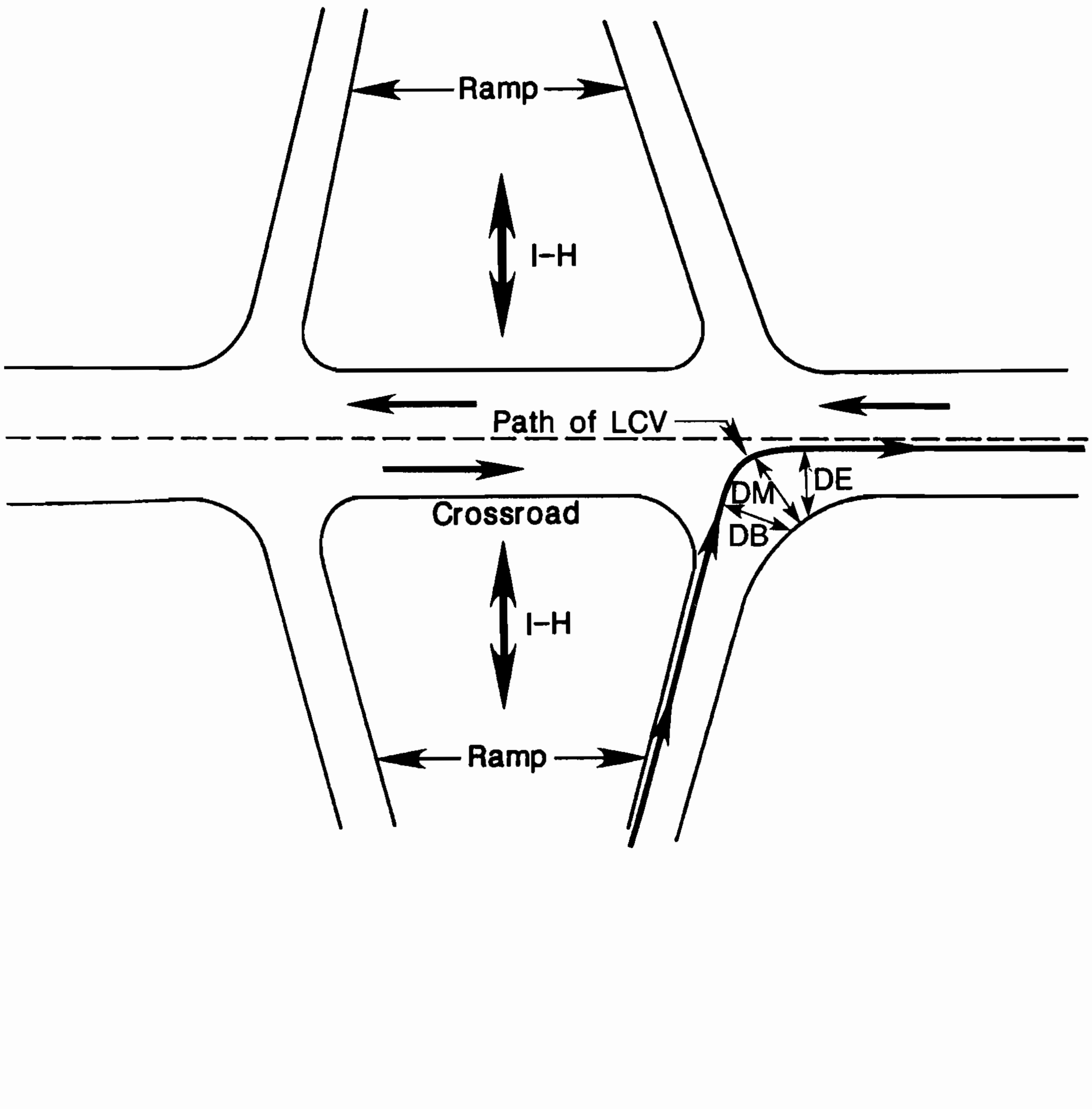


Fig B2. Turn movement 1 for case 1.

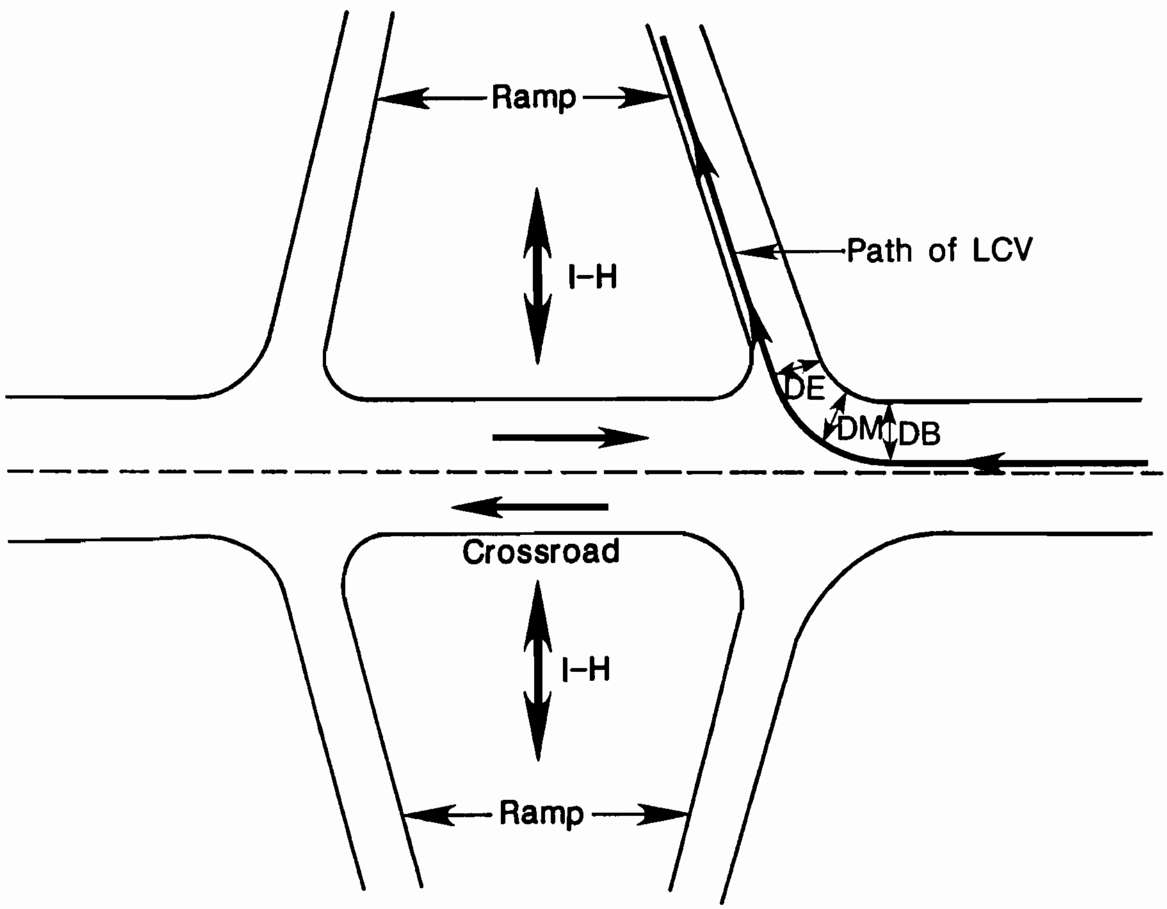


Fig B3. Turn movement 2 for case 1.

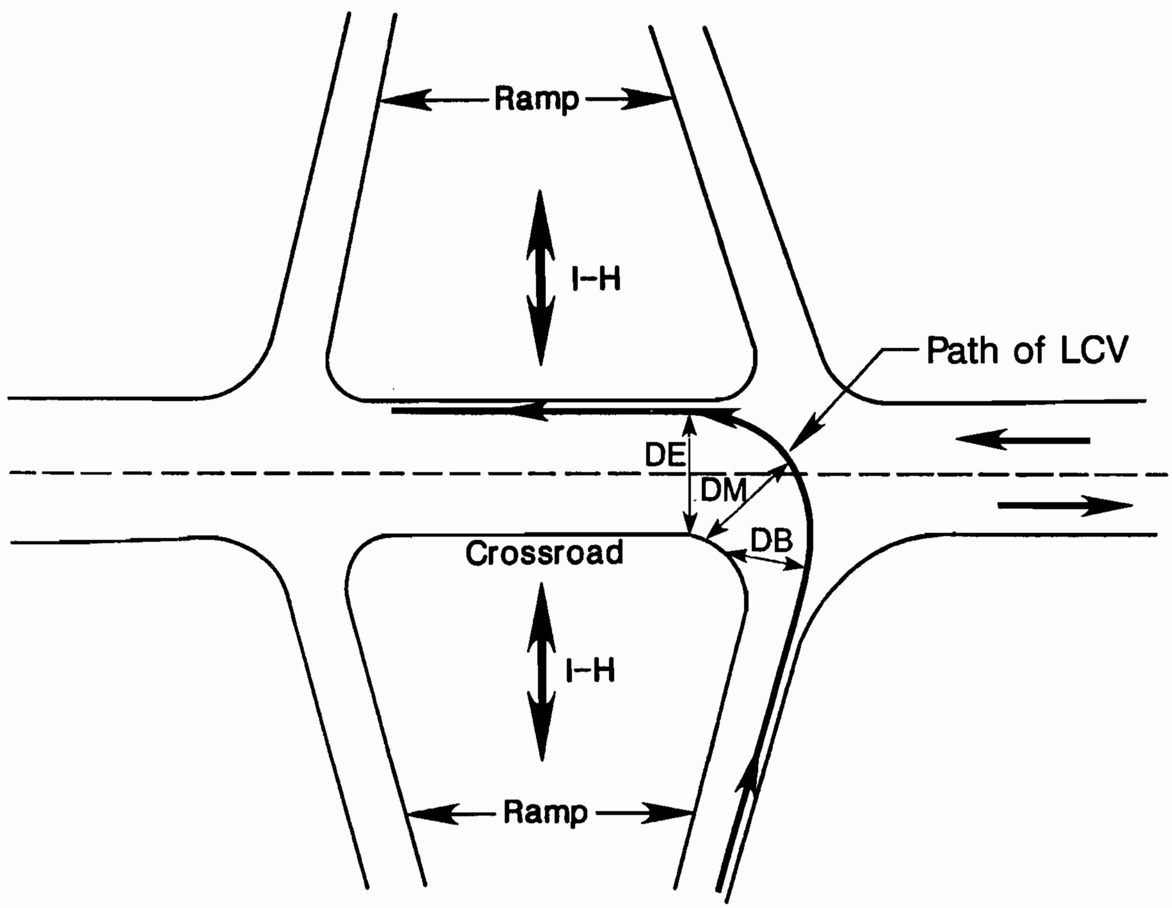


Fig B4. Turn movement 3 for case 1.

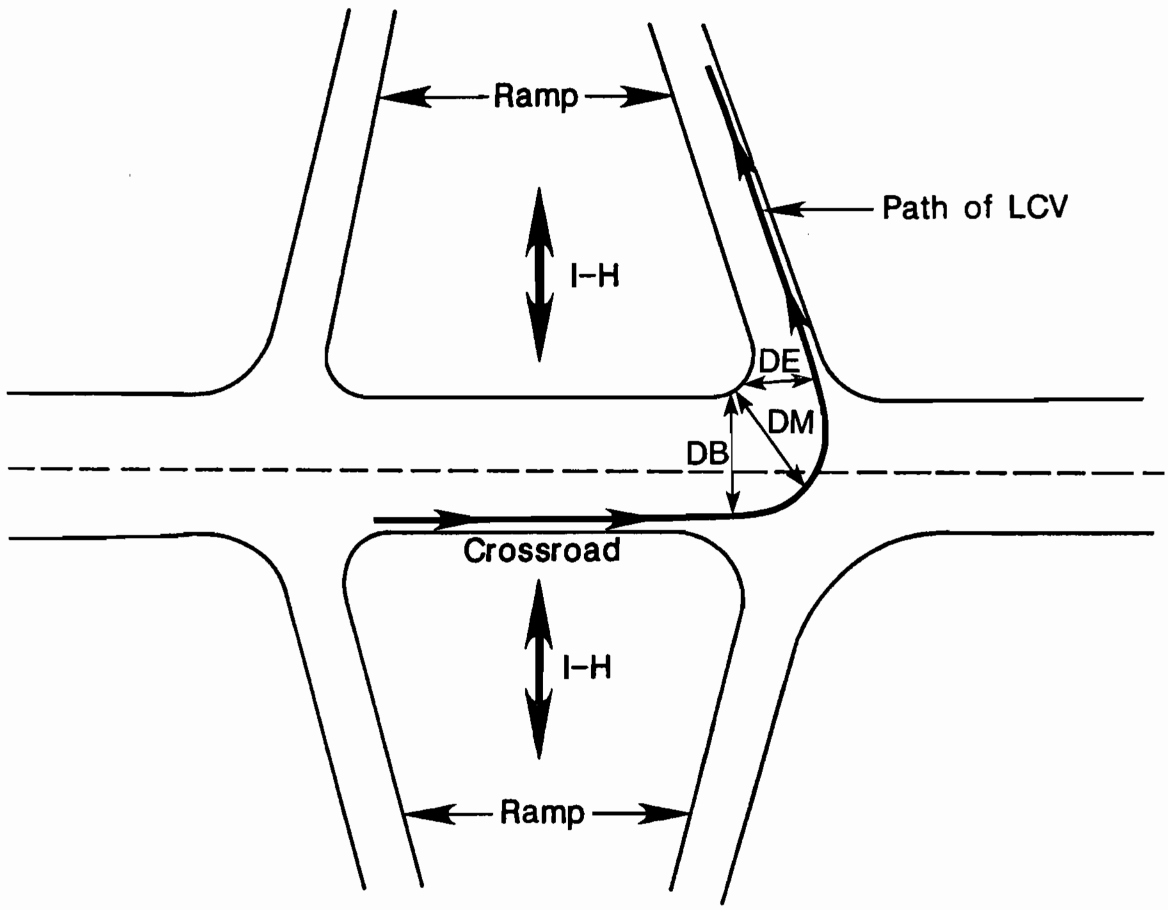


Fig B5. Turn movement 4 for case 1.

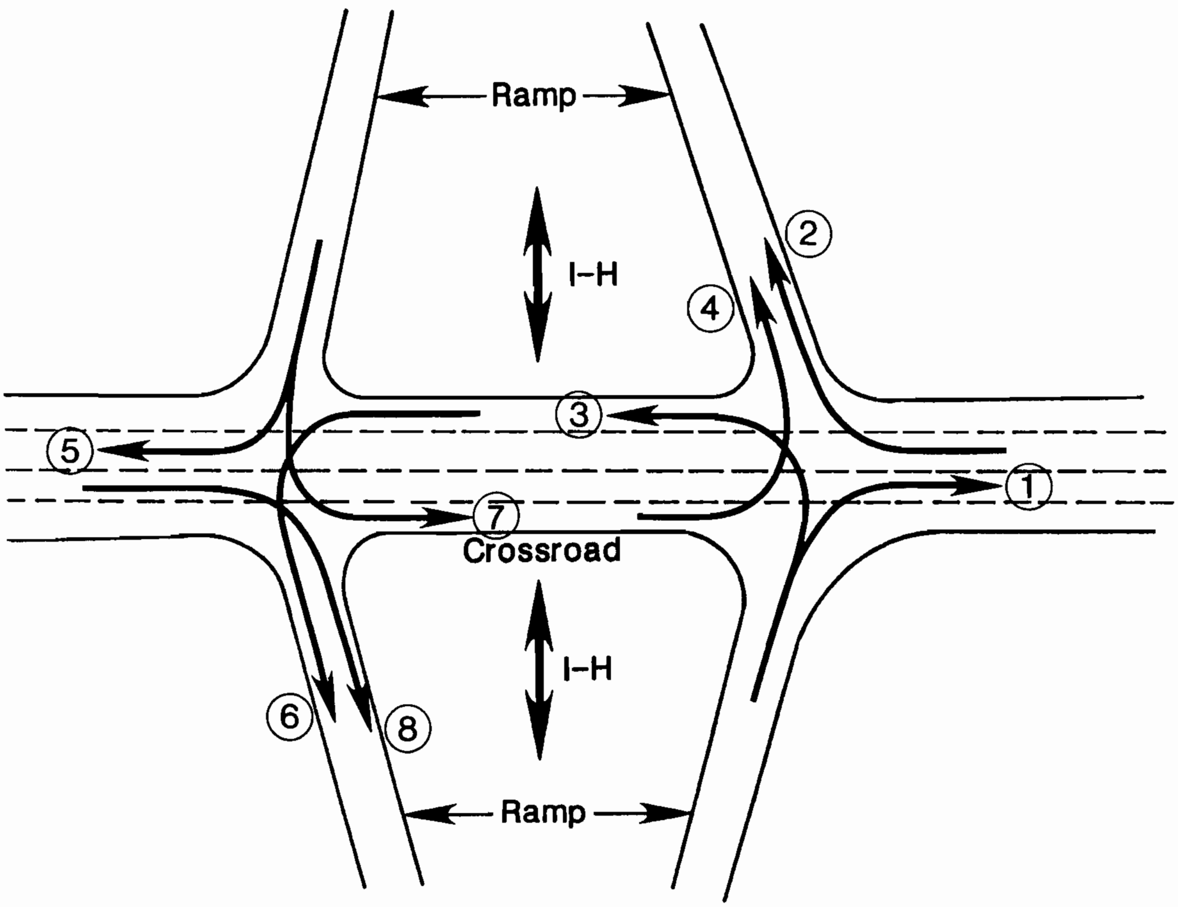


Fig B6. Case 2 - diamond interchange with two-way crossroad - two lanes each direction with 8 turn movements.

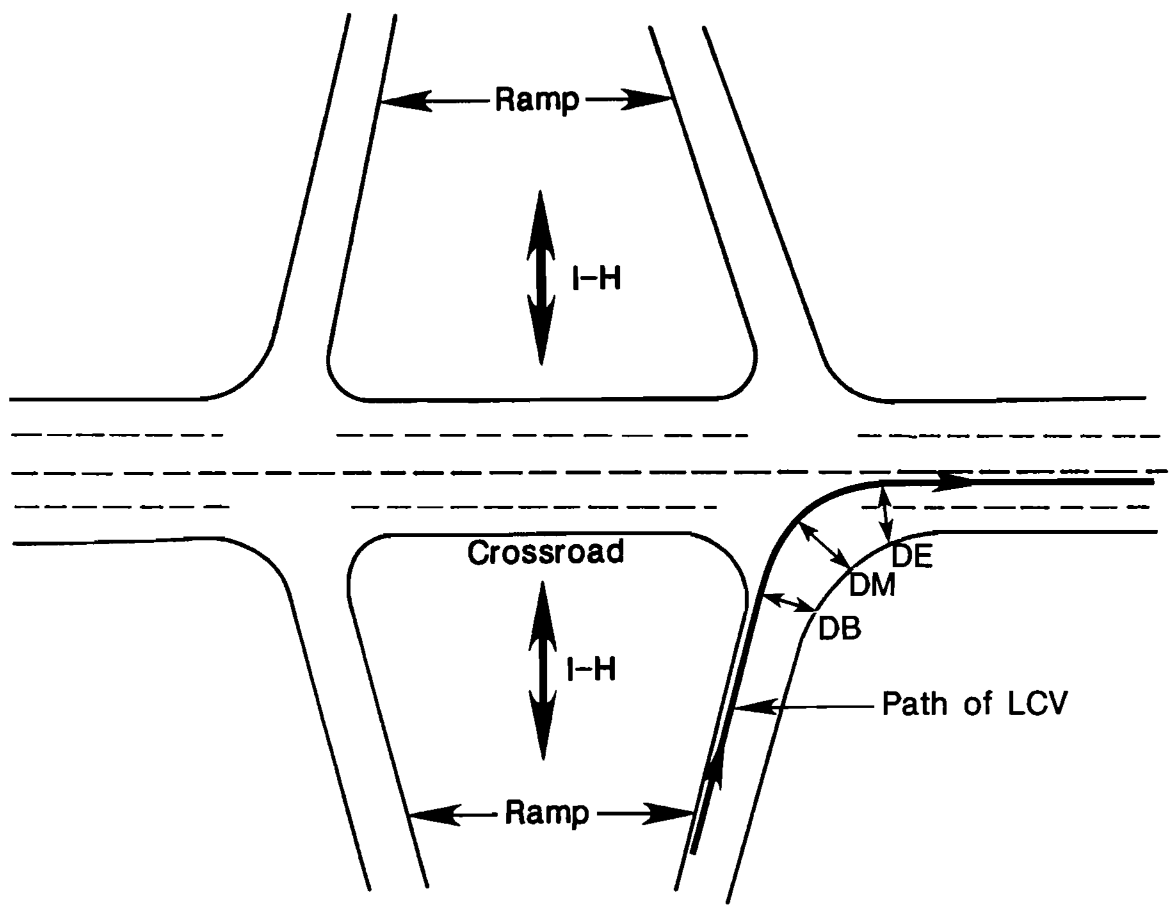


Fig B7. Turn movement 1 for case 2.

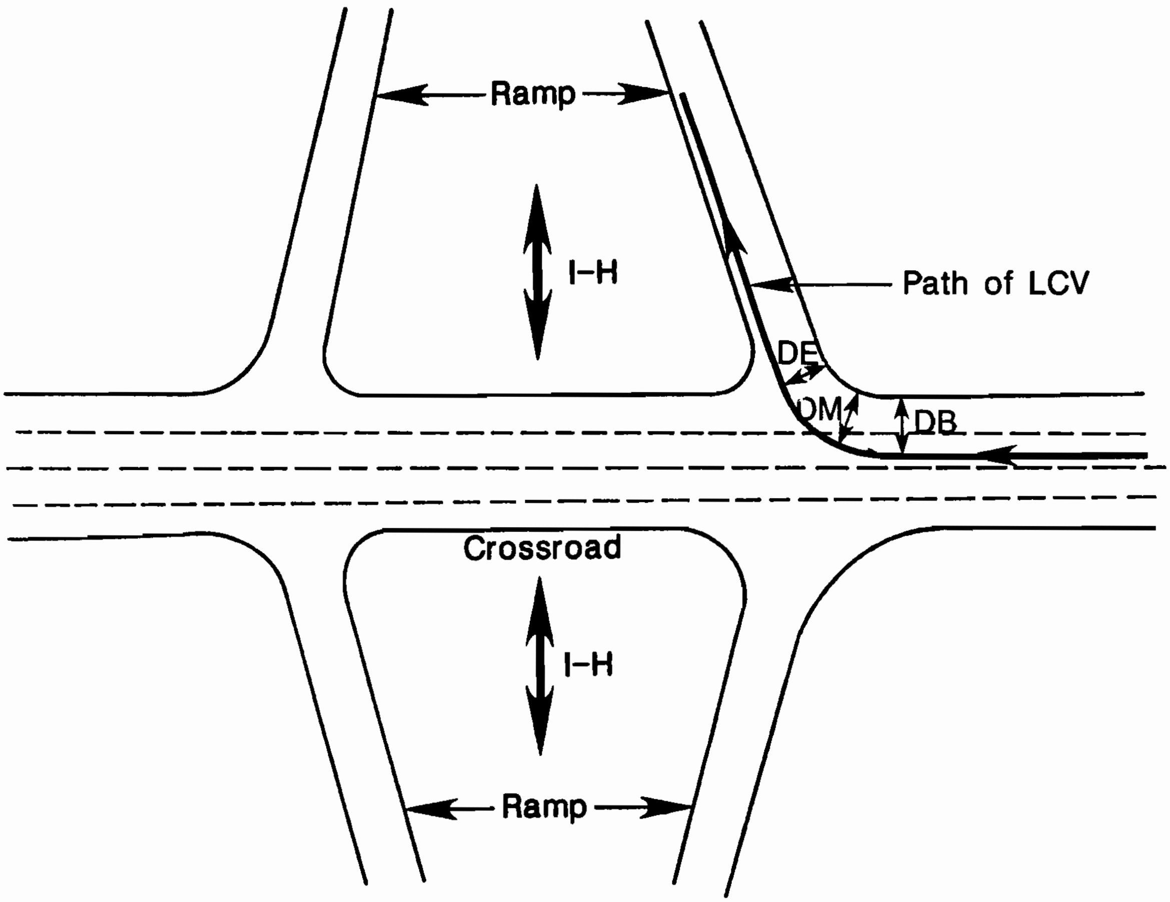


Fig B8. Turn movement 2 for case 2.

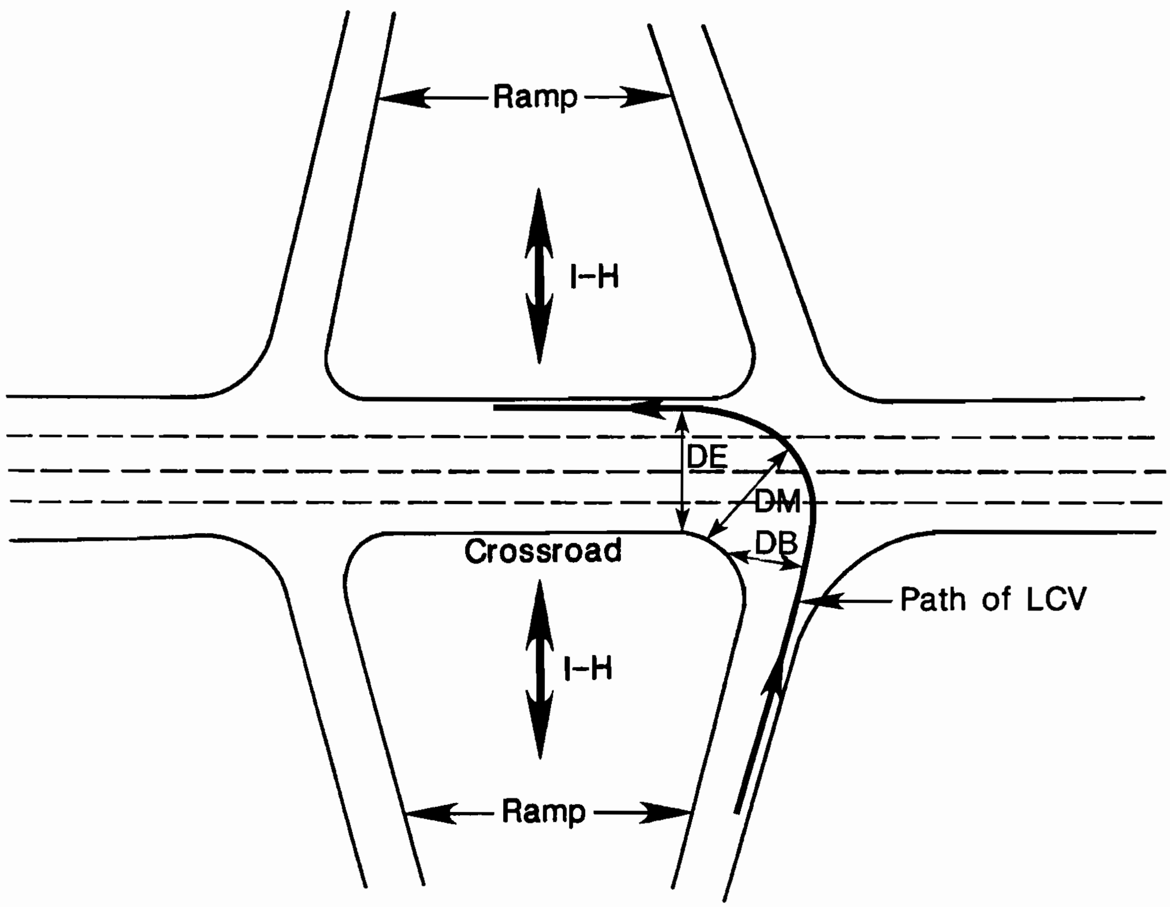


Fig B9. Turn movement 3 for case 2.

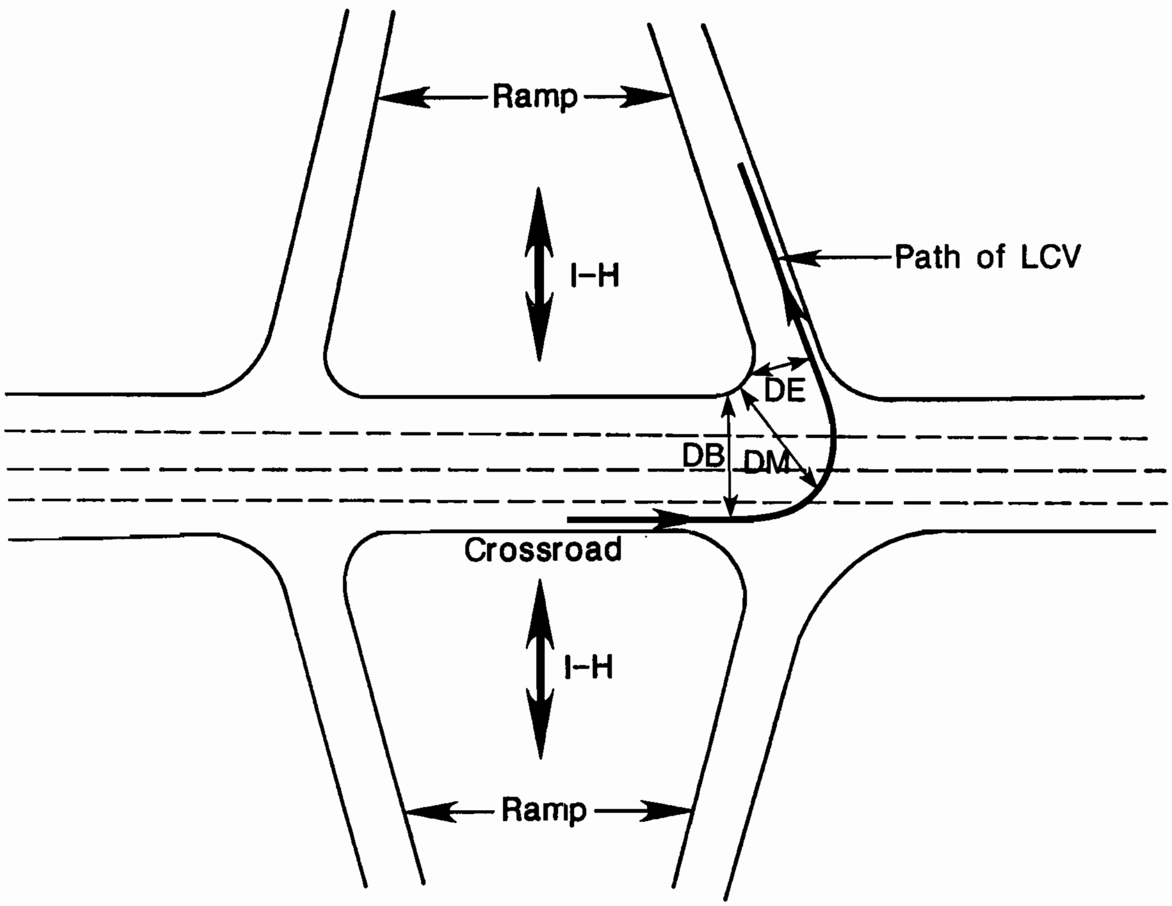


Fig B10. Turn movement 4 for case 2.

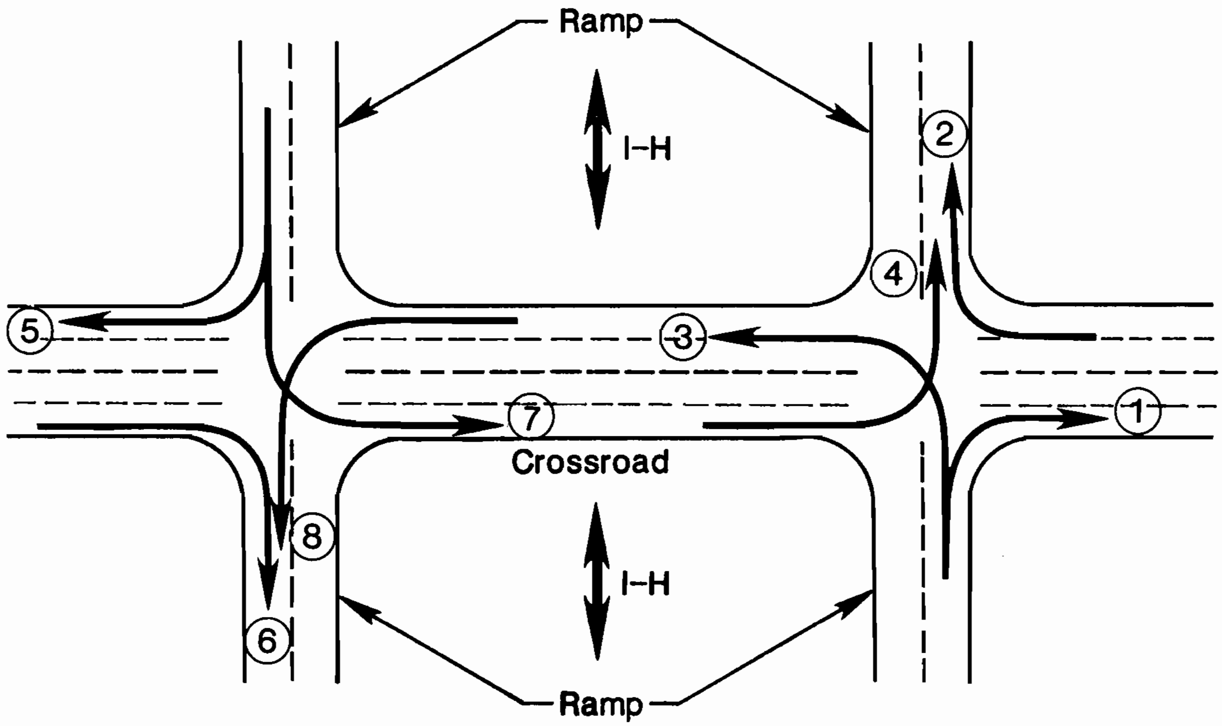


Fig B11. Case 3 - diamond interchange with two-way crossroad and two-way frontage road with turn movements 1 to 8.

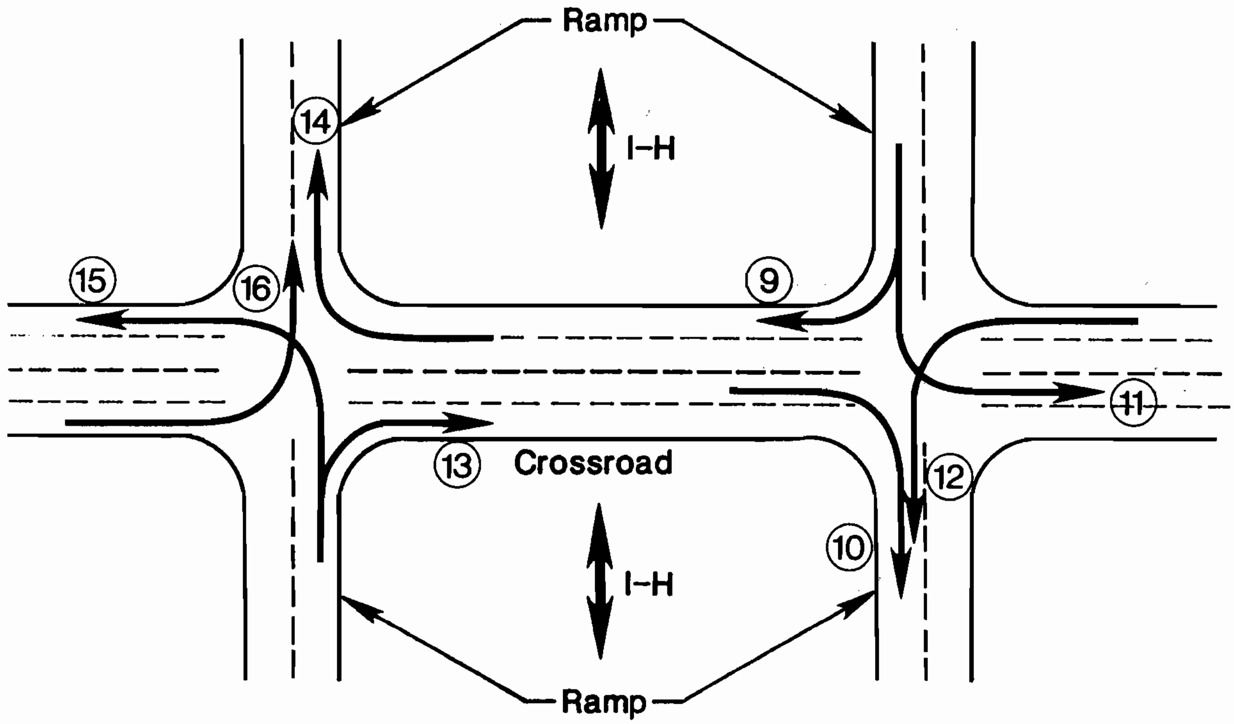


Fig B12. Case 3 - diamond interchange with two-way crossroad and two-way frontage road with turn movements 9 to 16.

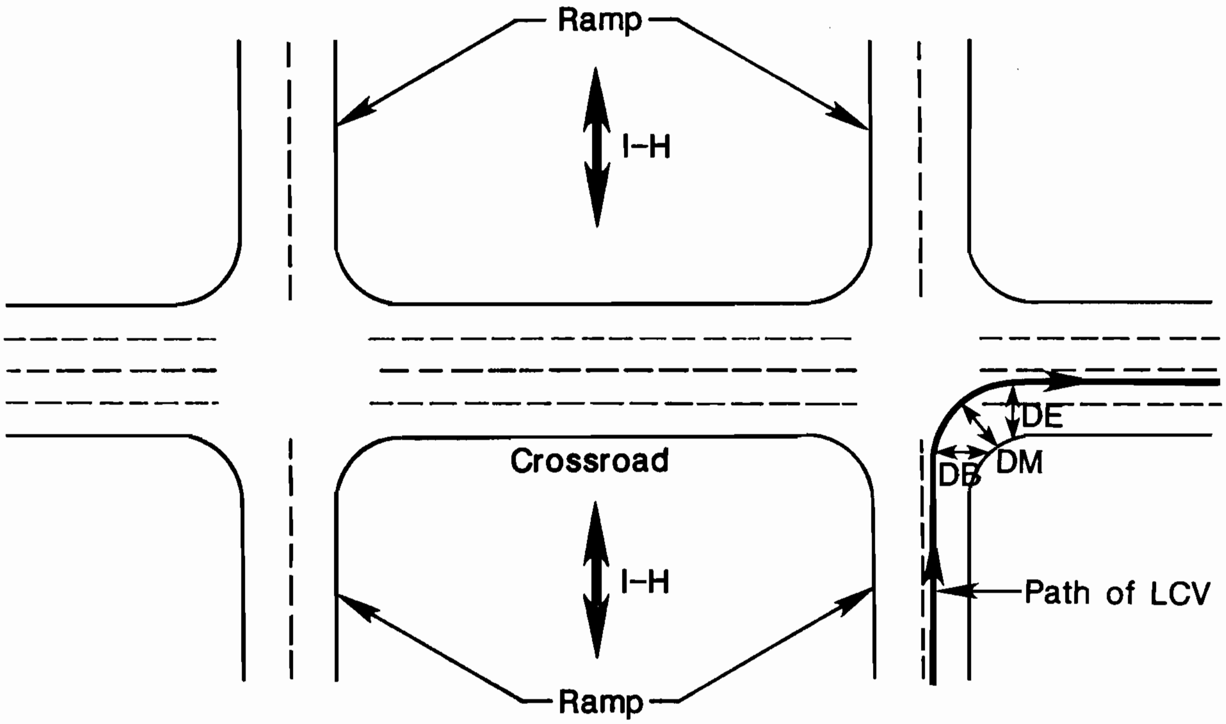


Fig B13. Turn movement 1 for case 3.

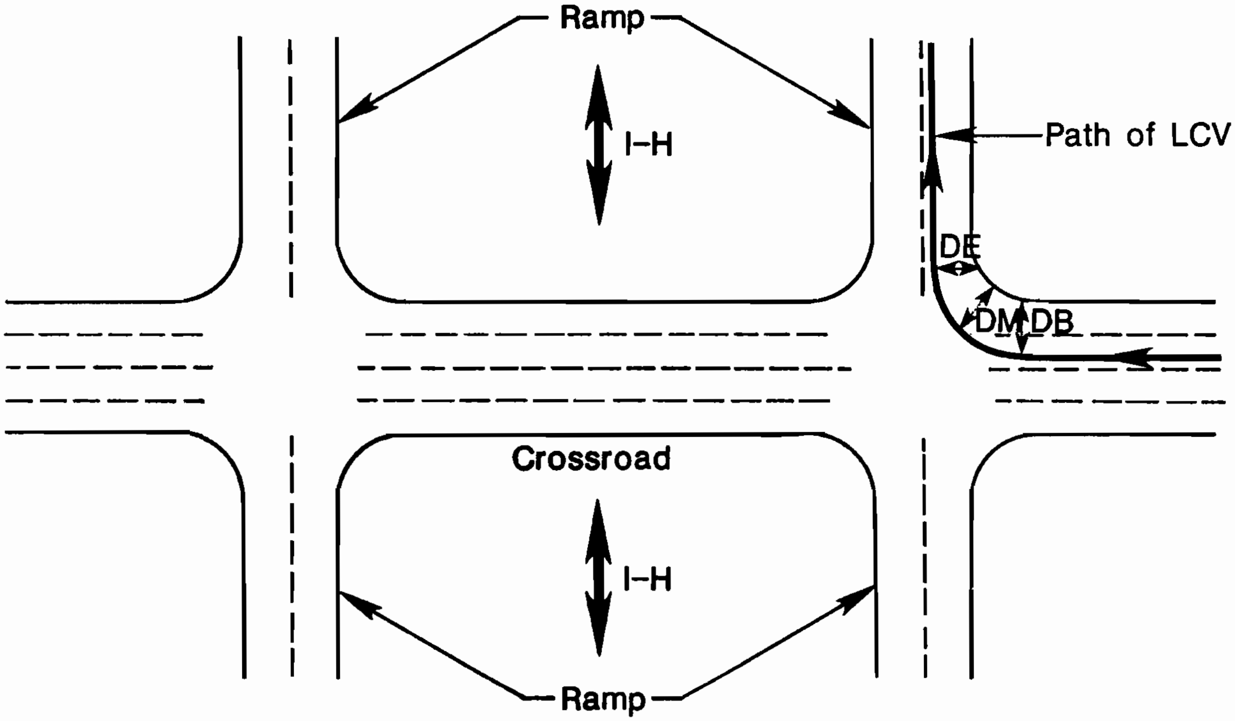


Fig B14. Turn movement 2 for case 3.

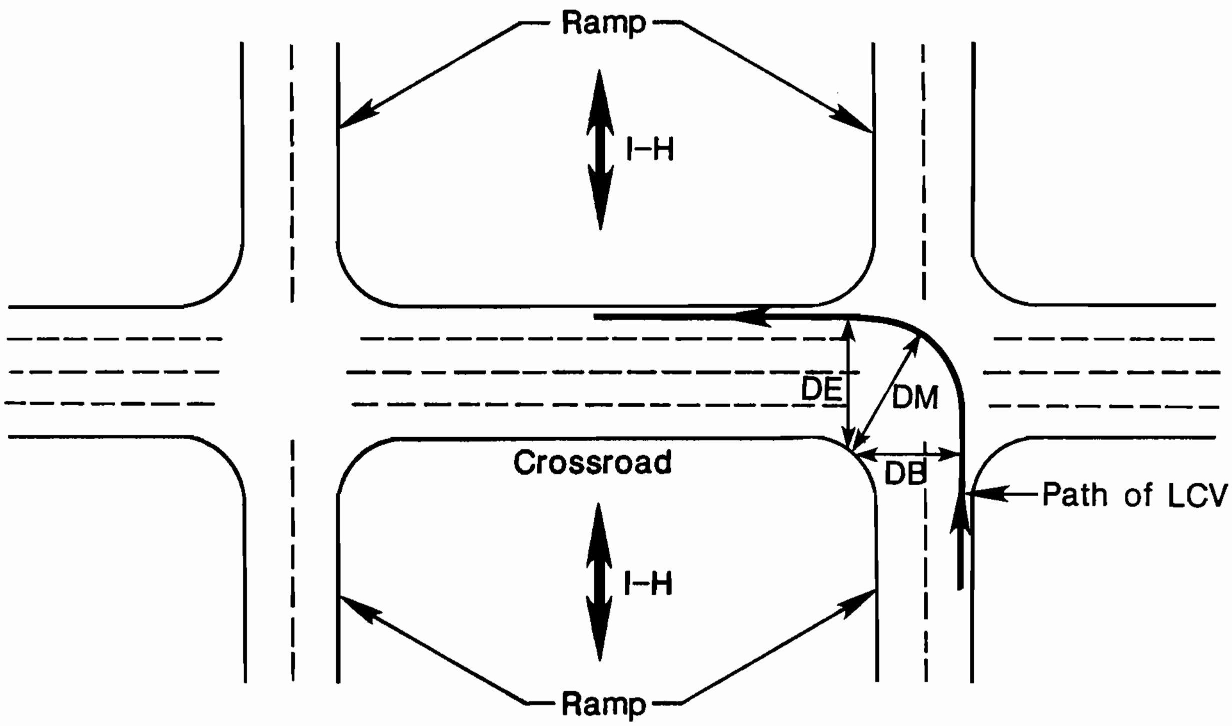


Fig B15. Turn movement 3 for case 3.

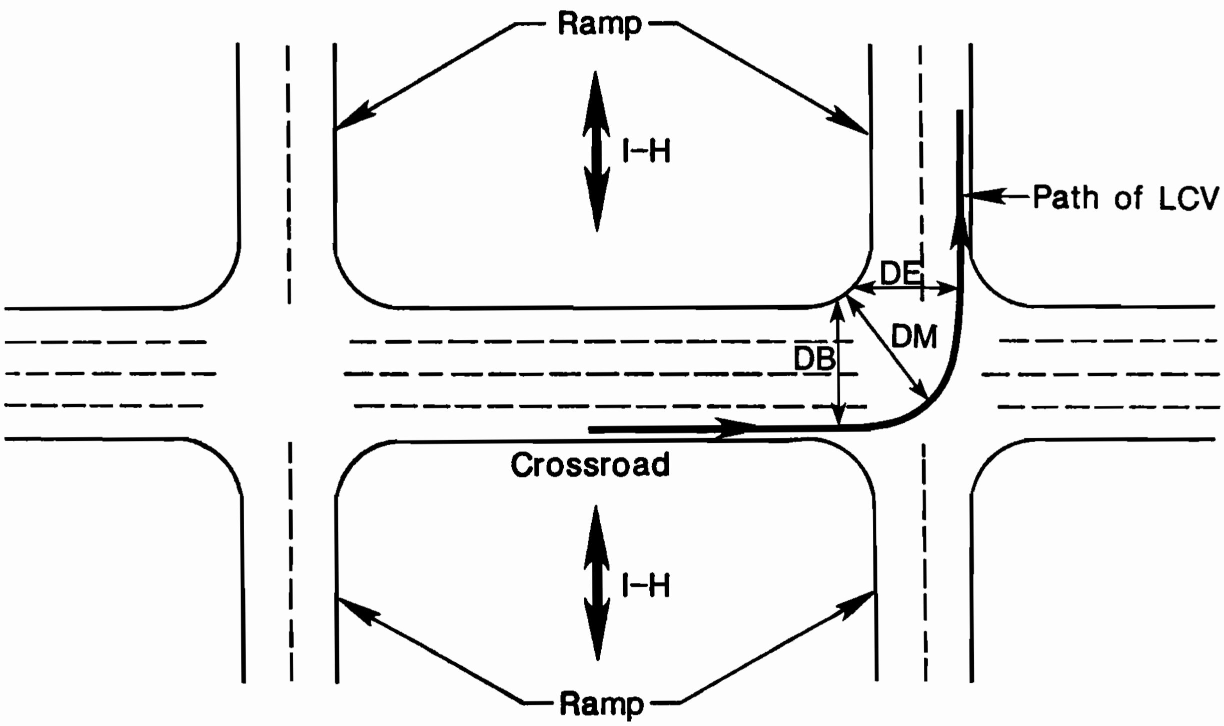


Fig B16. Turn movement 4 for case 3.

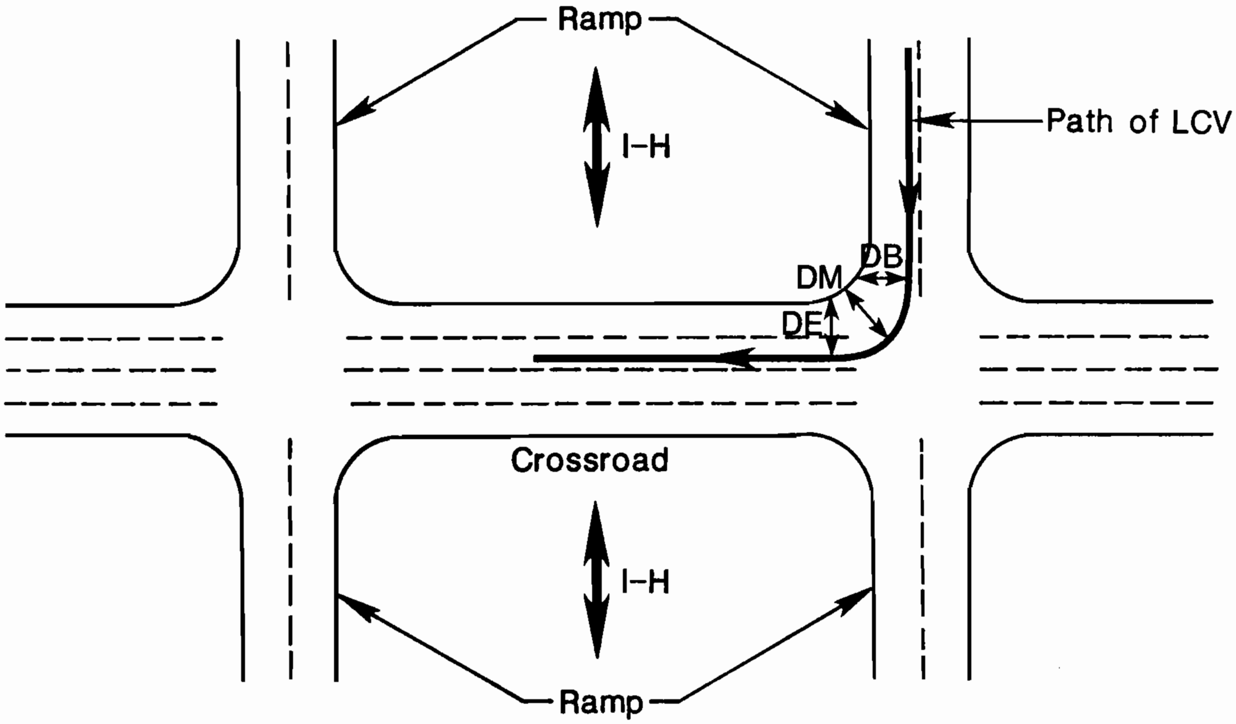


Fig B17. Turn movement 9 for case 3.

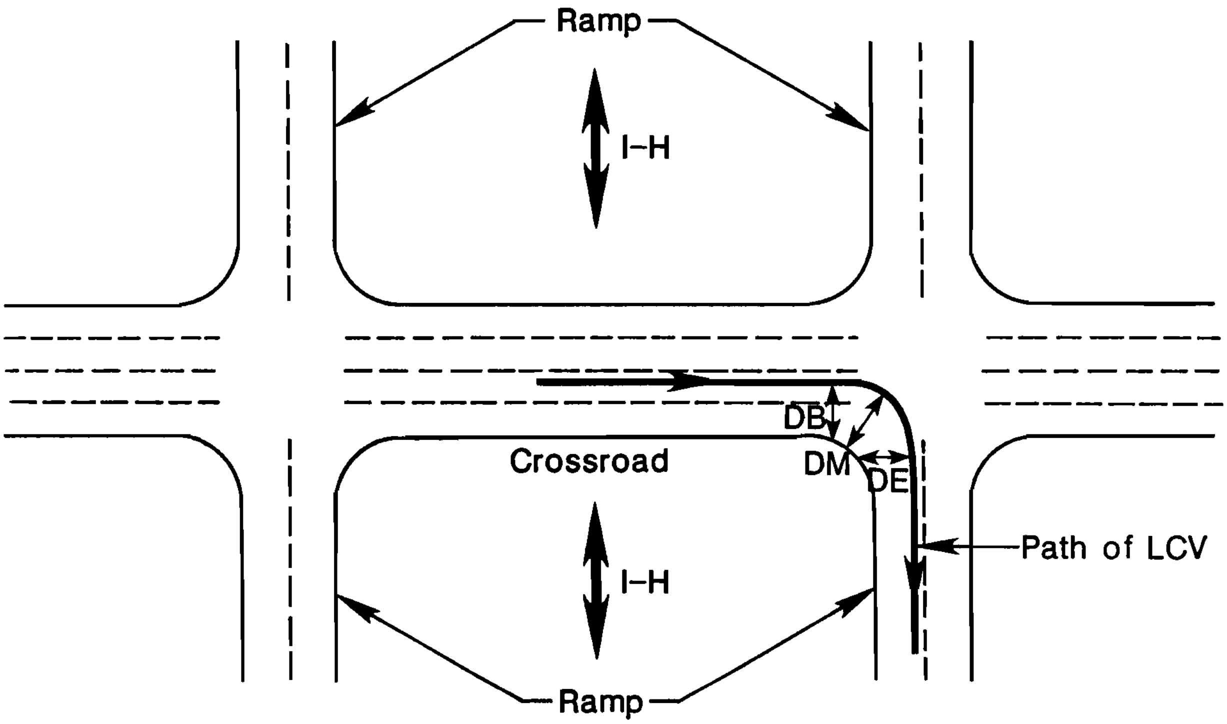


Fig B18. Turn movement 10 for case 3.

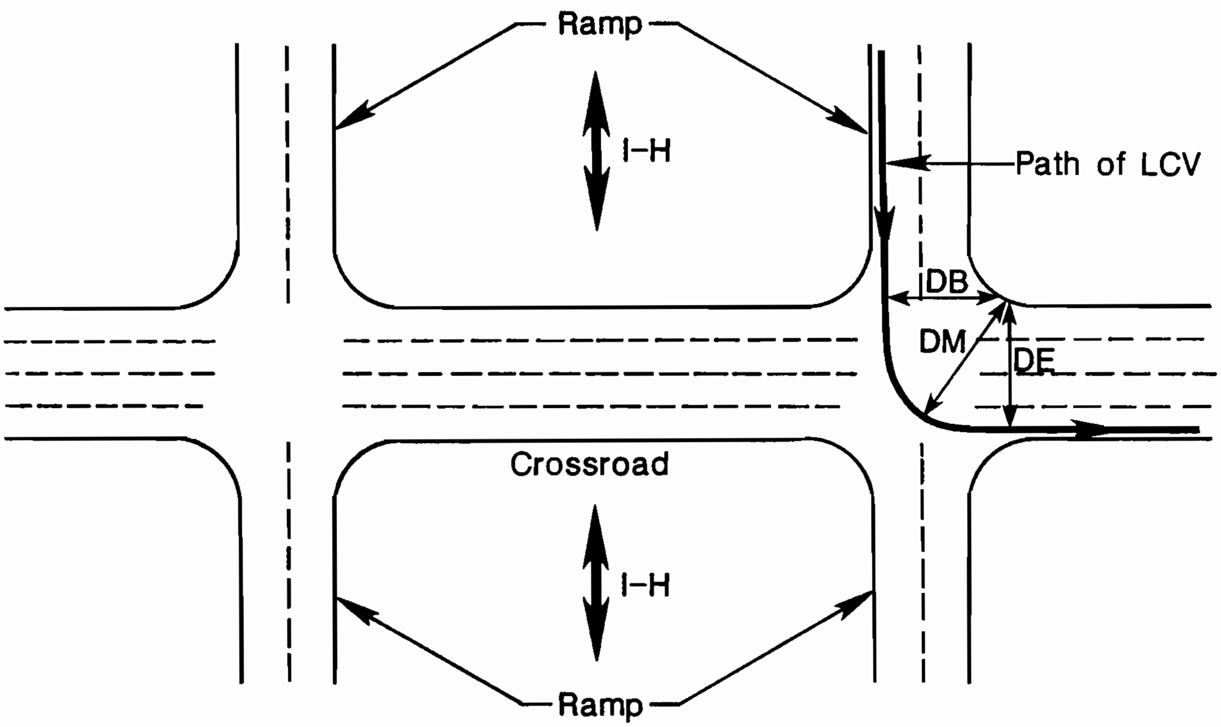


Fig B19. Turn movment 11 for case 3.

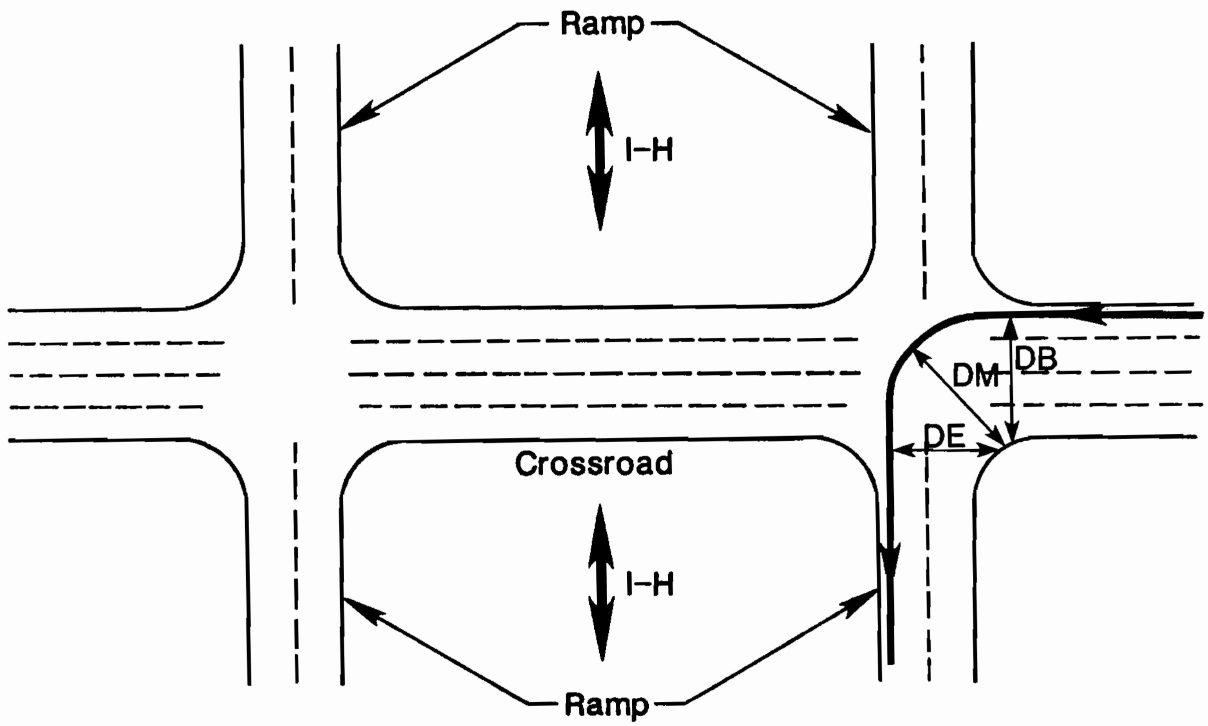


Fig B20. Turn movement 12 for case 3.

APPENDIX C. SWEPT PATH PLOTS FROM THE TRUCK OFFTRACKING MODEL (TOM)

Legend

Paths of the Outermost Front Wheel of Tractor and the Innermost Rear Wheel of Trailer

Path of the Inner Front Wheel of Tractor

Path of the Center of Rear Axle of Semi-Trailer

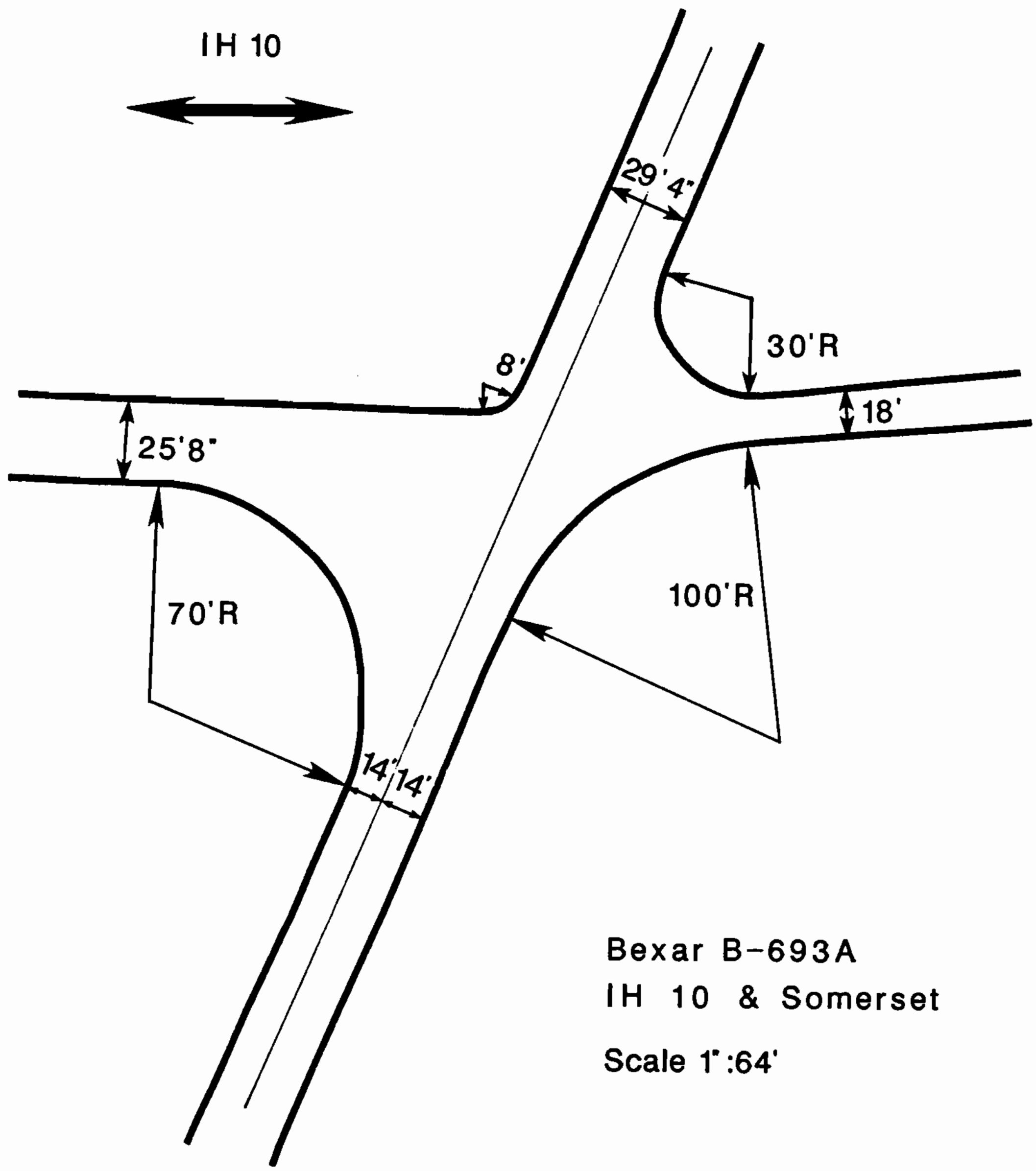


Fig C1. Configuration of an unchannelized diamond interchange ramp terminal - example 1.

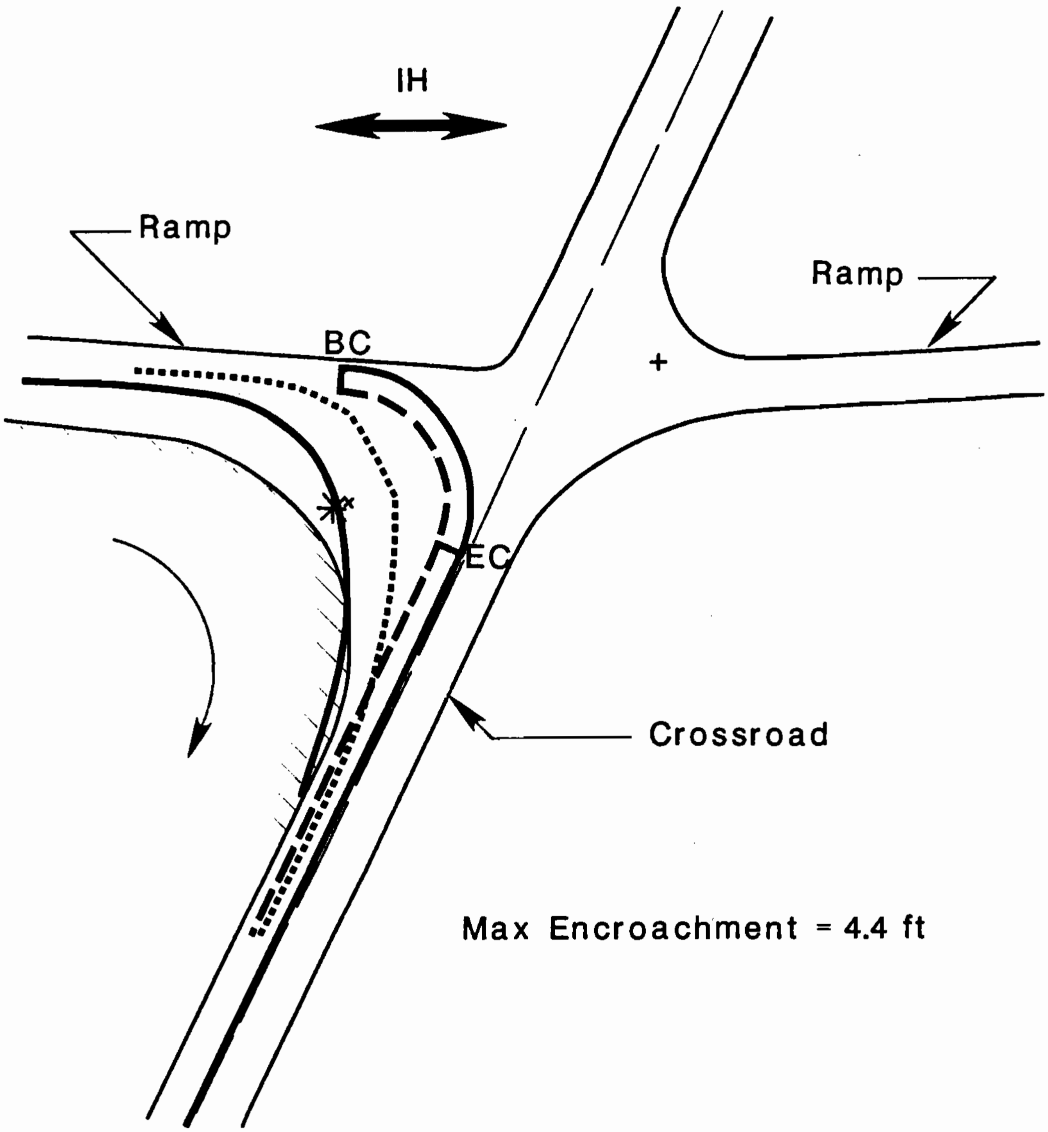


Fig C2. Swept path for right turn movement from ramp to crossroad.

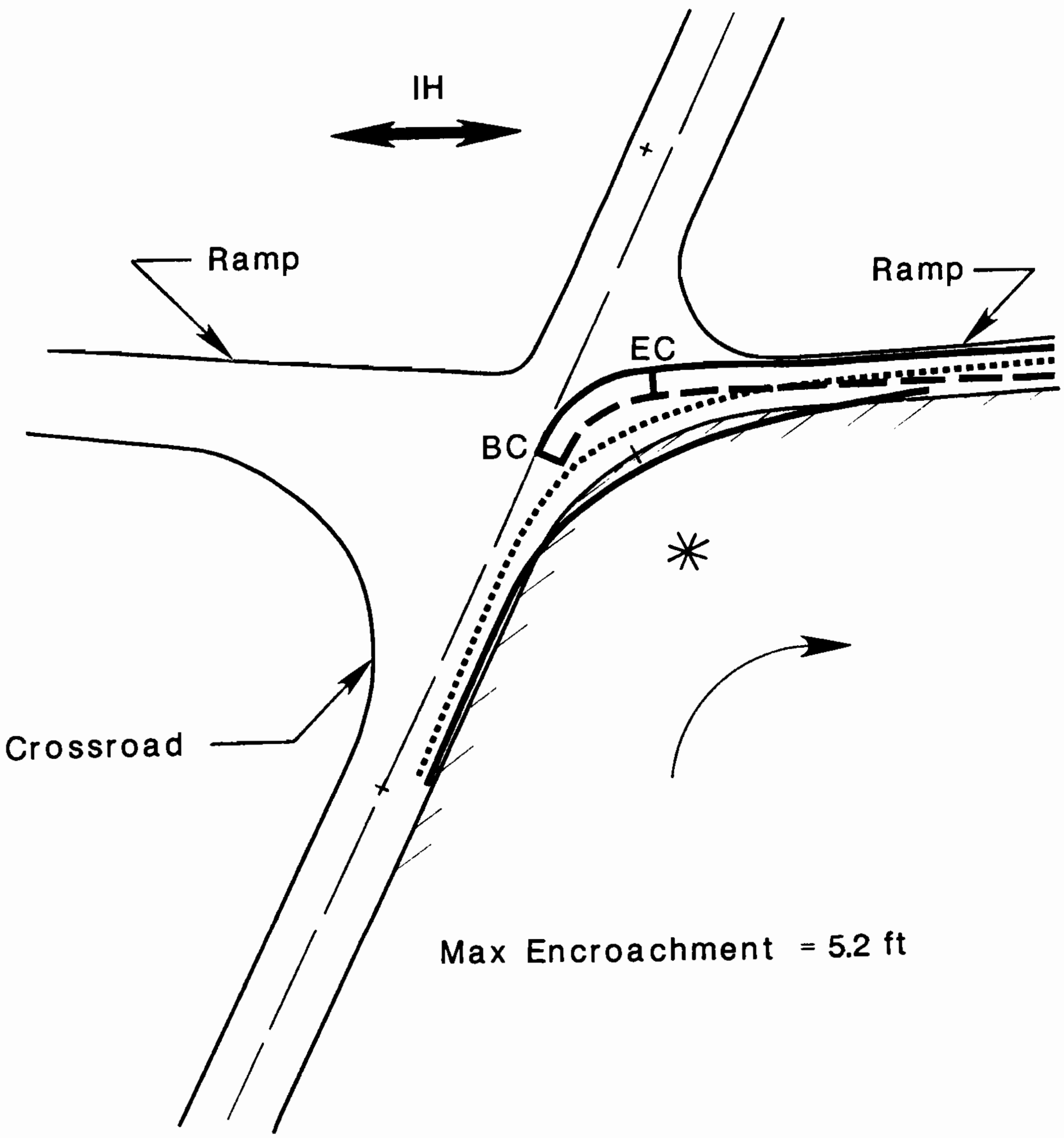


Fig C3. Swept path for a right turn movement from crossroad to ramp.

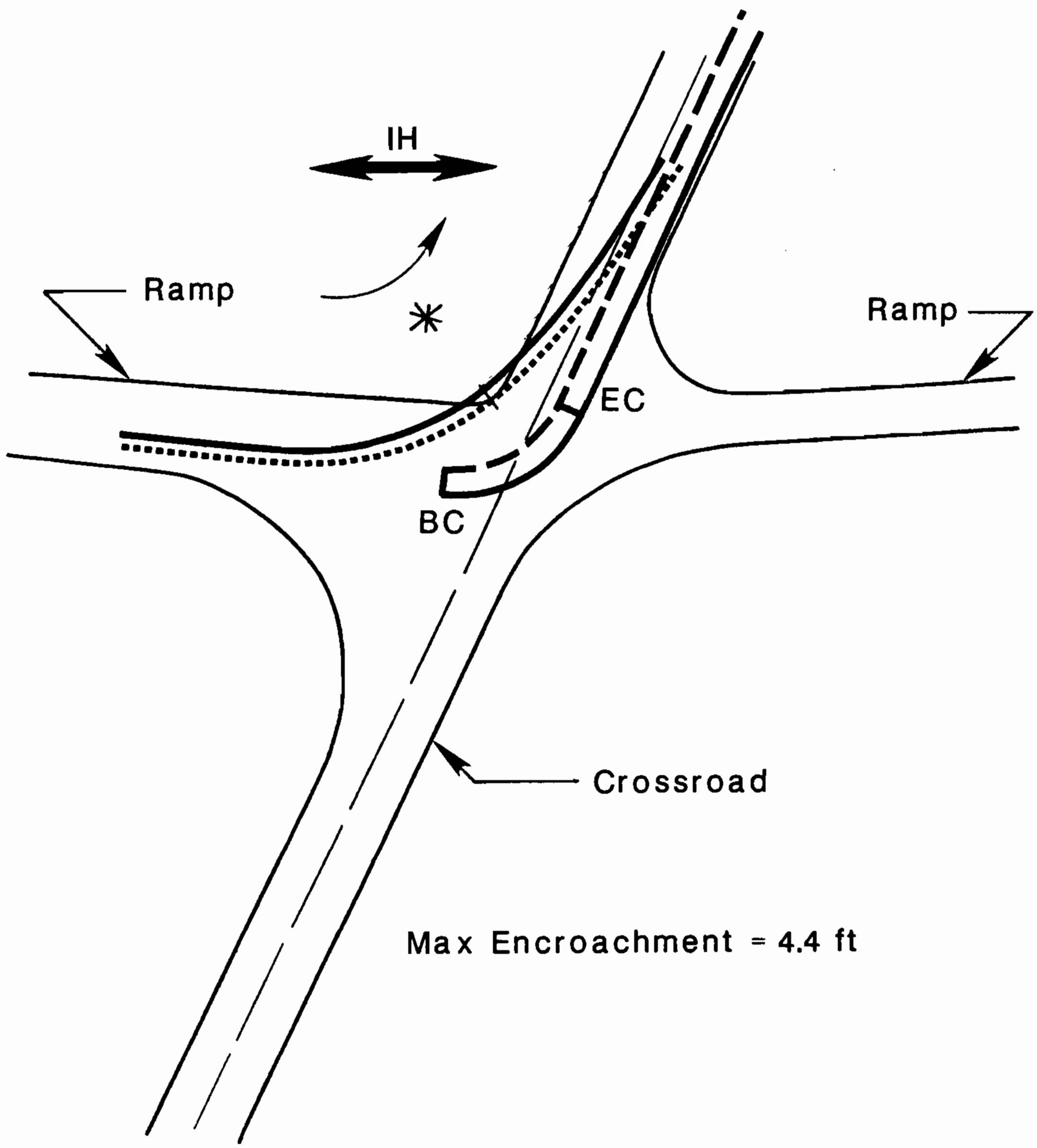


Fig C4. Swept path for left turn movement from ramp to crossroad.

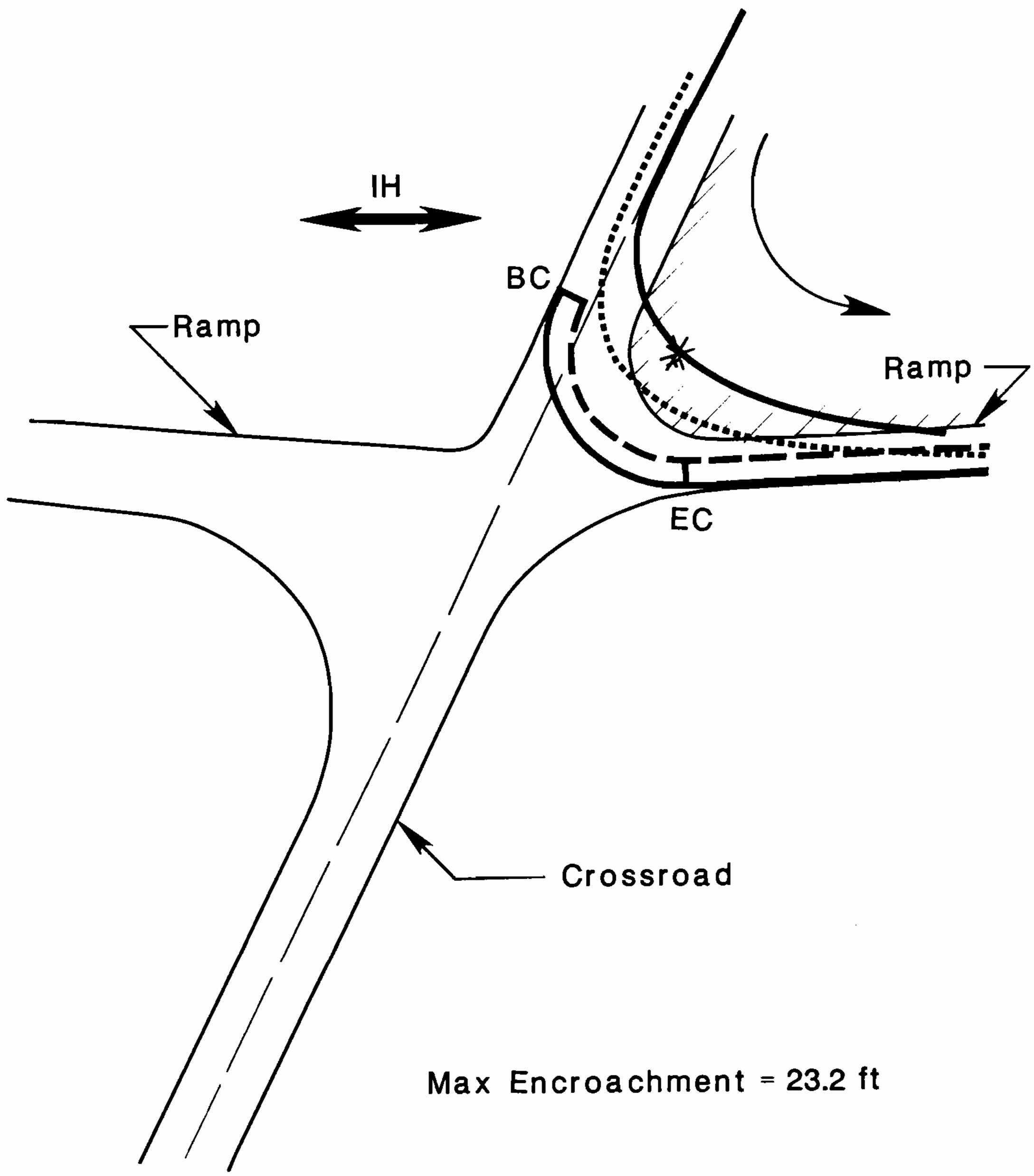


Fig C5. Swept path for left turn movement from crossroad to ramp.

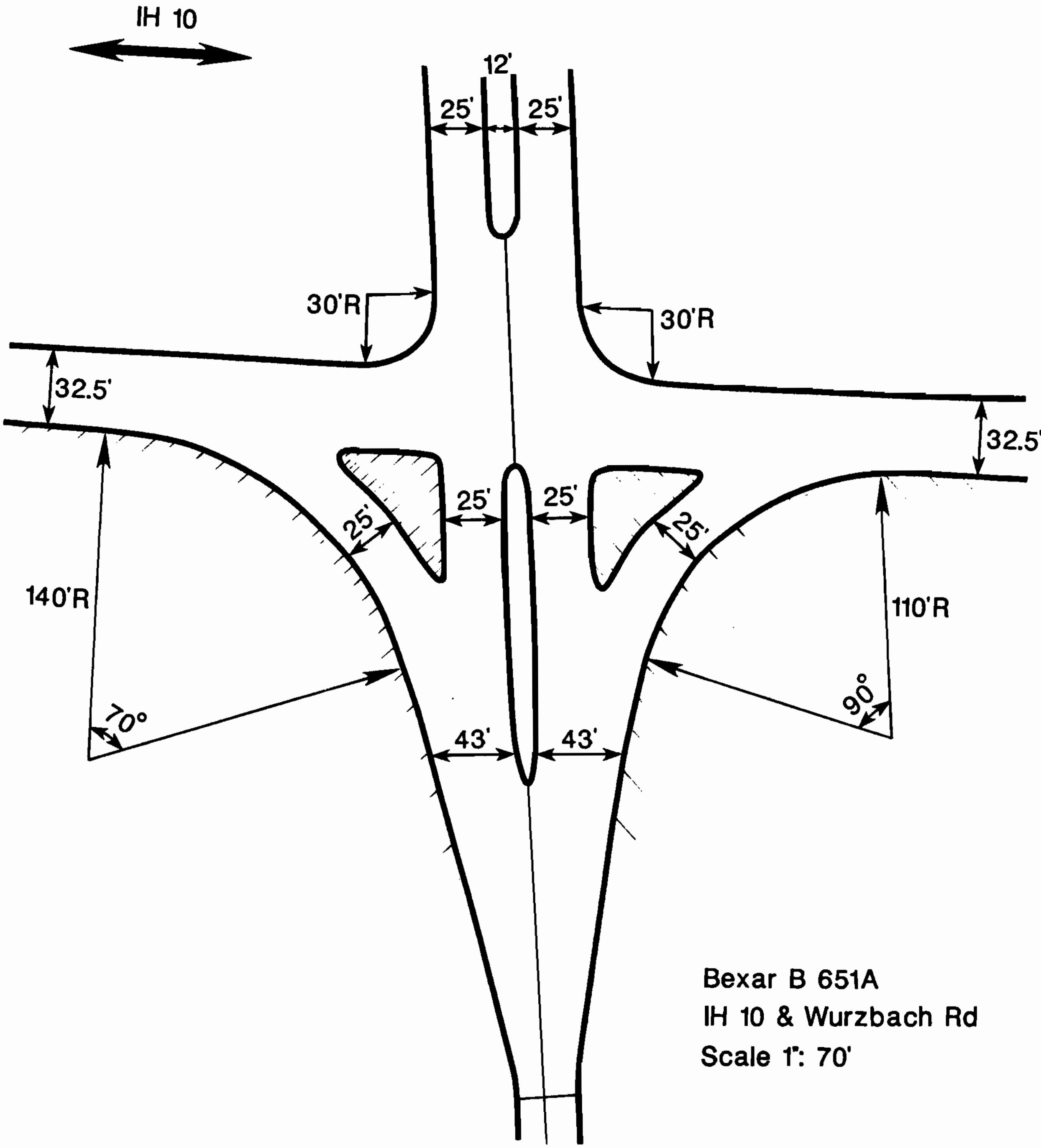


Fig C6. Configuration of a channelized diamond interchange ramp terminal - example 2.

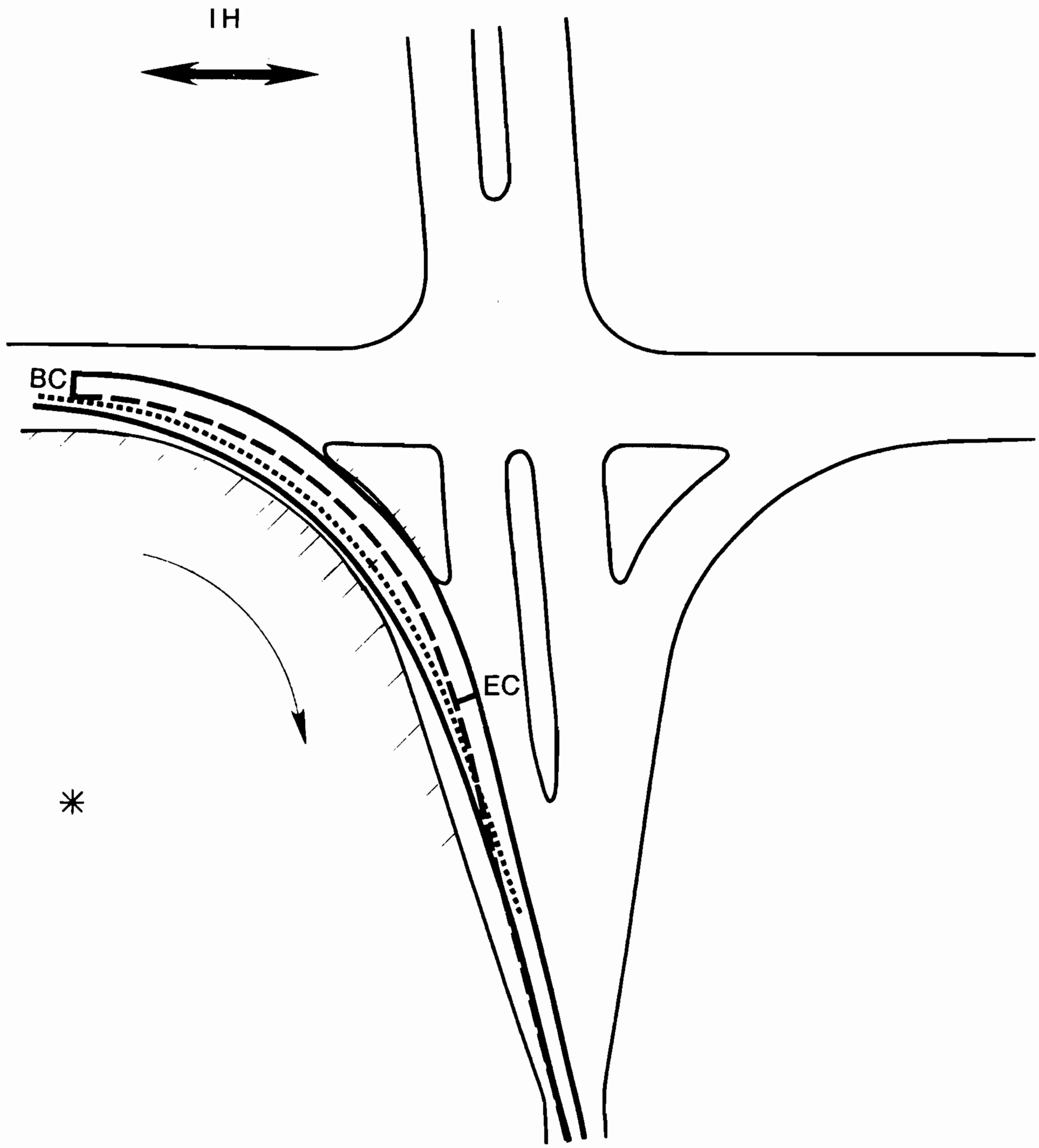


Fig C7. Swept path for right-turn movement from ramp to crossroad.

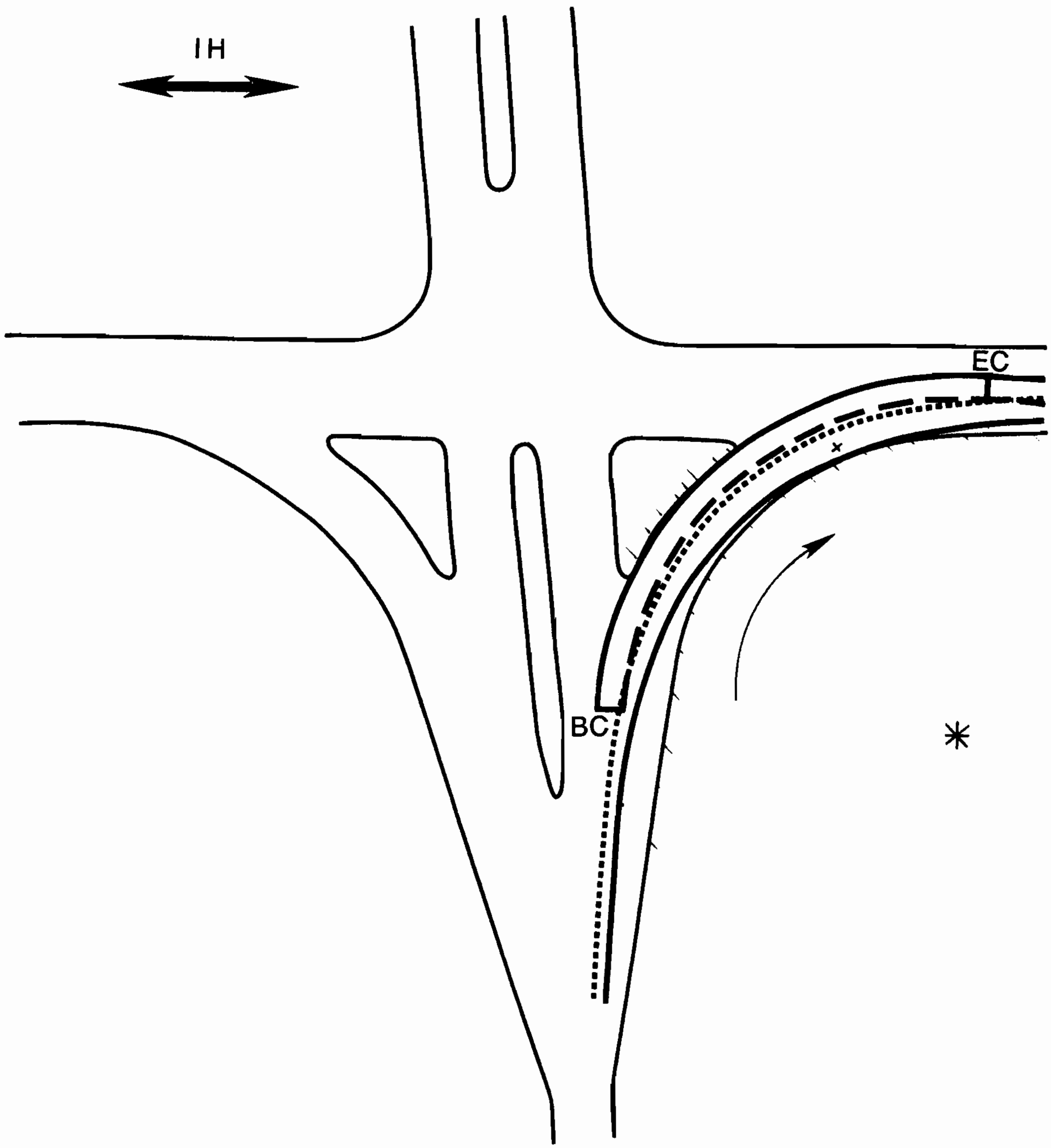


Fig C8. Swept path for right turn movement from crossroad to ramp.

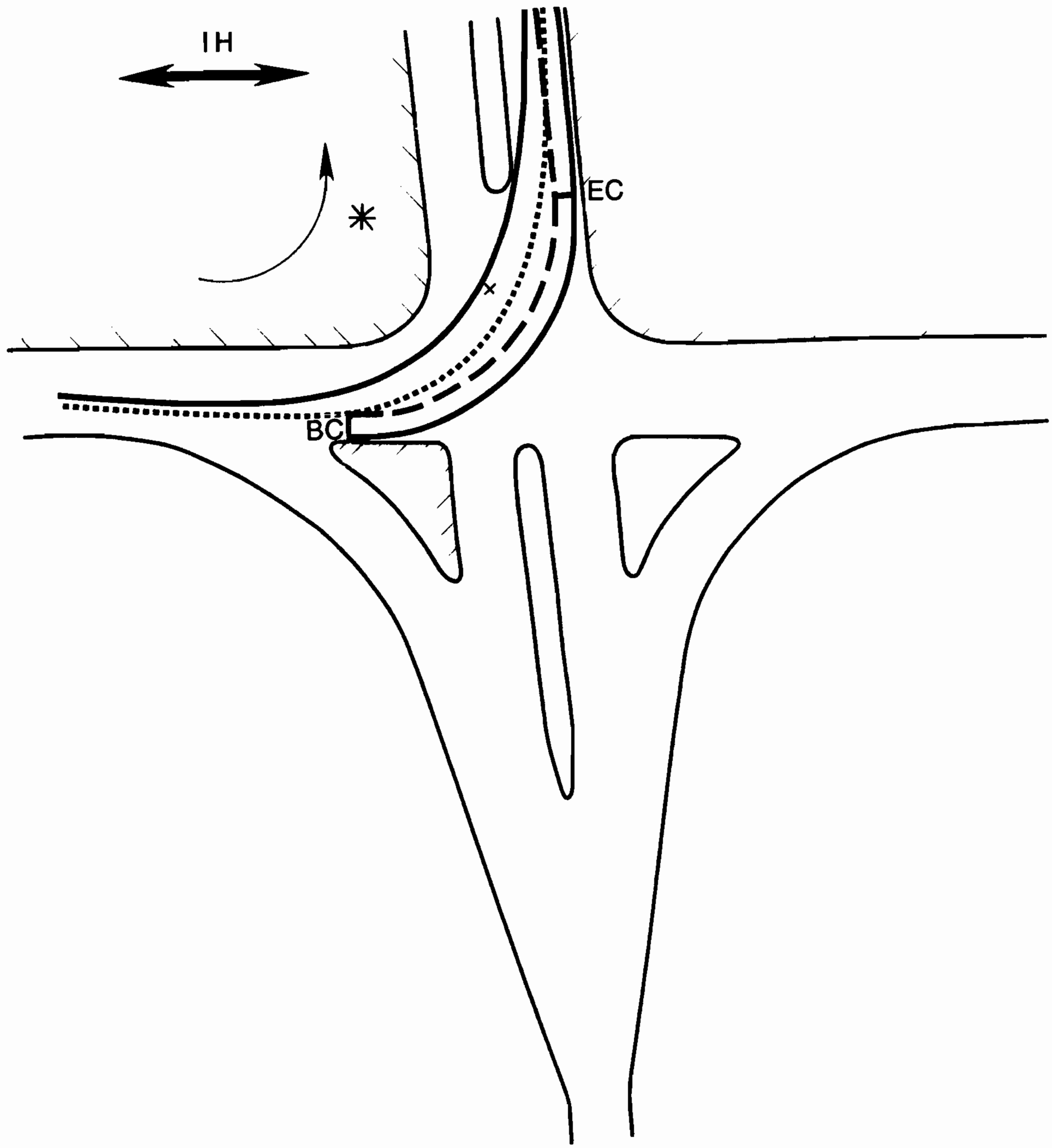


Fig C9. Swept path for left turn movement from ramp to crossroad.

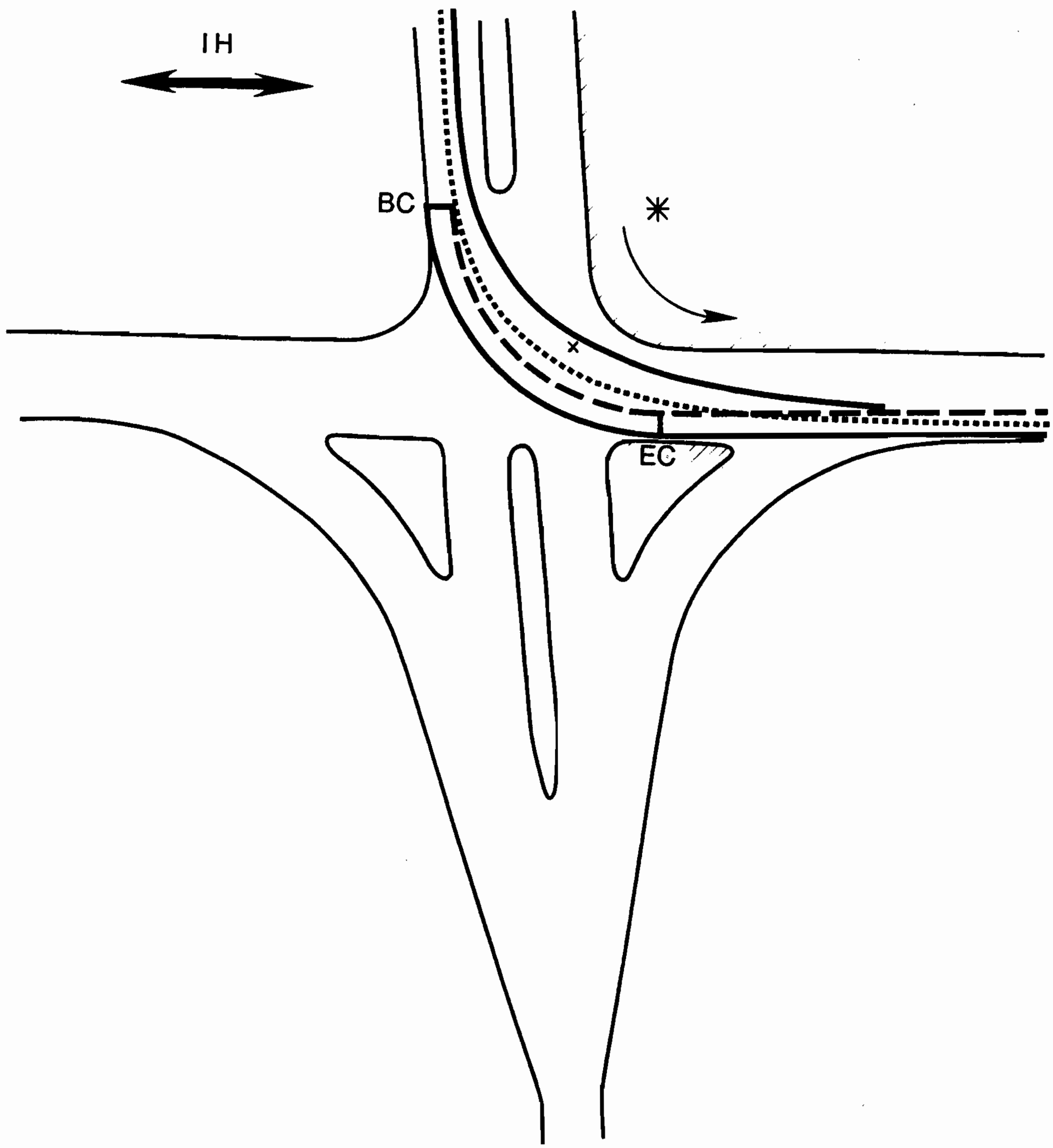


Fig C10. Swept path for left turn movement from crossroad to ramp.

APPENDIX D. TOM MAXIMUM OFFTRACKING VALUES FOR ALL TRUCK TYPES IN THE TRUCK SCENARIOS AND FOR ALL RADII AND ANGLES OF TURNS OBTAINED FROM SAMPLED DIAMOND INTERCHANGES

Rad	Angle	48 Conven-tional Semi	2 x 28 Western Double	48 + 28 Rocky Mountain Double	3 x 28 Triples		2 x 48 118 ft Turnpike Double	
		MOT	MOT	MOT	MOT	BC	MOT	EC
45	37	7.13	5.97	9.71	8.32	11.50	13.37	12.52
	40	7.59	6.33	10.38	8.87	12.22	14.34	13.38
	42	7.89	6.56	10.31	9.23	12.69	14.97	13.96
	44	8.18	6.79	11.24	9.58	13.15	15.61	14.52
	47	8.60	7.11	11.37	10.10	13.82	16.55	15.36
	51	9.15	7.53	12.70	10.76	14.70	17.79	16.46
	55	9.67	7.92	13.50	11.41	15.56	19.01	17.55
	60	10.29	8.38	14.47	12.18	16.59	20.51	18.90
	63	10.65	8.64	15.04	12.62	17.21	21.39	19.70
	65	10.88	8.81	15.41	12.91	17.61	21.98	20.24
	66	11.00	8.89	15.59	13.06	17.81	22.28	20.50
	67	11.11	8.97	15.78	13.20	18.01	22.57	20.77
	68	11.22	9.06	15.96	13.34	18.21	22.86	21.03
	70	11.44	9.21	16.32	13.62	18.61	23.44	21.57
	72	11.66	9.36	16.68	13.89	19.01	24.02	22.10
	73	11.77	9.44	16.85	14.03	19.21	24.30	22.36
	75	11.99	9.58	17.20	14.30	19.60	24.88	22.90
	76	12.08	9.65	17.38	14.43	19.80	25.16	23.16
	77	12.18	9.73	17.55	14.56	20.00	25.45	23.43
	78	12.28	9.79	17.72	14.69	20.20	25.73	23.70
	80	12.48	9.93	18.06	14.95	20.60	26.30	24.23
	82	12.68	10.06	18.40	15.20	21.00	26.87	24.77
	83	12.78	10.13	18.57	15.32	21.20	27.15	25.04
	84	12.88	10.19	18.73	15.45	21.41	27.43	25.31
	85	12.98	10.25	18.90	15.57	21.61	27.71	25.59
	86	13.05	10.31	19.06	15.69	21.81	28.00	25.86
	87	13.15	10.37	19.22	15.81	22.02	28.27	26.13
	90	13.42	10.55	19.71	16.17	22.65	29.11	26.96
	93	23.68	10.72	20.19	16.52	23.29	29.95	27.79
	94	13.77	10.78	20.35	16.63	23.51	30.23	28.08
	95	13.85	10.83	20.50	16.74	23.73	30.51	28.36
	96	13.94	10.88	20.66	16.86	23.95	30.78	28.64
	97	14.02	10.94	20.81	16.97	24.17	31.07	28.93
	98	14.10	10.99	20.97	17.08	24.40	31.35	29.22
	100	14.26	11.09	21.27	17.30	24.87	31.90	29.80
	102	14.42	11.19	21.58	17.51	25.35	32.45	30.38
	103	14.50	11.23	21.73	17.62	25.60	32.73	30.68
	104	14.58	11.28	21.88	17.72	25.85	33.01	30.98
	105	14.66	11.33	22.03	17.83	26.11	33.28	31.28
	107	14.81	11.42	22.33	18.03	26.65	33.85	31.90
	108	14.88	11.46	22.47	18.13	26.93	34.12	32.20
	110	15.03	11.55	22.77	18.34	27.50	34.68	32.83
	112	15.17	11.63	23.06	18.54	28.11	35.22	33.47
	113	15.25	11.68	23.20	18.63	28.43	35.51	33.80
	114	15.32	11.72	23.34	18.73	28.76	35.79	34.13
	115	15.39	11.76	23.49	18.83	29.11	36.06	34.46
	116	15.46	11.79	23.63	18.92	29.47	36.35	34.80

Rad	Angle	48 Conven-tional Semi	2 x 28 Western Double	48 + 28 Rocky Mountain Double	3 x 28 Triples		2 x 48 118 ft Turnpike Double	
		MOT	MOT	MOT	MOT	BC	MOT	EC
	120	15.13	11.95	24.18	19.30	31.09	37.47	36.19
	125	16.05	12.12	24.88	19.75	33.75	38.86	38.04
	129	16.30	12.25	25.43	20.11	37.00	39.96	39.64
	133	16.54	12.38	25.96	20.45	37.41	40.24	40.12
	147	17.30	12.75	27.79	21.56	--	36.21	33.01
	150	17.45	12.82	28.17	21.79	--	35.23	31.37
50	73	11.13	8.84	16.10	13.30	17.05	23.45	21.02
	77	11.49	9.07	16.71	13.76	17.57	24.50	21.92
	78	11.57	9.13	16.87	13.88	17.69	24.76	22.15
	90	12.53	9.74	18.60	15.13	19.10	27.82	24.84
	102	13.36	10.22	20.19	16.23	20.34	30.78	27.53
	103	13.42	10.26	20.32	16.31	20.43	31.02	27.76
	150	15.65	11.35	25.37	19.42	24.43	42.19	40.00
56	180	14.39	10.09	24.19	17.82	16.55	43.25	37.57
60	107	11.74	8.73	18.18	14.28	14.30	28.66	23.72
64	130	11.66	8.40	18.65	14.22	12.78	30.87	24.41
65	112	11.07	8.11	17.37	13.47	12.46	27.93	22.28
66	108	10.81	7.94	16.89	13.13	12.15	27.03	21.52
68	90	9.96	7.45	15.23	12.04	11.59	23.69	19.09
70	90	9.72	7.25	14.91	11.75	11.10	23.28	18.58
	133	10.66	7.61	17.16	12.96	11.10	28.87	21.88
72	135	10.36	7.37	16.73	12.59	10.66	28.31	21.18
73	90	9.36	6.96	14.44	11.34	10.45	22.69	17.87
75	105	9.52	6.92	14.96	11.53	10.06	24.24	18.51
77	142	9.69	6.84	15.73	11.73	9.70	27.07	19.61
80	72	8.12	6.12	12.26	9.76	9.22	18.84	14.94
	107	8.98	6.48	14.19	10.85	9.22	23.27	17.36
84	68	7.67	5.79	22.56	9.21	8.65	17.73	14.00
	105	8.53	6.14	13.50	10.30	8.65	22.19	16.36
85	63	7.40	5.62	11.07	8.87	8.51	16.33	13.41
	90	8.20	5.99	12.78	9.89	8.52	20.49	15.43

Rad	Angle	48 Conven-tional Semi	2 x 28 Western Double	48 + 28 Rocky Mountain Double	3 x 28 Triples		2 x 48 118 ft Turnpike Double	
		MOT	MOT	MOT	MOT	BC	MOT	EC
90	23	4.09	3.38	5.64	4.79	6.05	7.86	7.04
	87	7.73	5.63	12.05	9.31	7.93	19.36	14.43
	90	7.78	5.65	12.17	9.37	7.93	19.66	14.58
	139	8.14	5.74	13.20	9.80	7.93	22.87	15.90
	150	8.17	5.74	13.29	9.82	7.93	23.28	16.04
98	97	7.24	5.19	11.46	8.71	7.15	18.95	13.59
100	90	7.03	5.06	11.07	8.46	6.98	18.14	13.09
	115	7.19	5.10	11.54	8.64	6.98	19.01	13.65
103	100	6.90	4.93	10.98	8.29	6.74	18.35	12.94
104	122	6.92	4.89	11.14	8.30	6.66	19.13	13.12
105	125	6.85	4.84	11.04	8.21	6.59	19.03	13.00
110	115	6.50	4.60	10.44	7.79	6.24	17.87	12.22
115	100	6.16	4.38	9.84	7.39	5.93	16.61	11.47
118	83	5.92	4.24	9.35	7.10	5.76	15.44	10.89
	100	6.00	4.26	9.58	7.19	5.76	16.22	11.15
119	107	5.96	4.22	9.56	7.14	5.71	16.31	11.11
120	43	5.05	3.85	7.50	6.03	5.65	11.33	8.89
	90	5.86	4.18	9.31	7.02	5.65	15.57	10.82
122	104	5.80	4.11	9.29	6.94	5.55	15.83	10.78
	107	9.95	4.11	9.31	6.95	5.55	15.91	10.80
125	45	4.98	3.76	7.47	5.96	5.40	11.40	8.80
126	105	5.61	3.97	8.99	6.71	5.35	15.37	10.41
130	65	5.24	3.80	8.17	6.29	5.17	13.19	9.48
	105	5.43	3.84	8.70	6.49	5.17	14.90	10.05
	140	5.45	3.84	8.77	6.50	5.17	15.31	10.15
142	77	4.90	3.49	7.76	5.86	4.69	12.94	8.92
150	85	4.65	3.30	7.41	5.55	4.42	12.56	8.49
	87	4.65	3.30	7.43	5.56	4.42	12.60	8.51
	102	4.67	3.30	7.48	5.57	4.42	12.85	8.57

Rad	Angle	48 Conventional Semi	2 x 28 Western Double	48 + 28 Rocky Mountain Double	3 x 28 Triples		2 x 48 118 ft Turnpike Double	
		MOT	MOT	MOT	MOT	BC	MOT	EC
157	73	4.41	3.14	7.00	5.27	4.21	11.71	8.01
158	80	4.40	3.13	7.01	5.25	4.18	11.84	8.01
176	75	3.92	2.79	6.26	4.69	3.72	10.60	7.13
177	44	3.74	2.74	5.78	4.48	3.70	9.20	6.64
	137	3.93	2.78	6.29	4.68	3.70	10.90	7.17
180	78	3.85	2.73	6.13	4.59	3.64	10.43	6.98
	85	3.85	2.73	6.15	4.59	3.64	10.52	7.00
	180	3.86	2.74	6.19	4.60	3.64	10.72	7.05
193	80	3.58	2.54	5.72	4.27	3.38	9.77	6.49
230	104	2.99	2.12	4.77	3.56	2.81	8.22	5.40
250	42	2.71	1.94	4.26	3.23	2.58	7.03	4.83
	135	2.75	1.95	4.38	3.27	2.58	7.54	4.96
300	30	2.22	1.60	3.46	2.65	2.14	5.60	3.92
	38	2.26	1.61	3.56	2.69	2.14	5.92	4.02
	147	2.28	1.62	3.64	2.72	2.14	6.25	4.10
	150	2.28	1.62	3.64	2.72	2.14	6.25	4.10
325	75	2.10	1.49	3.35	2.50	1.97	5.74	3.77
450	37	1.51	1.07	2.39	1.79	1.41	4.08	2.69

APPENDIX E. FREQUENCY DISTRIBUTIONS FOR EXTRA PAVEMENT WIDTH REQUIRED AT DIAMOND INTERCHANGE RAMP TERMINALS

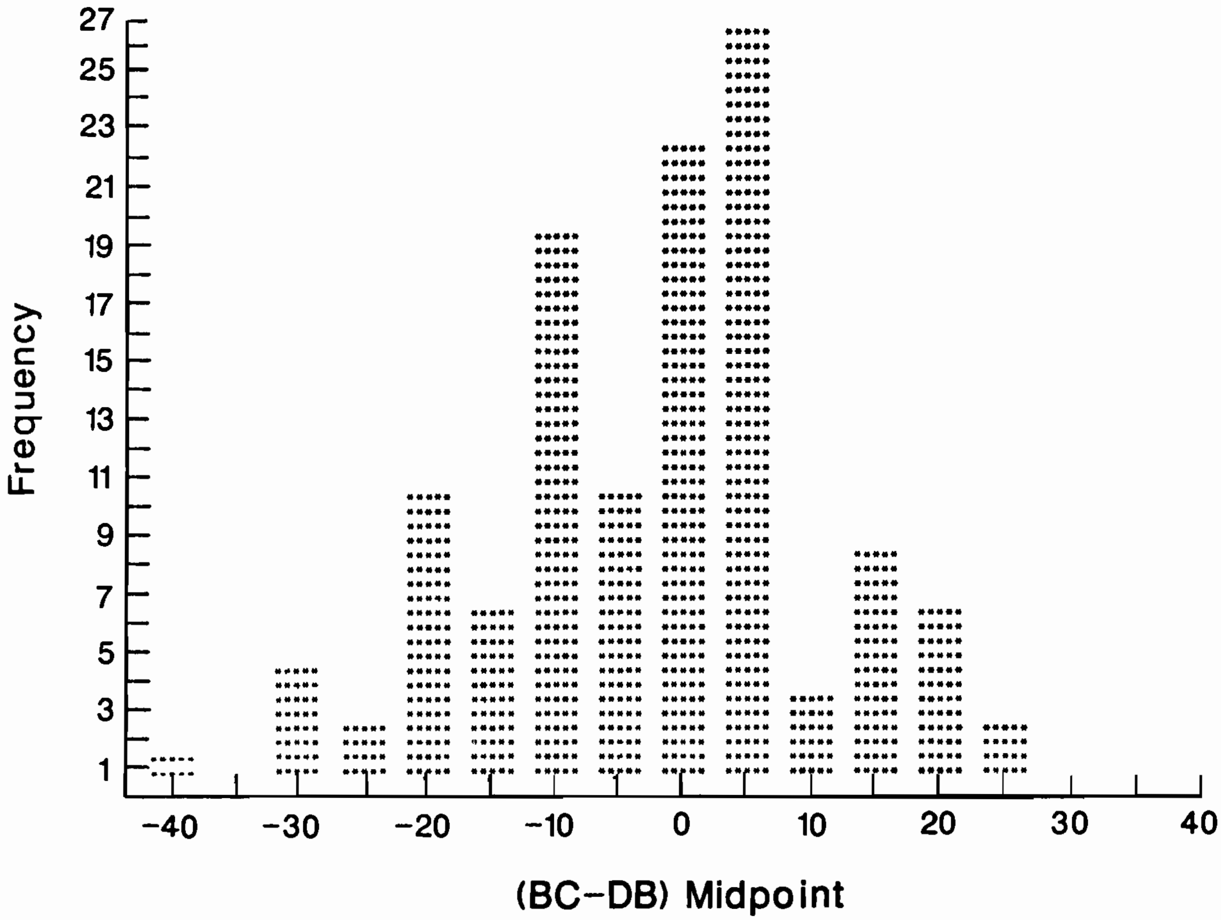


Fig E1. Distribution for case 1.

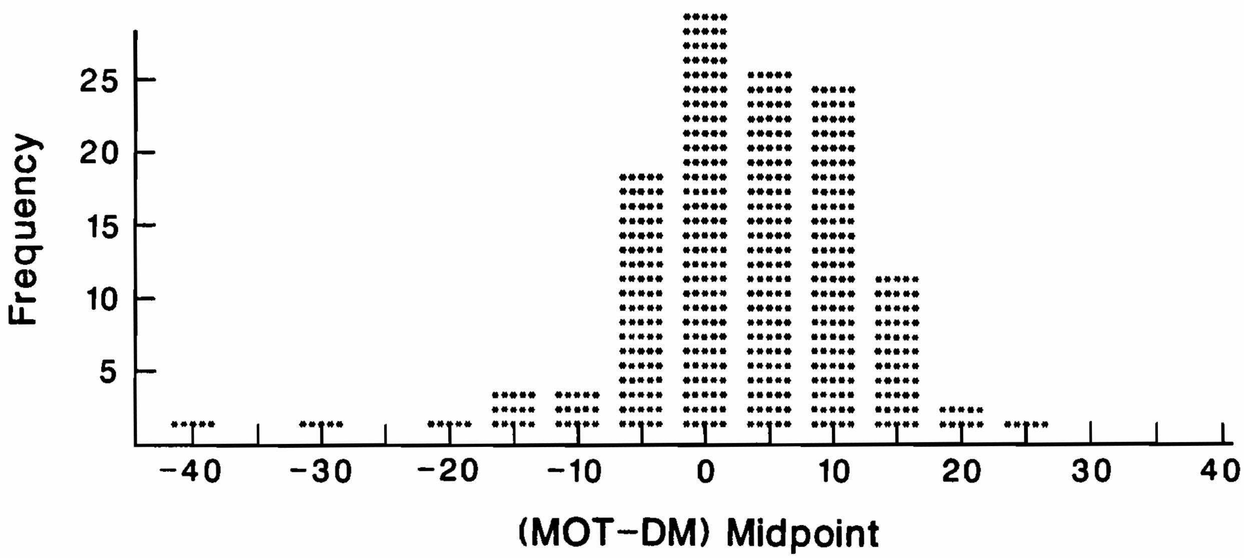


Fig E2. Distribution for case 2.

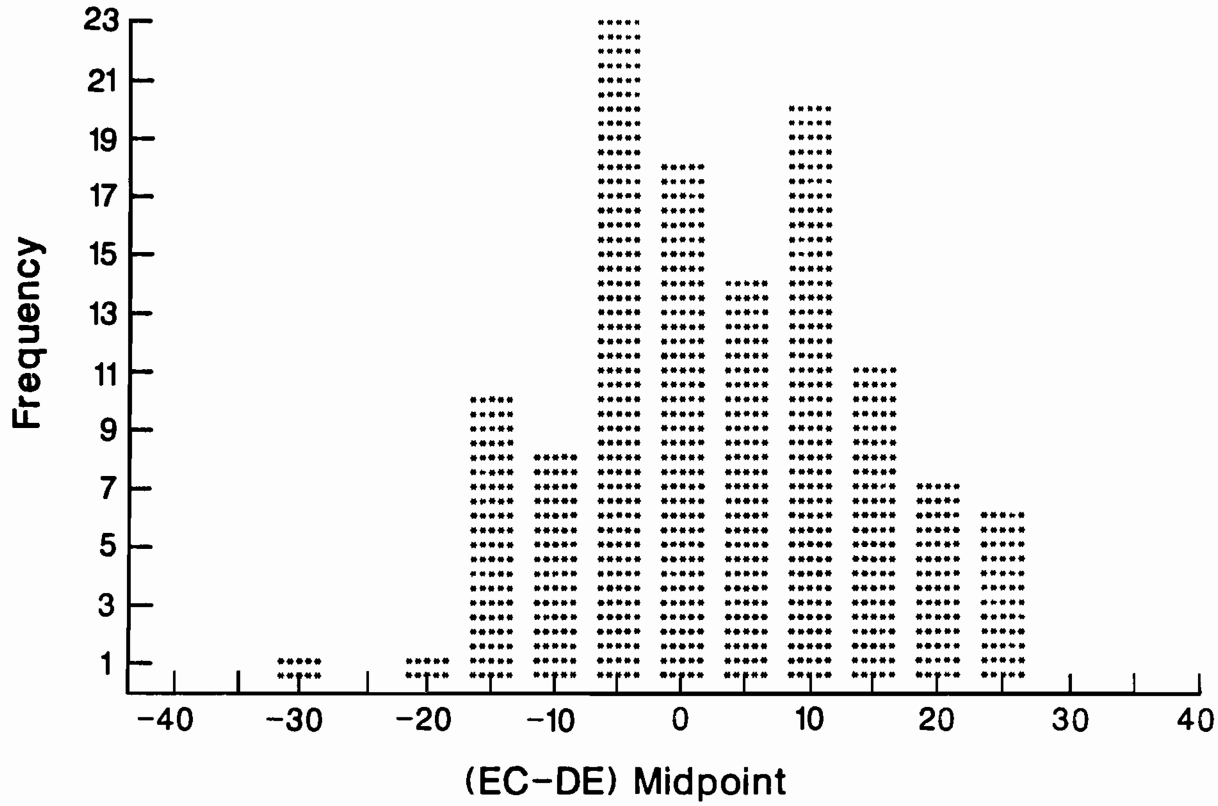


Fig E3. Distribution for case 3.

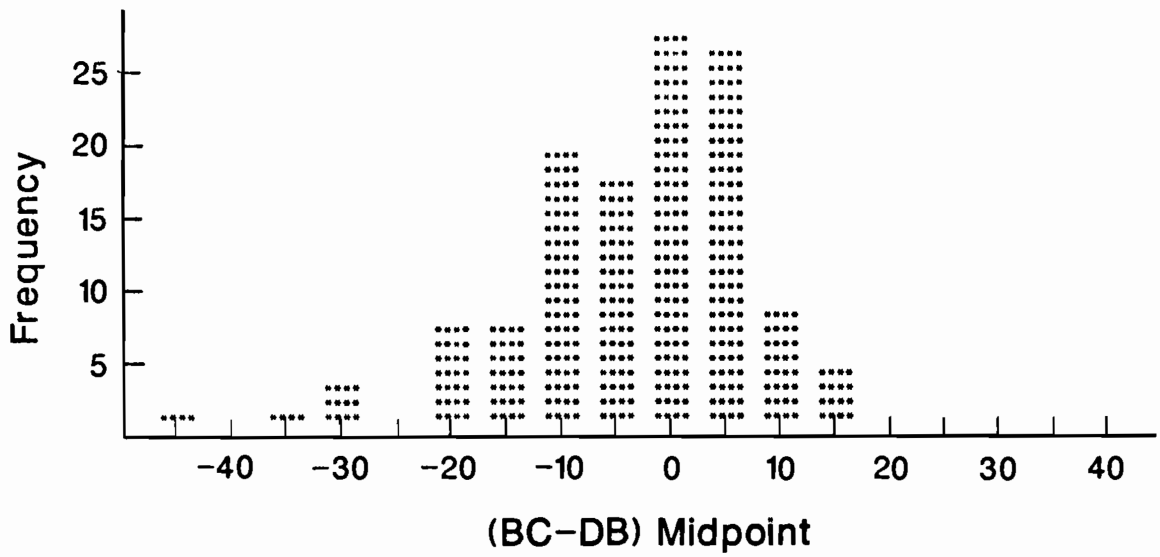


Fig E4. Distribution for case 4.

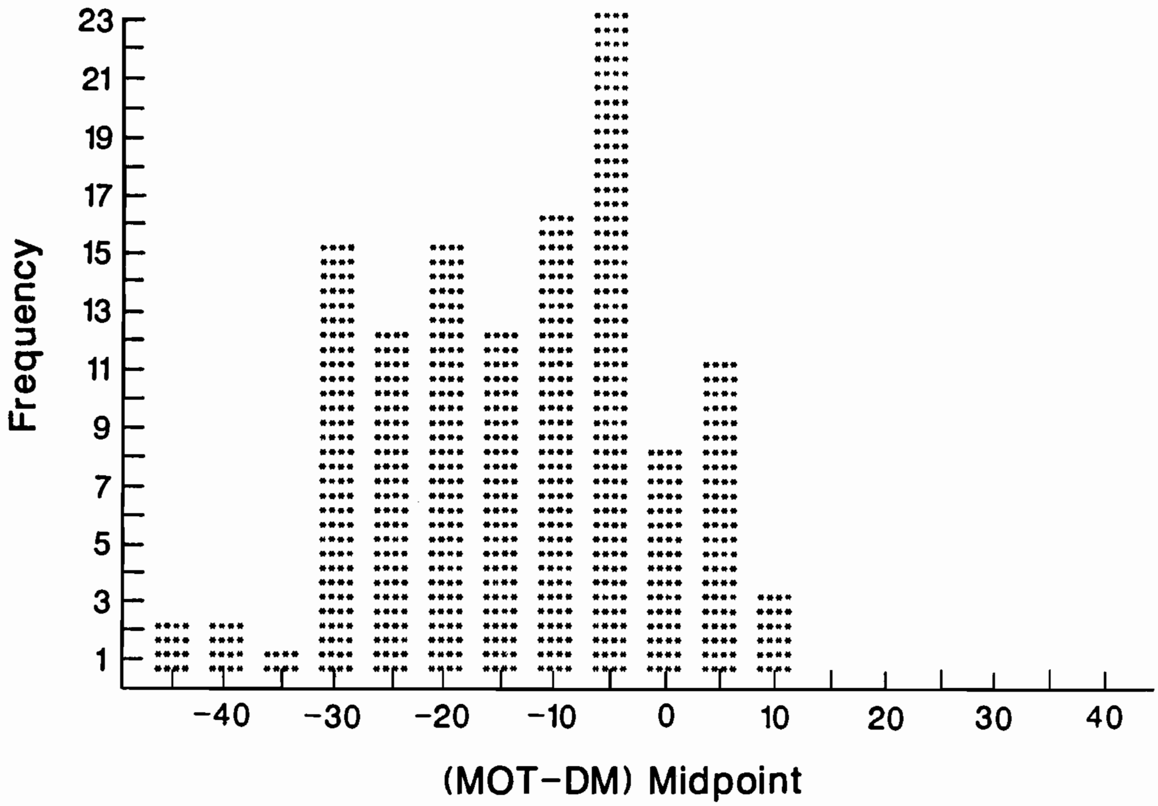


Fig E5. Distribution for case 5.

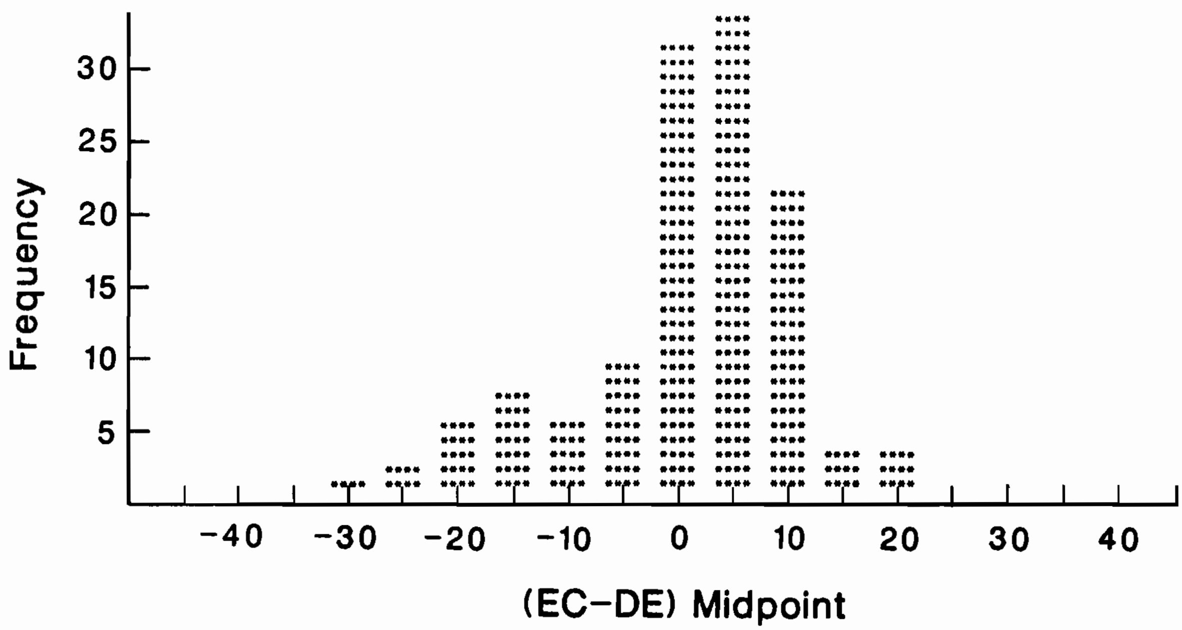


Fig E6. Distribution for case 6.

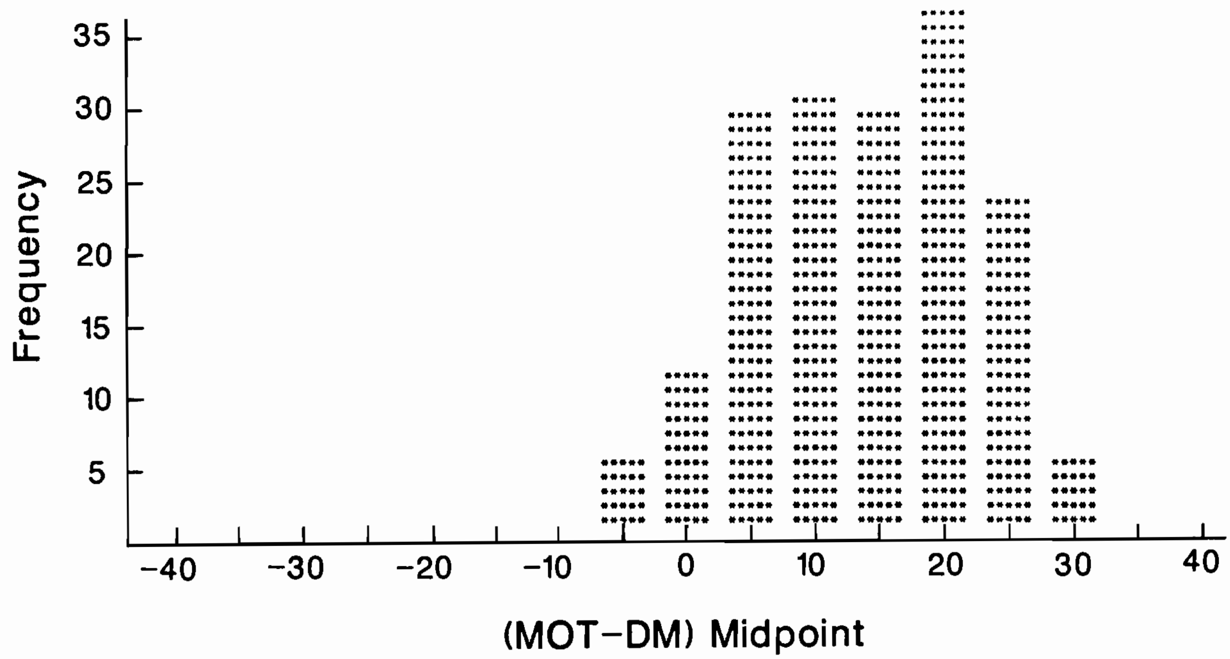


Fig E7. Distribution for case 7.

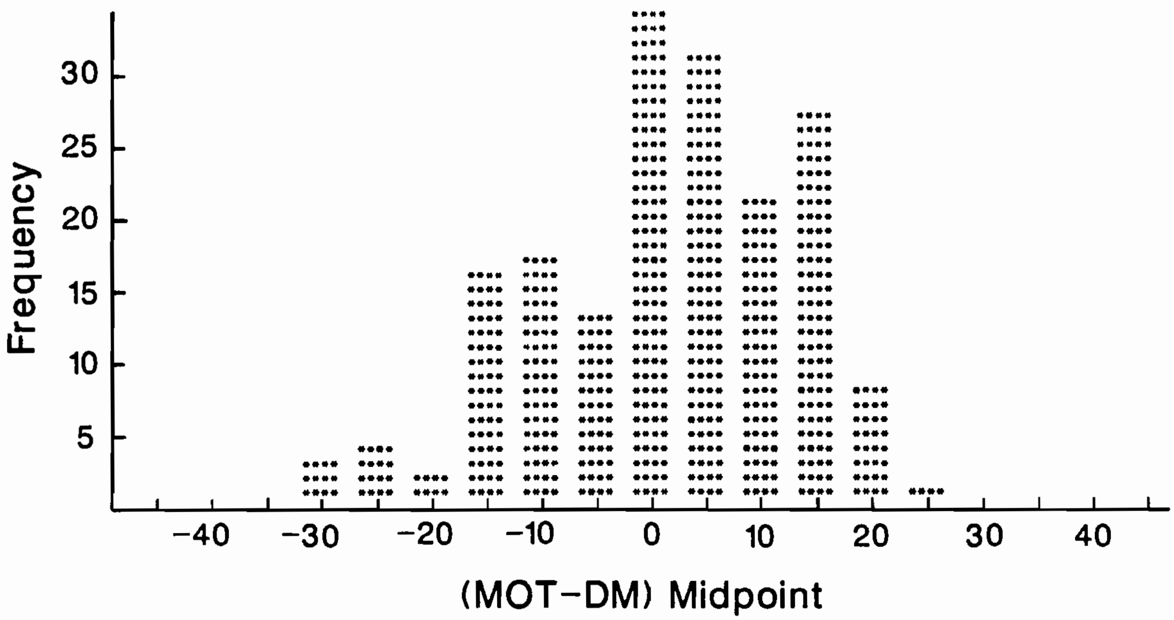


Fig E8. Distribution for case 8.

APPENDIX F. DATA COLLECTED ON INTERCHANGES ALONG INTERSTATE HIGHWAYS IN TEXAS

DIAMOND INTERCHANGES - Urban
(conventional)

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
	7+ART	C	I-10	2121-2	24	ELPASO	
	8 ART	C	"	"	"	"	
	9 ART	C	"	"	"	"	
	10 ART	C	"	"	"	"	
	11 ART	C	"	"	"	"	
	12 ART	C	"	"	"	"	
	13 ART	C	"	"	"	"	
	14 ART	C	"	"	"	"	
	15 ART	C	"	"	"	"	
	16 ART	C	"	"	"	"	
	17 ART	C	"	"	"	"	
	20+ART	C	"	2121-3	"	"	
	21 ART	C	"	"	"	"	
*	24 ART	D	"	"	"	"	E-459-A
*	25+ART	D	"	"	"	"	E-438-A
	26 ART	D	"	"	"	"	
	27 ART	D	"	"	"	"	
	28 ART	D	"	"	"	"	
	29 FM	D	"	"	"	"	
	30 ART	D	"	2121-3	"	"	
	31 ART	D	"	"	"	"	
	32 ART	D	"	"	"	"	
	119 ART	H	"	72-12	15	BEXAR	
**	120 ART	H	"	"	"	"	B-674-A
	121 ART	H	"	"	"	"	
	122 ART	H	"	"	"	"	
	123 ART	H	"	"	"	"	
	124 ART	H	"	"	"	"	
	125 ART	H	"	"	"	"	
	126 ART	H	"	"	"	"	
*	127 ART	H	"	"	"	"	B-659

		Code		Rt #	Ctrl-S#	Dist#	County	Plan#
	128	ART	H	I-10	72-12	15	BEXAR	
	129	ART	L	"	"	"	"	
	130	ART	L	"	"	"	"	
	131	SH	L	"	17-9	"	"	
	132	ART	L	"	17-9	"	"	
	133	ART	L	"	25-2	"	"	
	136	US	M	"	"	"	"	
	137	ART	M	"	"	"	"	
*	138	ART	M	"	"	"	"	B-608-C
	139	ART	M	I-10	25-2	15	BEXAR	
	140	SH	M	"	"	"	"	
	141	ART	M	"	"	"	"	
	207	ART	M	"	271-7	12	HARRIS	
	208	ART	Q	"	"	"	"	
	209	ART	Q	"	"	"	"	
	210	ART	Q	"	"	"	"	
	211	ART	R	"	"	"	"	
	212	ART	R	"	"	"	"	
	213	ART	R	"	"	"	"	
	214	ART	R	"	"	"	"	
	215	ART	R	"	"	"	"	
	216	ART	R	"	"	"	"	
	217	ART	R	"	"	"	"	
	218	ART	R	"	"	"	"	
	219	ART	R	"	508-1	"	"	
	220	ART	R	"	"	"	"	
	222	ART	R	"	"	"	"	
*	223	ART	R	"	"	"	"	H-618-C
*	225	SOIL	S	"	"	"	"	H-650-C
*	226	ART	S	"	"	"	"	H-634-11
	227	ART	S	"	"	"	"	
	228	ART	S	"	"	"	"	
	235	ART	T	"	"	"	"	
	236	ART	T	"	"	"	"	
	262	ART	A	I-10	28-13	20	JEFFERSON	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	276	ART	L	I-37	73-8	15	BEXAR	
	277	ART	L	"	"	"	"	
	279	ART	M	"	"	"	"	
	280	ART	M	"	"	"	"	
	313	FM	C	"	74-6	16	NUECES	
	314+	FM	C	"	"	"	"	
	315	ART	C	"	"	"	"	
	316	ART	C	"	"	"	"	
	317	ART	C	"	"	"	"	
	318	ART	C	"	"	"	"	
	320	ART	C	"	"	"	"	
	321	SH	C	"	"	"	"	
	322	ART	D	"	"	"	"	
	323	ART	D	"	"	"	"	
	324	ART	D	"	"	"	"	
	326	ART	D	"	"	"	"	
	327	ART	D	I-37	74-6	16	NUECES	
	330+	SH		I-35	18-6	21	WEBB	
	331	ART		"	"	"	"	
*	332	ART		"	"	"	"	W-449
	365	ART	L	"	17-9	15	BEXAR	
	366	ART	L	"	"	"	"	
	367	ART	L	"	"	"	"	
	372	ART	L	"	17-10	"	"	
	373	ART	M	"	"	"	"	
	374	ART	M	"	"	"	"	
*	375	ART	M	"	"	"	"	B-646-B
*	376	ART	I	"	"	"	"	B-686-A
	377	ART	I	"	"	"	"	
	378	ART	I	"	"	"	"	
	379+	ART	I	"	16-7	"	"	
	380	ART	I	"	"	"	"	
	381	ART	I	"	"	"	"	
	382	ART	I	"	"	"	"	
	414	ART	L	"	15-13	14	TRAVIS	
	415	ART	L	"	"	"	"	

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	417	ART	L	I-35	15-13	14	TRAVIS	
	418	ART	L	"	"	"	"	
	419	ART	L	"	"	"	"	
	420	ART	L	"	"	"	"	
	421	ART	L	"	"	"	"	
*	424	FM	I	"	"	"	"	T-772-B
	425	ART	I	"	"	"	"	
	426+	ART	I	"	"	"	"	
	427	SH	I	"	"	"	"	
	429	ART	I	"	"	"	"	
	430	ART	I	"	"	"	"	
	431	ART	I	"	"	"	"	
	432	ART	I	"	"	"	"	
	481+	ART	D	I-35	15-1	9	MCLENNAN	
*	482	ART	D	"	"	"	"	M-719-A
	485	ART	D	"	"	"	"	
	486	ART	D	"	"	"	"	
	490	ART	D	"	"	"	"	
	491	ART	B	"	"	"	"	
	492	FM	B	"	"	"	"	
	532	ART	H	I-35W	14-16	2	TARRANT	
	533	ART	H	"	"	"	"	
	534	ART	H	"	"	"	"	
	535	ART	H	I-35W	14-16	2	TARRANT	
	536	ART	H	"	"	"	"	
	537	ART	H	"	"	"	"	
	538	ART	H	"	"	"	"	
	539	ART	H	"	"	"	"	
	540	ART	H	"	"	"	"	
	541	ART	H	"	"	"	"	
	542	ART	E	"	"	"	"	
	543	ART	E	"	"	"	"	
	545	ART	E	"	"	"	"	
	572	ART	H	I-35E	442-2	18	DALLAS	
	573	ART	H	"	"	"	"	
	574	ART	H	"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	575	ART	H	I-35E	442-2	18	DALLAS	
	576	ART	H	"	"	"	"	
	577	ART	H	"	"	"	"	
	578	ART	H	"	"	"	"	
	580	ART	H	"	"	"	"	
	581	ART	H	"	"	"	"	
	582	ART	H	"	"	"	"	
	583	ART	E	"	196-3	"	"	
	584+	ART	E	"	"	"	"	
	585	ART	E	"	"	"	"	
	587	ART	D	"	"	"	"	
	588	ART	D	"	"	"	"	
	589	ART	D	"	"	"	"	
	590	SH	D	"	"	"	"	
	591	ART	D	"	"	"	"	
	592	ART	A	"	"	"	"	
	593	SH	A	"	"	"	"	
	594	ART	A	"	"	"	"	
	595	ART	A	"	"	"	"	
	596	SH	A	"	"	"	"	
	597	SH	A	"	"	"	"	
	598+	ART	A	"	"	"	"	
	834	ART	H	I-20	2374-5	2	TARRANT	
	836	ART	I	"	"	"	"	
	837	ART	I	"	"	"	"	
	838	ART	I	"	"	"	"	
	839	ART	I	"	"	"	"	
	840	ART	I	"	"	"	"	
	841	ART	I	"	"	"	"	
	843	ART	G	"	2374-4	18	DALLAS	
**	844	FM	G	I-20	2374-4	18	DALLAS	D-122-E
	845	ART	G	"	"	"	"	
	846	ART	G	"	"	"	"	
*	847	ART	G	"	"	"	"	D-120-E
	848	ART	G	"	"	"	"	
**	850	ART	K	"	"	"	"	

Code			Rt #	Ctrl-S#	Dist#	County	Plan#
851	ART	K	I-20	2374-4	18	DALLAS	
852	ART	K	"	2374-3	"	"	
853	ART	H	"	"	"	"	
854	ART	H	"	"	"	"	
855	ART	I	"	"	"	"	
856	ART	H	I-45	92-14	18	DALLAS	
857	ART	H	"	"	"	"	
858	ART	H	"	"	"	"	
859	ART	H	"	"	"	"	
860	ART	H	"	"	"	"	
940+	FM	M	I-45	110-6	12	HARRIS	
949	ART	R	"	500-3	"	"	
955	ART	R	"	"	"	"	
956	ART	R	"	"	"	"	
958	ART	R	"	"	"	"	
959	ART	R	"	"	"	"	
962	ART	W	"	"	"	"	
963	ART	W	"	"	"	"	
964	ART	W	"	"	"	"	
965	ART	W	"	"	"	"	
966+	ART	W	"	"	"	"	
967	ART	W	"	"	"	"	
968	ART	W	"	"	"	"	
986	ART	G	I-30	1068-1	2	TARRANT	
987	ART	G	"	"	"	"	
988	ART	G	"	"	"	"	
989	ART	G	"	"	"	"	
990	ART	G	"	"	"	"	
991	ART	H	"	"	"	"	
992	ART	H	"	"	"	"	
993	ART	H	"	"	"	"	
994	ART	H	"	"	"	"	
995	ART	H	"	"	"	"	
996	ART	H	"	"	"	"	
997	ART	H	"	1068-2	"	"	
998	ART	H	"	"	"	"	

		Code		Rt #	Ctrl-S#	Dist#	County	Plan#
	999	ART	G	I-30	1068-2	2	TARRANT	
	1000	ART	G	I-30	1068-4	18	DALLAS	
	1001	ART	E	"	"	"	"	
	1004	ART	E	"	9-11	"	"	
	1005	ART	E	"	"	"	"	
	1006	ART	E	"	"	"	"	
	1007	ART	E	"	"	"	"	
	1008	ART	E	"	"	"	"	
	1009	ART	E	"	"	"	"	
	1010	ART	E	"	"	"	"	
	1012	SH	E	"	"	"	"	
	1013	ART	E	"	"	"	"	
	1014	ART	F	"	"	"	"	
	1014	ART	F	"	"	"	"	
	1015	ART	F	"	"	"	"	
	1016	ART	F	"	"	"	"	
	1017	ART	F	"	"	"	"	
	1092	ART		I-40	275-1	4	POTTER	
	1097	ART	A	"	"	"	"	
	1100	ART	B	"	"	"	"	
	1139	ART	A	I-27	168-10	4	POTTER	
	1140	FM	A	I-27	168-9	4	RANDALL	
	1141	ART	A	"	"	"	"	
	1145	ART	A	"	"	"	"	
**	1146	SH	A	"	"	"	"	R-123-A
	1179	ART	I	I-410	521-4	15	BEXAR	
	1180	ART	I	"	"	"	"	
	1181	ART	I	"	"	"	"	
*	1182	ART	I	"	"	"	"	B-624-D
	1183	ART	H	"	"	"	"	
	1184	ART	H	"	"	"	"	
	1185	ART	H	"	"	"	"	
	1186	ART	H	"	"	"	"	
	1187	ART	H	"	"	"	"	
	1188	ART	H	"	"	"	"	
	1189	ART	H	"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
**	1190	SH	H	I-410	521-4	15	BEXAR	B-647-D
	1191	ART	H	"	"	"	"	
	1192	ART	H	"	"	"	"	
	1196	FM	H	"	"	"	"	
	1197+	ART	H	I-410	521-4	15	BEXAR	
	1198	ART	L	"	"	"	"	
	1199	ART	L	"	521-5	"	"	
	1201	ART	L	"	"	"	"	
	1202	FM	L	I-410	521-5	15	BEXAR	
	1203	ART	P	"	"	"	"	
	1204	SH	P	"	"	"	"	
	1205	ART	P	"	"	"	"	
	1206	ART	P	"	"	"	"	
	1207	SH	P	"	521-6	"	"	
	1209	SH	M	"	"	"	"	
	1210	ART	M	"	"	"	"	
**	1211	US	M	"	"	"	"	B-661-B
	1212	FM	M	"	"	"	"	
	1213	FM	I	"	"	"	"	
	1214	ART	R	I-610	271-14	12	HARRIS	
	1215	ART	R	"	"	"	"	
	1218	ART	R	"	"	"	"	
	1219	ART	R	"	"	"	"	
	1220	ART	R	"	"	"	"	
	1221	ART	R	"	"	"	"	
	1224	ART	R	"	"	"	"	
	1225	ART	S	"	"	"	"	
	1226	ART	S	"	"	"	"	
	1227	ART	S	"	"	"	"	
	1228	ART	S	"	271-15	"	"	
	1229	ART	S	"	"	"	"	
	1230	ART	S	"	"	"	"	
	1232	ART	W	"	271-16	"	"	
	1233	ART	V	"	"	"	"	
	1235+	ART	V	"	"	"	"	
	1237	ART	V	"	"	"	"	

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
*	1238 SH	V	I-610	271-16	12	HARRIS	H-661-C
	1239 ART	V	"	"	"	"	
	1240 ART	V	"	"	"	"	
	1241 ART	V	"	"	"	"	
	1242 ART	V	"	"	"	"	
	1244 ART	V	"	"	"	"	
	1245 ART	V	"	271-17	"	"	
	1247 ART	R	"	"	"	"	
	1248 ART	R	"	"	"	"	
	1251 ART	R	"	"	"	"	
	1252 ART	R	"	"	"	"	
	1253 ART	R	"	"	"	"	
	1259 ART	A	I-635	2374-1	18	DALLAS	
	1260 ART	A	"	"	"	"	
	1261 ART	A	"	"	"	"	
	1262 ART	B	I-635	2374-1	18	DALLAS	
	1263 ART	B	"	"	"	"	
	1265 ART	B	"	"	"	"	
	1266 ART	B	"	"	"	"	
	1268 ART	B	"	"	"	"	
	1269 ART	B	"	"	"	"	
	1270 ART	B	"	"	"	"	
	1271 ART	E	"	"	"	"	
	1272 ART	E	"	"	"	"	
	1273 ART	E	"	2374-2	"	"	
	1274 ART	E	"	"	"	"	
	1275 ART	E	"	"	"	"	
	1276 ART	E	"	"	"	"	
	1277 ART	E	"	"	"	"	
	1278 ART	E	"	"	"	"	
	1279 ART	E	"	"	"	"	
	1280 ART	E	"	"	"	"	
	1281 ART	E	"	"	"	"	
	1283 ART	I	"	"	"	"	
	1284 ART	I	"	"	"	"	
	1285 ART	I	"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	1286	ART	I	I-635	2374-2	18	DALLAS	
	1287	ART	H	I-820	8-12	2	TARRANT	
	1289	ART	H	"	"	"	"	
	1290	ART	H	"	"	"	"	
	1291	ART	H	"	"	"	"	
	1293	ART	H	"	"	"	"	
	1294	ART	H	"	8-13	"	"	
	1295+	ART	H	"	"	"	"	
	1296	ART	H	"	"	"	"	
*	1298+	ART	H	"	"	"	"	T-60-B
	1299	ART	H	"	"	"	"	
	1300	ART	H	"	"	"	"	
	1301	ART	H	"	"	"	"	
	1302	ART	H	"	"	"	"	
	1303	SH	H	"	"	"	"	
	1304	ART	H	"	"	"	"	
	1305	ART	H	"	"	"	"	
	1306+	ART	I	"	"	"	"	
	1307	ART	F	"	"	"	"	
	1308	ART	F	"	"	"	"	
	1309	ART	F	"	"	"	"	
	1310	ART	E	I-820	8-14	2	TARRANT	
	1311	ART	E	"	"	"	"	
**	1312	US	E	"	"	"	"	T-17-C
	1313	ART	E	"	"	"	"	
*	1314	ART	E	"	"	"	"	T-17-C
	1315	ART	E	"	"	"	"	
	1316	FM	E	"	"	"	"	
	1317	ART	E	"	"	"	"	
	1318	ART	D	"	"	"	"	
	1319	ART	D	"	"	"	"	
	1321	ART	D	"	8-15	"	"	
	1322	ART	D	"	"	"	"	
	1323	ART	G	"	"	"	"	
	1324	ART	G	"	"	"	"	
	1327	ART	G	"	"	"	"	
	1328	SH	G	"	"	"	"	

DIAMOND INTERCHANGES - Rural
(conventional)

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	1+	FM	A	I-10	2121-1	24	EL PASO	
	2	ART	A	"	"	"	"	
	3	SH	A	"	"	"	"	
	4	ART	A	"	"	"	"	
	5	SH	A	"	"	"	"	
	6	ART	B	"	2121-2	"	"	
	33	ART	D	"	2121-3	"	"	
	34	FM	D	"	"	"	"	
	35	FM	E	"	2121-4	"	"	
	36	FM	E	"	"	"	"	
	37	FM	F	"	"	"	"	
**	38+		G	"	2121-5	"	"	E-437-A
	39			I-10	2121-6	24	HUDSPETH	
	40+	FM		"	2-5	"	"	
	41			"	"	"	"	
	42+	FM		"	"	"	"	
	43+			"	2-6	"	"	
	44	FM		"	"	"	"	
	45			"	2-10	"	"	
	46	US		I-10	3-1	24	CULBERSON	
	47+			"	"	"	"	
	48+			"	"	"	"	
	49+			"	3-2	"	"	
	50	FM		"	3-3	"	"	
	51+			I-10	441-9	6	REEVES	
*	52+	US		"	"	"	"	R-516-A
	53	FM		"	"	"	"	
	54			"	441-5	"	"	
	55	FM		"	"	"	"	
	56+			"	441-6	"	"	
	57+			I-10	441-7	6	PECOS	
	58			"	"	"	"	

	Code	Rt #	Ctrl-S#	Dist#	County	Plan#
	59+	I-10	441-7	6	PECOS	
	60 FM	"	"	"	"	
	61 US	"	441-8	"	"	
	62 SH	"	"	"	"	
	63 FM	"	"	"	"	
	64+	"	140-1	"	"	
	65+	"	"	"	"	
	66+ FM	"	140-2	"	"	
	67	I-10	140-4	6	PECOS	
	68 FM	"	"	"	"	
	69+ FM	"	"	"	"	
*	70+ US	"	"	"	"	P-445-A
	71+ SH	"	140-6	"	"	
	72	"	"	"	"	
	73	I-10	140-13	7	CROCKETT	
	74	"	"	"	"	
	75+ US	"	"	"	"	
**	76	"	140-10	"	"	C-2554
	77	"	140-11	"	"	
	78+	"	"	"	"	
	79	"	"	"	"	
	80+	"	141-1	"	"	
	81	"	"	"	"	
	82 FM	I-10	141-1	7	SUTTON	
	83+ SH	"	141-3	"	"	
	84 US	"	"	"	"	
	85 US	"	141-4	"	"	
	86+ FM	"	141-5	"	"	
	87 FM	"	141-6	"	"	
	88 GRAVEL	"	141-7	"	"	
	89 FM	I-10	141-8	7	KIMBLE	
	90+ FM	"	"	"	"	
	91+ FM	"	"	"	"	
	92 FM	"	141-9	"	"	
	93+ GRAVEL	"	"	"	"	
	94 FM	"	"	"	"	
	95 US	"	"	"	"	

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
	96 FM		I-10	142-1	7	KIMBLE	
	97+ FM		"	"	"	"	
	98 GRAVEL		"	"	"	"	
	99+ PAVED		I-10	142-2	15	KERR	
	100 SH		"	142-12	"	"	
	101 SH		"	"	"	"	
	102 FM		"	"	"	"	
	103 ART		"	142-14	"	"	
	104 SH		"	"	"	"	
	105 FM		"	"	"	"	
	106 FM		"	"	"	"	
	107 US		I-10	142-15	15	KENDALL	
	108+ PAVED		"	72-5	"	"	
	109 PAVED		I-10	72-6	15	KENDALL	
	110 FM		"	"	"	"	
	111 ART	A	I-10	72-7	15	BEXAR	
	112+ FM	B	"	"	"	"	
	113+ ART	E	"	"	"	"	
*	114+ ART	E	"	72-8	"	"	B-601-C
*	115+ SH	E	"	"	"	"	B-601-C
	116 ART	E	"	"	"	"	
	118 ART	H	"	72-12	"	"	
	142 ART	I	"	25-2	"	"	
	143 FM	I	"	"	"	"	
	144 SH	I	"	"	"	"	
	145 ART	J	"	"	"	"	
	146 FM	J	"	"	"	"	
	147 FM	J	"	"	"	"	
	152 FM		I-10	535-1	15	GUADALUPE	
	153 FM		"	"	"	"	
	154 SH		"	"	"	"	
	155 US		"	"	"	"	
	156 FM		"	535-2	"	"	
	157 FM		"	"	"	"	
	158 GRAVEL		"	"	"	"	
	159 SH		"	"	"	"	

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	160	US		I-10	535-3	14	CALDWELL	
	161+	US		I-10	535-4	13	GONZALEZ	
	162	FM		"	"	"	"	
	163	SH		"	"	"	"	
	164	SH		"	535-5	"	"	
	165	US		"	"	"	"	
	166+	GRAVEL		I-10	535-6	13	FAYETTE	
	168	FM		"	"	"	"	
	169	US		"	535-7	"	"	
	170	US		"	"	"	"	
	171	FM		I-10	535-8	13	COLORADO	
	172	GRAVEL		"	"	"	"	
	173	PAVED		"	"	"	"	
	174	FM		"	"	"	"	
*	175	FM		"	"	"	"	C-1756
	176	SH		"	"	"	"	
	177	PAVED		"	"	"	"	
	178+	PAVED		"	271-1	"	"	
	179	FM		"	"	"	"	
	180	FM		I-10	271-1	13	COLORADO	
	181	GRAVEL		I-10	271-1	13	COLORADO	
	182	FM		"	"	"	"	
	183	PAVED		I-10	271-2	15	AUSTIN	
	184	SOIL		"	"	"	"	
	185	SH		"	271-3	"	"	
	186+	US		"	"	"	"	
	187	FM		"	"	"	"	
*	188	GRAVEL		"	"	"	"	A-766
	189+	PAVED		I-10	271-4	12	WALLER	
	190	FM		"	"	"	"	
	191	FM		"	"	"	"	
	192	PAVED		"	"	"	"	
	193	ART		I-10	271-5	12	FORT BEND	
	194	FM		"	"	"	"	
	195	ART	P	I-10	271-6	12	HARRIS	
	196	ART	P	"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	197	ART	P	I-10	271-6	12	HARRIS	
	198	ART	P	"	"	"	"	
	199	SH	Q	"	271-7	"	"	
	237	ART	T	"	508-1	"	"	
	238	ART	T	"	"	"	"	
	239	ART	T	"	"	"	"	
	240	ART	T	"	"	"	"	
	241	ART	T	"	"	"	"	
	242	ART	T	"	"	"	"	
	243	ART	T	"	"	"	"	
	244	SH		I-10	508-2	20	CHAMBERS	
	245	FM		"	"	"	"	
	246	PAVED		"	"	"	"	
	247	FM		"	"	"	"	
	252+	SH		"	508-3	"	"	
	253	PAVED		I-10	739-2	20	JEFFERSON	
	254	FM		"	"	"	"	
	255	PAVED		"	"	"	"	
	257	FM	B	"	"	"	"	
	258	ART	B	"	"	"	"	
	259	ART	B	"	"	"	"	
	267	FM	A	I-10	28-9	20	ORANGE	
	269+	FM	A	I-10	28-11	12	ORANGE	
	274	SH	D	"	"	"	"	
	275+	SH	D	"	"	"	"	
	281	SH	Q	I-37	73-8	15	BEXAR	
	282	ROAD	Q	"	73-9	"	"	
	283	SH	Q	"	"	"	"	
	284	ROAD	S	"	"	"	"	
	285	ROAD	S	"	"	"	"	
	286	FM		I-37	73-10	15	ATASCOSA	
	287	FM		"	"	"	"	
	288	SH		"	"	"	"	
*	289	PAVED		"	"	"	"	A-623-A
	290	FM		"	"	"	"	
	291	SH		"	"	"	"	

	Code	Rt #	Ctrl-S#	Dist#	County	Plan#
*	292+ FM	I-37	73-5	15	ATASCOSA	A-602-A
	293+ US	"	"	"	"	
	294 FM	"	"	"	"	
	295 FM	"	"	"	"	
	296 FM	I-37	73-7	16	LIVE OAK	
	297 US	"	"	"	"	
	298 SH	"	"	"	"	
	299 SOIL	"	"	"	"	
	300+ FM	"	"	"	"	
	301 FM	"	"	"	"	
	302 US	"	74-2	"	"	
	303 FM	"	"	"	"	
	304 FM	"	"	"	"	
	305 SH	I-37	74-3	16	SAN PATRICIO	
	306 SH	"	"	"	"	
	307 FM	"	74-4	"	"	
	308 PAVED	"	"	"	"	
	309 FM	"	74-5	"	"	
	310 SH	"	"	"	"	
	311 PAVED	"	"	"	"	
	312+ ART	I-37	74-6	16	NUECES	
*	333+ US	I-35	18-3	21	WEBB	W-454
	334+ SH	"	"	"	"	
	335 FM	I-35	18-2	15	LASALLE	
*	336+ FM	"	18-1	"	"	L-367
	337+	"	"	"	"	
	338 FM	I-35	17-8	15	LASALLE	
	339	"	"	"	"	
	340 FM	"	"	"	"	
	341 US	"	"	"	"	
*	342 SH	I-35	17-7	15	FRIO	F-963
	343 FM	I-35	17-7	15	FRIO	
	344+ US	"	"	"	"	
	345 FM	"	"	"	"	
	346 SOIL	"	"	"	"	
**	347 FM	"	"	"	"	F-961

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
	348 FM		I-35	17-6	15	FRIO	
	349+ US		"	"	"	"	
	350+ US		"	"	"	"	
	351 ART		"	"	"	"	
	352 FM		"	"	"	"	
	353 FM		I-35	17-5	15	MEDINA	
	354 SH		"	"	"	"	
	355 FM		"	"	"	"	
*	356 FM		"	"	"	"	B-609-C
	357 FM		I-35	17-4	15	ATASCOSA	
	358 FM		"	"	"	"	
	360 ART	O	"	"	"	"	
	361 ART	O	"	"	"	"	
	362 ART	O	"	"	"	"	
	364 ART	P	"	"	"	"	
	383 SH	F	"	16-7	"	"	
	385+ FM		I-35	16-6	15	GUADALUPE	
*	386 FM		"	"	"	"	G-1180
	387+ FM		I-35	16-5	15	COMAL	
	388 FM		"	"	"	"	
	389 ART		"	"	"	"	
	390+ ART		"	"	"	"	
*	391 ART		"	"	"	"	C-1847
	392 SH		"	"	"	"	
	393+ ART		"	"	"	"	
*	394 FM		"	"	"	"	C-1842
	395 FM		"	16-4	"	"	
	396 FM		"	"	"	"	
	398 FM		"	"	"	"	
	404 SH		"	"	"	"	
	405+ SH		"	"	"	"	
	406 PAVED		"	16-2	"	"	
	407+ FM		"	"	"	"	
	408 PAVED		"	"	"	"	
	409 FM		"	"	"	"	
	410 SH		"	"	"	"	

	Code		Rt *	Ctrl-S*	Dist*	County	Plan*
	411+ FM	N	I-35	16-1	14	TRAVIS	
	412+ ART	L	"	"	"	"	
	413+ SH	L	"	"	"	"	
	433 ART	E	"	"	"	"	
	434+ FM	E	"	"	"	"	
*	435+ FM	E	"	15-10	"	"	W-1089
	436 FM	E	"	"	"	"	
	437 SH	D	I-35	15-9	14	WILLIAMSON	
	438 FM	D	"	"	"	"	
	439 US	D	"	"	"	"	
	440+ ART	D	"	"	"	"	
	441+ ART	D	"	"	"	"	
	442+ SH	B	"	"	"	"	
	443 FM	B	"	"	"	"	
	444 SH	B	"	15-8	"	"	
	445 FM	B	"	"	"	"	
	446 ART	B	"	"	"	"	
	447 SH	B	"	"	"	"	
	448+ FM		"	"	"	"	
	449 PAVED		"	"	"	"	
	450 GRAVEL		"	"	"	"	
	451 FM		"	"	"	"	
	452 PAVED		I-35	15-7	9	BELL	
	453 PAVED		"	"	"	"	
	454 FM		"	"	"	"	
	455+ FM		"	"	"	"	
	456 ART		"	"	"	"	
	457 ART		"	"	"	"	
	458+ FM		"	"	"	"	
	459 ART	B	"	"	"	"	
	460 ART	B	"	"	"	"	
	461 ART	B	"	15-6	"	"	
	462 SH	B	"	"	"	"	
	463 SH	B	I-35	15-6	9	BELL	
	464 FM	F	"	15-14	"	"	
	465 ART	F	"	"	"	"	

Code			Rt #	Ctrl-S#	Dist#	County	Plan#
468	ART	C	I-35	15-14	9	BELL	
469	SH	C	"	15-4	"	"	
470	ART	C	"	"	"	"	
471	FM	C	"	"	"	"	
472	FM	C	"	"	"	"	
473	GRAVEL		"	"	"	"	
474	GRAVEL		I-35	15-3	9	FALLS	
475	FM		I-35	15-2	9	MCLENNAN	
476+	GRAVEL		"	"	"	"	
477	FM	E	"	15-1	"	"	
478	FM	E	"	"	"	"	
479	FM	E	"	"	"	"	
480+	FM	E	"	"	"	"	
493	FM	B	"	14-9	"	"	
494	ART	B	"	"	"	"	
495	PAVED		"	"	"	"	
496	FM		"	"	"	"	
497	FM		"	"	"	"	
498	ART		"	"	"	"	
499	FM		I-35	14-7	9	HILL	
500	GRAVEL		"	"	"	"	
501	FM		"	"	"	"	
502	ART		"	14-24	"	"	
503	FM		"	"	"	"	
504	SH		"	"	"	"	
505	FM		"	"	"	"	
506	FM		I-35W	14-23	9	HILL	
507	FM		"	"	"	"	
508	FM		"	"	"	"	
509	FM		"	"	"	"	
510	FM		I-35W	14-22	2	JOHNSON	
511	FM		"	"	"	"	
512+	FM		"	14-4	"	"	
513	GRAVEL		"	"	"	"	
514+	GRAVEL		"	"	"	"	
515+	GRAVEL		"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	516	PAVED		I-35W	14-4	2	JOHNSON	
	517	FM		"	"	"	"	
	518	US		"	14-3	"	"	
	519	GRAVEL		"	"	"	"	
	520	FM		I-35W	14-3	2	JOHNSON	
	521	PAVED		"	"	"	"	
	522	PAVED		"	"	"	"	
	523	FM		"	"	"	"	
	524+	ART	K	I-35W	14-2	2	TARRANT	
	525+	ART	K	"	"	"	"	
	526	FM	K	"	"	"	"	
	527+	ART	K	"	"	"	"	
	528	ART	K	"	"	"	"	
	546	ART	E	"	14-16	"	"	
	548	ART	B	"	18-12	"	"	
	549	SH	F	I-35W	18-13	18	DENTON	
	550	FM	F	"	"	"	"	
	551	FM	C	"	"	"	"	
	552	ART	D	"	"	"	"	
	553	FM		I-35E	48-9	9	HILL	
	554	FM		"	"	"	"	
	555	FM		I-35E	48-8	18	ELLIS	
	556	PAVED		"	"	"	"	
	557	FM		"	"	"	"	
	558	PAVED		"	"	"	"	
	559	FM		"	48-4	"	"	
	560	FM		"	"	"	"	
	561	ART		"	"	"	"	
	562	FM		"	"	"	"	
	563	GRAVEL		"	"	"	"	
	564			"	442-3	"	"	
	565	FM		"	"	"	"	
**	566	ART	K	I-35E	442-2	18	DALLAS	E-330-A
	567	ART	K	"	"	"	"	
	568	ART	K	"	"	"	"	
	569	ART	K	"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	570	ART	K	I-35E	442-2	18	DALLAS	
	571	ART	K	"	"	"	"	
	599	FM	H	I-35E	196-2	18	DENTON	
	600	SH	H	"	"	"	"	
	601	ART	H	"	"	"	"	
	602	FM	H	"	"	"	"	
	603	FM	H	"	"	"	"	
	604+	ART	D	"	196-1	"	"	
	605	ART	D	"	"	"	"	
	606	ART	D	"	"	"	"	
	608	FM	D	"	195-3	"	"	
	609	US	D	I-35W	195-3	18	DENTON	
	610	ART	A	"	"	"	"	
	611	ART	A	"	"	"	"	
	612	ART	A	I-35	195-2	18	DENTON	
	613	US	A	"	"	"	"	
	614	US	A	"	"	"	"	
	615	ART	A	"	"	"	"	
	616	FM	A	"	"	"	"	
	617	FM	A	"	"	"	"	
	618	SH		"	"	"	"	
	619	FM		"	"	"	"	
	620+	GRAVEL		"	"	"	"	
	621+	PAVED		"	"	"	"	
	622+	GRAVEL		"	"	"	"	
*	623+	GRAVEL		"	"	"	"	D-592
	624	GRAVEL		I-35	195-1	3	COOKE	
	625+	FM		"	"	"	"	
	626	FM		"	"	"	"	
	627	GRAVEL		"	"	"	"	
	628	ART		"	"	"	"	
	629	FM		"	"	"	"	
	630	FM		"	194-2	"	"	
	631	FM		I-20	3-6	6	REEVES	
	632+	FM		"	3-7	"	"	
	633	SH		"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	634	ART		I-20	3-7	6	REEVES	
	635	US		"	"	"	"	
	636+	US		"	"	"	"	
*	637	FM		I-20	4-2	6	WARD	W-267
	638	SH		"	4-4	"	"	
**	639	SH		"	"	"	"	W-253
	640	FM		"	"	"	"	
	641	SH		"	"	"	"	
	642	SH		"	"	"	"	
	643+	SH		"	"	"	"	
	644+	SH		I-20	4-6	6	ECTOR	
	645	FM	C	"	4-7	"	"	
	646	FM	D	"	"	"	"	
	647	US	D	"	5-13	"	"	
	648	ART	D	"	"	"	"	
	649	SH	D	"	"	"	"	
	650	FM	A	I-20	5-14	6	MIDLAND	
	651	SH	B	"	"	"	"	
	652	ART	B	"	"	"	"	
	653	SH	B	I-20	5-14	6	MIDLAND	
	655	FM	B	"	5-15	"	"	
	656	FM	B	"	5-3	"	"	
	657	FM		I-20	5-4	6	MARTIN	
	658	SH		"	"	"	"	
	659+	FM		I-20	5-5	8	HOWARD	
	660	FM		"	"	"	"	
	661+	PAVED		"	"	"	"	
	662+	FM		"	"	"	"	
	663	US		"	"	"	"	
	664	SH		"	5-6	"	"	
	665	SH		"	"	"	"	
	666+	ART		"	"	"	"	
	668	ART		"	"	"	"	
	669	ART		"	"	"	"	
	670	FM		"	"	"	"	
	671	PAVED		"	"	"	"	

	Code	Rt *	Ctrl-S*	Dist*	County	Plan*
	672 FM	I-20	5-6	8	HOWARD	
	673 PAVED	"	"	"	"	
	674+ GRAVEL	I-20	5-7	8	MITCHELL	
	675+ GRAVEL	"	"	"	"	
	676 FM	"	"	"	"	
	677 ART	"	5-8	"	"	
	678 GRAVEL	"	"	"	"	
	679 FM	"	"	"	"	
	680 ART	"	"	"	"	
	681 SH	"	"	"	"	
	682 SH	"	"	"	"	
	683 ART	"	6-1	"	"	
	684 FM	"	"	"	"	
	687 SH	"	"	"	"	
	688+ FM	"	"	"	"	
	689+ ART	"	"	"	"	
	690 ART	"	"	"	"	
	692 FM	"	"	"	"	
	695+ SH	"	"	"	"	
	696 FM	"	"	"	"	
	697 ART	I-20	6-2	8	NOLAN	
*	698+ SH	"	"	"	"	N-373
**	699 ART	"	"	"	"	N-373
	700 ART	"	"	"	"	
	701 SH	"	"	"	"	
	702+ SH	"	6-3	"	"	
	703 ART	"	"	"	"	
	704 FM	"	"	"	"	
	705+ PAVED	"	"	"	"	
	706+ PAVED	"	"	"	"	
	707 GRAVEL	"	"	"	"	
	710 SH	"	"	"	"	
	711 GRAVEL	I-20	6-4	8	TAYLOR	
	712 FM	"	"	"	"	
	713 FM	"	"	"	"	
	714 PAVED	"	"	"	"	

	Code	Rt *	Ctrl-S*	Dist*	County	Plan*
	715 GRAVEL	I-20	6-4	8	TAYLOR	
	716+ SH	"	"	"	"	
	717 FM	"	"	"	"	
	718 FM	"	"	"	"	
	719 GRAVEL	"	"	"	"	
	720 FM	"	6-5	"	"	
	721 SH	"	"	"	"	
	722 ART	"	"	"	"	
	723 ART	"	"	"	"	
	724+ ART	"	"	"	"	
	727 FM	"	6-6	"	"	
	728 SH	"	"	"	"	
	729 SH	"	"	"	"	
	730 FM	I-20	6-7	8	CALLAHAN	
	731+ FM	"	"	"	"	
	732 GRAVEL	"	"	"	"	
	733 GRAVEL	"	"	"	"	
	734 FM	"	"	"	"	
**	735 US	"	7-1	"	"	C-266
	736 US	"	"	"	"	
	737 FM	"	"	"	"	
	738 EARTH	"	7-2	"	"	
	739 GRAVEL	"	"	"	"	
	740 FM	"	"	"	"	
	741 GRAVEL	"	"	"	"	
	742+ GRAVEL	I-20	7-3	23	EASTLAND	
	743+ GRAVEL	"	"	"	"	
	744 SH	"	"	"	"	
	745 ART	"	"	"	"	
	746 US	"	"	"	"	
	747 GRAVEL	"	"	"	"	
	748 SH	"	"	"	"	
	749 SH	"	"	"	"	
	750 GRAVEL	"	"	"	"	
	751 FM	"	7-6	"	"	
	752 FM	"	"	"	"	

	Code	Rt #	Ctrl-S#	Dist#	County	Plan#
	753 FM	I-20	7-6	23	EASTLAND	
*	754 ART	"	"	"	"	E-16-A
	755 ART	"	"	"	"	
	756 SH	"	"	"	"	
	757 SOIL	"	314-5	"	"	
	758 SH	I-20	314-4	2	ERATH	
	759 FM	I-20	314-3	2	PALO PINTO	
	760 PAVED	"	"	"	"	
	761 SH	"	"	"	"	
*	762 GRAVEL	"	"	"	"	P-3-A
*	763 FM	"	"	"	"	P-2-A
	764+ GRAVEL	"	"	314-2"		
	765 US	"	"	"	"	
	766+ PAVED	I-20	314-1	2	PARKER	
	767+ FM	"	"	"	"	
	768+ FM	"	"	"	"	
	769 ART	"	314-7	"	"	
	770 FM	"	"	"	"	
	771 SH	"	"	"	"	
	772 FM	"	"	"	"	
	773 ART	"	"	"	"	
	774 FM	"	8-3	"	"	
	775 FM	"	"	"	"	
	776 ART	I-20	95-2	18	DALLAS	
	777 SH	"	"	"	"	
	778 FM	I-20	95-3	18	KAUFMAN	
	779 ART	"	"	"	"	
	780 FM	"	"	"	"	
	781 GRAVEL	"	"	95-4 "		
	782 FM	"	495-1	"	"	
	783 FM	"	"	"	"	
	784 SH	"	"	"	"	
	785 ART	I-20	495-1	18	KAUFMAN	
	786 FM	"	"	"	"	
	787 GRAVEL	"	"	"	"	
	788 FM	"	"	"	"	

Code			Rt #	Ctrl-S#	Dist#	County	Plan#
789	FM		I-20	495-2	10	VAN ZANDT	
790	PAVED		"	"	"	"	
791	PAVED		"	"	"	"	
792	PAVED		"	"	"	"	
793	PAVED		"	"	"	"	
794	SH		"	"	"	"	
795	FM		"	"	"	"	
796	SH		"	"	"	"	
797	FM		"	495-3	"	"	
798	FM		"	"	"	"	
799	PAVED		"	"	"	"	
800	SOIL		"	"	"	"	
801	FM		"	"	"	"	
802	FM		"	"	"	"	
803	SOIL		"	"	"	"	
804	SOIL		I-20	495-4	10	SMITH	
805	FM		"	"	"	"	
806	FM		"	"	"	"	
807	ART		"	"	"	"	
808	US		"	"	"	"	
809	ART		"	"	"	"	
810	ART		"	495-5	"	"	
811	FM		"	"	"	"	
812	FM		"	"	"	"	
813	SH		"	"	"	"	
814	US		"	"	"	"	
815	FM		"	495-6	"	"	
816	PAVED		"	"	"	"	
817	PAVED		"	"	"	"	
818	FM	C	I-20	495-7	10	GREGG	
819	SH	C	"	"	"	"	
820	SH	C	"	"	"	"	
821	FM	D	"	"	"	"	
822+	SH	D	I-20	495-8	19	HARRISON	
823	FM		"	"	"	"	
824	FM		"	"	"	"	

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
*	825 FM		I-20	495-8	19	HARRISON	H-780
	826 SH		"	495-9	"	"	
	827 US		"	"	"	"	
	828 FM		I-20	495-9	19	HARRISON	
	829+ US		"	495-10	"	"	
	830+ SOIL		"	"	"	"	
	831+ FM		"	"	"	"	
	832 FM		"	"	"	"	
	833 SH		"	"	"	"	
	861 ART	K	I-45	92-2	18	DALLAS	
	865 ART	K	"	"	"	"	
	867 ART	L	"	"	"	"	
	868 ART		I-45	92-3	18	ELLIS	
	869+ ART		"	"	"	"	
	870 PAVED		"	"	"	"	
	871+ US		"	92-4	"	"	
	872 FM		"	"	"	"	
	873 US		"	"	"	"	
	874 FM		"	"	"	"	
	875 ART		"	"	"	"	
	876 SH		"	"	"	"	
	877 FM		"	"	"	"	
	878+ FM		"	92-5	"	"	
	879 ART		I-45	92-6	18	NAVARRO	
	880+ FM		"	"	"	"	
	882 ART		"	"	"	"	
	883 SH		"	"	"	"	
	884 ART		"	"	"	"	
	885 US		"	93-1	"	"	
	886 FM		"	"	"	"	
	887 GRAVEL		"	"	166-1"		
	888 FM		"	"	"	"	
	889 FM		I-45	675-1	17	FREESTONE	
	890 GRAVEL		"	"	"	"	
	891 FM		"	"	"	"	
	892 GRAVEL		"	"	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	893	FM		I-45	675-1	17	FREESTONE	
	894	US			675-2			
*	895+	SOIL		"	"	"	"	F-895
**	896	SH		"	"	"	"	F-890
	897	FM		"	"	"	"	
	898	SH		I-45	675-3	17	LEON	
	899	US		"	"	"	"	
	900	EARTH		"	"	"	"	
	901	SH		"	"	"	"	
	902	FM			675-4			
*	903	GRAVEL		"	"	"	"	L-671
	904	SH		"	"	"	"	
	905	SOIL		I-45	675-5	17	MADISON	
	906	US		"	"	"	"	
	907	SH		"	"	"	"	
	908	SH		"	"	"	"	
	909	FM		I-45	675-6	17	WALKER	
	910	FM		"	"	"	"	
	911	SH		"	"	"	"	
	912	SH		"	"	"	"	
	914	FM		"	"	"	"	
	915	SH		"	"	"	"	
	916	SH		"	"	"	"	
	917	FM		"	"	"	"	
	918	ART	C	I-45	675-8	12	MONTGOMERY	
	919	ART	C	"	"	"	"	
	920	FM	F	"	"	"	"	
	921	FM	F	"	"	"	"	
	922	ART	F	"	"	"	"	
	923	SH	F	"	"	"	"	
	924	SH	F	"	"	"	"	
	925	SH	J	"	"	"	"	
	926	FM	J	"	"	"	"	
	927+	ART	J	"	110-4	"	"	
	929+	ART	N	"	"	"	"	
*	931	ART	N	"	"	"	"	M-1641

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	932+	US	J	I-45	675-8	12	MONTGOMERY	
	933	ART	D	I-45	110-5	12	HARRIS	
**	934	FM	D	"	"	"	"	H-641-A
	935	ART	D	"	"	"	"	
	936	FM	H	"	"	"	"	
	938	ART	H	"	110-6	"	"	
	939	ART	H	"	"	"	"	
	969+	ART	Z	"	500-3	"	"	
	970	ART	Z	"	"	"	"	
	971	FM	A	I-45	500-4	12	GALVESTON	
	972	ART	A	"	"	"	"	
	973	FM	A	"	"	"	"	
*	974	FM	A	"	"	"	"	G-157-A
	975	ART	C	"	"	"	"	
	976	FM	D	"	"	"	"	
	977	ART	D	"	"	"	"	
	978	FM	D	"	"	"	"	
	979	FM	D	"	"	"	"	
	980	FM	D	"	"	"	"	
	981	FM	E	"	500-1	"	"	
	983+	ART	G	I-30	1068-1	2	TARRANT	
	984	ART	G	"	"	"	"	
	985+	FM	G	"	"	"	"	
	1021	ART	F	I-30	9-11	18	DALLAS	
	1022	FM		I-30	9-12	18	ROCKWALL	
	1023	SH		"	"	"	"	
	1025	FM		"	"	"	"	
	1026	FM		"	"	"	"	
	1027	FM		"	"	"	"	
	1028	FM		I-30	9-13	1	HUNT	
	1029+	FM		"	"	"	"	
	1030+	FM		"	"	"	"	
	1031	FM		"	"	"	"	
	1032	FM		"	"	"	"	
	1033	US		"	"	"	"	

	Code	Rt *	Ctrl-S*	Dist*	County	Plan*
	1034 SH	I-30	9-13	1	HUNT	
*	1035 ART	"	"	"	"	H-2176-A
	1036 SH	"	"	"	"	
	1041 FM	"	"	"	"	
	1044 SH	"	10-2	"	"	
	1045 FM	"	"	"	"	
	1046+ SH	"	"	"	"	
	1047 PAVED	"	"	"	"	
	1048 FM	"	"	"	"	
	1049 SOIL	"	"	"	"	
	1050+ US	I-30	610-1	1	HOPKINS	
	1051 FM	"	"	"	"	
	1052 FM	"	"	"	"	
	1053 SOIL	I-30	610-2	1	FRANKLIN	
	1054 SH	"	"	"	"	
	1055+ SH	"	"	"	"	
	1056 SOIL	"	"	"	"	
	1057 ART	I-30	610-3	19	TITUS	
	1058+ SOIL	"	"	"	"	
	1059 US	"	"	"	"	
	1060 US	"	"	"	"	
	1062 FM	"	"	"	"	
	1063+ FM	"	"	"	"	
	1064 US	I-30	610-4	19	MORRIS	
	1065 FM	"	610-5	"	BOWIE	
	1066 FM	"	"	"	"	
	1067 SH	"	610-6	"	"	
	1068 US	"	"	"	"	
	1069 SH	"	"	"	"	
	1070 SH	"	"	"	"	
	1071 FM	"	"	"	"	
	1072 SH	"	610-7	"	"	
*	1073 FM	"	"	"	"	B-1021-A
	1074 FM	"	"	"	"	
	1075 FM	"	"	"	"	
*	1076 FM	"	"	"	"	B-1020-A

Code	Rt #	Ctrl-S#	Dist#	County	Plan#
1077+ SH	I-40	90-1	4	DEAF SMITH	
1078+ SOIL	I-40	90-3	4	OLDHAM	
1079+ FM	"	"	"	"	
1080 SOIL	"	"	"	"	
1082 US	"	"	"	"	
1086 FM	"	"	"	"	
1089 FM	"	"	"	"	
1103+ ART	I-40	275-1	4	POTTER	
1104 SH	"	"	"	"	
1105 ART	"	"	"	"	
1106 FM	"	"	"	"	
1107 SH	I-40	275-1	4	POTTER	
1108 FM	"	"	"	"	
1109 FM	I-40	275-2	4	CARSON	
1110+ FM	"	"	"	"	
1111 SOIL	"	"	"	"	
1112 SOIL	"	"	"	"	
1113 SH	"	275-3	"	"	
1114 SH	"	"	"	"	
1118 FM	"	"	"	"	
1119 FM	"	"	"	"	
1120 FM	"	"	"	"	
1121+ US	I-40	275-5	4	GRAY	
1122+ SH	"	275-7	"	"	
1123+ SH	"	"	"	"	
1124+ FM	I-40	275-10	25	DONLEY	
1125 FM	I-40	275-11	4	GRAY	
1126 FM	"	"	"	"	
1127 ART	"	"	"	"	
1128 FM	"	"	"	"	
1129 ART	"	"	"	"	
1130 FM	I-40	275-12	25	WHEELER	
1131 FM	"	"	"	"	
1132 FM	"	"	"	"	
1133 US	"	"	"	"	
1134+ ART	"	275-13	"	"	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
*	1135	FM		I-40	275-13	25	WHEELER	
*	1136	FM		"	"	"	"	W-672
	1137+	EARTH		"	"	"	"	
*	1138+	SH		"	"	"	"	W-672
	1147	ART		I-27	168-9	4	RANDALL	
	1149	FM		"	67-17	"	"	
	1150	PAVED		"	"	"	"	
	1151	SOIL		"	"	"	"	
	1152	FM		"	"	"	"	
	1153	SOIL		"	"	"	"	
	1154	FM		"	"	"	"	
	1155	FM		I-27	67-4	5	HALE	
	1157	SH		"	"	"	"	
	1158	US		I-27	67-4	5	HALE	
	1161	FM		"	"	"	"	
	1162	FM		"	67-6	"	"	
	1166	FM		"	"	"	"	
	1167	FM		"	"	"	"	
	1168	FM		I-27	67-7	5	LUBBOCK	
	1169	ART		"	"	"	"	
	1170	FM		"	"	"	"	
	1171	ART		"	"	"	"	
	1172	ART	B	"	"	"	"	
	1173	FM	B	"	"	"	"	
	1174	ART	B	"	"	"	"	
*	1177+	ART	B	"	"	"	"	L-1386-A
	1178	SH	B	"	"	"	"	
	1254	ART	A	I-635	2374-7	18	DALLAS	
	1255	ART	A	"	"	"	"	
	1256	ART	A	"	"	"	"	
	1257	ART	A	"	"	"	"	
	1258	ART	A	"	"	"	"	

DIAMOND INTERCHANGES - Urban
(w/ turnaround)

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	19	SH	C	I-10	2121-3	24	EL PASO	
	22	SH	C	"	"	"	"	
*	23	ART	C	"	"	"	"	E-469-A
	117	ART	H	I-10	72-12	15	BEXAR	
	134	ART	L	"	25-2	"	"	
*	200	ART	Q	I-10	271-7	12	HARRIS	B-644-A
	201+	ART	Q	I-10	271-7	12	HARRIS	
	202	ART	Q	"	"	"	"	
*	203	ART	Q	"	"	"	"	H-646-C
	204	ART	Q	"	"	"	"	
	205	ART	Q	"	"	"	"	
	206	ART	Q	"	"	"	"	
	224	ART	S	"	508-1	"	"	
	229	ART	S	"	"	"	"	
	230	ART	S	"	"	"	"	
	231	ART	S	"	"	"	"	
	232	ART	S	"	"	"	"	
	260	US	A	I-10	739-2	20	JEFFERSON	
	261	ART	A	"	28-13	"	"	
	263	ART	A	"	"	"	"	
	264	ART	A	"	"	"	"	
	279	ART	L	I-37	73-8	15	BEXAR	
	368	SH	L	I-35	17-2	15	BEXAR	
	369	ART	L	"	"	"	"	
	370	ART	L	"	"	"	"	
	371	ART	L	"	"	"	"	
	416	SH	L	I-35	15-13	14	TRAVIS	
	428	US	I	I-35	15-13	14	TRAVIS	
	487	US	D	I-35	15-1	9	MCLENNAN	
	488	ART	D	"	"	"	"	
	489	SH	D	"	"	"	"	

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	530+	ART	K	"	"	"	"	
	531+	ART	H	"	"	"	"	
	586	ART	E	I-35E	196-3	18	DALLAS	
*	835	ART	I	I-20	2374-5	2	TARRANT	T-47-D
	842+	ART	I	"	"	"	"	
	953	ART	R	I-45	500-3	12	HARRIS	
	954	ART	R	"	"	"	"	
	957	US	R	"	"	"	"	
	960	ART	W	I-45	500-3	12	HARRIS	
	1002	ART	E	I-30	1068-4	18	DALLAS	
	1093	ART	A	I-40	275-1	4	POTTER	
	1095	ART	A	I-40	275-1	4	POTTER	
	1096	ART	A	"	"	"	"	
*	1098	ART	A	"	"	"	"	P-687
	1099	ART	B	"	"	"	"	
	1101	ART	B	"	"	"	"	
	1102	ART	B	"	"	"	"	
	1142	ART	A	I-27	168-9	4	RANDALL	
	1143	ART	A	"	"	"	"	
*	1144	ART	A	"	"	"	"	R-145
	1193	ART	H	I-410	521-4	15	BEXAR	
	1194	SH	H	"	"	"	"	
	1195	ART	H	"	"	"	"	
	1200	ART	L	"	521-5	"	"	
	1222	ART	R	I-610	271-14	12	HARRIS	
	1223	ART	R	"	"	"	"	
	1231	ART	S	"	502-1	"	"	
	1246	ART	R	"	271-17	"	"	
	1249	FM	R	"	"	"	"	
	1250	ART	R	"	"	"	"	
	1282	SH	F	I-635	2374-2	18	DALLAS	
	1288	ART	H	I-820	8-12	2	TARRANT	
*	1292	FM	H	"	"	"	"	T-56-A
*	1297	ART	H	"	8-13	"	"	T-56-A
	1320	ART	D	"	8-14	"	"	
	1325	US	G	"	8-15	"	"	
	1326	ART	G	"	"	"	"	

DIAMOND INTERCHANGES - Rural
(w/ turnaround)

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	268	ART	A	I-10	28-11	20	ORANGE	
	272	SH	D	I-10	28-11	20	ORANGE	
*	403	SH		I-35	16-3	14	HAYS	H-1054
	607	SH	D	I-35E	196-1	18	DENTON	
	725	ART		I-20	6-5	8	TAYLOR	
	726	ART		I-20	6-6	8	TAYLOR	
	982	SH	E	I-45	500-1	12	GALVESTON	
	1090	SH	A	I-40	275-1	4	POTTER	
	1091	ART	A	I-40	275-1	4	POTTER	
	1175	ART	B	I-27	67-7	5	LUBBOCK	
	1176	ART	B	I-27	67-7	5	LUBBOCK	

DIAMOND INTERCHANGES - Urban
(Split)

	Code			Rt *	Ctrl-S*	Dist*	County	Plan*
	18	ART		I-10	2121-2	24	EL PASO	
	135	ART	M	I-10	25-2	15	BEXAR	
	221	ART	A	I-10	508-1	12	HARRIS	
	265	ART	A	I-10	28-13	20	JEFFERSON	
	266	ART	A	I-10	28-13	20	JEFFERSON	
	278	ART	L	I-37	73-8	15	BEXAR	
	319	ART	C	I-37	74-6	16	NUECES	
	325	ART	D	I-37	74-6	16	NUECES	
	328	ART		I-35	18-6	21	WEBB	
	329	ART		I-35	18-6	21	WEBB	
	423	ART	I	I-35	15-13	14	TRAVIS	
	483	ART	D	I-35	15-1	9	MCLENNAN	
	484	ART	D	I-35	15-1	9	MCLENNAN	
	579	ART	H	I-35E	442-2	18	DALLAS	
	849	ART	J	I-20	2374-4	18	DALLAS	
	952+	ART	R	I-45	500-3	12	HARRIS	
*	1003	ART	E	I-30	9-11	18	DALLAS	D-122-B
	1094	ART	A	I-40	275-1	4	POTTER	
	1208	SH	Q	I-410	521-6	15	BEXAR	
	1216	ART	R	I-610	271-14	12	HARRIS	
	1234	ART	V	I-610	271-16	12	HARRIS	
	1243	US	V	I-610	271-16	12	HARRIS	
	1267	ART	B	I-635	2374-1	18	DALLAS	

DIAMOND INTERCHANGES - Rural
(Split)

	Code		Rt *	Ctrl-S*	Dist*	County	Plan*
167	US&FM		I-10	535-6	13	FAYETTE	
466	US	F	I-35	15-14	9	BELL	
467	FM&SH	C	I-35	15-14	9	BELL	
547	ART	B	I-35W	18-12	2	TARRANT	
654	FM&SH	B	I-20	5-15	6	MIDLAND	
1061	FM&SH		I-30	610-3	19	TITUS	

SPLIT-DIAMOND INTERCHANGE WITH JUG HANDLES - URBAN

Code	Rt #	Ctrl-S#	Dist#	County	Plan#
1011 ART E	I-30	9-11	18	DALLAS	
1018 ART F	"	"	"	"	
1019 ART F	"	"	"	"	
1020 ART F	"	"	"	"	

SPLIT-DIAMOND INTERCHANGE WITH JUG HANDLES - RURAL

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
148	PAVED		I-10	25-3	15	GUADALUPE	
149	PAVED		"	"	"	"	
150	FM		"	"	"	"	
151	GRAVEL		"	"	"	"	
248	FM		I-10	508-3	20	CHAMBERS	
249	PAVED		"	"	"	"	
250	FM		"	"	"	"	
251	GRAVEL		"	"	"	"	
252	FM		"	"	"	"	
256	ART	B	I-10	739-2	20	JEFFERSON	
270	FM		"	28-11	12	ORANGE	
271+	FM	B	"	"	"	"	
273	FM	D	"	28-14	"	"	
359	ART	O	I-35	17-3	15	BEXAR	
363	ART	P	"	"	"	"	
384	ART	F	"	16-7	"	"	
397	ART		"	16-4	"	COMAL	
399	ART		"	16-3	14	HAYS	
400	ART		"	"	"	"	
401	ART		"	"	"	"	
402	ART		"	"	"	"	
667	ART		I-20	5-6	8	HOWARD	
685	SOIL		"	6-1	8	MITCHELL	
686	GRAVEL		"	"	"	"	
691	GRAVEL		"	6-2	"	NOLAN	
* 693	GRAVEL		"	"	"	"	N-382
694	GRAVEL		"	"	"	"	
708	GRAVEL		"	6-3	"	"	
709	GRAVEL		"	"	"	"	
862	ART	K	I-45	92-2	18	DALLAS	
863	ART	K	"	"	"	"	
864	ART	K	"	"	"	"	
866	ART	K	"	"	"	"	
881	FM		"	92-6	"	NAVARRO	

	Code			Rt #	Ctrl-S#	Dist#	County	Plan#
	913+	ART		I-45	675-7	17	WALKER	
	928+	ART	J	I-30	110-4	12	MONTGOMERY	
	930	ART	N	"	"	"	"	
	937+	ART	H	"	110-5	12	HARRIS	
	1024	SH		I-30	9-12	18	ROCKWALL	
	1037	ART		"	9-13	1	HUNT	
	1038+	FM		I-30	9-13	1	HUNT	
	1039	ART		"	9-9	"	HOPKINS	
	1040	FM		"	"	"	"	
	1042	SOIL		"	"	"	"	
	1043	FM		"	"	"	"	
	1081	FM		I-40	90-3	4	OLDHAM	
*	1083	SOIL		"	90-4	"	"	0-139
	1084	PAVED		"	"	"	"	
	1085	SOIL		"	"	"	"	
	1087	PAVED		"	90-5	"	POTTER	
*	1088	PAVED		"	"	"	"	0-139
	1115	PAVED		"	275-3	"	CARSON	
*	1116	SOIL		"	"	"	"	C-560
*	1117	FM		"	275-4	"	"	C-560
	1148	FM		I-27	168-9	"	RANDALL	
	1156	FM		"	67-4	5	HALE	
	1159	FM		"	67-5	"	"	
	1160	SOIL		"	"	"	"	
	1163	FM		"	67-6	"	"	
	1164	FM		"	"	"	"	
	1165	SOIL		"	"	"	"	

DIAMOND INTERCHANGES - Urban
(X)

	Code		Rt *	Ctrl-S*	Dist*	County	Plan*
	233	ART S	I-10	508-1	12	HARRIS	
	234	ART S	I-10	508-1	12	HARRIS	
*	422	ART I	I-35	15-13	14	TRAVIS	T-736-A
	544	ART E	I-35W	14-16	2	TARRANT	
	941	ART M	I-45	110-6	12	HARRIS	
	942	FM M	I-45	110-6	12	HARRIS	
	943	ART M	I-45	500-3	12	HARRIS	
	944	ART M	I-45	500-3	12	HARRIS	
	945	ART M	I-45	500-3	12	HARRIS	
	946	ART M	I-45	500-3	12	HARRIS	
	947	ART M	I-45	500-3	12	HARRIS	
	948	ART M	I-45	500-3	12	HARRIS	
	950	ART R	I-45	500-3	12	HARRIS	
	951	ART R	I-45	500-3	12	HARRIS	
	961	ART W	I-45	500-3	12	HARRIS	
	1217	ART R	I-610	271-14	12	HARRIS	
	1236	ART V	I-610	271-16	12	HARRIS	
	1264	SH B	I-635	2374-1	18	DALLAS	

FULL-DIRECTIONAL INTERCHANGES - URBAN

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
17	SYS(410)	H	I-10	72-12	15	BEXAR	
19	US	L	I-10	17-9	15	BEXAR	
20	SYS(37)	L	I-10	25-2	15	BEXAR	
25	SYS(610)	R	I-10	271-7	12	HARRIS	
26+	SYS(45)	R	"	"	"	"	
27+	SYS(45)	R	"	"	"	"	
29	SYS(610)	S	I-10	508-1	"	"	
33+	US		I-10	28-13	20	JEFFERSON	
36	SYS(35)	L	I-37	73-8	15	BEXAR	
37	SYS(410)	M	"	"	"	"	
43+	SH	C	I-37	74-6	16	NUECES	
44+	SH	D	"	"	"	"	
66	SYS(30)	H	I-35W	14-16	2	TARRANT	
68	SYS(820)	E	"	"	"	"	
73	SYS(20)	K	I-35E	442-2	18	DALLAS	
75+	SYS(30)	E	"	196-3	"	"	
76+	SYS(30)	E	"	"	"	"	
107	SYS(635)	F	I-20	95-2	18	DALLAS	
110+	SYS(820)	H	I-20	2374-5	2	TARRANT	
113	US	G	I-20	2374-4	18	DALLAS	
114	SYS(45)	H	"	2374-3	"	"	
115	SYS(30)	E	I-45	92-14	18	DALLAS	
126	SYS(610)	R	I-45	500-3	12	HARRIS	
143	SYS(635)	F	I-30	9-11	18	DALLAS	
166	SH	I	I-410	521-6	15	BEXAR	
168	US	R	I-610	271-14	12	HARRIS	
169	SH	S	"	271-15	"	"	
170	SH	V	"	271-16	"	"	
171	ART	V	"	"	"	"	
172	US	R	"	271-17	"	"	
175	US	I	I-635	2374-3	18	DALLAS	
177	SYS(20)	H	I-820	8-13	2	TARRANT	
179+	SH	F	I-820	8-13	2	TARRANT	

FULL-DIRECTIONAL INTERCHANGES - RURAL

Code		Rt #	Ctrl-S#	Dist#	County	Plan#
42+	US	I-37	74-6	16	NUECES	
64+	SYS(35E,W)	I-35	14-23	9	HILL	
112+	SH	I-20	2374-4	18	DALLAS	
130	SYS(820) G	I-30	1068-1	2	TARRANT	
173+	SH	C I-635	2374-6	2	TARRANT	

SEMI-DIRECTIONAL INTERCHANGE - RURAL

Code	Rt #	Ctrl-S#	Dist#	County	Plan#
1+ US C	I-10	2121-2	24	ELPASO	
3+ SH	I-10	2121-6	24	HUDSPETH	
4+	I-10	2-10	24	HUDSPETH	
5+ SH	I-10	2-11	24	CULBERSON	
6+ SYST(20)	I-10	441-9	6	REEVES	
7+ US	I-10	441-8	6	PECOS	
8 US	I-10	441-8	6	PECOS	
9+ US	I-10	140-1	6	PECOS	
10+ SH	I-10	142-1	7	KIMBLE	
11+ US	I-10	142-1	7	KIMBLE	
12+ US	I-10	142-1	7	KIMBLE	
13+ US	I-10	72-5	15	KENDALL	
14+ US	I-10	72-5	15	KENDALL	
15+ US	I-10	72-6	15	KENDALL	
16+ SH H	I-10	72-12	15	BEXAR	
21+ SH	I-10	25-3	15	GUADALUPE	
22+ SH	I-10	535-8	13	COLORADO	
23+ US	I-10	271-2	13	AUSTIN	
24+ US	I-10	271-14	12	WALLER	
30+ SH T	I-10	508-1	12	HARRIS	
31+ SH	I-10	508-1	20	CHAMBERS	
32+ US	I-10	739-2	20	JEFFERSON	
35+ SH A	I-10	28-11	20	ORANGE	
38+ US Q	I-37	73-8	15	BEXAR	
39+ US	I-37	73-10	15	ATASCOSA	
40+ US	I-37	73-7	16	LIVE OAK	
41+ US	I-37	74-5	16	SAN PATRICIO	
46+ US	I-35	17-5	15	MEDINA	
47+ US O	I-35	17-3	15	BEXAR	
48+ SH P	I-35	17-2	15	BEXAR	
53+ US	I-35	16-5	15	COMAL	
54+ US	I-35	16-4	15	COMAL	

Code			Rt *	Ctrl-S*	Dist*	County	Plan*
55+	SH	E	I-35	15-13	14	TRAVIS	
56	FM	D	I-35	15-9	14	WILLIAMSON	
57+	US	E	I-35	15-6	9	BELL	
58+	SH	C	I-35	15-14	9	BELL	
59+	SH	F	I-35	16-7	15	BEXAR	
62+	SH	B	I-35	15-1	9	MCLENNAN	
63+	US		I-35	14-7	9	HILL	
65+	SH		I-35W	14-23	9	HILL	
69+	SH	B	I-35W	14-16	2	TARRANT	
70+	SYST(35E)		I-35W	18-13	18	DENTON	
71+	US		I-35E	48-4	18	ELLIS	
72+	SH		I-35E	442-3	18	ELLIS	
85+	ART	E	I-35E	196-1	18	DENTON	
86+	US	D	I-35E	195-3	18	DENTON	
87+	US		I-20	3-7	6	REEVES	
88+	US		I-20	4-2	6	WARD	
89+	ART		I-20	4-4	6	WARD	
90+	US		I-20	4-4	6	WARD	
91+	US	D	I-20	4-7	6	ECTOR	
92+	US	B	I-20	5-15	6	MIDLAND	
93+	US		I-20	5-4	6	MARTIN	
94+	US		I-20	5-4	6	MARTIN	
95+	SH		I-20	5-5	8	HOWARD	
96+	SH		I-20	5-6	8	HOWARD	
97+	SH		I-20	5-8	8	MITCHELL	
98+	SH		I-20	6-1	8	MITCHELL	
99+	SH		I-20	6-2	8	NOLAN	
100+	SH		I-20	6-2	8	NOLAN	
101+	SH		I-20	6-3	8	NOLAN	
102+	US		I-20	6-5	8	TAYLOR	
103+	SH		I-20	6-6	8	TAYLOR	
104+	FM		I-20	7-6	23	EASTLAND	
105+	US		I-20	314-1	2	PARKER	
106+	US		I-20	314-7	2	PARKER	
108+	US		I-20	95-4	18	KAUFMAN	

Code		Rt *	Ctrl-S*	Dist*	County	Plan*
109	US	I-20	495-7	10	GREGG	
116+	US	I-45	92-14	18	DALLAS	
117+	US	I-45	92-4	18	ELLIS	
118+	US	I-45	92-4	18	ELLIS	
120+	US	I-45	166-1	18	NAVARRO	
121+	SH	I-45	166-1	18	NAVARRO	
122+	US	I-45	675-7	17	WALKER	
123+	US	I-45	675-7	17	WALKER	
124	SH	H I-45	110-6	12	HARRIS	
128	SH	D I-45	500-4	12	GALVESTON	
129+	US	G I-30	1068-1	2	TARRANT	
144+	SH	I-30	9-13	1	HUNT	
145+	SH	I-30	9-9	1	HOPKINS	
146	SH	I-30	9-9	1	HOPKINS	
147+	FM	I-30	610-3	19	TITUS	
148+	US	A I-30	610-7	19	BOWIE	
149+	US	I-40	90-3	4	OLDHAM	
150+	US	I-40	90-4	4	OLDHAM	
151+	US	A I-40	275-1	4	POTTER	
154	US	B I-40	275-1	4	POTTER	
155+	US	I-40	275-2	4	CARSON	
156+	US	I-40	275-4	4	CARSON	
157+	US	I-40	275-11	4	GRAY	
158+	US	I-40	275-11	4	GRAY	
159+	US	I-40	275-12	25	WHEELER	
160	US	I-27	168-9	4	RANDALL	
161+	SH	I-27	675-4	5	HALE	
162+	SH	I-27	675-5	5	HALE	

SEMI-DIRECTIONAL INTERCHANGE - URBAN

Code			Rt *	Ctrl-S*	Dist*	County	Plan*
2	US	C	I-10	2121-2	24	ELPASO	
18+	SYST(35)	L	I-10	72-12	15	BEXAR	
28	US	R	I-10	508-1	12	HARRIS	
34+	US	A	I-10	28-13	20	JEFFERSON	
45+	US	D	I-37	74-6	16	NUECES	
49+	SH	L	I-35	17-9	15	BEXAR	
50+	SYS(410)	I	"	17-10	"	"	
51+	SYS(410)	I	"	17-10	"	"	
52+	SYS(410)	I	"	17-10	"	"	
61	SH	D	I-35	15-1	9	MCLENNAN	
67	SH	H	I-35W	14-16	2	TARRANT	
74+	US	H	I-35E	442-2	18	DALLAS	
77	SH	E	"	196-3	"	"	
78	SH	E	"	"	"	"	
79	US	E	"	"	"	"	
80+	SH	D	"	"	"	"	
81+	SH	D	"	"	"	"	
82+	ART	D	"	"	"	"	
83+	SH	D	"	"	"	"	
84	SYS(635)	A	"	"	"	"	
111+	US	I	I-20	2374-5	2	TARRANT	
125	SH	M	I-45	110-6	12	HARRIS	
127	ART	R	I-45	500-3	12	HARRIS	
131	US	G	I-30	1068-1	2	TARRANT	
132	ART	H	"	"	"	"	
133	SH	H	"	"	"	"	
134	US	H	"	1068-2	"	"	
135	ART	H	"	"	"	"	
136	ART	I	"	"	"	"	
137	ART	I	"	"	"	"	
138	ART	I	"	"	"	"	

	Code		Rt #	Ctrl-S#	Dist#	County	Plan#
139	ART	G	I-30	1068-4	18	DALLAS	
140	SH	G	"	"	"	"	
141	ART	G	"	"	"	"	
142	US	E	"	"	"	"	
152	SYST(27)	A	I-40	275-1	4	POTTER	
153+	SH	B	"	"	"	"	
163+	SH	I	I-410	521-4	15	BEXAR	
164+	ART	I	"	"	"	"	
165	FM	H	I-410	521-4	15	BEXAR	
167+	US	R	I-610	271-14	12	HARRIS	
174	US	B	I-635	2374-1	18	DALLAS	
176+	SH	H	I-820	8-12	2	TARRANT	
178+	SH	F	I-820	8-13	2	TARRANT	

FULL CLOVERLEAF INTERCHANGE - URBAN

Code			Rt #	Ctrl-S#	Dist. #	County	Plan#
4	SYST(410)	M	I-10	25-2	15	BEXAR	
5	SH	M	I-37	73-8	15	BEXAR	
8	SYST(820)	H	I-35W	14-16	2	TARRANT	
10	SH	D	I-20	4-7	6	ECTOR	
14	SH	H	I-35E	442-2	18	DALLAS	
18	FM	I	I-20	2374-5	2	TARRANT	
19	SH	H	I-45	92-14	18	DALLAS	
20	FM	J	I-45	110-4	12	MONTGOMERY	
21	ART	W	I-45	500-3	12	HARRIS	
22	FM	W	I-45	500-3	12	HARRIS	
23	ART	Z	I-45	500-3	12	HARRIS	
24	SH	G	I-30	1068-1	2	TARRANT	
25	SH		I-30	9-13	1	HUNT	
27	SH	H	I-410	521-4	15	BEXAR	
28	US	L	I-410	521-4	15	BEXAR	
29	ART	B	I-635	2374-1	18	DALLAS	
31	SH	E	I-820	8-14	2	TARRANT	
32	SH	D	I-820	8-14	2	TARRANT	
33	US	G	I-820	8-15	2	TARRANT	

FULL CLOVERLEAF INTERCHANGE- RURAL

Code			Rt #	Ctrl-S#	Dist.#	County	Plan#
2	SH	E	I-10	2121-4	24	EL PASO	
6	SYST(410)	P	I-35	17-2	15	BEXAR	
7	SH	F	I-35	15-1	9	MCLENNAN	
13	US		I-35E	48-4	18	ELLIS	
17	SH		I-20	6-6	8	TAYLOR	
26	US	A	I-30	610-7	19	BOWIE	

PARTIAL CLOVERLEAF INTERCHANGES -URBAN

Code			Rt #	Ctrl-S#	Dist#	County	Plan#
9	SH	H	I-35W	14-16	2	TARRANT	
10	SH	E	I-35W	14-16	2	TARRANT	
30	US	H	I-820	8-13	2	TARRANT	

PARTIAL CLOVERLEAF INTERCHANGES - RURAL

Code			Rt #	Ctrl-S#	Dist. #	County	Plan#
1	FM	C	I-10	2121-2	24	EL PASO	
3	FM		I-10	142-14	15	KERR	
11	FM	D	I-35W	18-13	18	DENTON	
12	SH		I-35E	48-4	18	ELLIS	
15	US		I-35	194-2	3	COOKE	
16	US		I-20	6-5	8	TAYLOR	

COMBINATION INTERCHANGE - URBAN

Code			Rt #	Ctrl-S#	Dist#	County	Plan#
2	ART	M	I-37	73-8	15	BEXAR	
4	ART	I	I-35	15-13	14	TRAVIS	
8	ART	H	I-35E	442-2	18	DALLAS	
12	ART	H	I-30	1068-2	2	TARRANT	

COMBINATION INTERCHANGE - RURAL

Code			Rt *	Ctrl-S*	Dist. *	County	Plan*
1	SH	E	I-10	72-8	15	BEXAR	
3	FM	C	I-35	15-14	9	BELL	
5	ART	B	I-35	14-8	9	MCLENNAN	
6	FM	B	I-35	14-8	9	MCLENNAN	
7	US		I-35	14-24	9	HILL	
9	FM		I-35	194-2	3	COOKE	
11	SH	D	I-20	495-7	10	GREGG	
119+	US		I-45	93-1	18	NAVARRO	
1269	ART	B	I-635	2374-1	18	DALLAS	

DIAMOND INTERCHANGES - Rural
(X)

Code	Rt #	Ctrl-S#	Dist. #	County	Job #	Sh. #

APPENDIX G: ANOVA MODEL

$$Y_{ijklmno} = \_ + L_i + T_j + LT_{ij} + OLT_{(ij)k}$$
$$+ M_l + LM_{il} + TM_{jl} + LTM_{ijl}$$
$$+ OLTM_{(ij)kl} + C_m + LC_{im}$$
$$+ TC_{jm} + LTC_{ijm} + OLTC_{(ij)km} + MC_{lm}$$
$$+ LMC_{ilm} + TMC_{jlm} + LTMC_{ijlm}$$
$$+ OLTMC_{(ij)klm} + D_n$$
$$+ LD_{in} + TD_{jn} + LTD_{ijn} + OLTD_{(ij)kn}$$
$$+ MD_{ln} + LMD_{iln} + TMD_{jln} + LTMD_{ijln}$$
$$+ OLTMD_{(ij)kln} + CD_{mn} + LCD_{imn}$$
$$+ TCD_{jmn} + LTCD_{ijmn} + OLTCD_{(ij)kmn}$$
$$+ MCD_{lmn} + LMCD_{ilmn} + TMCD_{jlmn}$$
$$+ LTMCD_{ijlmn} + OLTMCD_{(ij)klmn}$$

$i = 1, 2 \quad j = 1, 2, 3, 4$
$k = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16$
$l = 1, 2$
$m = 1, 2, 3, 4$
$n = 1, 2, 3$

where

Y_{ijklmn} = measured distance

μ = overall mean

L_i = effect of the i-th location (fixed)

T_j = effect of the j-th crossroad type (fixed)

LT_{ij} = effect of the interaction of the i-th location with the j-th crossroad type

$OLT_{(ij)k}$ = effect of the k-th occurrence (random value) of an interchange at the i-th location and j-th crossroad type $NID(o, \sigma^2_o)$(assumed Normally and Independently Distributed with mean of 0 and variance (σ_o^2)

M_l = effect of the l-th movement type (fixed)

LM_{il} = effect of the interaction of the i-th location with the l-th movement type

TM_{jl} = effect of the interaction of the j-th crossroad type with the l-th movement type

LTM_{ijl} = effect of the interaction of the i-th location with the j-th crossroad type with the l-th movement type

$OLTM_{(ij)kl}$ = effect of the l-th movement type in the k-th occurrence of interchange at the i-th location and j-th crossroad type NID (o, σ^2_{om})

C_m = effect of the m-th direction of travel (fixed)

LC_{im} = effect of the interaction of the i-th location with the m-th direction of travel

TC_{jm} = effect of the interaction of the j-th crossroad type with the m-th direction of travel

LTC_{ijm} = effect of the interaction of the i-th location with the j-th crossroad type with the m-th direction of travel

$OLTC_{(ij)km}$ = effect of the m-th direction of travel in the k-th occurrence of interchange at the i-th location and j-th crossroad type, NID (o, σ^2_{oc})

MC_{lm} = effect of the interaction of the l-th movement type with the m-th direction of travel

LMC_{ilm} = effect of the interaction of the i-th location with the l-th movement type with the m-th direction of travel

$LTMC_{ijlm}$ = effect of the interaction of the i-th location with the j-th crossroad type with the l-th movement type with the m-th direction of travel

$OLTMC_{(ij)klm}$ = effect of the m-th direction of travel of the l-th movement type in the k-th occurrence of interchange at the i-th location and the j-th crossroad type, NID (o, σ^2_{omc})

D_n = effect of the n-th distance (fixed)

LD_{in} = effect of the interaction of the i-th location with the n-th distance

TD_{jn} = effect of the interaction of the j-th crossroad type with the n-th distance

LTD_{ijn} = effect of the interaction of the i-th location with the j-th crossroad type with the n-th distance

$OLTD_{(ij)kn}$ = effect of the n-th distance in the k-th occurrence of interchange at the i-th location of the j-th crossroad type, NID (o, σ^2_{od})

MD_{ln} = effect of the interaction of the l-th movement type with the n-th distance

LMD_{iln} = effect of the interaction of the i-th location with the l-th movement type with the n-th distance

TMD_{jln} = effect of the interaction of the j-th location with the l-th movement type with the n-th distance

$LTMD_{ijln}$ = effect of the interaction of the i-th location with the j-th crossroad type with the l-th movement type with the n-th distance

$OLTMD_{(ij)kln}$ = effect of the n-th distance of the l-th movement type in the k-th occurrence of interchange at the i-th location and j-th crossroad type, NID (o, σ^2_{omd})

CD_{mn} = effect of the interaction of the m-th direction of travel with the n-th distance

LCD_{imn} = effect of the interaction of the i-th location with the m-th direction of travel with the n-th distance

TCD_{jmn} = effect of the interaction of the j-th crossroad type with the m-th direction of travel with the n-th distance

$LTCD_{ijmn}$ = effect of the interaction of the i-th location with the j-th crossroad type with the m-th direction of travel with the n-th distance

$OLTCD_{(ij)kmn}$ = effect of the n-th distance of the m-th direction of travel in the k-th occurrence of interchange at the i-th location and j-th crossroad type, NID (o, σ^2_{ocd})

MCD_{lmn} = effect of the interaction of the l-th movement type with the m-th direction of travel with the n-th distance

$LMCD_{ilmn}$ = effect of the interaction of the i-th location with the l-th movement type with the m-th direction of travel with the n-th distance

$TMCD_{jlmn}$ = effect of the interaction of the j-th crossroad type with the l-th movement type with the m-th direction of travel with the n-th distance

$LTMCD_{ijlmn}$ = effect of the interaction of the i-th location with the j-th crossroad type with the l-th movement type with the m-th direction of travel with the n-th distance.

$OLTMCD_{(ij)klmn}$ = within error or split split split plot error of the n-th distance of the m-th direction of travel of the l-th movement type in the k-th occurrence of interchange at the i-th location and the j-th crossroad type NID (o, σ^2_{omcd})

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