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16. Abstract

Pavement markings are an important part of the traffic control system, especially on rural two-lane roadways where these treatments often are the major traffic control measure. Compared to other types of longitudinal markings, the effect of edge lines on safety and driver behavior has been much less investigated. However, such markings may have a positive impact on the reduction of crashes on two-lane rural roads, as well as on the general comfort level of driving.

This study compiled an inventory of rural two-lane highways under the operation of the Texas Department of Transportation (TxDOT), investigated typical dimensions and characteristics of such roadways, and utilized this information to perform a detailed accident statistic analysis.

Crash statistics comparisons were made for highways with and without edge lines. In addition to general accident frequency analysis, varying traffic lane and shoulder widths, and roadway curvature, factors such as accident type, intersection presence, light condition, surface condition, crash-supporting factors, severity, driver age, and driver gender were considered.

The research found that edge-line treatments on rural two-lane roadways may reduce accident frequency up to 26 percent and the highest safety impacts occur on curved segments of roadways with lane widths of 9 to 10 feet. In addition, edge-line presence shows some positive safety impact in reducing speeding-related accidents during darkness that may be related to better driver path and speed perception.

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SAFETY IMPACT OF EDGE LINES ON RURAL TWO-LANE HIGHWAYS

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Products

This report contains product P1 “Texas Rural Two-Lane Roadways Inventory” whose structure is described in Chapter 2 and the complete inventory can be found on the attached CD.

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1. Edge-Line Pavement Markings on Rural Two-Lane Roadways

1.1 Introduction

In the United States, two-lane rural roads account for 629,309 miles, or almost 90 percent of the rural highway system. As highway travel demand grows and funding for new road capacity dwindles, the two-lane highway network may become even more important in several ways.

Current traffic volumes on many rural segments are very small while volumes on urban segments are large and growing. Scarce maintenance funds have been traditionally allocated to highways with large and growing traffic demands which represent a small fraction of the highway system. Thus, rural highways, representing the largest fraction of the total system, are viewed by some as a problematic drain on available maintenance resources. Maximization of the effectiveness of all rural highway maintenance expenditures is therefore very important. This project is charged with the task of determining the cost-effectiveness of edge-line pavement markings on rural two-lane highways.

Clearly, if safety benefits of edge-line pavement markings can be identified as significant, the cost-effectiveness could be easily demonstrated. Crashes on rural two-lane roads continue to be a concern. According to data from the Fatality Analysis Reporting System, in 1998 in the United States, more than 20,000, or almost 50 percent of the nation's 41,471 fatalities, occurred on such roads (Ref 1).

Narrow width of traffic lanes and shoulders, no separation between opposing traffic, and small radius horizontal curves are the major design features affecting accident occurrence on these roads. Zegeer's model for accident prediction on two-lane roads showed that widening traffic lanes, in addition to paving and widening shoulders, should reduce the number of related accidents by 22 percent (Ref 1). Studies indicate that accident rates for curves range from 1.5 to 4 times those of similar tangent sections (Ref 2). The United States' studies of the safety effects of different curve improvements indicated the following crash reductions (Ref 3):

- Increasing curve radius reduces crash frequency by as much as 80 percent, depending on the central angle and amount of flattening.
- Widening lanes on horizontal curves may reduce accidents by up to 21 percent.
- Widening paved shoulders can reduce accidents by as much as 33 percent.

The above-mentioned studies are only a few examples of numerous research results that show effectiveness of geometric design improvements for accident reduction on two-lane roads. However, limited resources, constraints due to right-of-way, and environmental features often restrict the highway designer's ability to develop geometric designs that exceed minimum design standards. Therefore, traffic control treatments may have a great potential for safety improvements on these roads. One such treatment is edge-line pavement marking.

1.2 General Functions of Pavement Markings

Pavement markings have definite functions in a proper traffic control system. They are applied for the purposes of regulating and guiding the movement of traffic and promoting safety. They provide effective means of conveying certain regulations, warnings, and information in clearly understandable terms, without diverting the driver's attention from the roadway. Markings are classified into the following types:

- *Longitudinal Markings* typically include pavement centerlines, lane-separation lines, pavement-edge lines, no passing zone markings, and turning-lane lines at intersections.
- *Transverse Markings* are mostly stop lines at intersections. Other applications of transverse pavement markings are to alert drivers of an upcoming change or hazard in the roadway.
- *Message Markings* include words, symbols, and arrows.
- *Miscellaneous Markings* include curb painting, parking stall markings, and road grade crossing.
- *Object Markings* include markings for highlighting obstacles near the roadway.

One of the most important marking families is longitudinal markings that help control lateral position of vehicles on the roadway, channel traffic into proper roadway positions, and separate opposing streams of traffic. Depending on the applications, these markings include:

- *Centerlines* divide a roadway between opposing flows.
- *Lane Lines* separate adjacent traffic lanes in the same direction.
- *No-Passing Zones Lines* are used at vertical and horizontal curves and at other locations where passing sight distance is restricted or other hazardous conditions exist.
- *Pavement-Edge Lines* delineate roadway edges.

Figure 1.1 represents a typical application of longitudinal pavement markings on two-lane roadways.

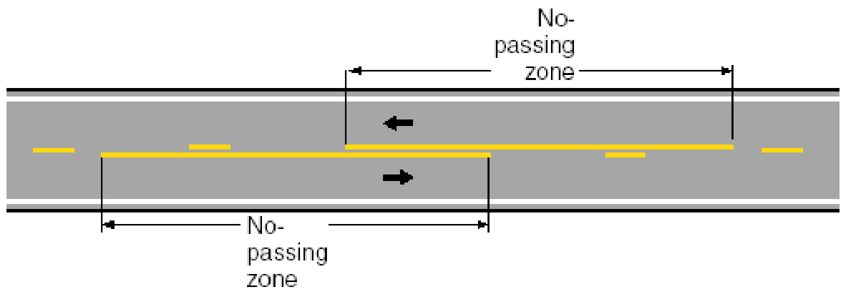


Figure 1.1 Typical Two-Way Two-Lane Marking with No-Passing Zones

Corresponding with the Manual on Uniform Traffic Control Devices (MUTCD), the widths and patterns of longitudinal lines shall be as follows:

- A normal line is 100 to 150 mm (4 to 6 in.) wide.
- A wide line is at least twice the width of a normal line. The width of the line indicates the degree of emphasis.
- A double line consists of two parallel lines separated by a discernible space.
- A broken line consists of normal line segments separated by gaps.
- A dotted line shall consist of noticeably shorter line segments separated by shorter gaps than used for a broken line.
- The width of a dotted line shall be at least the same as the width of the line it extends.

Compared to the first three types of longitudinal markings, the effect of edge-line pavement markings on safety and driver behavior has been much less investigated. However, such markings may have a positive impact on the reduction of crashes on two-lane rural roads, as well as on the general comfort level of driving.

1.3 Operational and Safety Effects of Edge-Line Pavement Markings

The effect of pavement edge marking on the lateral placement of vehicles was most intensively investigated in the 1950s and early 1960s (Refs 4, 5, 6). Studies performed in the United States showed that on two-lane tangent sections of 24- and 20-foot pavement width, a continuous edge line resulted in moving traffic closer to the centerline of the pavement, and this effect was much more significant at night.

This tendency was also observed in the situation of meeting vehicles. Both passenger cars meeting passenger cars and passenger cars meeting commercial vehicles had less clearance between the passing vehicles after the continuous line had been installed. At the same time, greater distance was observed between vehicles meeting at night than those meeting in the daytime.

The effect of a continuous edge line on curved highway sections was also to move traffic closer to the centerline.

Based on these results in the 1960s, it was recommended to apply pavement edge markings on all 24-foot (7.3 m) two-lane highways, but not on two-lane highways narrower than 24 feet (7.3 m). It was noted that the need for edge markings varies with adequacy of the shoulder. Absence of an adequate shoulder (either none at all, one less than 8 feet [2.4 m] wide, or one which is unsurfaced) suggests the need for an edge line.

Currently the MUTCD requires the application of edge-line markings on "rural arterials and collectors with a traveled way of 6.1 m (20 ft) or more in width and average annual daily traffic volume (AADT) of 3,000 vehicles per day or greater" (Ref 7).

European research tends to indicate that when edge-line markings were implemented on rural two-lane roads, vehicles moved closer to the right edge (Refs 8, 9, 10).

The reviewed literature does not provide clear conclusions regarding the apparent contradiction between data from Europe and the United States as a result of limited descriptions of observed road parameters. Considering that in the 1960s when the main studies were conducted, the majority of rural two-lane roads in the United States rarely had shoulders, while in Europe many similar roads were designed with at least 1 meter (3 ft) shoulders, one might hypothesize that opposite impacts of edge lines were caused by this design difference. It may also be an effect of vehicle dimensions which were larger in the United States than in Europe.

The United States' investigations of speed before and after edge-line implementation showed that after implementation of pavement edge lines, the daytime average speed increased 4.1 mph (6.6 km/h) and the night-time average speed increased 6.5 mph (10.5 km/h) (Ref 5). Average speeds at night were consistently less than daytime average speeds; however, after painting of the pavement edge line, the speed differential between night and day speeds was reduced from 4.1 to 1.7 mph (6.6 to 2.7 km/h). Therefore, edge markings appear to have some influence on operating speeds, which can be explained by the hypothesis that drivers perceive traffic conditions as safer due to delineation of the pavement edge (Ref 5).

Studies of accident statistics before and after pavement edge-line placement on two-lane rural roads have produced many contradictory results; however some conclusions are consistent across multiple studies. The significant conclusions from these are as follows (Ref 5, 6, 8, 9, 10, 11):

- On two-lane rural roads with a paved surface of at least 20 foot (6.1 m) width, the use of pavement edge marking resulted in a significant reduction in fatality and injury-causing accidents. Different studies indicated around 20 percent reduction in total accidents, around 25 percent reduction in the number of personal injuries, and from 37 to 59 percent reduction in fatalities.
- Accidents at intersections, alleys, and driveways were significantly reduced (from 46 to 63 percent), but accidents between access points showed no significant change. To explain these findings, it has been suggested that pavement edge markings encourage drivers to look farther ahead and thus become aware of vehicles about to enter or leave the highway at points of access. Another explanation is that the gap in edge markings at intersections makes drivers aware that there is an intersection ahead.
- Night accidents were reduced, but the change was marginal as far as statistical significance is concerned. At the same time many researchers noted that an outer edge line provides pavement delineation and a point for a driver to focus his eyes when faced with oncoming headlights.
- The various types of collisions showed no significant change except for angle collisions at intersections, which showed reduction from 60 to 80 percent. Some studies indicated also a reduction of run-off-the-road crashes around 30 percent during the day and around 50 percent at night.
- An edge line along roadways where pedestrians must use shoulders because of the absence of sidewalks offers additional security to both pedestrians and drivers, providing an area for pedestrians to walk and at the same time delineating the limits of the traveled roadway for drivers.

2. Texas Rural Two-Lane Roadways

Because the impact of edge lines on traffic operation and safety can vary on different highway sections depending on roadway parameters, the first step of the present study was to collect information regarding existing rural two-lane roads maintained by the Texas Department of Transportation (TxDOT), including typical dimensions, and identify highway sections with currently-implemented edge lines. The major criteria for roadway classification included traffic lane and shoulder widths, traffic volumes, and numbers of horizontal curves and their radii.

2.1 Texas Reference Marker System (TRM)

The TRM system documents the entire state-maintained highway network of on-system roadways in Texas. The TRM databases contain administrative responsibilities, classifications assigned by federal or state authorities, mileage, roadbed properties, and geometric information for every segment of every highway in the network.

Each highway is broken into segments that are located via a reference marker system. As shown in Figure 2.1, reference markers run from state line to state line and increase from west to east and north to south, depending on the highway's general direction. Numbers are placed by imposing a grid on the map of Texas and numbering the extreme western and northern points as ten, with subsequent markers increasing by two. Reference numbers do not start over at county lines, and are continuous across the state. Roadway segments and features can be located on a roadway with a given reference marker number and a positive or negative displacement from the marker.

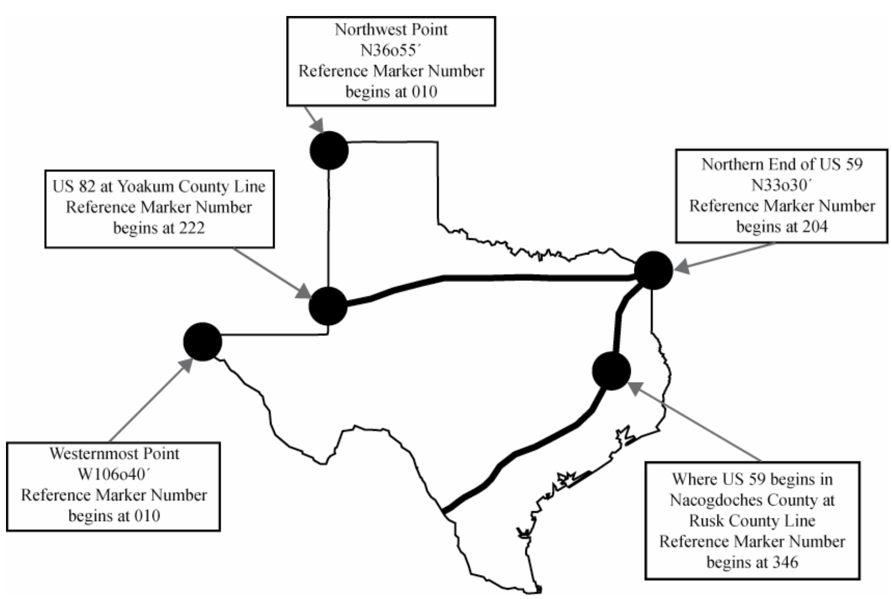


Figure 2.1 Reference Marker Example

Contained within the TRM system are two databases: the End-of-Year (EOY) database and the Geometrics (GEO-HINI) database.

The TRM EOY database contains roadway lengths, roadbed configurations, average annual daily traffic volume AADT information, as well as administrative responsibilities and federal and state classifications for all roadways. Highways are divided into sections based on uniformity of lane width, shoulder width, and AADT. Sections may also be created where major features exist, such as intersections or extensive construction zones.

The TRM GEO-HINI database contains geometrics for all curves on all highways in the state. Each curve is given a unique curve identifier number, and the beginning and end of each curve is located through a given reference marker and displacement from that marker.

The GEO-HINI database classifies curves into three types, based on the number of points required to define the curve. Curve type values are:

- Point Curve is a change in direction at 1 point.
- Normal Curve is a change in direction at 2 points.
- Spiral Curve is a change in direction at 3 or 4 points.

A point curve documents the point of intersection of two straight route segments and the angle of change that occurs there. Point curves have an angle of change, but no given length.

A normal curve defines a stretch of roadway that curves at a constant rate. For normal curves, the GEO-HINI database gives curve length, degree of curvature, delta degree (change in direction at the point of intersection), and tangent lengths.

Spiral curves consist of a normal curve segment with a varying rate curve at one or both ends. A spiral curve with only one varying rate segment is defined by three points, while a spiral curve with a varying rate segment at both ends is defined by four points. The GEO-HINI database documents spiral curve length, degrees of curvature, delta degrees, and tangent lengths for the varying and constant rate curve segments. Spiral curves occur very infrequently on the two-lane rural roads contained in the TRM database.

Both databases are in basic flat file format where each row contains a roadway section or curve in the EOY and GEO-HINI databases respectively. Each column contains a number or letter combination to represent a roadway characteristic for the corresponding section or curve. The TRM databases contain a wealth of information ranging from lane and shoulder widths to road surface types and load limits. Detailed descriptions of the TRM EOY and GEO-HINI file formats are shown in Appendix A.

2.2 Texas Rural Two-Lane Roadways Inventory (TRTI)

The TRM databases contain data for every state-maintained roadway in Texas, but this study focuses only on two-lane, undivided rural highways. Accordingly, the TRM database received from TxDOT by the Center for Transportation Research (CTR) only contained two-lane, undivided rural highways. The database prepared by TxDOT eliminated roads if they did not meet the following criteria as given by the CTR research team: number of through lanes equal to two, median width equal to zero, and a rural-urban code equal to one, meaning that all roadways in cities with population greater than 5000 were eliminated. The resulting database contains 57,367 miles of roadway on 4,041 highways divided into almost 50,000 road sections with over 70,000 curves. The inventory is separated by TxDOT district using ID values as defined in Table 2.1.

Table 2.1 TxDOT District ID Values

Value	District	Value	District
01	Paris (PAR)	13	Yoakum (YKM)
02	Fort Worth (FTW)	14	Austin (AUS)
03	Wichita Falls (WFS)	15	San Antonio (SAT)
04	Amarillo (AMA)	16	Corpus Christi (CRP)
05	Lubbock (LBB)	17	Bryan (BRY)
06	Odessa (ODA)	18	Dallas (DAL)
07	San Angelo (SJT)	19	Atlanta (ATL)
08	Abilene (ABI)	20	Beaumont (BMT)
09	Waco (WAC)	21	Pharr (PHR)
10	Tyler (TYL)	22	Laredo (LAR)
11	Lufkin (LFK)	23	Brownwood (BWD)
12	Houston (HOU)	24	El Paso (ELP)
		25	Childress (CHD)

The EOY database supplied information for roadway lengths, lane widths, shoulder widths, and AADT statistics, while the GEO-HINI database supplied all curve data. Lane widths were calculated based on surface widths from the EOY database. As shown in Figure 2.2, the TRM definition of surface width is the combined width of the main lanes not including shoulder widths. As a result, lane width is equal to half the surface width, assuming that lane widths are equal in both travel directions. In cases where surface width is an odd number, thus resulting in a non-integer lane width, the lane width is rounded down to the nearest whole number.

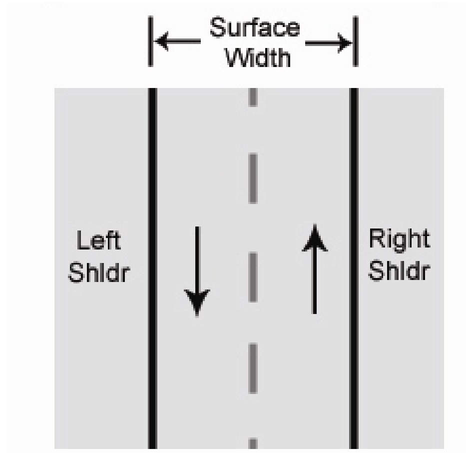


Figure 2.2 TRM Surface Width Definition

The EOY database gives both right and left shoulder widths. As shown in Figure 2.3, for a two-lane road the right shoulder width is on the right-hand side when traveling in ascending reference marker direction (east to west or north to south). Within each district, centerline mileages are given for sections where left and right shoulder widths are equal.

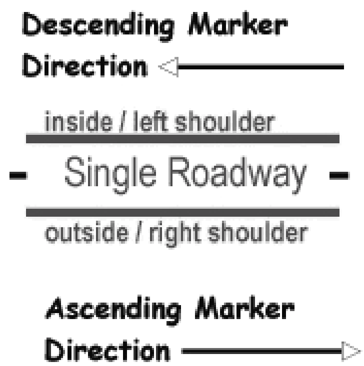


Figure 2.3 TRM Shoulder Definition

AADT statistics were calculated from data in the EOY database. The TRTI gives average AADT, 15^{th} and 85^{th} percentile AADT, and standard deviation for AADT for all lane width and shoulder width combinations.

Curvature statistics were calculated using the GEO-HINI database. For each lane width and shoulder width pair, the number of point curves, normal curves, and spiral curves per mile was calculated. Point curves were separated into two groups by delta angle: curves with a delta angle less than or equal to 10 degrees are likely to not be perceived as a curve by the driver, while those with a delta angle greater than 10 degrees are usually perceived as curves and usually are abrupt, 90-degree changes in direction that occur due to property lines, cemeteries, or other obstructions. For normal curves, average, 15th, and 85th percentile radii statistics are given. Due to the small number of spiral curves found on rural two-lane highways, radii statistics were omitted for spiral curves.

Edge marking data was obtained from a TxDOT district survey conducted for TxDOT project 0-4965 (Rural Two-Lane Roadway Crash Analysis) by CTR and Texas Transportation Institute (TTI) under supervision of Dr. Kara Kockelman, Danny Morris, and Dr. John Mounce.

Another source for edge striping information was the right-of-way (ROW) image database supplied by TxDOT. As demonstrated in Figure 2.4, the ROW image database provides still images on state-maintained highways at 500-foot intervals, and these images are documented via the TRM system. Images in the ROW database are organized by county and highway number.

Figure 2.4 ROW Image Example

The TxDOT district survey contained 56,525 miles of two-lane, rural roadways and edge striping information for all but 4,605 miles of such highways. Use of the ROW image database allowed determination of the edge line status for 4,365 of the 4,605 missing miles. This resulted in a final total of 56,285 miles of two-lane rural roadways with edge striping information, but this was still 1,080 miles (2 percent) short of the 57,367 miles of highways found in the TRM EOY database. However, most of this unknown mileage (791 miles) was on highways located in the Pharr district, which had no information available from the edge striping database.

The small remaining discrepancy between the two databases of 289 miles, or less than 1 percent, could be caused by a number of factors, most notably the fact that the edge striping database was wholly compiled in late 2004 but the TRM EOY database, while officially compiled in 2003, probably still contains some amount of outdated information. Given the constant growth of urban areas in Texas, there is a high probability that some highways designated as rural in the TRM database are now located in urban areas, which would result in a smaller mileage of roads in the edge striping database.

Another concern with the edge striping information is that the quality of the edge line is not taken into consideration. Highways may be designated as having edge lines even though those lines are worn due to lack of maintenance and therefore provide little benefit to the driver.

The collected data were combined into a separate database named the Texas Rural Two-Lane Roadways Inventory (TRTI). The inventory was prepared in Microsoft Excel spreadsheet format, is separated into worksheets by TxDOT districts, and is organized correspondingly with Table 2.2.

The complete inventory is attached to the present report on CD.

Table 2.2 TRTI Organization

Header Name	Column Name		Column Position	Definition
Highway Mileage	*LW*		*A*	Lane width in feet; values of 6, 8, 9, 10, 11, 12, 13, 14, and 15 feet or greater
	CLM		*B*	Center-line mileage with lane width equal to specified lane width in column A
	SW		*C*	Shoulder width in feet; ranges from 0 to 15 and greater
	CLM		*D*	Center-line mileage with shoulder widths specified in column C for the lane width specified in column A
Edge Line Presence	*Yes*	*CLM*	*E*	Center-line mileage with edge lines on highways with specified lane widths (column A) and shoulder widths (column C)
		Percent	*F*	Center-line mileage with edge lines on highways with specified lane widths (column A) and shoulder widths (column C) as a percentage of total center-line mileage given in column D
	No	*CLM*	*G*	Center-line mileage without edge lines on highways with specified lane widths (column A) and shoulder widths (column C)
		Percent	*H*	Center-line mileage without edge lines on highways with specified lane widths (column A) and shoulder widths (column C) as a percentage of total center-line mileage given in column D
AADT*	*AADT Mean*		*I*	Mean average annual daily traffic volume, vehicles per day (vpd)
	AADT SD		*J*	Average annual daily traffic volume standard deviation, vpd
	AADT 15%		*K*	Fifteenth percentile average annual daily traffic volume, vpd
	AADT 85%		*L*	Eighty-fifth percentile average annual daily traffic volume, vpd
Curves*	*Point ≤ 10˚*	*No.*	*M*	Total number of point curves with change in direction at the point of tangency less than or equal to 10 degrees
		No. / Mile	*N*	Number of point curves per mile with change in direction at the point of tangency less than or equal to 10 degrees
	Point > 10˚	*No.*	*O*	Total number of point curves with change in direction at the point of tangency greater than 10 degrees
		No. / Mile	*P*	Number of point curves per mile with change in direction at the point of tangency greater than 10 degrees
	*Normal***	*No.*	*Q*	Total number of normal curves
		No. / Mile	*R*	Number of normal curves per mile
		Mean Rad.	*S*	Mean normal curve radius, ft
		15% Rad.	*T*	Fifteenth percentile normal curve radius, ft
		85% Rad.	*U*	Eighty-fifth percentile normal curve radius, ft
	Spiral	*No.*	*V*	Total number of spiral curves
Highway Name	*HW*		*W-IQ*	List of highways that have at least one section with lane widths specified in column A and shoulder widths specified In column C

*Values calculated in columns I through V represent summaries for all sections with specified lane and shoulder widths (columns A and C)

** Mean, 15th percentile, and 85th percentile normal curves radius statistcs were calculated only for curves with radii less than 5000 feet

2.3 Characteristics of Rural Two-Lane Highways in Texas

The developed inventory allows for description of the distribution of roadway characteristics including lane widths, shoulder widths, AADT, horizontal curvature, and edge striping on the Texas rural two-lane highway system. Detailed representations of different roadway characteristics were conducted for each TxDOT district and are included as a part of the inventory. The present chapter summarizes the obtained findings.

As a first step, the general distribution of two-lane rural highways by district was compiled, as represented in Table 2.3.

Table 2.3 Two-Lane Rural Road Mileage by District

District ID	District Name	Total Mileage
1	Paris (PAR)	2662
2	Fort Worth (FTW)	1954
3	Wichita Falls (WFS)	2300
4	Amarillo (AMA)	3080
5	Lubbock (LBB)	4141
6	Odessa (ODA)	2202
7	San Angelo (SJT)	2767
8	Abilene (ABI)	2812
9	Waco (WAC)	2660
10	Tyler (TYL)	2873
11	Lufkin (LFK)	2451
12	Houston (HOU)	1053
13	Yoakum (YKM)	2967
14	Austin (AUS)	1971
15	San Antonio (SAT)	2545
16	Corpus Christi (CRP)	2024
17	Bryan (BRY)	2474
18	Dallas (DAL)	1700
19	Atlanta (ATL)	1989
20	Beaumont (BMT)	1666
21	Pharr (PHR)	1416
22	Laredo (LAR)	1826
23	Brownwood (BWD)	2330
24	El Paso (ELP)	1279
25	Childress (CHD)	2226

Further conducted analysis studies the representation of roadway characteristics on rural two-lane highways.

2.3.2 Lane and Shoulder Widths

The summary of all two-lane rural highways in the state classified by lane widths, shown in Figure 2.5, reveals that most such roadways have lane widths of 10 or 12 feet. Of the 57,367 miles of two-lane rural highways in Texas, over 38 percent, or 22,134 miles, have 10-foot lane widths while 32 percent, or 18,243 miles, have 12-foot lane widths. Lane widths of 9, 11, and 13 feet account for 5,516, 5,090, and 5,149 miles, or 10, 9, and 9 percent of total highway mileage respectively. Lane widths less than 9 or greater than 13 feet make up the remaining 2 percent of the total.

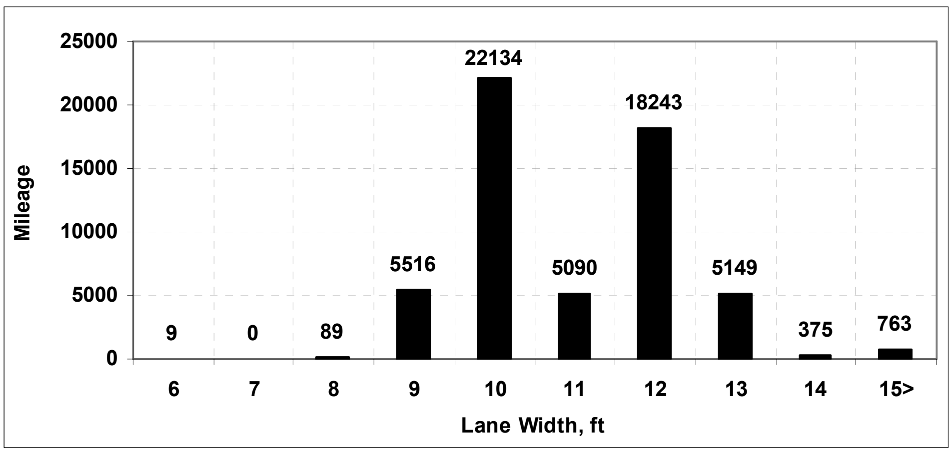


Figure 2.5 Two-Lane Rural Road Mileage by Lane Width

Most districts follow the state-wide lane width trends with the majority of roads having 10-foot or 12-foot lane widths. However, a few notably outstanding districts exist:

- The Odessa and Houston districts have an abnormally large fraction of roads with 12-foot lane widths. Seventy-two percent of rural two-lanes in the Odessa district and 68 percent of rural two-lanes in the Houston district have lane widths of 12 feet.
- Thirty-three percent of rural two-lanes in the Dallas district have 11-foot lane widths, while only 22 percent have 10-foot lane widths.
- The Beaumont district contains a large percentage of roads with lane widths of 9 or 13 feet. Thirty-five percent of rural two-lanes have 9-foot or 13-foot lane widths.

Throughout the state, 763 miles, or 1.3 percent of all rural two-lane roadways have lane widths equal to or greater than 15 feet. Such lane widths seem unrealistic for rural two-lane roads. Thus, lane widths greater than or equal to 15 feet were assumed to be errors in the TRM database. Likewise, shoulder widths equal to or greater than 15 feet were also assumed to be incorrect. For the 56,132 miles of roadway with lane widths of 9, 10, 11, 12, or 13 feet, only 8 miles, or 0.01 percent have a left or right shoulder width in the error range.

Because lane-width analysis revealed that 98 percent of all rural two-lane roadways have lane widths of 9 to 13 feet, detailed shoulder width analysis was only performed on these roadways and the results are represented in Figures 2.6, 2.7, and 2.8. Although left and right shoulder width can differ on a stretch of roadway, the analyzed databases show that this only occurs on 1.2 percent, or 680 miles of highway. These sections were grouped into a *non-equal* shoulder width category. Thus, all given centerline mileage statistics for shoulder width are for roadways with the same shoulder width on both sides of the road.

As shown in Figure 2.6, the data indicates that rural two-lane highways with the narrowest lane widths of 9 or 10 feet mostly have shoulder widths equal to or less than 4 feet. Of the 27,650 miles of such roadways, 41 percent of the centerline miles have a shoulder width equal to 4 feet and 88 percent have shoulder widths of 4 feet or less. For such highways, shoulder widths of 0, 1, 2 and 3 feet have a fairly even split of 14, 10, 10, and 13 percent respectively. Some notable outlying districts are:

- In the Abilene district, 95 percent of rural two-lane roads with 9- or 10-foot lane widths have no shoulders. Ninety-three percent of narrow two-lane roads in the Corpus Christi district have no shoulders.
- Seventy-five percent of the 457 miles of narrow two-lane roads in the Pharr district have no shoulders, while 20 percent have 6-foot shoulders.

Shoulder widths for lane widths of 11 and 12 feet show greater variance, as seen in Figure 2.7. For the 23,333 miles of such highways, 97 percent have shoulder widths equal to or less than 10 feet. However, no single shoulder width value holds a clear majority: shoulder width percentages range from 2 to 18 percent with the highest values of 18, 14, 13, and 11 percent for shoulder widths of 8, 6, 0, and 10 feet respectively. A few districts show outstanding statistics:

- In the Austin district, 26 percent of rural two-lane roads with 11-foot lane widths and 28 percent of rural two-lane roads with 12-foot lane widths have unequal shoulder widths.
- Of the 1,276 miles of rural two-lane roads with 11- or 12-foot lane widths in the Dallas district, 56 percent have no shoulders.

Rural two-lane highways with a wide lane width of 13 feet have an overwhelming majority of mileage with shoulder widths of 8 or 9 feet. As shown in Figure 2.8, 39 percent have 8-foot shoulder widths while 42 percent have 9-foot shoulders.

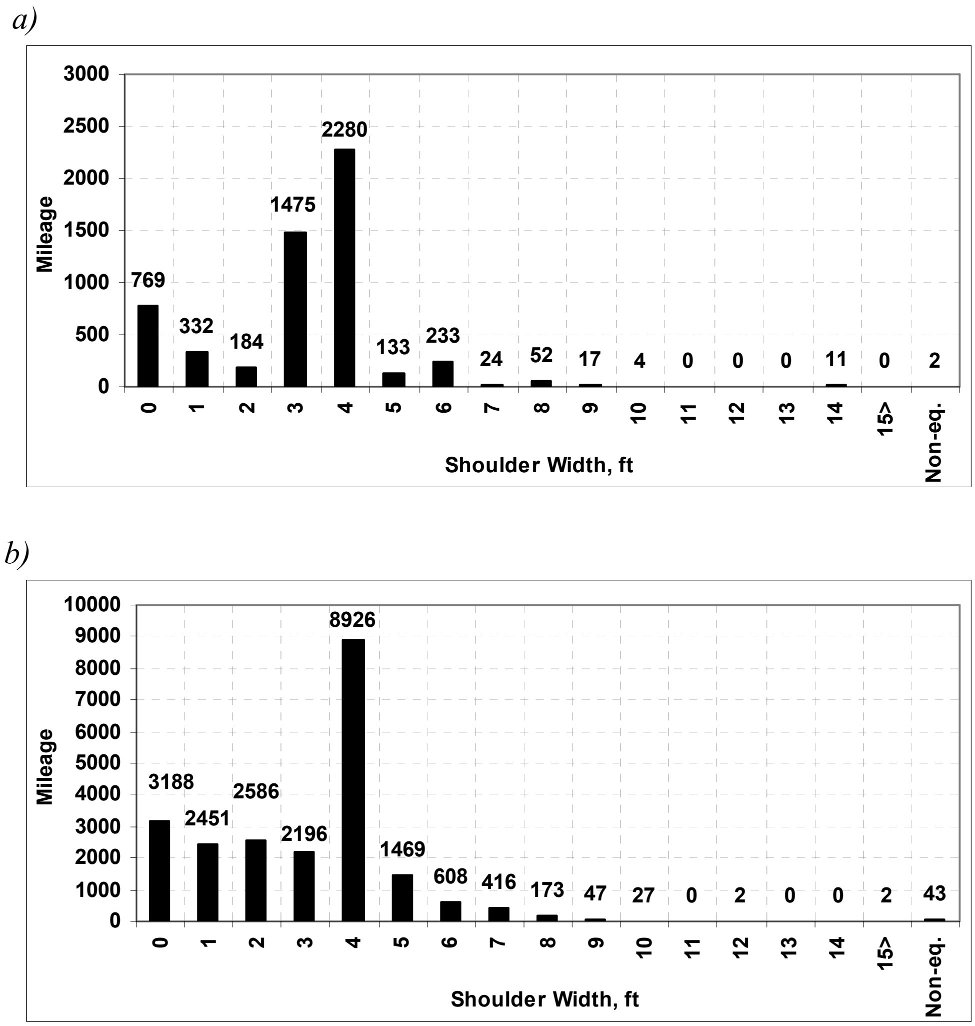
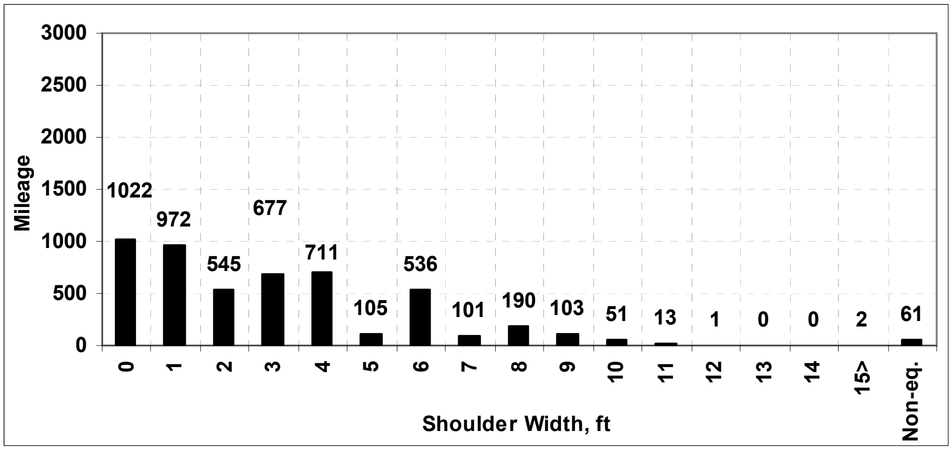


Figure 2.6 Rural Two-Lane Mileage by Shoulder Width (Narrow Lane Widths)
a) Lane Width of 9 ft b) Lane Width of 10 ft

a)



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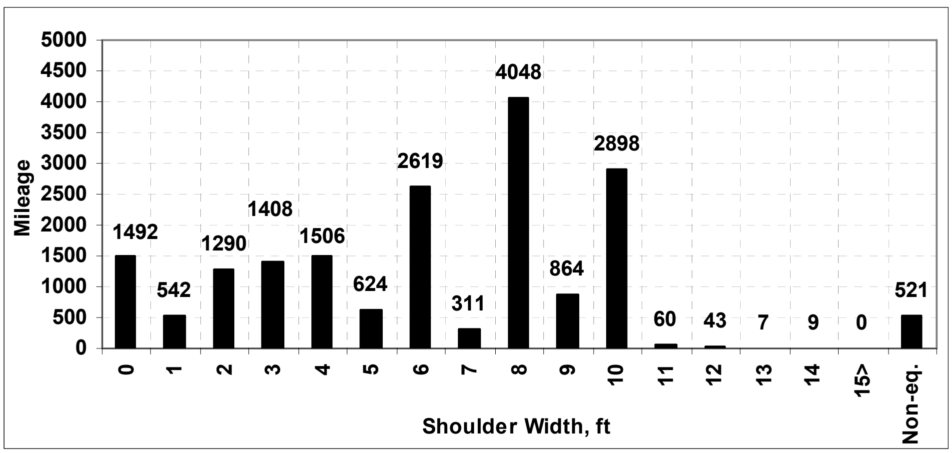


Figure 2.7 Rural Two-Lane Mileage by Shoulder Width (Medium Lane Widths)
a) Lane Width of 11 ft b) Lane Width of 12 ft

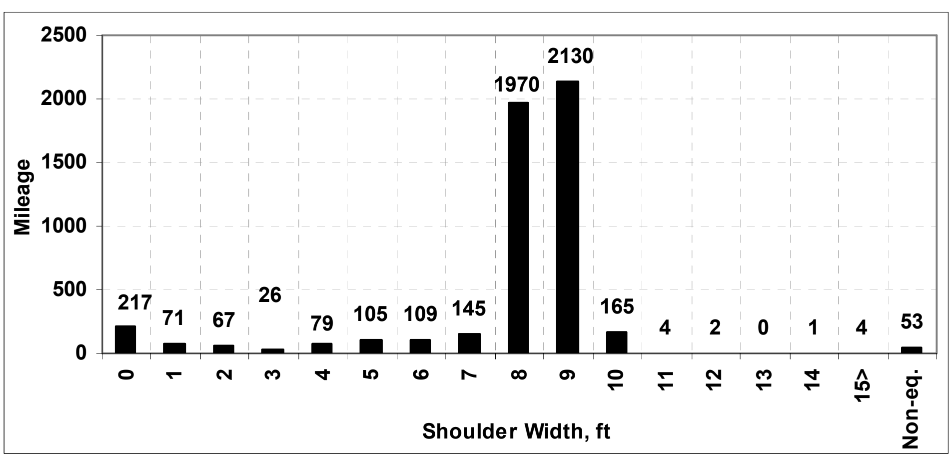


Figure 2.8 Rural Two-Lane Mileage by Shoulder Width (Lane Width of 13 ft)

2.3.3 Traffic Volume

Average annual daily traffic volume (AADT) analysis was performed for all rural two-lane roads. As shown in Table 2.4, average values range from 699 vehicles-per-day (VPD) in the Childress district to 5959 VPD in the Houston district. The Dallas, Houston, Ft. Worth, Pharr, Beaumont, and Tyler districts all have AADTs above 3000 VPD, while the Amarillo, Lubbock, Odessa, and Childress districts all have values below 1000 VPD.

Table 2.4 Average AADT by District

District ID	District Name	AADT (Average for District)	District ID	District Name	AADT (Average for District)
1	Paris (PAR)	2390	**14**	Austin (AUS)	2973
2	Fort Worth (FTW)	4177	**15**	San Antonio (SAT)	2986
3	Wichita Falls (WFS)	1474	**16**	Corpus Christi (CRP)	2275
4	Amarillo (AMA)	711	**17**	Bryan (BRY)	3070
5	Lubbock (LBB)	988	**18**	Dallas (DAL)	4502
6	Odessa (ODA)	702	**19**	Atlanta (ATL)	2671
7	San Angelo (SJT)	1287	**20**	Beaumont (BMT)	3160
8	Abilene (ABI)	1274	**21**	Pharr (PHR)	3880
9	Waco (WAC)	2261	**22**	Laredo (LAR)	2082
10	Tyler (TYL)	3096	**23**	Brownwood (BWD)	1613
11	Lufkin (LFK)	1779	**24**	El Paso (ELP)	1818
12	Houston (HOU)	5959	**25**	Childress (CHD)	699
13	Yoakum (YKM)	2361			

AADT data by lane width, shown in Figure 2.9, reveals that wider roadways are typically characterized by increased traffic volume, and this trend is seen in almost all districts. Any outlying districts are due to very small sample sizes for particular lane width values.

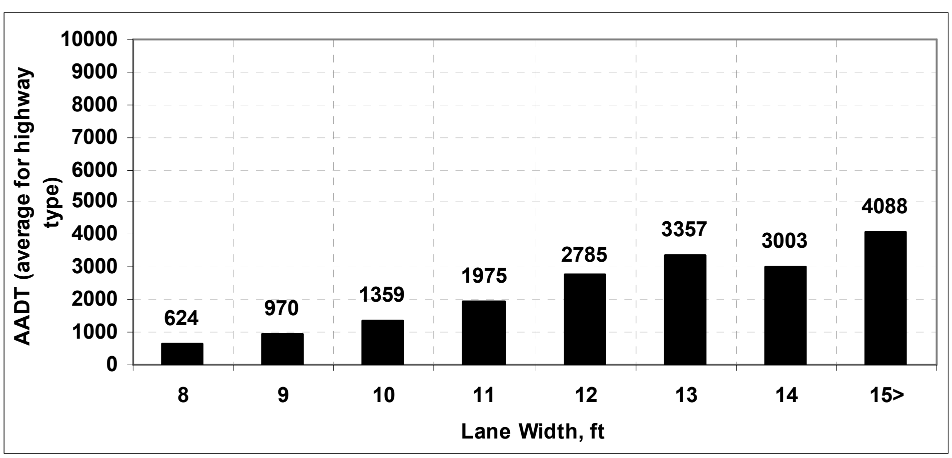
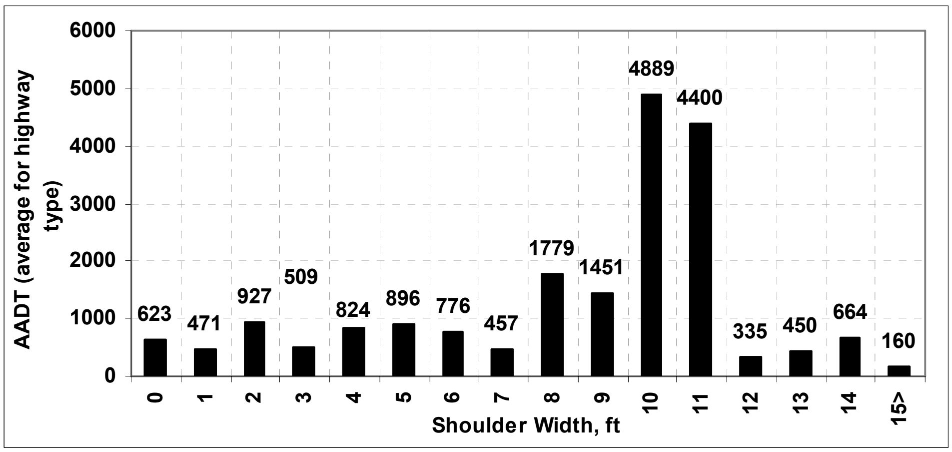


Figure 2.9 Two-Lane Rural Road AADT by Lane Width

Detailed AADT research was only performed on roadway sections with lane widths of 9, 10, 11, 12, and 13 feet. As shown in Figures 2.10, 2.11, and 2.12, highways with wider shoulders are typically characterized by the highest traffic volumes on narrow roadways with lane widths of 9, 10, and 11 feet while such a trend is not as evident on wider highways (12- and 13-foot lane widths). For narrow roadways, AADT shows limited variation on highways with shoulder widths up to 7 feet while sections with shoulder widths of 8 to 11 feet have significantly higher traffic volumes.

a)



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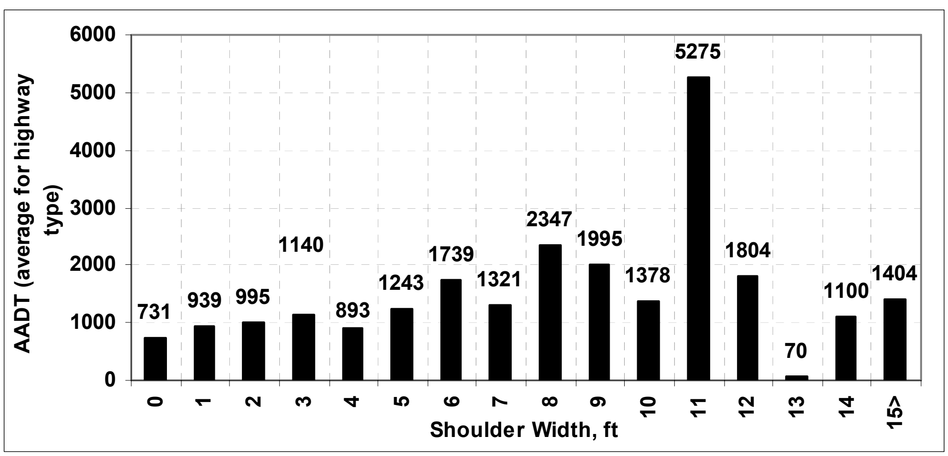
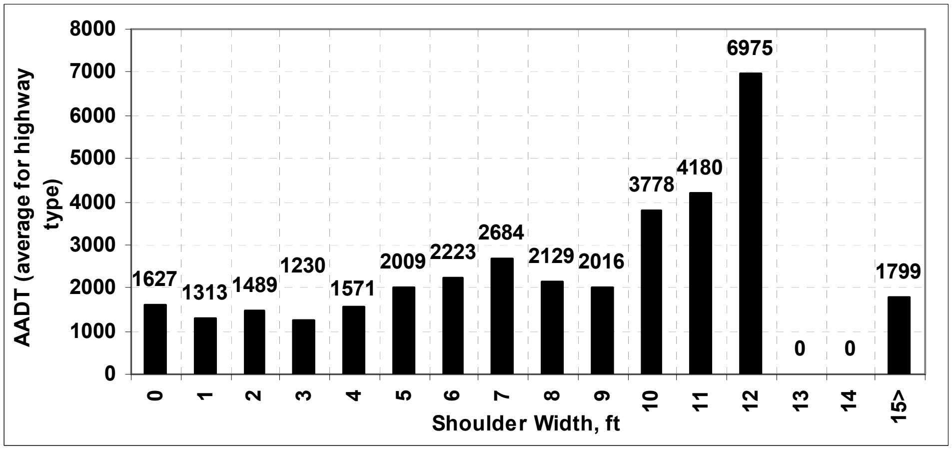


Figure 2.10 Rural Two-Lane AADT by Shoulder Width (Narrow Lane Widths)
a) Lane Width of 9 ft b) Lane Width of 10 ft

a)



b)

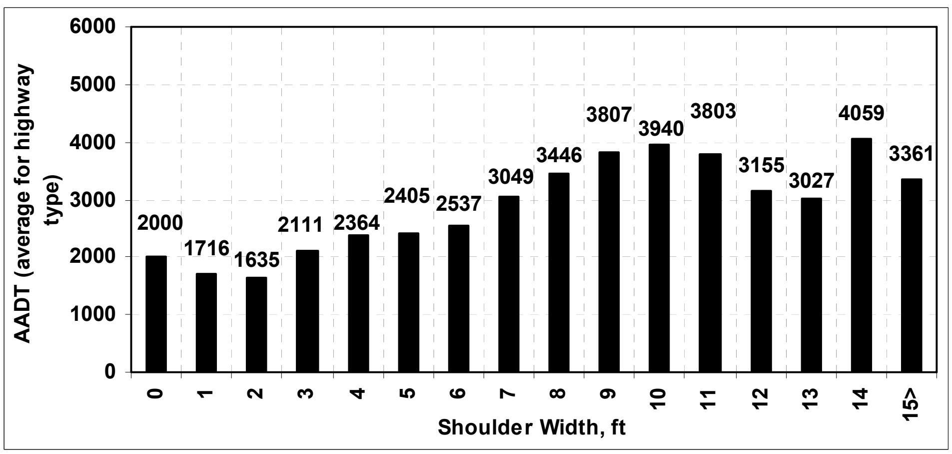


Figure 2.11 Rural Two-Lane AADT by Shoulder Width (Medium Lane Widths)
a) Lane Width of 11 ft b) Lane Width of 12 ft

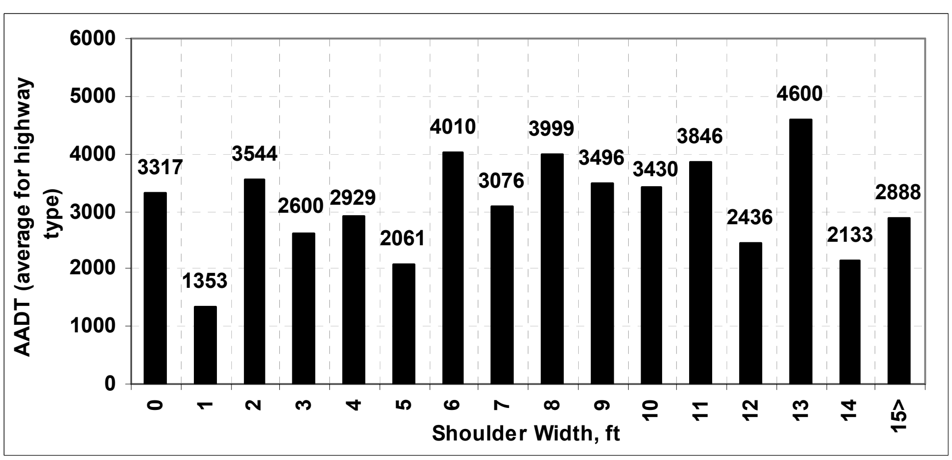


Figure 2.12 Rural Two-Lane AADT by Shoulder Width (Lane Width of 13 ft)

2.3.4 Roadway Curvature

The data indicated that *normal* curves (see Chapter 2.1) are the major curve type on rural two-lane highways accounting for 96 percent of all curves, and therefore detailed representation was investigated for such curves only. The number of normal curves per mile on rural two-lane highways of all lane widths and shoulder widths is shown in Table 2.5 separated by TxDOT district. The number of curves per mile varies among districts from 0.46, or approximately 1 curve every 2 miles, to 1.97, or almost 2 curves per mile.

Table 2.5 Number of Normal Curves per Mile by District

District ID	District Name	Normal Curves per Mile	District ID	District Name	Normal Curves per Mile
1	Paris (PAR)	1.39	**14**	Austin (AUS)	1.97
2	Fort Worth (FTW)	1.31	**15**	San Antonio (SAT)	1.07
3	Wichita Falls (WFS)	0.88	**16**	Corpus Christi (CRP)	0.98
4	Amarillo (AMA)	0.94	**17**	Bryan (BRY)	1.01
5	Lubbock (LBB)	1.16	**18**	Dallas (DAL)	1.30
6	Odessa (ODA)	1.07	**19**	Atlanta (ATL)	1.44
7	San Angelo (SJT)	1.03	**20**	Beaumont (BMT)	1.83
8	Abilene (ABI)	0.86	**21**	Pharr (PHR)	0.63
9	Waco (WAC)	0.98	**22**	Laredo (LAR)	0.46
10	Tyler (TYL)	1.02	**23**	Brownwood (BWD)	1.40
11	Lufkin (LFK)	1.04	**24**	El Paso (ELP)	1.19
12	Houston (HOU)	1.16	**25**	Childress (CHD)	0.64
13	Yoakum (YKM)	0.93			

Across all rural two-lane roads in the state, the average number of normal curves per highway mile is 1.11. The three highest normal curves per mile values, 1.97, 1.83, and 1.44, are found in the Austin, Beaumont, and Atlanta districts respectively. The three lowest values of 0.46, 0.63, and 0.64 normal curves per mile are in the Laredo, Pharr, and Childress districts.

Next, the number of normal curves per highway mile was studied by lane width state wide, as illustrated in Figure 2.13. On highways with lane widths of 9, 10, 11, 12, or 13 feet, the highest frequency of normal curves was observed on roadways with lane widths of 9 and 10 feet that average 1.63 curves per mile, while those with larger lane widths of 11, 12, and 13 feet average only 0.95 curves per mile.

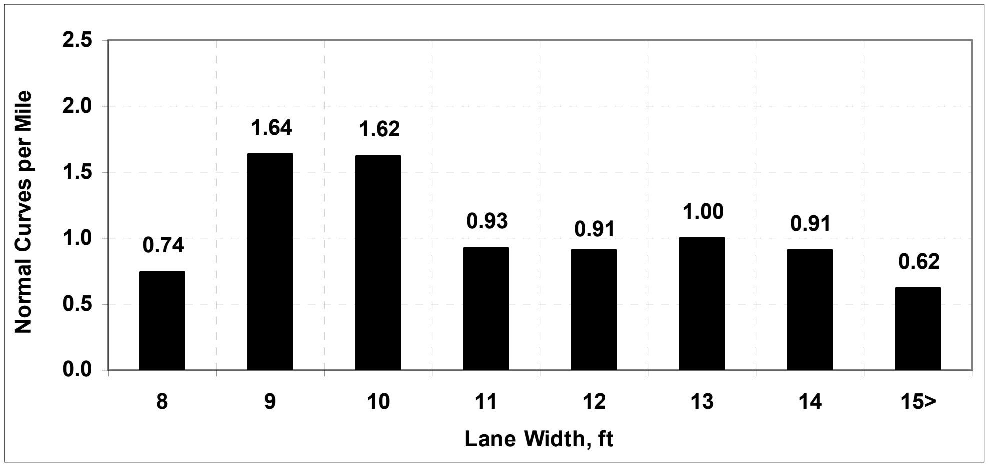


Figure 2.13 Number of Normal Curves per Mile for All Districts by Lane Width

In addition to curvature frequency, it is important to analyze curvature radii. The TRM GEO-HINI database shows that 67,070 normal curves exist across the state. However, information necessary to calculate curvature radius, by either degree of curvature or delta angle and tangent length, was absent from 3,692 curves (6 percent), and thus these curves could not be included in analysis. Further, exactly 5,768 curves (9 percent) contained conflicting data that led to significantly differing values when calculating curve radius via the degree of curvature or delta angle and tangent length methods. Therefore, these curves were also eliminated.

It was also found that 10,963 curves (16 percent) had calculated radii of 5,000 feet or greater. Given design characteristics of two-lane rural highways, curves with such radii seem unrealistically high. Even if by some reason such curves do exist, these curves can also be eliminated from analysis because numerous studies have shown that curves with such radii have no difference in operational and safety impacts compared to straight segments.

For the remaining 46,647 normal curves, average normal curve radius by district is shown in Table 2.6, and results by lane width statewide are shown in Figure 2.14.

Table 2.6 Average Normal Curve Radius by District

District ID	District Name	Average Normal Curve Radius, ft	District ID	District Name	Average Normal Curve Radius, ft
1	Paris (PAR)	1586	**14**	Austin (AUS)	2071
2	Fort Worth (FTW)	1703	**15**	San Antonio (SAT)	2157
3	Wichita Falls (WFS)	1794	**16**	Corpus Christi (CRP)	2162
4	Amarillo (AMA)	1812	**17**	Bryan (BRY)	2144
5	Lubbock (LBB)	1820	**18**	Dallas (DAL)	1316
6	Odessa (ODA)	2344	**19**	Atlanta (ATL)	1633
7	San Angelo (SJT)	1649	**20**	Beaumont (BMT)	1740
8	Abilene (ABI)	1582	**21**	Pharr (PHR)	1871
9	Waco (WAC)	1540	**22**	Laredo (LAR)	1800
10	Tyler (TYL)	2274	**23**	Brownwood (BWD)	1582
11	Lufkin (LFK)	2073	**24**	El Paso (ELP)	1482
12	Houston (HOU)	2283	**25**	Childress (CHD)	1699
13	Yoakum (YKM)	2278			

Average normal curve radius across all two-lane rural roads in the state is 1,856 feet. The four districts with highest normal curve average radius values, Odessa, Houston, Yoakum, and Tyler, all have averages over 2,200 feet (2,344, 2,283, 2,278, and 2,274 feet respectively) while the three lowest districts, Dallas, El Paso, and Waco, all have averages under 1,600 feet (1,316, 1,482, and 1,540 feet respectively).

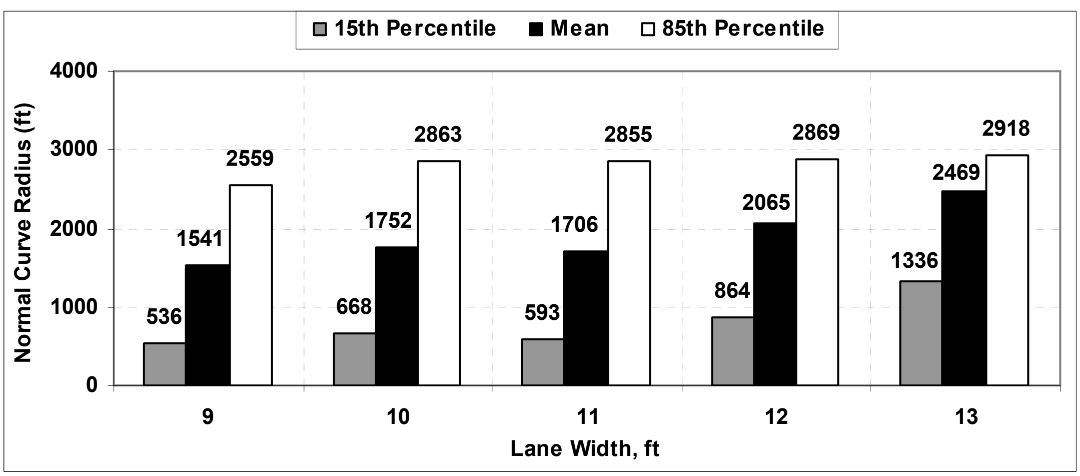


Figure 2.14 Normal Curve Radius Statistics by Lane Width

Average normal curve radius shows some correlation to lane width: as lane width increases from 9 to 13 feet, average radius increases from 1,541 to 2,469 feet or an increase of 60 percent. The smallest radii show some correlation to lane width as well. On average, for highways with lane widths of 9 to 11 feet, less than 15 percent of curves have a radius of 600 feet or fewer, while this value is 1,100 feet for wider highways of 12- and 13-feet lane widths. The large curve radii are distributed more uniformly across all observed roadway classes with the average 85^{th} percentile radius among all lane widths valued at 2,813 feet.

2.3.5 Edge Striping Results

Highway mileage with and without edge lines was studied for all districts and by varying lane widths and shoulder widths. Of all two-lane rural highways, 59.1 percent of total mileage is edge striped. Table 2.7 shows the percentage of highway mileage with edge lines by district:

Table 2.7 Edge Line Statistics by District

District ID	District Name	Mileage With Edge Lines	Percentage of Total Mileage with Edge Lines
1	Paris (PAR)	1381	51.9
2	Fort Worth (FTW)	583	29.8
3	Wichita Falls (WFS)	911	39.6
4	Amarillo (AMA)	1383	44.9
5	Lubbock (LBB)	2276	55.0
6	Odessa (ODA)	1935	87.9
7	San Angelo (SJT)	1677	60.6
8	Abilene (ABI)	1422	50.6
9	Waco (WAC)	1947	73.2
10	Tyler (TYL)	1363	47.4
11	Lufkin (LFK)	1662	67.8
12	Houston (HOU)	1016	96.5
13	Yoakum (YKM)	2429	81.9
14	Austin (AUS)	526	26.7
15	San Antonio (SAT)	1048	41.2
16	Corpus Christi (CRP)	1189	58.8
17	Bryan (BRY)	2047	82.7
18	Dallas (DAL)	1339	78.8
19	Atlanta (ATL)	1946	97.9
20	Beaumont (BMT)	1177	70.6
21	Pharr (PHR)	873	61.7
22	Laredo (LAR)	914	50.1
23	Brownwood (BWD)	1194	51.2
24	El Paso (ELP)	683	53.4
25	Childress (CHD)	960	43.1

The percentage of edge-striped highways varies greatly across the state: values range from 26.7 percent in the Austin district to 97.9 percent in the Atlanta district. The three highest districts are Atlanta, Houston, and Odessa with 97.9, 96.5, and 87.9 percent respectively, while the three lowest districts are Austin, Fort Worth, and Wichita Falls with 26.7, 29.8, and 39.6 percent respectively.

Figure 2.15 shows the percentage of total highway mileage with different lane widths treated by edge lines.

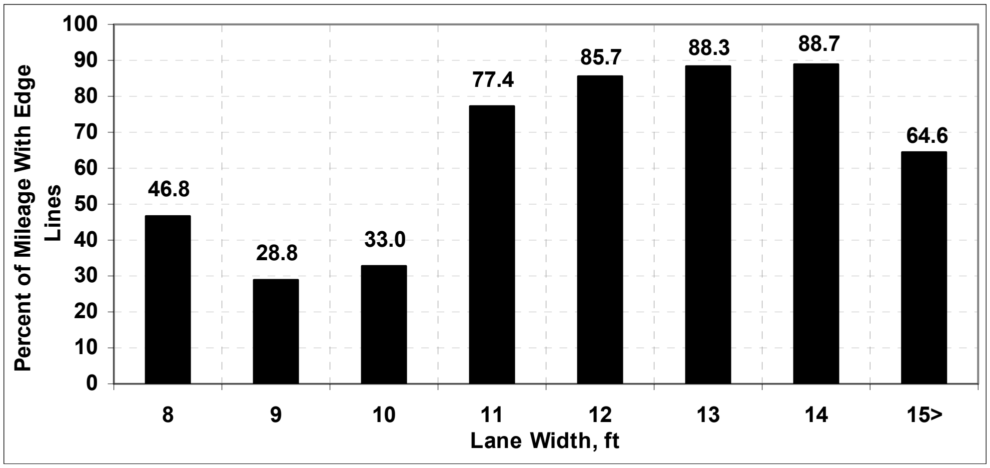
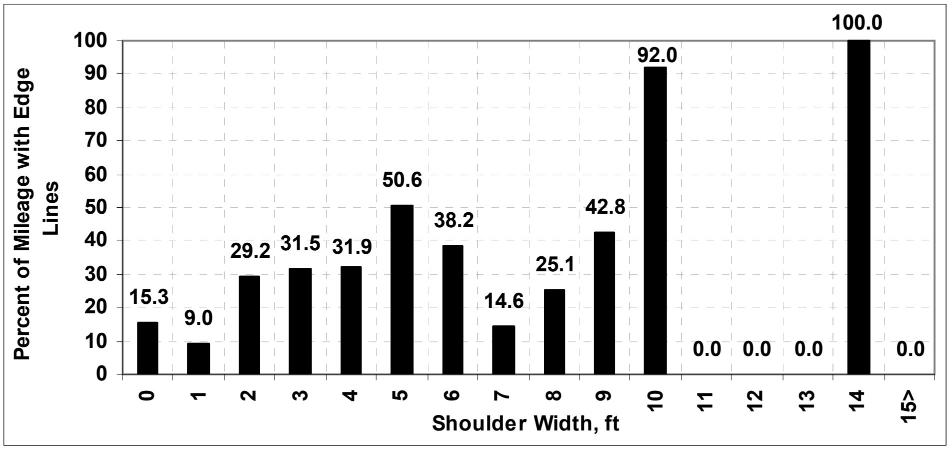


Figure 2.15 Edge Striping Frequency by Lane Width

Across the state, only 32.2 percent of rural two-lane roads with lane widths of 8, 9, or 10 feet have edge lines, but this percentage greatly increases to 84.3 percent for lane widths of 11 or more feet. The trend of more frequent edge striping increasing with lane widths greater than 10 feet is seen in all TxDOT districts.

Edge striping percentages by shoulder width are shown for lane widths of 9, 10, 11, 12, and 13 feet in Figures 2.16, 2.17, and 2.18. As data indicated, edge lines are predominantly absent on sections with shoulder widths less than 10 and 8 feet for narrow highways with lane widths of 9 and 10 feet correspondingly. No similar trends were observed for highways with lane widths of 11 feet and greater, where the majority of sections are treated with edge lines.

a)



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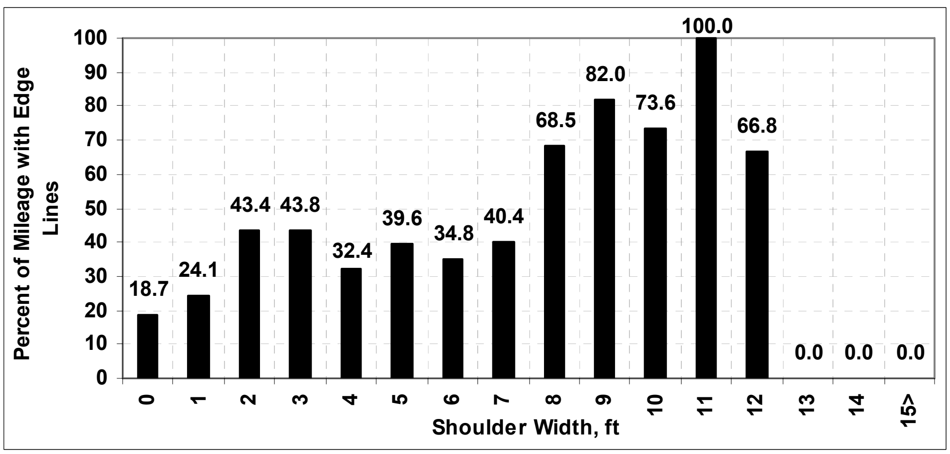


Figure 2.16 Edge Striping Percentage by Shoulder Width (Narrow Lane Widths)
a) Lane Width of 9 ft b) Lane Width of 10 ft

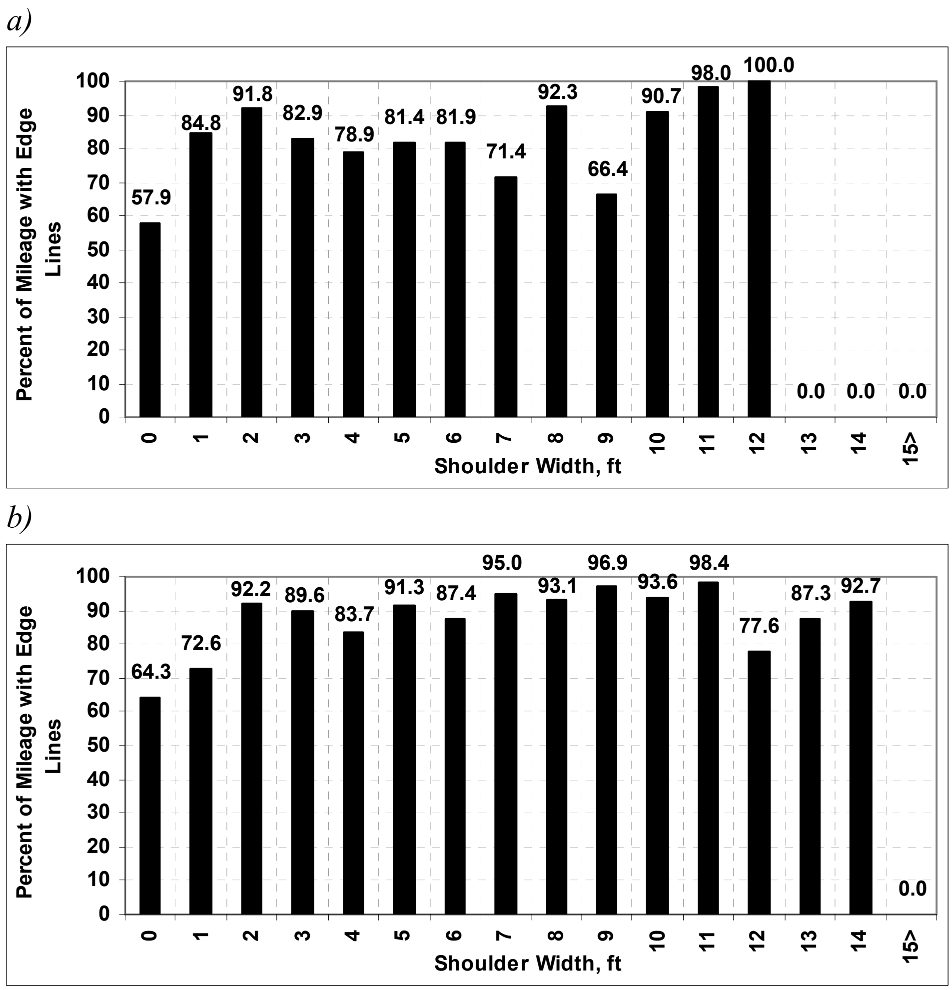


Figure 2.17 Edge Striping Percentage by Shoulder Width (Medium Lane Widths)
a) Lane Width of 11 ft b) Lane Width of 12 ft

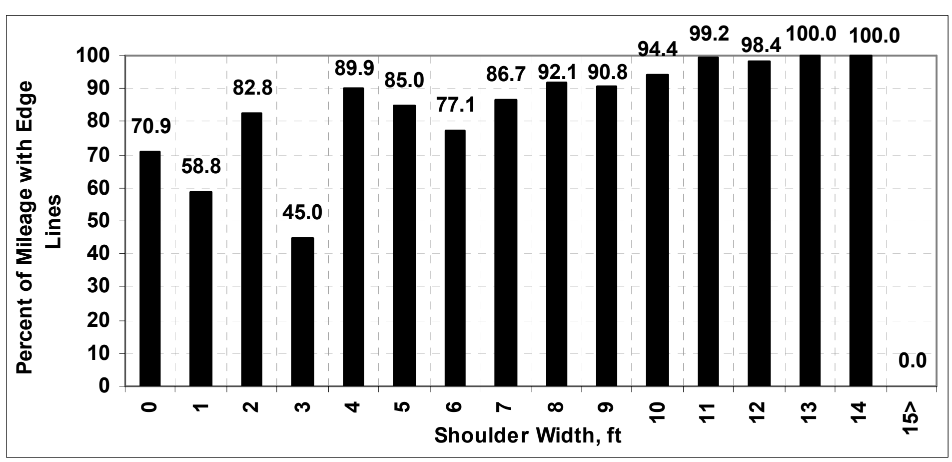


Figure 2.18 Edge Striping Percentage by Shoulder Width (Lane Width of 13 ft)

3. Accident Statistics on Rural Two-Lane Highways

3.1 Overview

Crash statistic analyses are a useful tool for comparing safety on similar roadways, but some problems inherent to crash analyses limit the validity of findings from such studies.

First, a comprehensive crash study, especially on low-volume roads such as rural two-lane highways, needs valid data from approximately 3-5 years. However, it cannot be said that roadway conditions remained the same over this entire period. Factors such as poor pavement marking maintenance, addition of new driveways, or roadway construction may severely alter roadway characteristics over the 3-5 year study period.

Second, accidents are a random event, even on dangerous highways. This fact can be especially difficult to overcome when studying low-volume roadways because the number of accidents occurring on a highway section representing an investigated parameter over the study period could be too small for analysis. In addition, police reports, from which all accident statistics databases are derived, contain numerous insufficiencies especially concerning accident contributing factors. Further, many property-damage-only (PDO) accidents and run-off-the-road (ROR) incidents on rural two lane roads may not even be reported. This error is of extreme importance to this study because edge line pavement markings may play a crucial roll in preventing such types of accidents.

Though given all above-mentioned insufficiencies, crash statistics analyses still continue to be the major source for safety analysis. From a traffic engineering perspective, the combination of a crash statistic study with driver behavior investigations will increase efficiency of the engineering countermeasures for safety improvements and help to avoid inappropriate traffic conditions and inadequate driver perception that can potentially lead to accidents.

Therefore, as a first stage of such complex studies, the crash statistics analysis targeting identification of potential safety impacts of edge lines was conducted and represented in the present chapter.

To obtain valid results, proper selection of highway sections representing typical combinations of roadway parameters is of crucial importance. Such selection was conducted based on the findings summarized in the Texas Rural Two-Lane Roadways Inventory TRTI.

As it was previously hypothesized, the safety impacts of edge lines may vary depending on such roadway parameters as traffic lane and shoulder widths, horizontal curvature, and traffic volume. Therefore, those criteria were used for further analysis.

Traffic lane widths. The TxDOT Project Management Committee has suggested that the current project should focus on studying the impact of edge lines on roadways of 24 feet or less. However, the collected data shows that nearly all highways with 24-foot roadway widths (12-foot lane widths) have edge lines. Also, it was identified in the TRTI that the narrowest lane width on Texas rural two-lane highways is 8 feet, but the state-wide mileage of such roadways is only 89 miles. Such situations do not allow for representative section selection and valid accident statistics comparison. Therefore, roadways with traffic lane widths of 9, 10, and 11 feet, which represent the majority of rural two-lane highways and are frequently not treated with edge lines, were selected for further analysis.

Shoulder widths. The TRTI indicates that more than 80 percent of rural two-lane highways with lane widths of 9, 10, and 11 feet have shoulder widths of 4 feet or less. Thus, only highways with such shoulders were further evaluated. The initial analysis of roadway mileages showed that sub-classification of shoulder widths by 1-foot intervals from 0 to 4 feet would create samples of insufficient size for valid conclusions. Due to this fact, shoulder widths were grouped into two classes, 0 to 2 and 3 to 4 feet.

Horizontal curvature. As indicated by different studies, horizontal curves with radii higher than 700 feet have limited impact on driver performance and so this value was selected as an upper classification criterion. The utilized accident database identifies small-radius curves with a coding that corresponds to curvature degree 18 and over without detailed values. A curvature degree equal to 18 corresponds to a normal curve radius of 320 feet and therefore this was selected as a lower classification criterion. Accordingly, roadway curvature was classified into three groups: small radius (less than 320 ft), medium radius (320 to 717 ft), and large radius (greater than 717 ft) curves.

Traffic volume. Though AADT was also taken into consideration in the TRTI, analysis indicated, as shown in Chapter 2.3.3, that average traffic volumes on all two-lane rural highways are too low to justify elimination of any highway sections from further analysis. Further, traffic volume is taken into account when performing an accident statistic analysis by analyzing accident ratio instead of total number of accidents, as discussed below in the present chapter.

Therefore, the highway sections with and without edge lines were analyzed taking into account the above-mentioned characteristics.

3.2 Data Collection and Database Creation

The source for crash statistics analysis was the accident database of the Texas Department of Public Safety (DPS). This database contains detailed information for every reported motor vehicle accident, is coded in plain text format, and is split into three separate record types, A, B, and C.

Record A contains information pertinent to the accident itself, such as accident location, day and time, road class, roadway alignment and conditions, surface conditions, weather and light conditions, accident severity, and the manner in which the collision occurred. Record A also contains coded information regarding the area where the accident happened, such as urban-rural classification, DPS district, and county and city codes.

Record B contains detailed information related to the vehicle(s) and driver(s) involved. This record also contains driver-related accident-contributing factors as well as information concerning any injuries sustained.

Record C provides information relative to casualties or occupants of the involved motor vehicles.

A sample of Records A and B are represented in Appendix B.

Each accident in the DPS database is given a unique accident number which allowed for information from the A, B, and C records to be grouped for each accident. From the DPS records, all records for the years 1998, 1999, 2000, and 2001 were combined into a flat-file accident database. The created database is structured so that one row is designated for each accident and each row contains all data from records A, B, and C.

After the DPS records were combined, accidents related to rural, two-lane highways were selected and accidents not related to the current study were deleted. Next, the new accident database was compared to the TxDOT EOY database regarding construction activity for the study period and accidents occurring during such activity were eliminated. Finally, the database contained detailed descriptions for 31,432 accidents that happened during the 4 year research period.

3.3 Data Analysis

The major purpose of this analysis is to identify the safety impact of edge line treatments on rural, two-lane roadways. To conduct such analysis, it is critically important to eliminate the impact of other factors such as roadway alignment and traffic volume. First, highways were classified by lane widths of 9, 10, or 11 feet. Each lane-width group was further split by separating highways with shoulder widths of 0-2 feet and 3-4 feet. In all observed groups and subgroups, the effect of roadway horizontal curvature was considered and curves were divided into three groups: small radius (less than 320 ft), medium radius (320 to 717 ft), and large radius (greater than 717 ft).

Accidents in the DPS database were linked to highway sections in the TTRI through use of the control-section-milepoint system that locates accidents to the nearest tenth of a mile.

In order to obtain statistically significant findings from an accident analysis, section study lengths must be long enough to encompass a reasonable sample of accidents. In the case of this accident study, a minimum section length of 3 miles was chosen to avoid unreasonably high accident ratios on short highway sections with a small number of accidents. After eliminating sections less than 3 miles in length from analysis, the remaining 2,822 sections total 12,875 miles and contain 9,774 crashes. Of these sections, 974 have edge lines while 1,848 do not have edge lines.

After appropriate highway sections were chosen for analysis, crash statistics comparisons could begin for highways with and without edge lines. In addition to general accident frequency analysis, factors such as accident type, intersection presence, light condition, surface condition, crash-supporting factors, severity, driver age, and driver gender were considered.

On the first part of analysis, the general comparison of accident ratios was performed for highways with edge lines to highways without edge lines without accounting for lane width, shoulder width, and curvature.

The next stage of analysis targeted the impact of lane width and shoulder width because the effect of edge lines may vary with increases or decreases of those roadway cross-sectional characteristics. Literature review indicated that edge striping on highways with narrow lanes may force vehicles too close to the centerline, resulting in an increase of head-on collisions, while edge striping on highways with wider lanes may not create this problem (Ref 12).

Another important issue in an edge line safety study is the separation of straight and tangent portions of roadway because edge lines may greatly affect the driver's ability to accurately perceive a horizontal curve and adequately navigate. With driving experience, a driver accumulates associations between visual curvature of the horizontal curves and corresponding values of centrifugal force at different speeds. Based on these relations, drivers select the appropriate curve entry speed. Therefore, adequate speed selection, and thus safe navigation of the curve is greatly determined by the quality of advanced estimation of visual curvature. The main characteristic that provides drivers with information about horizontal curves is the visual curvature of the basic lines in the roadway perspective, and studies show that human subjective estimation of curve radius is more accurate with more basic lines, such as edge lines, in the perspective view (Ref 13). On straight sections, the driver does not require as much information to correctly place the vehicle laterally, so the effect of edge lines may be minimal. Because the effect of edge lines may greatly vary between straight and tangent roadway segments, all subsequent accident variable analyses were conducted with respect to roadway curvature.

Based on the previous research results and the hypothetical safety impact of edge lines formulated in Chapter 1, the following crash characteristics were selected for analysis. Accident type was the first important crash characteristic taken into account. Literature review found significant but inconsistent conclusions regarding whether the presence of an edge line tends to make drivers position the vehicle closer to the edge of the pavement or closer to the center stripe. Placement of the vehicle towards the center stripe may increase the possibility of head-on collisions, while positioning of the vehicle towards the pavement edge may increase the possibility of ROR collisions.

Intersection-related accidents were also studied. Edge-striped highway sections are marked with gaps in the edge line at intersections, which may increase a driver's ability to recognize approaching intersections and driveways and therefore could result in a decrease in intersection-related accidents.

Light and surface condition both have a great impact on a driver's need for an edge line and the amount of added information that the driver gains from an edge line. During daylight with dry surface conditions, the driver is able to determine the edge of the paved road surface even when no edge line is present because the contrast between the pavement and surrounding environment is so great. The driver also has excellent sight distance and will rely less on pavement markings for lateral lane position cues. However, at night, or in other insufficient lighting conditions, research shows that a driver will laterally position the vehicle mostly by using the edge and center line stripes. In addition, research has shown that pavement markings located to the right of the vehicle, such as edge lines, are detected more easily at night when compared to markings to left of the vehicle (Ref 14).

Because edge lines may affect a driver's control of the vehicle, they may also affect crash severity. Edge lines provide a driver with better delineation of the pavement edge, and may decrease the overall accident frequency. However, this information causes the driver to perceive the traffic conditions as being safer and thus drivers may increase their speed that in turn may increase the severity of crashes (Ref 5).

Driver age and gender may also play a role in determining how edge lines affect drivers and safety. For example, one driver age research study investigated first detection distance of retro-reflective pavement markers under low- and high-beam illumination at night and found that the overall average detection distance increased almost 55 percent for older drivers (over 65 years of age) compared to younger drivers (under 25 years of age) (Ref 15).

Finally, crash-contributing factors concerning the driver were considered. These factors were taken from the police report and include speeding, failure to yield right-of-way, disregard for signs or signals, improper turns, improper passing, following too closely, and influence of drugs or alcohol.

Numbers of crash occurrences may be related to the numbers of opportunities for such occurrences, or *exposure*, which can be described using traffic volumes and section lengths. Therefore an accident ratio was used to take into account the section lengths and AADT of each section and yield a ratio of number of accidents per million vehicle miles traveled (AMVMT).

Because traffic volumes are only known as an average for each section, the assumption was made that vehicles included in the AADT for each section traveled the entire length of the section. The relatively short lengths and absence of major intersections on analyzed highway sections also supports the use of this assumption.

Once accident ratios were calculated for the highway sections, mean accident ratios and variances can be compared for the sample of highways with edge lines and the sample of highways without edge lines. To determine the significance of any differences in mean between the two samples, a statistical significance test was performed. Although a t-test or one-way analysis of variance is often used to determine if two samples originated from different populations, these tests cannot be used with data in this study because the accident frequencies are not normally distributed.

Instead, the non-parametric Krukal-Wallis test was selected because it eliminates the need for normality in a population by ordering the combined observations by rank, then computing the sum of ranks for each sample. The Krukal-Wallis method is also advantageous because it yields a P-value, allowing for simple calculation of significance levels.

For the study of certain crash variables, accident ratio analysis was not always appropriate. In the case of light condition, surface condition, intersection presence, and driver age and gender, relevant section length and AADT information was not available to draw valid accident frequency conclusions. For example, correct accident ratios could not be calculated for varying light conditions because AADT varies between daylight and darkness, but the supplied databases only have one overall AADT value. This same problem presents itself when looking at surface conditions. In the case of intersection presence, the number of intersections and driveways per mile is not known and for driver age and gender the vehicle miles traveled for each driver age and gender group is not known. Also, detailed classification of accidents by variables such as severity or crash-contributing factors may cause limited sample sizes of analyzed groups that will reduce the validity of test results. In such cases, the analyzed characteristics were combined to increase sample sizes and were described as percentages of the total observed values.

3.4 Accident Frequency on Highways with and without Edge Lines

3.4.1 General Comparison

Initial analysis focused on a general comparison of accident frequencies for highway sections with edge lines and highway sections without edge lines while not considering any roadway or accident variables. This general analysis served as a necessary starting point for the edge line safety analysis.

Accident ratios were calculated for each highway section by using the total number of accidents that occurred on each section, the length of each section, and the average AADT of each section. From these accident ratios, cumulative frequency distribution curves along with mean and standard deviation statistics for highway sections with edge lines and highway sections without edge lines were determined and are shown below.

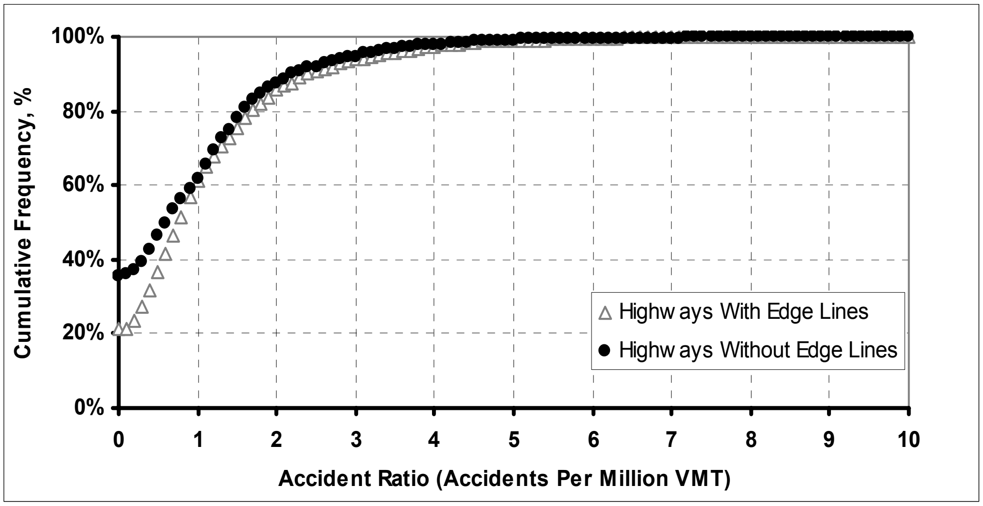


Figure 3.1 Distribution of Accident Ratios on All Sections

Table 3.1 Statistical Characteristics of Accident Ratio Distribution on All Sections

Highways	Accident Ratio, accidents per million VMT		
	Mean	**Std. Dev.**	**Variance**
With Edge Lines	1.04	1.10	1.21
Without Edge Lines	0.91	1.21	1.47

As shown in Table 3.1, the mean accident ratio for highways with edge lines (1.04 AMVMT) is higher than for highways without edge lines (0.91 AMVMT) with a significance of greater than 0.999 according to the returned Krukal-Wallis test statistic of 23.07. However, the cumulative frequency curve reveals an interesting fact in the data: a large percentage of sections have zero accidents over the observation period, and this percentage is much higher for highways without edge lines than for highways with edge lines (36 percent versus 21 percent).

Given the short section lengths and small traffic volumes on rural two-lane roads, some percentage of sections with zero accidents was expected. However, such a large difference between the number of zero-accident sections for highways with and without edge lines was not expected.

One hypothesis is that rural two-lane roads without edge lines most likely have lower volumes than similar roads with edge lines and, considering the random nature of accidents, highways with edge lines will thus have fewer sections where no accidents occurred.

To test this hypothesis, total vehicle miles traveled (VMT) over the study period were calculated for each section and a mean comparison between highways with and without edge lines was made. Sections with edge lines have a mean of 5.06 million VMT with a standard deviation of 6.02, while sections without edge lines have mean of 2.84 million VMT with a standard deviation of 4.23. The mean VMT for highways without edge lines is around half of the mean VMT for highways with edge lines, so highways without edge lines are indeed more likely to have no accidents over the study period. Because such a large number of sections without edge lines have an accident ratio of zero, the mean accident ratio for sections without edge lines was pulled downward.

Working with such a large number of zero-accident sections also adversely affects the ability of the Krukal-Wallis test to accurately determine whether the samples truly originated from different populations. Because sections without edge lines have a much higher number of zero-accident sections, the ranks for sections without edge lines will be consistently lower than the ranks for highways with edge lines resulting in a Krukal-Wallis statistic that is artificially high.

Taking into account the above-mentioned deficiencies in the all-section analysis, the next logical step was to analyze only highway sections that have repeated accidents (non-zero accident ratios). Statistics for these *accident-prone* highway sections where two or more accidents occurred during the observation period are shown in Table 3.2 and Figure 3.2.

Table 3.2 Statistical Characteristics of Accident Ratio Distribution for Accident-Prone Sections

Highways	**Accident Ratio, accidents per million VMT**		
	Mean	**Std. Dev.**	**Variance**
With Edge Lines	1.50	1.10	1.22
Without Edge Lines	1.63	1.37	1.88

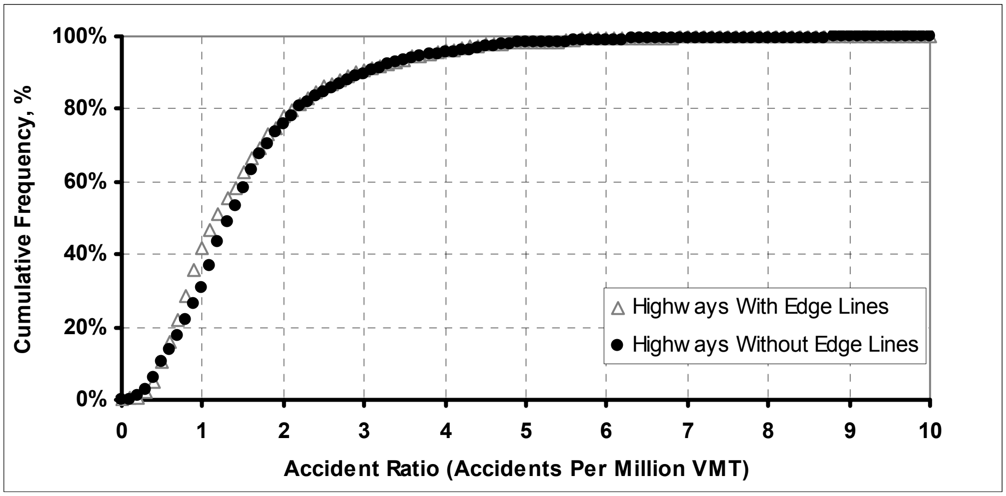


Figure 3.2 Distribution of Accident Ratios on Accident-Prone Sections

After deleting all 1,442 sections with zero or one accidents, accident-prone highways without edge lines have a higher mean accident ratio than highways with edge lines (1.63 versus 1.50 AMVMT). The Kruskal-Wallis statistic is 6.41 and indicates that the null hypothesis can be rejected with a significance level of 0.99.

Therefore, the analysis shows that when all highways are included, those with edge lines have a higher average accident ratio; however, if only sections with two or more reported accidents are considered, highways without edge lines have a higher average accident ratio. This could indicate that crashes on highways without edge lines are more concentrated on certain accident-prone sections, while crashes on highways with edge lines are more evenly distributed over all sections.

3.4.2 Comparison for Highways with Different Traffic Lane Widths

Lane width and shoulder width of rural two-lane roads may alter the effectiveness of edge-line treatments. To study lane-width variance, highways were first grouped by lane widths of 9, 10, and 11 feet and accident ratios for highways with and without edge lines were compared for each group.

The distribution of accident ratios on all highway sections (including non-accident sections) with different lane widths is represented in Appendix C. On highways with lane widths of 9 feet, the mean accident ratio on sections with edge lines was 1.09 AMVMT versus a mean of 1.04 AMVMT for sections without edge lines. For highways with lane widths of 10 feet, those values were 1.06 and 0.88 AMVMT, and for lane widths of 11 feet, corresponding values were 1.01 and 0.94 AMVMT. The statistical analysis showed that within each observed lane-width group of 9, 10, and 11 feet, sections with edge lines have significantly higher accident ratios than sections without edge lines with levels of significance of 0.97, 0.99, and 0.63 respectively.

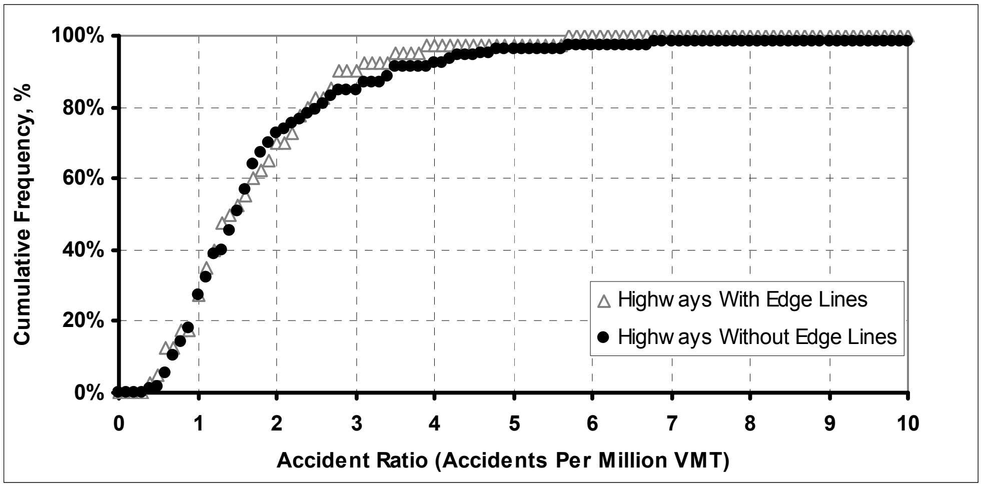
However, as indicated by general analysis (see Chapter 3.4.1), due to significant differences in traffic volume between highways with and without edge lines the analysis of all highways sections (including non-accident sections) is problematic, and analysis of only accident-prone highway sections is more informative. This fact also is true for the current analysis.

Thus, sections with two or more accidents (accident-prone) were studied for each lane-width group. For 146 accident-prone sections of highways with lane widths of 9 feet, a higher mean accident ratio was observed on highways without edge lines (1.74 AMVMT) than on highways with edge lines (1.60 AMVMT). However, as evidenced by Kruskal-Wallis analysis, both samples came from the same population with a significance level of 0.78. For the 832 accident-prone sections with lane widths of 10 feet, the mean accident ratios were 1.59 and 1.60 AMVMT correspondingly for highways with and without edge lines, and for 402 accident-prone sections with lane widths of 11 feet, those values were 1.37 and 1.42 AMVMT. Statistical analysis also indicated low significance levels, 0.47 and 0.40, of the observed differences in accident ratio distributions for highways with and without edge lines within lane-width groups of 10 and 11 feet. The distributions of accident ratios for all above-mentioned groups are represented in Figure 3.3 with statistical characteristics shown in Table 3.3.

Table 3.3 Statistical Characteristics of Accident Ratio Distribution on Accident-Prone Sections by Lane Width

Lane Width, ft	**Accident Ratio, accidents per million VMT**		
	Mean	**Std. Dev.**	**Variance**
Highways With Edge Lines			
9	1.60	0.86	0.74
10	1.60	1.21	1.47
11	1.37	0.99	0.97
Highways Without Edge Lines			
9	1.74	1.14	1.30
10	1.59	1.13	1.28
11	1.42	0.99	0.98

a)



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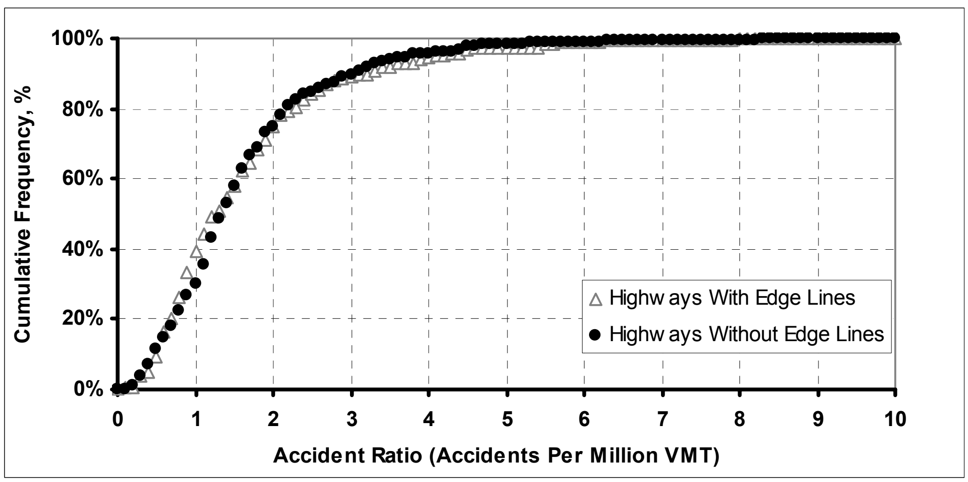

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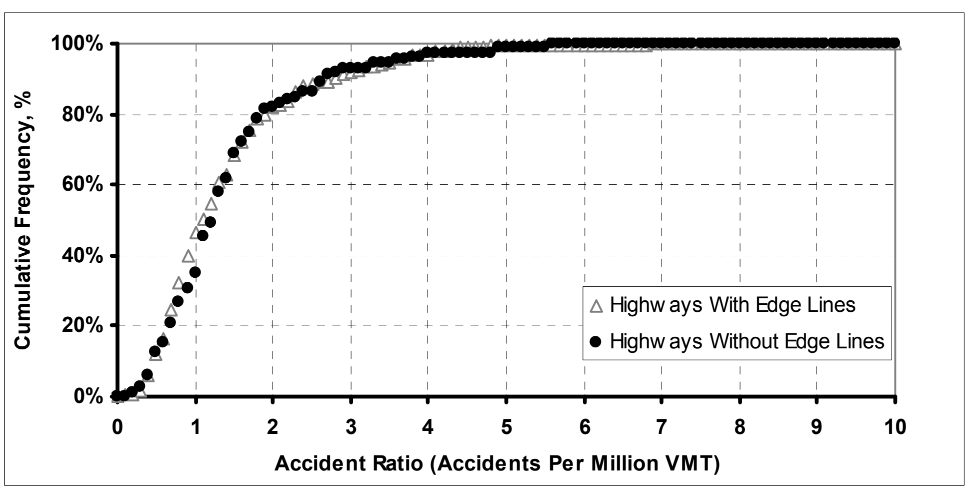
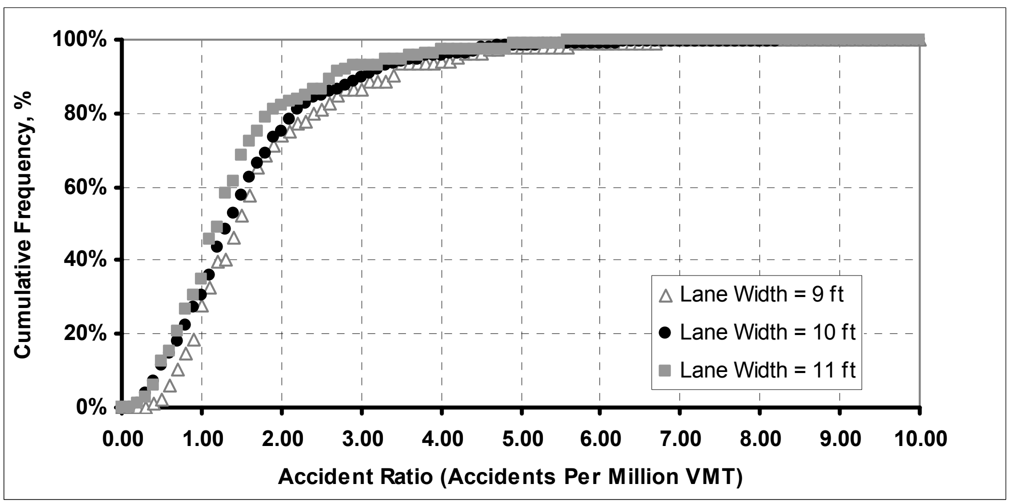


Figure 3.3 Distribution of Accident Ratios on Accident-Prone Sections by Lane Width
a) Lane Width of 9 ft b) Lane Width of 10 ft c) Lane Width of 11 ft

Next, lane-width impact was analyzed separately on highways with and without edge lines. On highways without edge lines, mean values of accident ratios for the analyzed three groups were 1.74, 1.59, and 1.42 AMVMT respectively for sections with 9-, 10-, and 11-foot lane widths and Kruskal-Wallis analysis revealed that sections from each lane-width group originated from different populations with a significance of 0.95.

For highways with edge lines, analysis indicated that only sections with 11-foot lane widths significantly varied from the other two lane-width groups. Table 3.4 represents statistical characteristics of the observed accident ratio distributions with graphical representations shown in Figure 3.4.

a)



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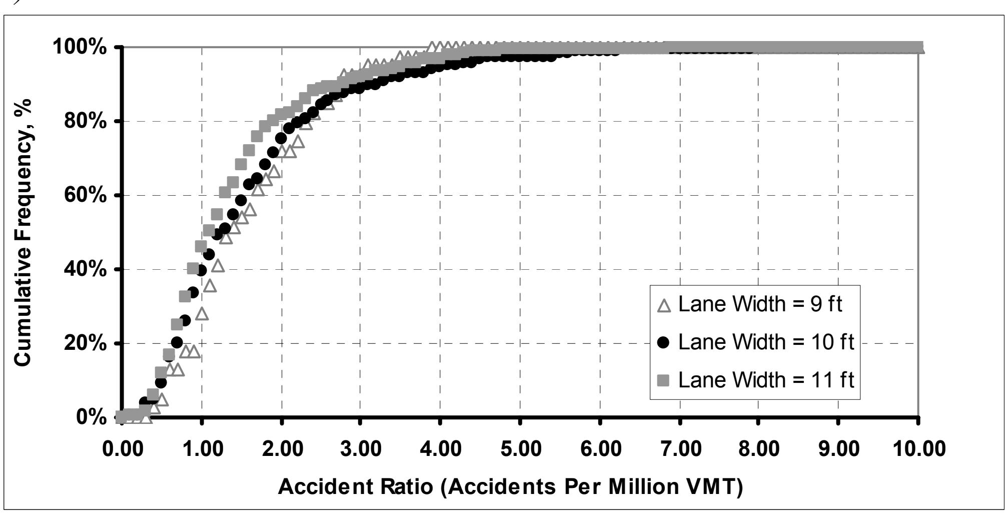


Figure 3.4 Distribution of Accident Ratios on Highways With Different Lane Widths
a) Highways Without Edge Lines b)Highways With Edge Lines

The analyses provided the following conclusions:

The analyzed data indicated low significance of edge-line impact on accident frequency on accident-prone sections within all three lane-width groups, but at the same time, the mean accident ratio is usually higher for highways without edge lines (all three lane-width groups) with the greatest difference for narrow roads of 9-foot lane width.

The analysis of lane-width impact on highways without edge lines indicated significant differences of accident frequency on sections with 9-, 10-, and 11-foot lane widths with the highest value on narrow roadways of 9 feet. Similar analysis on highways with edge lines only indicated a reduction on highways with 11-foot lane widths.

Both of these findings indicate some positive safety effect of edge line treatment on narrow roads and allow the assumption that this impact is greatest on the narrowest roadways.

3.4.3 Comparison for Highways with Different Shoulder Widths

Similar to the study of varying traffic lane width, shoulder-width analysis began with grouping highways with shoulder widths of 0-2 feet and 3-4 feet. Each shoulder-width group was then analyzed on highways with lane widths of 9, 10, or 11 feet, resulting in six different lane width and shoulder width combinations.

Accident ratio distributions on all highway sections (including non-accident sections) separated by lane width and shoulder width groups mentioned above are shown in Appendix C. Analysis shows that mean accident ratios are higher on highways with edge lines than on highways without edge lines for every shoulder-width group except for highways with lane widths of 9 feet and shoulders of 3-4 feet. Significance levels are 0.93, 0.80, 0.88, 0.99, 0.42, and 0.91 respectively for lane-width and shoulder-width groups ranging from 9-foot lanes and 0-2 foot shoulders to 11-foot lanes and 3-4 foot shoulders.

Accident ratio statistics for accident-prone sections, as shown in Table 3.4 and Figures 3.5 and 3.6, indicate that highways without edge lines have higher mean accident ratios for lane widths of 9 feet with shoulder widths of 0-2 and 3-4 feet as well as for highways with lane widths of 11 feet and shoulder widths of 3-4 feet while highways with edge lines have higher mean accident ratios for highways with lane widths of 10 feet and shoulder widths of 0-2 and 3-4 feet as well as for highways with lane widths of 11 feet and shoulder widths of 0-2 feet. However, none of these differences show high significance: significance levels are 0.23, 0.35, 0.45, 0.19, 0.08, and 0.53 respectively for all lane-width/shoulder-width groups.

Table 3.4 Statistical Distribution for Accident-Prone Highways by Shoulder Width

Lane Width, ft	Shoulder Width, ft	Accident Ratio, accidents per million VMT		
		Mean	**Std. Dev.**	**Variance**
Highways With Edge Lines				
9	**0-2**	2.20	1.51	2.28
	3-4	1.48	0.74	0.54
10	**0-2**	1.70	1.35	1.83
	3-4	1.49	1.03	1.06
11	**0-2**	1.45	1.00	1.01
	3-4	1.15	0.90	0.81
Highways Without Edge Lines				
9	**0-2**	2.41	3.15	9.93
	3-4	1.81	1.83	3.35
10	**0-2**	1.67	1.18	1.38
	3-4	1.48	1.07	1.14
11	**0-2**	1.42	0.95	0.90
	3-4	1.45	1.25	1.56

Next, the effect of shoulder width was studied separately for highways with and without edge lines and for each lane-width group. On accident-prone sections, highways with edge lines and shoulder widths of 0-2 feet have significantly higher mean accident ratios than on such highways with shoulder widths of 3-4 feet for all lane-width groups. For edge-striped highways with lane widths of 9 feet, the mean accident ratio is 2.20 AMVMT for highways with shoulder widths of 0-2 feet versus 1.48 AMVMT for shoulder widths of 3-4 feet and this difference is identified with significance level of 0.80. Corresponding values for edge-striped highways with lane widths of 10 feet are 1.70 and 1.49 AMVMT with difference significance of 0.77, and 1.45 versus 1.15 AMVMT with significance of 0.99 for 11-foot lane-width highways.

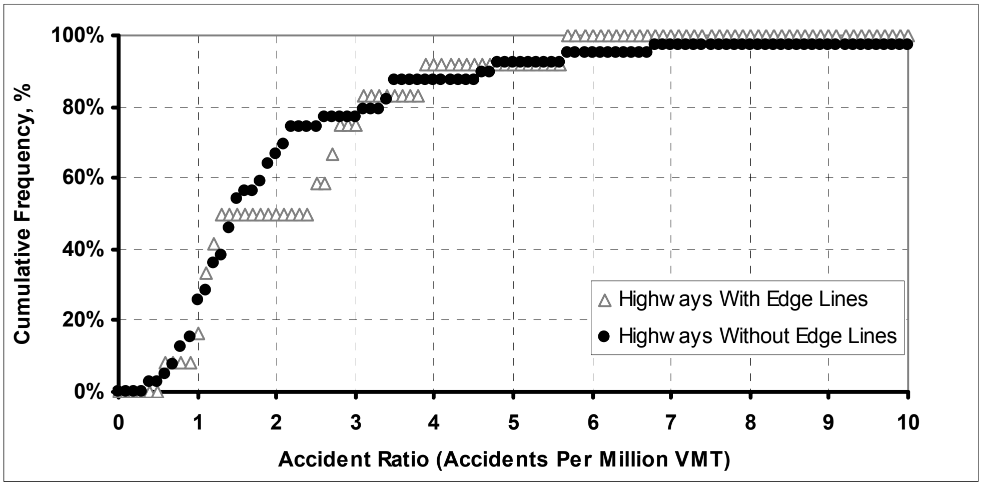
For highways without edge lines, sections with lane widths of 9 feet and shoulder widths of 0-2 feet had a mean accident ratio of 2.41 AMVMT compared to 1.81 AMVMT for lane widths of 9 feet and shoulder widths of 3-4 feet, but this difference is not statistically significant (0.55 significance level). Mean accident ratios for highways with lane widths of 10 feet are 1.67 and 1.48 AMVMT for shoulder widths of 0-2 and 3-4 feet respectively with the difference being statistically significant at the 0.96 level. Corresponding values for highways with lane widths of 11 feet are 1.42 and 1.45 AMVMT and this very small difference is not significant (significance level 0.50).

The analysis clearly shows a significant increase of accident frequency with shoulder width reduction among all lane-width groups. At the same time, the comparison of accident ratio increase indicated similar values on highways with and without edge lines. As shown in Table 3.4, the change in accident ratio between the 2 shoulder-width groups on sections with edge line on highways with lane widths of 9 feet was 0.72 AMVMT versus 0.60 AMVMT on sections without edge lines. Since this difference is not statistically significant, the analysis did not identify a significant relationship between shoulder width and presence or absence of edge lines.

Summarizing all the above-mentioned findings, no significant impact of edge lines on accident frequency was observed across the analyzed shoulder widths cases.

Important note: The TRTI indicates that the majority of two-lane rural highways in Texas without edge lines have the same pavement type for both the travel lane and the shoulder. Therefore, the driver perceives all paved surface from the center line to the edge of the road as a travel lane rather than as a travel lane with a separate shoulder. This fact reduces the validity of the conducted analysis.

a)



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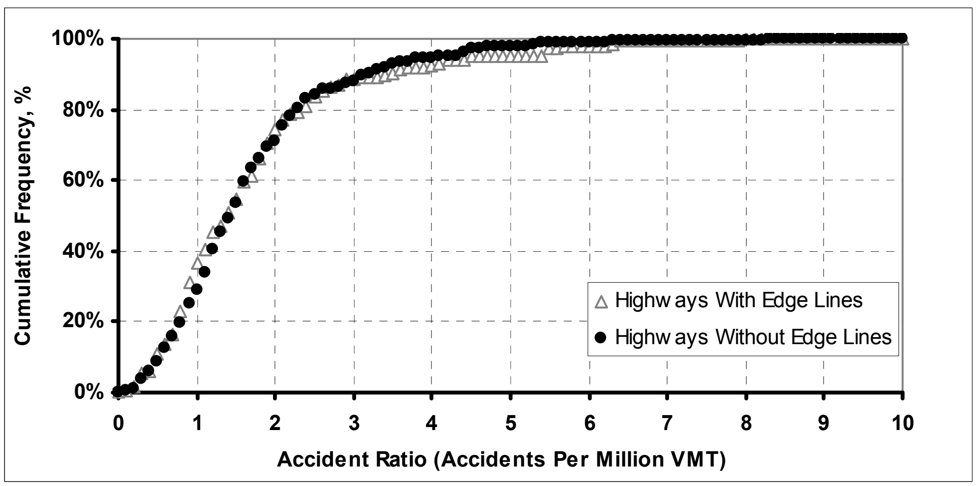

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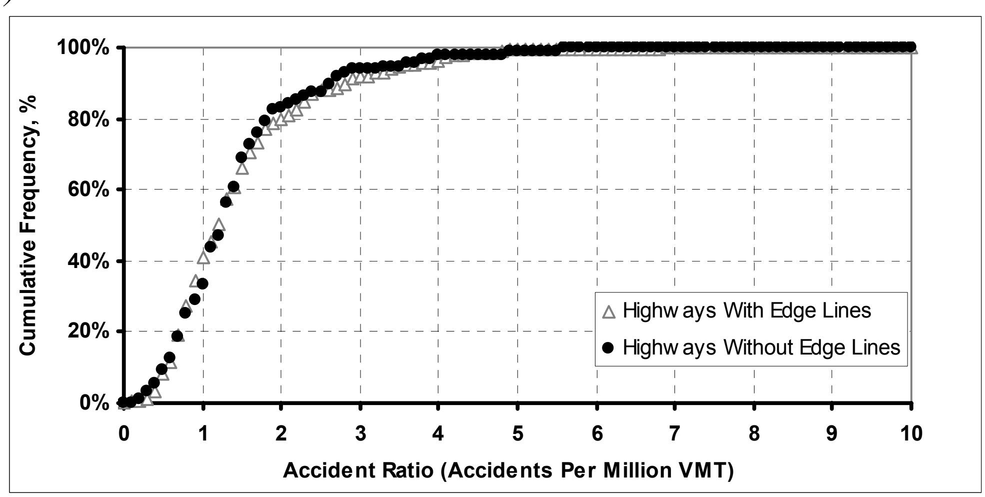
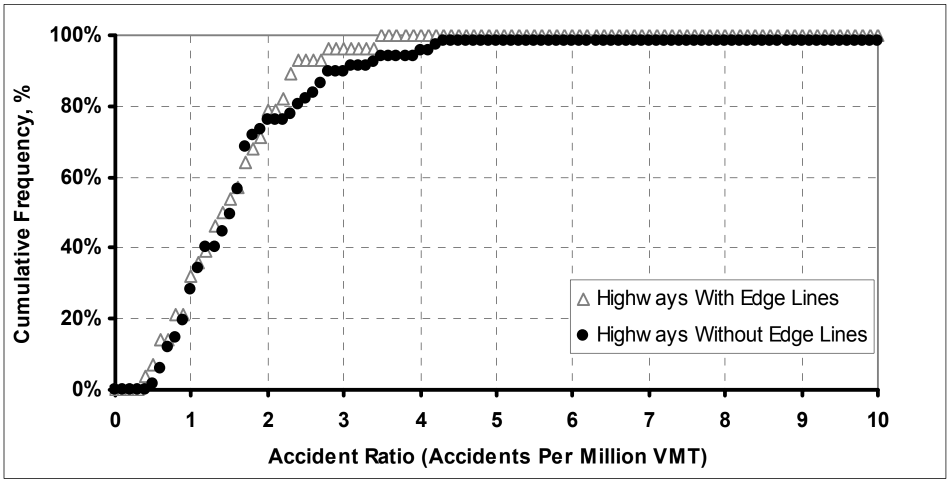


Figure 3.5 Distributions on Accident-Prone Sections by Lane Width for Shoulder Widths of 0-2 ft
a) Lane Width of 9 ft b) Lane Width of 10 ft c) Lane Width of 11 ft

a)



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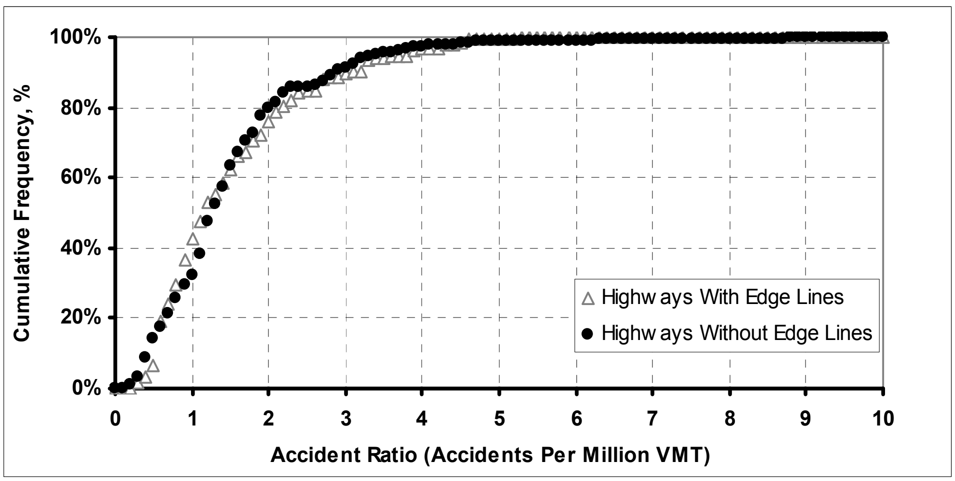

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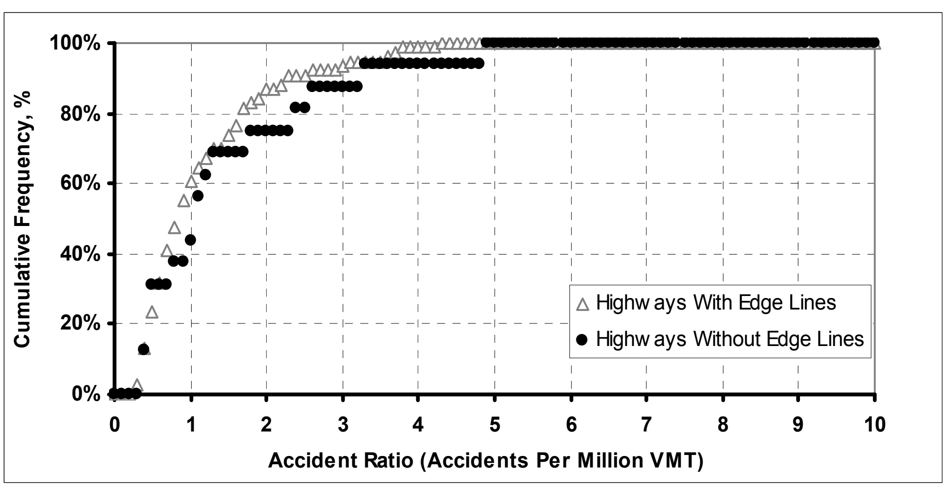


Figure 3.6 Distribution of Accident-Prone Sections by Lane Width for Shoulder Widths of 3-4 ft
a) Lane Width of 9 ft b) Lane Width of 10 ft c) Lane Width of 11 ft

3.5 Comparison of Straight and Curved Segments

Because edge lines may greatly affect the driver's ability to accurately guide the vehicle through a horizontal curve, roadway curvature was the next roadway variable studied. The radii were calculated based on the curvature degree given in the TxDOT TRM GEO-HINI and DPS databases.

For the purposes of this research, curves were initially grouped into three radii classes: small radius (less than 320 ft), medium radius (320 to 717 ft), and large radius (greater than 717 ft). Accidents were deemed to occur on straight roadway segments if they were coded as *no curve* in the DPS database.

To properly calculate accident ratios when separating accidents by roadway curvature, total section lengths cannot be used. Instead, the lengths of straight and curved segments should be separated in each highway section under analysis to compute each corresponding accident ratio. These lengths were calculated from the TRM GEO-HINI database. For calculation of accident ratio, as noted in Section 3.3, the AADT was assumed to be uniform over the entire highway section including the curved elements.

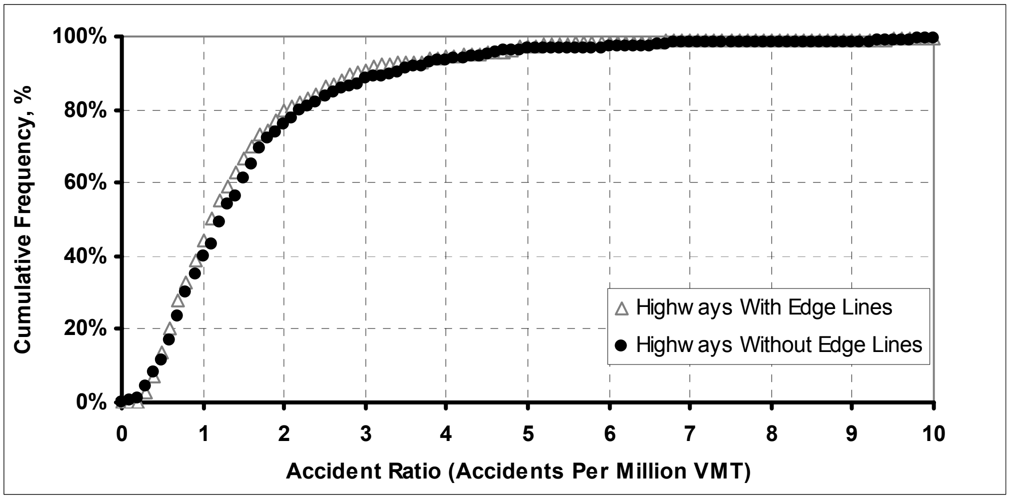
In thirty-five sections (approximately 1 percent of the total number of analyzed sections), the DPS database indicated that an accident occurred on a curve having a radius class that did not exist in the GEO-HINI database. These conflicting sections were deleted from analysis.

First, all straight segments of all highway sections (including non-accident sections) were compared, and results are shown in Appendix C. Analysis of all sections reveals that highways with edge lines have a higher mean accident ratio than highways without edge lines (0.97 versus 0.90 AMVMT) and this difference is large enough to be statistically significant (significance level 0.99).

Once straight segments were analyzed, study of curved segments could begin, but examination of small and medium radius curves proved to be problematic for a number of reasons. For one, the total length of medium and small radius curves on some highways sections was often very small which led to extremely high accident ratios, some greater than 400 accidents per million VMT, and very high variance (greater than 500). To alleviate this problem, examination of curves by radii was abandoned and curves of large, medium, and small radius were grouped together into one curve class. Examination of all curved segments of all highway sections reveals that highways without edge lines have a higher accident frequency than highways with edge lines. The corresponding average accident ratios were 2.41 and 2.16 AMVMT and the analysis of the sample differences indicated different populations with significance of 0.99.

Next, curvature analysis was conducted for accident-prone sections only and statistical characteristics of observed accident ratio distributions are represented in Table 3.5 and Figure 3.7. This analysis shows that highways without edge lines are characterized by higher accident frequency than highways with edge lines for both straight and curved segments. For straight segments, the average was 1.81 AMVMT on sections without edge lines versus 1.70 AMVMT for edge-striped sections. The corresponding values were 5.80 AMVMT and 4.30 AMVMT for curved segments. The Kruskal-Wallis analysis indicated that the samples represent different populations with significances of 0.90 and 0.94 respectively for straight and curved segments.

a)



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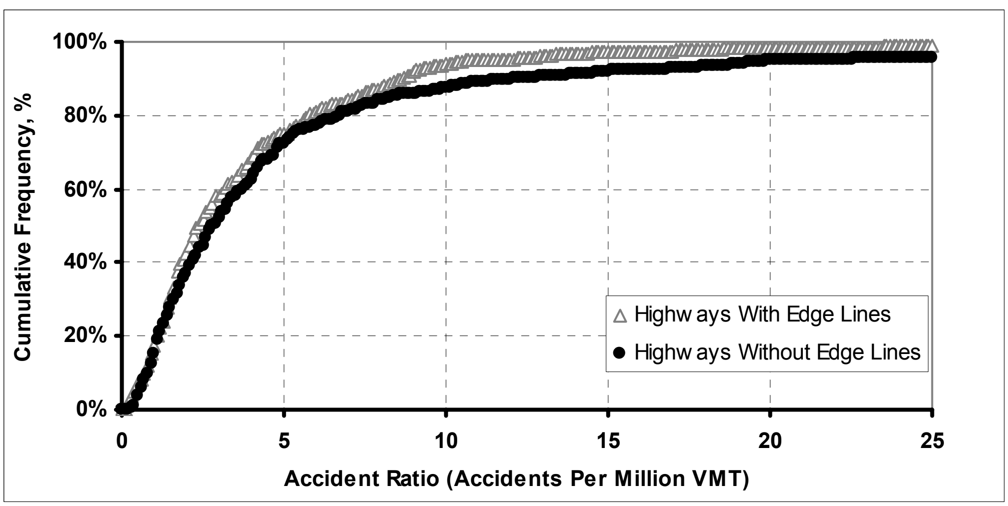


Figure 3.7 Distribution of Accident Ratios on Accident-Prone Sections
a) Straight Segments b) Curved Segments

Table 3.5 Statistical Characteristics of Accident Ratio Distribution for Accident-Prone Sections

Curvature	Accident Ratio, accidents per million VMT		
	Mean	**Std. Dev.**	**Variance**
Highways With Edge Lines			
Straight	1.70	3.71	13.79
Curved	4.30	7.93	62.83
Highways Without Edge Lines			
Straight	1.81	3.38	11.43
Curved	5.80	10.40	108.19

In the case of both all-section and accident-prone section analysis, highways without edge lines have a significantly higher accident ratio than highways with edge lines on curved roadway segments. Further, the percentage difference between mean accident ratios on straight and curved segments for highways with edge lines and highways without edge lines is greater on curved segments than on straight segments for both all-section and accident-prone sections analyses (10.4 percent versus 7.7 percent for all sections and 25.8 percent versus 6.1 percent for accident-prone sections). This implies that the impact of edge-line presence is greater on curves than on straight highway segments.

Horizontal curvature was also studied with separation of highways by lane widths of 9, 10, and 11 feet. Analysis of all sections (including non-accident sections), detailed in Appendix C, by both lane width and curvature shows results similar to the curvature-only analysis: highways without edge lines have higher accident frequencies for almost all lane widths.

On accident-prone sections, shown in Table 3.6 and Figures 3.8 and 3.9, higher accident ratios were observed on segments without edge lines than those with edge lines for nearly all lane-width classes. The highest impact of edge lines was observed on curved segments. Over all lane widths, curved segments without edge lines have an average of 1.72 AMVMT more than curved segments with edge lines with the maximum difference occurring on narrow roadways (9-foot lane width). Significance levels are high for all lane-width groups on curved segments (0.79 for lane widths of 9 feet, 0.80 for 10 feet, and 0.98 for 11 feet).

Accident frequencies were also compared separately for highways with and without edge lines to judge the effects of increasing lane width on straight or curved segments. On straight segments with edge lines, Kruskal-Wallis analysis shows that accident frequencies do not significantly vary with lane width (significance level only 0.44); however, analysis shows that on curved segments, highways with edge lines and lane widths of 11 feet have a significantly lower mean accident ratio than those with lane widths of 9 or 10 feet (significance level of 0.99). Highways with lane widths of 9 feet do not significantly differ from highways with lane widths of 10 feet.

On straight highway segments without edge lines, accident frequencies in the 11-foot lane width group are significantly lower than those in the 9- and 10-foot groups (significance level of 0.95), but the 9- and 10-foot groups do not significantly differ from each other (significance of null-hypothesis rejection is only 0.24). On curved segments without edge lines, highways with lane widths of 10 and 11 feet have lower accident ratios than narrow highways of 9-foot lane widths with significance levels of 0.99 and 0.88 respectively. The lane-width groups of 10 and 11 feet show no significant difference.

Based on the analysis conducted, three major conclusions can be made:

On accident-prone highway sections, accident frequency is higher on highways without edge lines on both straight and curved segments.

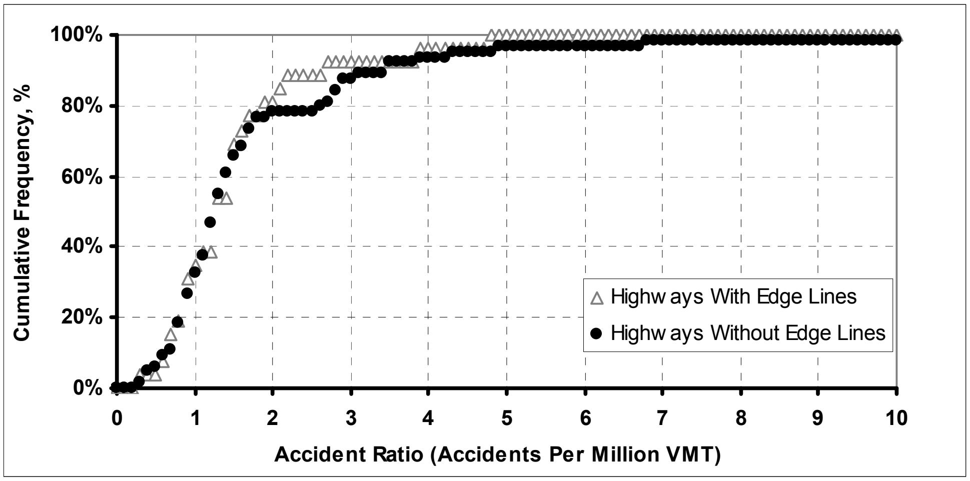
The reduction of accidents due to edge-line presence was observed to be significantly higher on curves than on straight segments.

For the analyzed traffic lane widths, the major safety impact of edge lines is on narrow roadways (9-foot lane widths).

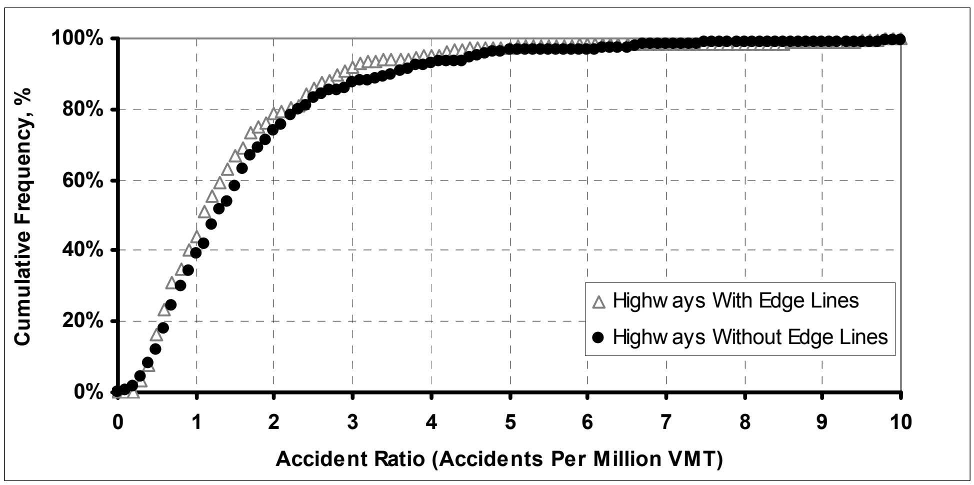
Table 3.6 Statistical Characteristics of Accident Ratio Distribution for Accident-Prone Sections by Curvature and Lane Width

Curvature	Lane Width, ft	Accident Ratio, accidents per million VMT		
		Mean	Std. Dev.	Variance
Highways With Edge Lines				
Straight	9	1.50	0.99	0.98
	10	1.48	1.38	1.92
	11	1.46	1.20	1.44
Curved	9	3.84	2.48	6.15
	10	3.98	3.70	13.70
	11	3.06	3.24	10.50
Highways Without Edge Lines				
Straight	9	1.59	1.18	1.39
	10	1.67	1.51	2.28
	11	1.27	1.23	1.51
Curved	9	5.73	5.45	29.73
	10	5.09	8.73	76.21
	11	5.22	6.65	44.24

a)



b)



c)

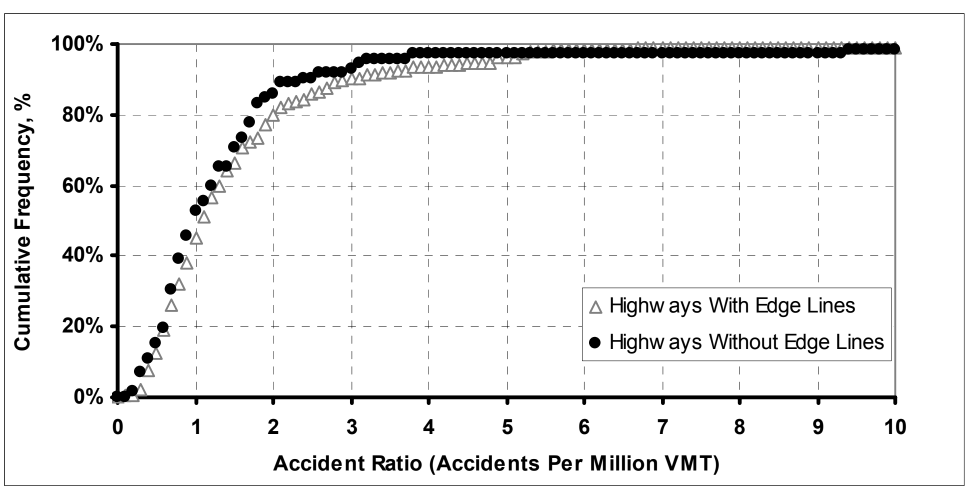
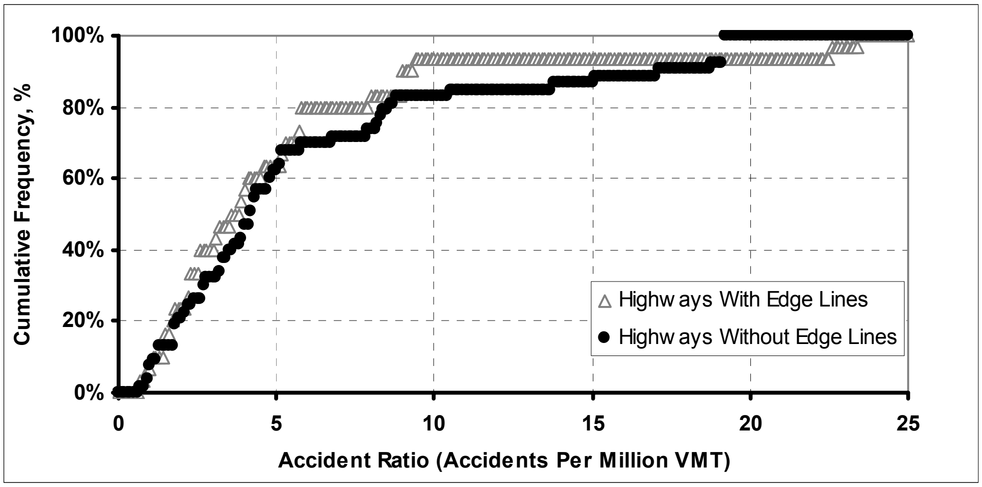
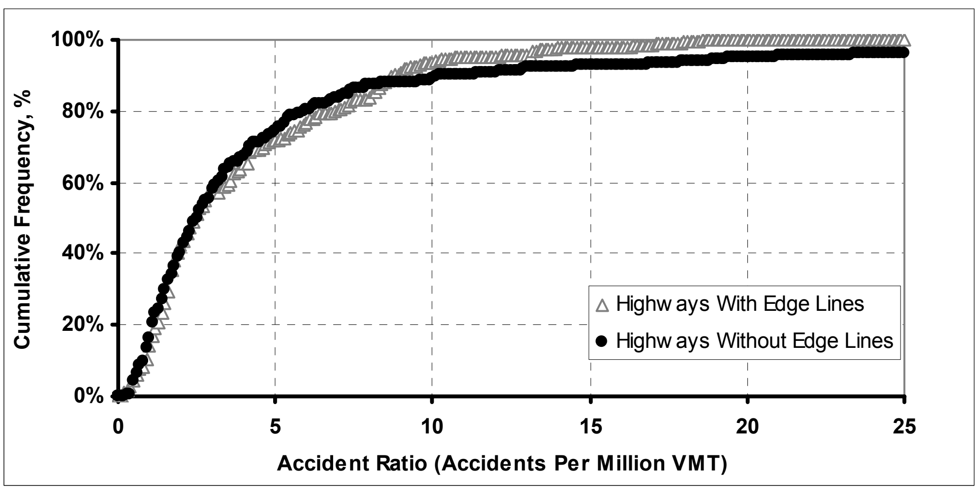


Figure 3.8 Distribution of Accident Ratios on Accident-Prone Straight Segments by Lane Width
a) Lane Widths of 9 ft   b) Lane Widths of 10 ft   c) Lane Widths of 11 ft

a)



b)



c)

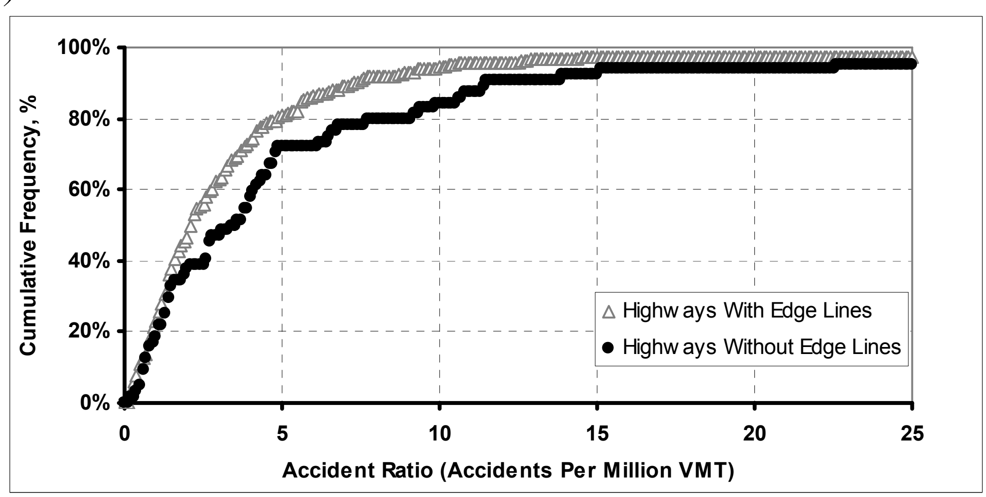


Figure 3.9 Distribution of Accident Ratios on Accident-Prone Curved Segments by Lane Width
a) Lane Widths of 9 ft b) Lane Widths of 10 ft c) Lane Widths of 11 ft

3.6 Accident Type Analysis

The DPS database contains detailed information concerning the manner in which accidents occurred and allowed for examination of the following accident types: rear end, sideswipe, head-on, run-off-the-road (ROR), accidents related to railroad crossings or bridges, as well as the total number of vehicles involved in the accident. Given this information, a proportion of each accident type was calculated as a percentage of the total number of accidents. The frequencies of accidents of different types were compared for highways with and without edge lines and further considering the impact of lane widths and curvature. Results are represented in Table 3.7.

Types of accidents were classified into the following groups:

- Rear-end – includes all accidents that were coded in the DPS database as "Both vehicles going straight – rear end."
- Sideswipe - includes all accidents that were coded in the DPS database as "Both vehicles going straight – sideswipe."
- Head-on – includes all accidents coded as "Both vehicles going straight" under the "Two-Motor Vehicles – Going Opposite Directions" header of the DPS database.
- ROR - accidents were determined to be ROR if the accident only involved one vehicle, was coded as "Off roadway on shoulder" or "Off roadway beyond shoulder" in the DPS database "Roadway Related" column, and the vehicle struck a roadside or off-roadside object in the "Object Struck" column not related to a railroad crossing, bridge, or work zone.
- Railroad – includes all accidents that occurred in the zone of influence of a railroad crossing.
- Bridge – includes all accidents that occurred on bridges.
- Other – this group includes such accidents related to work-zones, vehicle problems, pedestrians, animals, insufficiencies of roadway surface, and fallen trees.

The comparison of number of vehicles involved indicated that for both highways with and without edge lines there is a predominance of single-vehicle crashes.

The major accident types on highways with edge lines were identified as ROR, head-on, and rear-end and these represented 53.7, 5.0, and 3.7 percent of all crashes respectively. For highways without edge lines, corresponding values were 64.9, 3.5, and 2.6 percent.

Consideration of lane widths reveals that increasing lane widths has no significant effect on number of vehicles involved. However, occurrences of ROR accidents were observed to be highest on the narrowest highways (lane widths of 9 feet) for both highways with and without edge lines.

Horizontal alignment impact analysis indicated that curved highway segments have substantially higher percentages of ROR crashes than straight segments for both highways with and without edge lines. On curved segments with edge lines, the percentage of ROR accidents averages 69 percent of all crashes across all lane widths, but this percentage is substantially higher on highways without edge lines (80 percent). In addition, ROR accidents are highest for narrow lane widths (9 feet) on both highways with and without edge lines, and the highest overall ROR percentage of any group (83.4 percent) occurs on curved segments of highways with lane widths of 9 feet and no edge lines.

Table 3.7 Distribution of Accidents by Accident Type and Number of Vehicles Involved

Horizontal Alignment	Lane Width	Percentage of Total Accidents										Total Number of Accidents
		Vehicles Involved			Accident Type							
		1	2	≥3	Rear-End	Sideswipe	Head-on	ROR	Railroad	Bridge	Other	
Highways With Edge Lines												
All Segments	All	75.1	22.4	0.0	3.7	0.2	5.0	53.7	0.0	0.5	36.9	5086
All Segments	9	75.2	21.6	0.0	5.1	0.0	3.5	55.2	0.0	1.0	35.3	315
	10	75.0	22.8	0.0	3.9	0.3	5.3	54.3	0.0	0.5	35.7	2440
	11	75.2	22.1	0.0	3.3	0.2	4.8	52.7	0.0	0.5	38.4	2331
Straight Segments Only	9	62.7	33.3	3.9	9.2	0.0	2.0	37.8	0.0	0.7	50.5	153
	10	67.5	29.6	2.9	6.2	0.4	4.8	42.0	0.0	1.2	45.4	1242
	11	68.5	27.6	3.9	4.9	0.4	4.6	41.5	0.0	1.1	47.4	1357
Curved Segments Only	9	87.0	10.5	2.5	1.2	0.0	4.9	71.6	0.0	1.2	21.0	162
	10	82.8	15.8	1.4	1.5	0.2	5.8	67.1	0.0	0.7	24.7	1198
	11	84.4	14.4	1.2	1.1	0.0	5.1	68.4	0.0	0.3	25.0	974
Highways Without Edge Lines												
All Segments	All	81.2	17.7	0.0	2.6	0.2	3.5	64.9	0.0	0.9	27.8	4688
All Segments	9	85.3	14.4	0.0	2.9	0.0	3.4	68.4	0.0	0.4	25.0	557
	10	80.0	18.7	0.0	2.7	0.2	3.8	63.8	0.0	0.9	28.6	3440
	11	83.9	15.8	0.0	2.2	0.3	2.3	67.6	0.0	1.6	26.0	691
Straight Segments Only	9	76.8	22.5	0.7	5.2	0.0	4.1	51.7	0.0	0.7	38.4	271
	10	74.6	23.6	1.8	3.6	0.2	3.7	52.2	0.2	1.5	38.7	1873
	11	81.1	18.6	0.3	2.8	0.6	2.3	57.6	0.0	2.3	34.5	354
Curved Segments Only	9	93.4	6.6	0.0	0.7	0.0	2.8	84.3	0.0	0.0	12.2	286
	10	86.5	12.8	0.8	1.6	0.1	4.0	77.7	0.0	0.8	15.9	1567
	11	86.9	12.8	0.3	1.5	0.0	2.4	78.0	0.0	0.9	17.2	337

3.7 Analysis of Crash Distribution In and Between Intersections

The next important factor included in the analysis was distribution of crashes in and between intersections.

The DPS database includes four definitions for the relationship of the proximity of an accident to an intersection (see Appendix B): non-intersection, driveway-related, intersection-related, and at-an-intersection. For this study, all accidents coded corresponding to the last three sub-classes were combined as *intersection-related*. The obtained proportions of corresponding crashes are represented in Table 3.8.

In both cases of highways with and without edge lines, the majority of accidents occurred between intersections (76.3 percent for highways with edge lines and 81.8 percent for highways without edge lines). Regarding lane width for highways with and without edge lines, percentages of non-intersection accidents do not substantially vary with increasing lane width. However, slightly higher percentages of non-intersection accidents are found on narrow highways with 9-foot lane widths.

Comparing horizontally curved to straight highway segments for highways with and without edge lines, the percentage of non-intersection accidents is greater on curves than on straight segments among all lane-width classes.

Based on evidence presented in Table 3.8, for all analyzed highway classes, non-intersection accidents occur with greater frequency on highways without edge lines than those with edge lines.

The proportion of intersection-related accidents was observed to be higher overall on highways with edge lines (23.7 percent) than without edge lines (18.2 percent). This fact is most likely explained by the difference in traffic volumes on those types of highways (see Chapter 3.4.1) and in turn by possible lower intersection frequencies on highways without edge lines. At the same time, slightly higher percentages of intersection-related accidents were observed on curved segments of narrow highways (9-foot lane widths) without edge lines, which correspond with the findings from the previous analyses.

Table 3.8 Distribution of Accidents Related to Intersections

Horizontal Alignment	Lane Width	Percentage of Total Accidents				Total Number of Accidents
		Intersection-Related			Non Intersection	
		At Intersection	Intersection Related	Driveway Related		
Highways With Edge Lines						
All Segments	**All**	7.3	6.9	9.5	76.3	5086
All Segments	**9**	8.6	5.1	7.3	79.0	315
	10	7.0	7.4	10.0	75.6	2440
	11	7.4	6.6	9.2	76.7	2331
Straight Segments Only	**9**	13.7	7.2	13.7	65.4	153
	10	8.8	8.5	12.6	70.1	1242
	11	9.1	6.9	12.1	71.8	1357
Curved Segments Only	**9**	3.7	3.1	1.2	92.0	162
	10	5.3	6.2	7.3	81.3	1198
	11	5.0	6.3	5.2	83.5	974
Highways Without Edge Lines						
All Segments	**All**	5.5	5.8	6.9	81.8	4688
All Segments	**9**	3.2	5.6	6.5	84.7	557
	10	5.9	5.8	7.2	81.2	3440
	11	5.2	6.2	5.8	82.8	691
Straight Segments Only	**9**	4.8	6.6	8.9	79.7	271
	10	8.1	6.1	9.0	76.8	1873
	11	7.1	7.1	5.9	79.9	354
Curved Segments Only	**9**	1.7	4.5	4.2	89.5	286
	10	3.2	5.4	5.0	86.3	1567
	11	3.3	5.3	5.6	85.8	337

3.8 Lighting Condition

According to the DPS database, five lighting condition categories are given: daylight, dusk, dawn, darkness (not lighted), and darkness (lighted). The proportions of crashes corresponding to different light conditions are represented in Table 3.9.

Percentages of dusk, dawn, and darkness (lighted) accidents are generally less than 2 percent, so the lighting condition analysis focused on comparing accident percentages for daylight and darkness (non-lighted) conditions.

The majority of accidents on both highways with and without edge lines occurred during daylight (55 percent and 54 percent respectively) but considering that traffic volumes at night are very low on such roads, the percentage of accidents at night-time (39 percent for highways with edge lines and 40 percent for highways without edge lines) seems to be very high.

No significant differences in accident proportions during daylight and darkness between highways with and without edge lines were observed over all analyzed highway classes. At the same time, slightly higher accident frequencies can be noted on curved segments without edge lines during daytime while straight segments have a higher accident frequency at night-time.

For more accurate identification of edge line safety impacts an accident ratio analysis may be more informative, but the available databases do not provide information regarding daytime and night-time traffic volumes.

Table 3.9 Distribution of Accidents by Light Condition

Horizontal Alignment	Lane Width	Percentage of Total Accidents: Light Condition					Total Number of Accidents
		Daylight	Darkness (not lighted)	Darkness (lighted)	Dusk	Dawn	
Highways With Edge Lines							
All Segments	All	55.2	39.5	1.9	1.6	1.8	5086
All Segments	9	60.3	34.3	1.6	2.2	1.6	315
	10	55.2	39.7	1.9	1.7	1.6	2440
	11	54.5	39.9	2.0	1.5	2.1	2331
Straight Segments Only	9	64.1	32.0	1.3	2.6	0.0	153
	10	56.0	39.2	1.6	1.4	1.8	1242
	11	53.6	40.6	2.1	1.9	1.8	1357
Curved Segments Only	9	56.8	36.4	1.9	1.9	3.1	162
	10	54.3	40.2	2.2	1.9	1.4	1198
	11	55.6	39.0	1.8	0.9	2.6	974
Highways Without Edge Lines							
All Segments	All	54.0	39.9	1.7	2.1	2.3	4688
All Segments	9	54.9	39.9	1.4	1.3	2.5	557
	10	54.4	39.7	1.8	2.1	1.9	3440
	11	50.8	41.2	1.6	2.5	3.9	691
Straight Segments Only	9	50.9	43.2	1.5	1.5	3.0	271
	10	51.5	42.4	1.7	2.3	2.1	1873
	11	44.6	46.3	2.0	3.4	3.7	354
Curved Segments Only	9	58.7	36.7	1.4	1.0	2.1	286
	10	58.0	36.4	1.9	1.9	1.8	1567
	11	57.3	35.9	1.2	1.5	4.2	337

3.9 Surface Condition

Percentages of accidents by varying surface condition were next examined. Though the DPS database gives four surface conditions (dry, wet, muddy, and snowy/icy), this analysis focused on only wet and dry surface conditions due to the extremely small percentage of accidents that occurred during muddy or snowy conditions (typically less than 2 percent).

Overall, 80.7 percent of accidents on highways with edge lines occurred under dry surface conditions and 18.2 percent of accidents occurred under wet conditions. On highways without edge lines, these values are very similar: 80.8 percent and 17.8 percent respectively.

No clear trends or differences are seen regarding surface condition response on highways with and without edge lines as lane width varies.

However, the percentage of accidents occurring during wet surface conditions increases on curved segments when compared to straight segments for both highways with and without edge lines. In the case of highways with edge lines, the average percentage across all lane widths of accidents on wet surfaces jumps from 15.2 percent on straight segments to 18.9 percent on curved segments, or an increase of 4.7 percent. On highways without edge lines, values are 13.7 percent and 19.6 percent, or an increase of 5.9 percent on curved segments.

It was observed that on narrow roadways (9-foot lane widths) there are no differences in the proportion of accidents occurring on wet surfaces for straight and curved segments on highways with edge lines. However, for these types of highways without edge lines, curved segments continue to have higher accident frequencies than straight segments. Therefore, it can be concluded that the presence of edge lines on narrow roadways reduces the difference in accident frequency on straight and curved segments during wet surface conditions.

Table 3.10 Distribution of Accidents by Surface Condition

Horizontal Alignment	Lane Width	Percentage of Total Accidents Surface Condition			Total Number of Accidents
		Dry	Wet	Other	
Highways With Edge Lines					
All Segments	**All**	80.7	18.2	1.1	5086
All Segments	**9**	85.4	13.7	1.0	315
	10	79.8	19.3	0.9	2440
	11	81.0	17.7	1.2	2331
Straight Segments Only	**9**	86.3	13.7	0.0	153
	10	82.1	16.5	1.4	1242
	11	83.4	15.4	1.2	1357
Curved Segments Only	**9**	84.6	13.6	1.9	162
	10	77.4	22.2	0.4	1198
	11	77.7	20.9	1.3	974
Highways Without Edge Lines					
All Segments	**All**	80.8	17.8	1.4	4688
All Segments	**9**	84.4	14.4	1.3	557
	10	80.1	18.5	1.3	3440
	11	81.2	16.6	2.2	691
Straight Segments Only	**9**	83.8	13.7	2.6	271
	10	82.6	15.5	1.9	1873
	11	85.9	11.9	2.3	354
Curved Segments Only	**9**	85.0	15.0	0.0	286
	10	77.2	22.2	0.6	1567
	11	76.3	21.7	2.1	337

3.10 Severity

The DPS accident database contains information concerning injuries and fatalities occurring to drivers and occupants of all vehicles involved in crashes. Five severity levels are given, as noted in Appendix B: non-injury, possible injury, non-incapacitating injury, incapacitating injury, and fatality. Severity was studied generally for highways with and without edge lines, as well as for varying lane widths, horizontal curvature, intersection and non-intersection-related accidents, and light condition. The collected statistics are represented in Tables 3.11-3.15.

Overall, the data shows almost no difference in crash severity on highways with and without edge lines for all analyzed conditions.

As lane width increases, the percentage of non-injury accidents in turn increases on both highways with edge lines (3 percent increase from 9-foot to 11-foot lane width) and highways without edge lines (7 percent increase).

Comparing curved and straight segments, the percentage of incapacitating injury and fatality accidents increases on horizontal curves for highways with and without edge lines. On highways with edge lines, incapacitating injury accidents increase from 9.9 percent on straight segments to 12.3 percent on curved segments and fatalities increase from 2.6 percent to 3.4 percent while these increases are 9.9 percent to 12.4 percent and 2.6 percent to 3.9 percent respectively on highways without edge lines.

Table 3.11 Distribution of Accidents by Severity – General

Horizontal Alignment	Lane Width	Percentage of Total Accidents – Severity					Total Number of Accidents
		Non-Injury	Possible Injury	Non-Incap. Injury	Incap. Injury	Fatal	
Highways With Edge Lines							
All Segments	**All**	38.8	23.4	23.9	10.9	3.0	5086
All Segments	**9**	35.5	25.1	25.8	10.7	2.9	315
	10	38.7	23.9	23.5	11.3	2.6	2440
	11	39.3	22.8	24.0	10.6	3.3	2331
Straight Only	**All**	39.2	25.2	23.0	9.9	2.6	2752
Curved Only	**All**	38.2	21.1	25.0	12.3	3.4	2334
Highways Without Edge Lines							
All Segments	**All**	39.1	22.6	24.0	11.0	3.2	4688
All Segments	**9**	35.0	22.4	25.7	13.6	3.3	557
	10	39.0	22.6	24.0	10.8	3.5	3440
	11	42.0	22.4	23.0	10.3	2.3	691
Straight Only	**All**	40.8	23.7	23.0	9.9	2.6	2498
Curved Only	**All**	37.2	21.2	25.3	12.4	3.9	2190

Table 3.12 Distribution of Intersection-Related Accidents by Severity (Daylight)

Horizontal Alignment	Lane Width	Percentage of Total Accidents					Total Number of Accidents
		Severity					
		Non-Injury	Possible Injury	Non-Incap. Injury	Incap. Injury	Fatal	
Highways With Edge Lines							
All Segments	**All**	34.6	31.3	22.8	9.8	1.6	1230
All Segments	**9**	28.3	29.0	29.3	10.9	2.5	81
	10	34.9	31.3	22.2	10.4	1.2	610
	11	35.3	31.7	22.3	8.8	1.9	539
Straight Only	**All**	34.5	32.4	22.2	9.3	1.6	842
Curved Only	**All**	34.9	28.6	24.2	10.8	1.4	388
Highways Without Edge Lines							
All Segments	**All**	36.2	28.3	23.8	9.9	1.8	973
All Segments	**9**	32.7	33.1	23.3	9.8	1.2	94
	10	36.8	27.4	24.2	9.9	1.7	728
	11	35.9	29.2	22.8	9.8	2.3	151
Straight Only	**All**	36.2	28.8	23.2	10.0	1.9	657
Curved Only	**All**	36.2	27.2	25.3	9.6	1.6	316

Table 3.13 Distribution of Intersection-Related Accidents by Severity (Darkness)

Horizontal Alignment	Lane Width	Percentage of Total Accidents					Total Number of Accidents
		Severity					
		Non-Injury	Possible Injury	Non-Incap. Injury	Incap. Injury	Fatal	
Highways With Edge Lines							
All Segments	**All**	37.9	24.9	24.2	10.6	2.4	382
All Segments	**9**	53.1	18.8	18.8	7.8	1.6	19
	10	34.8	26.8	23.2	12.7	2.5	185
	11	39.2	23.7	25.8	8.9	2.3	178
Straight Only	**All**	38.5	27.7	22.5	9.7	1.6	220
Curved Only	**All**	36.9	20.6	26.8	12.1	3.6	162
Highways Without Edge Lines							
All Segments	**All**	37.5	23.0	24.5	13.4	1.7	318
All Segments	**9**	29.7	28.6	27.5	11.0	3.3	35
	10	36.5	23.1	24.3	14.3	1.9	232
	11	45.1	19.7	23.7	11.6	0.0	51
Straight Only	**All**	36.7	25.6	24.4	12.3	1.0	183
Curved Only	**All**	38.7	19.2	24.6	14.9	2.6	135

Table 3.14 Distribution of Between-Intersection Accidents by Severity (Daylight)

Horizontal Alignment	Lane Width	Percentage of Total Accidents – Severity					Total Number of Accidents
		Non-Injury	Possible Injury	Non-Incap. Injury	Incap. Injury	Fatal	
Highways With Edge Lines							
All Segments	**All**	23.9	22.5	25.5	12.1	3.1	1920
All Segments	**9**	33.3	25.8	27.3	11.7	1.9	122
	10	37.3	22.7	25.1	12.2	2.8	895
	11	36.9	21.9	25.6	12.0	3.6	903
Straight Only	**All**	37.7	23.7	24.7	11.0	2.9	899
Curved Only	**All**	36.0	21.3	26.2	13.1	3.4	1021
Highways Without Edge Lines							
All Segments	**All**	36.7	21.7	26.1	12.1	3.4	1832
All Segments	**9**	30.6	21.2	27.7	17.3	3.1	233
	10	36.4	21.8	26.2	11.7	3.8	1338
	11	41.9	21.7	24.6	9.7	2.2	261
Straight Only	**All**	38.0	21.8	25.9	11.4	2.8	829
Curved Only	**All**	35.6	21.6	26.2	12.6	4.0	1003

Table 3.15 Distribution of Between-Intersection Accidents by Severity (Darkness)

Horizontal Alignment	Lane Width	Percentage of Total Accidents – Severity					Total Number of Accidents
		Non-Injury	Possible Injury	Non-Incap. Injury	Incap. Injury	Fatal	
Highways With Edge Lines							
All Segments	**All**	43.6	18.3	23.2	10.9	4.0	1554
All Segments	**9**	42.0	20.7	22.3	10.5	4.5	92
	10	43.9	18.5	23.1	11.0	3.4	750
	11	43.6	17.8	23.5	10.8	4.4	712
Straight Only	**All**	45.2	19.2	22.4	9.6	3.6	791
Curved Only	**All**	41.8	17.2	24.2	12.3	4.4	763
Highways Without Edge Lines							
All Segments	**All**	43.8	19.6	22.0	10.4	4.1	1565
All Segments	**9**	41.4	17.5	24.1	12.4	4.7	195
	10	43.3	20.5	22.0	9.8	4.4	1142
	11	47.4	17.8	20.8	11.2	2.8	228
Straight Only	**All**	47.8	21.1	19.4	8.4	3.2	829
Curved Only	**All**	39.1	17.9	25.1	12.8	5.1	736

3.11 Driver-Related Crash-Supporting Factors

Driver-related crash-supporting factors, as recorded by the officer who filled out the police report at the accident scene, are included in the DPS database as well. As shown in Appendix B (*Contributing Factors*), factors are split into two groups, labeled Factor 1 and Factor 2, and each accident can be marked as having one factor in each group.

For the purposes of this research, some factors were eliminated or combined due to extremely small sample size. In the case of Factor 1, final variables included in the project are speeding, failure to yield ROW, disregard for sign or signal, improper turn (all types), and unknown or other factor. For Factor 2, possible factors are following too closely, improper passing factors, alcohol or drug use, and unknown or other. In both factor groups, unknown or other are predominantly determined by the absence of an identified factor in the police report.

Crash-supporting factors were studied generally for highways with and without edge lines, as well as for varying lane width conditions, curved and straight segments, intersection and non-intersection-related accidents, and light conditions. The results are detailed in Tables 3.16-3.20.

Among all investigated roadway parameters, the predominant crash-supporting factor is speeding followed by failure to yield ROW and then disregard for signs and signals. Overall, the percentage of crashes where those factors were noted are 41.1, 3.8, and 3.6 percent respectively for highways with edge lines and 40.3, 4.4, and 4.6 percent for highways without edge lines. From factors included in the second group, not considering alcohol and drug use, the major supporting factor was identified as passing inadequacy representing 3.0 and 2.4 percent of all crashes on highways with and without edge lines respectively.

The detailed consideration of lane widths and horizontal alignment does not show any significant differences between highways with and without edge lines.

The analysis of intersection-related accidents showed that on highways without edge lines, excessive speed was noted less frequently than for highways with edge lines during daytime, but the opposite occurred for the disregarding signs and signals factor. During night-time, both of the above-mentioned factors were more frequent on highways without edge lines. The highest difference between those factors was observed on narrow roadways (9 foot lane width).

Comparing daylight and night-time, the speeding factor increased on both highways with and without edge lines during darkness, but this increase was greater on non-edge-striped sections (16 percent) than on edge-striped sections (6 percent). The failure to yield ROW and passing inadequacy factors were less frequent during nighttime while disregard for signs and signals increased but there were no significant differences between highways with and without edge lines.

Speeding was the major supporting factor for accidents between intersections for both highways with and without edge lines as well as with detailed consideration of lane widths and horizontal alignment. Overall, this factor was noted in 50.7 percent of all crashes during daylight and in 41.8 percent of all crashes at night-time for edge-striped highway segments between intersections. The corresponding values for highways without edge lines were 50.7 percent and 40.6 percent of all crashes.

The obtained data does not allow identification of significant differences between crash-supporting factors on highways with and without edge lines. However, the smaller increase of speeding-related accidents at night-time (compared to daytime) near intersections with edge lines compared to without edge lines may be related to better driver perception of traffic conditions due to edge-line presence.

Table 3.16 Distribution of Accidents by Crash-Supporting Factors

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Factor 1					Factor 2				
		Speeding	Fail to Yield ROW	Disregard Sign or Signal	Improper Turn	Unknown or Other	Follow Too close	Passing Related	Alcohol or Drugs	Unknown or Other	
Highways With Edge Lines											
All Segments	**All**	41.1	3.8	3.6	0.3	51.0	1.4	3.0	16.1	79.5	5086
All Segments	**9**	44.0	4.9	2.3	0.1	48.1	1.4	3.0	17.5	78.0	315
	10	42.4	4.0	3.0	0.4	50.2	1.1	3.2	15.7	80.1	2440
	11	39.4	3.5	4.4	0.3	52.2	1.7	2.9	16.4	79.1	2331
Straight Only	**All**	32.0	3.9	4.0	0.4	59.5	1.7	3.8	13.9	80.6	2752
Curved Only	**All**	52.3	3.8	3.0	0.1	40.7	1.0	1.8	19.0	78.2	2334
Highways Without Edge Lines											
All Segments	**All**	40.3	4.4	4.6	0.2	50.3	0.9	2.4	16.5	80.1	4688
All Segments	**9**	41.1	5.0	6.2	0.1	47.5	0.8	1.4	16.1	81.7	557
	10	39.4	4.4	4.6	0.3	51.2	0.9	2.5	16.7	79.9	3440
	11	42.9	4.4	3.7	0.2	48.7	1.2	2.8	16.0	80.0	691
Straight Only	**All**	30.8	5.0	5.4	0.2	58.5	1.0	3.0	13.8	82.2	2498
Curved Only	**All**	51.3	3.5	3.3	0.2	41.5	0.8	1.7	20.1	77.5	2190

Table 3.17 Distribution of Intersection-Related Accidents by Crash-Supporting Factors (Daylight)

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Factor 1					Factor 2				
		Speeding	Fail to Yield ROW	Disregard Sign or Signal	Improper Turn	Unknown or Other	Follow Too close	Passing Related	Alcohol or Drugs	Unknown or Other	
Highways With Edge Lines											
All Segments	All	32.9	11.3	2.5	0.4	52.8	3.6	6.6	3.6	86.2	1230
All Segments	9	33.0	15.6	2.9	0.0	48.6	2.9	5.8	3.3	88.0	81
	10	32.7	12.0	2.0	0.4	52.9	2.7	6.3	3.7	87.3	610
	11	33.2	9.8	2.9	0.5	53.4	4.6	7.1	3.4	84.8	539
Straight Only	All	30.7	11.2	2.4	0.5	55.1	3.7	7.4	3.1	85.8	842
Curved Only	All	38.4	11.4	2.7	0.3	47.1	3.3	4.7	4.7	87.3	388
Highways Without Edge Lines											
All Segments	All	27.1	12.3	5.2	0.5	54.8	1.9	5.8	3.2	89.0	973
All Segments	9	24.5	14.3	6.9	0.4	53.9	2.9	3.3	2.4	91.4	94
	10	26.9	12.4	4.9	0.6	55.1	1.8	5.6	3.4	89.2	728
	11	29.2	11.0	5.6	0.2	54.1	1.9	7.9	2.9	87.3	151
Straight Only	All	24.9	13.3	6.1	0.6	55.0	2.2	6.4	2.5	88.9	657
Curved Only	All	32.0	10.1	3.2	0.4	54.3	1.2	4.6	4.8	89.4	316

Table 3.18 Distribution of Intersection-Related Accidents by Crash-Supporting Factors (Darkness)

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Factor 1					Factor 2				
		Speeding	Fail to Yield ROW	Disregard Sign or Signal	Improper Turn	Unknown or Other	Follow Too close	Passing Related	Alcohol or Drugs	Unknown or Other	
Highways With Edge Lines											
All Segments	**All**	38.9	3.9	11.8	0.6	44.6	0.4	3.4	25.2	71.0	382
All Segments	**9**	40.6	3.1	6.3	0.0	48.4	1.6	3.1	31.3	64.1	19
	10	41.5	3.7	9.7	0.8	44.2	0.3	4.3	23.2	72.2	185
	11	36.1	4.1	14.6	0.5	44.5	0.3	2.5	26.7	70.5	178
Straight Only	**All**	32.7	4.1	13.5	0.9	48.6	0.7	4.6	22.9	71.9	220
Curved Only	**All**	48.2	3.6	9.3	0.2	38.5	0.0	1.6	28.8	69.6	162
Highways Without Edge Lines											
All Segments	**All**	42.6	5.2	12.9	0.2	38.9	0.7	2.1	26.5	70.7	318
All Segments	**9**	47.3	5.5	17.6	0.0	29.7	0.0	1.1	23.1	75.8	35
	10	42.0	4.8	13.3	0.2	39.6	0.7	2.6	27.0	69.7	232
	11	42.2	6.4	9.2	0.6	41.6	1.2	1.2	26.6	71.1	51
Straight Only	**All**	36.1	6.3	14.9	0.2	42.3	0.2	2.8	22.8	74.2	183
Curved Only	**All**	51.9	3.7	10.0	0.3	34.1	1.4	1.1	31.8	65.6	135

Table 3.19 Distribution of Between-Intersection Accidents by Crash-Supporting Factors (Daylight)

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Factor 1					Factor 2				
		Speeding	Fail to Yield ROW	Disregard Sign or Signal	Improper Turn	Unknown or Other	Follow Too close	Passing Related	Alcohol or Drugs	Unknown or Other	
Highways With Edge Lines											
All Segments	**All**	50.7	0.1	0.0	0.0	48.9	1.1	1.5	8.0	89.4	1920
All Segments	**9**	53.3	0.7	0.0	0.2	45.2	1.0	1.4	9.8	87.8	122
	10	52.5	0.1	0.1	0.1	47.1	0.8	1.7	7.7	89.8	895
	11	48.7	0.1	0.0	0.0	51.0	1.5	1.4	8.0	89.2	903
Straight Only	**All**	37.9	0.2	0.1	0.1	61.5	1.7	2.5	6.6	89.1	899
Curved Only	**All**	63.3	0.0	0.0	0.0	36.5	0.6	0.5	9.3	89.6	1021
Highways Without Edge Lines											
All Segments	**All**	50.7	0.1	0.1	0.1	48.8	0.8	1.4	9.4	88.4	1832
All Segments	**9**	53.0	0.3	0.2	0.2	46.4	0.2	0.8	10.9	88.2	233
	10	49.1	0.1	0.1	0.1	50.3	0.8	1.4	9.1	88.6	1338
	11	55.0	0.1	0.0	0.0	44.9	1.3	1.8	9.3	87.6	261
Straight Only	**All**	36.4	0.2	0.2	0.1	63.0	1.3	2.3	8.5	87.9	829
Curved Only	**All**	63.1	0.0	0.0	0.1	36.5	0.4	0.7	10.1	88.8	1003

Table 3.20 Distribution of Between-Intersection Accidents by Crash-Supporting Factors (Darkness)

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Factor 1					Factor 2				
		Speeding	Fail to Yield ROW	Disregard Sign or Signal	Improper Turn	Unknown or Other	Follow Too close	Passing Related	Alcohol or Drugs	Unknown or Other	
Highways With Edge Lines											
All Segments	**All**	41.8	0.0	0.0	0.1	57.8	0.3	0.6	27.7	71.4	1554
All Segments	**9**	49.0	0.0	0.0	0.0	50.3	0.3	1.6	25.8	72.3	92
	10	42.9	0.0	0.0	0.1	56.6	0.3	0.6	28.2	70.9	750
	11	39.7	0.0	0.0	0.0	60.0	0.3	0.5	27.4	71.8	712
Straight Only	**All**	26.7	0.1	0.1	0.1	72.7	0.5	0.8	22.8	75.8	791
Curved Only	**All**	59.2	0.0	0.0	0.0	40.6	0.1	0.4	33.2	66.3	763
Highways Without Edge Lines											
All Segments	**All**	40.6	0.1	0.1	0.1	58.8	0.2	0.3	27.0	72.5	1565
All Segments	**9**	39.8	0.0	0.0	0.0	60.0	0.2	0.4	28.0	71.5	195
	10	39.5	0.1	0.1	0.1	59.9	0.1	0.3	27.4	72.1	1142
	11	45.2	0.0	0.0	0.0	54.3	0.4	0.3	25.1	74.3	228
Straight Only	**All**	25.7	0.2	0.1	0.1	73.8	0.2	0.4	21.6	77.8	829
Curved Only	**All**	58.4	0.0	0.0	0.1	41.1	0.2	0.3	33.5	66.1	736

3.12 Driver Age and Gender

Driver age and gender variables, both recorded in the DPS accident database (Appendix B), were studied for all highways including varying traffic-lane widths and horizontal curvature and results are enumerated in Table 3.21. Driver age was split into six categories, 16-20, 21-30, 31-40, 41-50, 51-60, and greater than 60 years old. A small percentage (2 percent) of drivers' ages was unknown according to the DPS database.

For all highway classes, the distribution of drivers of different age groups involved in accidents changes very little. Drivers from 16 to 30 years old are involved in approximately half of all crashes with drivers aged 16-20 years old accounting for approximately 25 percent of all crashes. No differences can be found between highways with and without edge lines.

Across all highway categories, driver gender percentages show little variation: male drivers account for approximately 66 percent of all accidents, or a ratio of 2 to 1 compared to female drivers. This large discrepancy between genders could be caused by a lower population of female drivers than male drivers on rural two-lane roadways, but this data is not available in either the DPS or TxDOT databases, so the conjecture cannot be adequately tested. The gender discrepancy could also be caused by the higher sensitivity of the female nervous system that may provide better performance for female drivers in low-informational-input systems such as those typical for rural two-lane roads.

Table 3.21 Distribution of Accidents by Driver Age and Gender

Horizontal Alignment	Lane Width	Percentage of Total Accidents									Total Number of Accidents
		Driver Gender		Driver Age							
		Male	Female	16-20	21-30	31-40	41-50	51-60	Greater Than 60	Unknown	
Highways With Edge Lines											
All Segments	**All**	65.1	34.9	23.7	24.6	19.9	14.6	7.7	7.2	2.1	5086
All Segments	**9**	65.4	34.6	26.0	22.1	19.9	13.2	9.3	7.1	1.9	315
	10	64.9	35.1	24.4	23.8	19.7	14.9	7.6	7.3	2.1	2440
	11	65.2	34.8	22.6	25.7	20.1	14.5	7.5	7.1	2.2	2331
Straight Only	**All**	64.5	35.5	23.6	23.8	19.6	14.5	8.1	7.9	2.1	2752
Curved Only	**All**	65.9	34.1	23.7	25.6	20.3	14.7	7.1	6.2	2.1	2334
Highways Without Edge Lines											
All Segments	**All**	65.6	34.4	24.7	25.0	18.9	14.6	7.0	7.0	2.1	4688
All Segments	**9**	66.4	33.6	24.6	24.7	19.8	14.2	6.9	7.4	2.0	557
	10	65.1	34.9	24.9	25.3	19.0	14.4	6.7	7.2	2.0	3440
	11	66.8	33.2	24.3	24.2	18.4	15.7	8.3	6.0	2.5	691
Straight Only	**All**	64.8	35.2	24.3	24.6	18.7	14.5	7.1	8.2	2.1	2498
Curved Only	**All**	66.6	33.4	25.3	25.5	19.2	14.8	6.9	5.5	2.2	2190

4. Summary and Conclusions

Rural two-lane roadways in Texas number 57,367 miles and comprise more than 70 percent of the highway system maintained by TxDOT.

Approximately 98 percent of such roadways have lane widths of 9-13 feet with a predominance of highways with lane widths of 10 and 12 feet, containing 22,134 and 18,243 miles respectively. Highways with lane widths of 9, 11, and 13 feet each account for approximately 5,000 miles.

Of the 27,650 miles of highways with the narrowest lane widths of 9 or 10 feet, 88 percent have shoulder widths equal to or less than 4 feet with the most frequent shoulder widths of exactly 4 feet (41 percent). Highways with increased lane widths tend to have wider shoulders. For the 23,333 miles of highways with lane widths of 11 or 12 feet, 97 percent have shoulder widths equal to or less than 10 feet, and for lane widths of 13 feet there is an overwhelming majority of mileage with shoulder widths of 8 or 9 feet. A significant amount of highways with lane widths of 9, 10, and 11 feet have no shoulder or a shoulder of only 1 foot, accounting for 20, 26, and 39 percent of total mileage of such highways correspondingly. This situation was observed much less on wider highways with lane widths of 12- and 13-feet in which such shoulder widths contained 11 and 8 percent respectively.

For all rural, two-lane highways in Texas, the mean AADT is approximately 2,400 vehicles-per-day and ranges from 700 to almost 6,000 VPD with the highest volumes appropriately observed on highways with the most advanced design parameters (widest lanes and shoulders).

Overall for observed highways the major curve type was *normal*, which accounts for 96 percent of the over 70,000 existing curves. Other curve types, *point* and *spiral*, represent less than 2 percent each.

Across all rural two-lane highways in the state, the average number of normal curves per highway mile is 1.11 and ranges between 0.46 and 1.97 normal curves per mile by TxDOT district. The highest frequency of curves is observed on narrow roadways with 9- and 10-foot lane widths and such roadways contain an average 1.63 normal curves per mile. Highways with lane widths of 11, 12, and 13 feet show little variance and contain an average 0.95 normal curves per mile. Narrow roadways also have higher frequencies of small-radius curves. For roadways with lane widths of 9-11 feet, the average 15^{th} percentile radius is 600 feet; whereas for highways with 12- and 13-foot lane widths, the value is 1,100 feet.

Across the state, 59 percent of investigated highways have edge lines, but this percentage varies greatly across districts: values range from 27 percent to 98 percent.

Narrow highways with lane widths of 8, 9, and 10 feet are less frequently treated with edge lines than highways with wider lane widths. Across the state, only 32.2 percent of narrow two-lane roadways have edge lines, but this percentage greatly increases to 84.3 percent for wider highways. Further, the smallest edge-line treatment mileages are found on highways with both narrow lane widths and narrow shoulder widths.

The conducted comparative analysis of crash statistics on highways with and without edge lines allowed for the following conclusions:

If considering both non-accident and accident-prone (two or more accidents) highway sections together, highways without edge lines are characterized by lower accident frequency than highways with edge lines. This phenomenon was observed for all analyzed parameters and can be explained by the far lower number of vehicle-miles-traveled on highways without edge lines, which led to many more sections that have zero or one accident compared to sections with edge lines.

However, on accident-prone sections, highways without edge lines have an 8 percent higher mean accident ratio than similar sections with edge lines, supporting the previous hypothesis that crashes on highways without edge lines are concentrated on certain accident-prone segments.

The difference between accident frequency for highways with and without edge lines is greatest on narrow roads of 9-foot lane width and the highest overall accident ratio was observed with absence of edge lines. Both of these findings indicate some positive safety effect of edge line treatment on narrow roads and allow the assumption that this impact is greatest on the narrowest roadways. No significant impact of edge lines on accident frequency was observed across the analyzed shoulder widths cases of 0-2 and 3-4 feet. This can be attributed to the fact that the driver perceives all paved surface from the center line to the edge of the road as a travel lane rather than as a travel lane with a separate shoulder, reducing the validity of the conducted shoulder-width analysis.

In relation to horizontal curvature, the reduction of accidents due to edge-line presence was observed to be significantly higher on curved than on straight segments: straight portions of roadway showed a 6 percent decrease in accident frequency on highways with edge lines but this decrease was 26 percent for curved segments. For the analyzed traffic lane widths, the major safety impact of edge lines on straight segments was observed at lane widths of 10 feet which showed an 11 percent accident reduction. For curved segments, the highest impact occurred at 9-foot lane widths and was valued at 32 percent.

Overall, for all lane widths, the frequency of run-off-the-road (ROR) accidents is 11 percent higher on highways without edge lines than with edge lines and the highest difference (12 percent) was observed for lane widths of 9 feet. Occurrences of ROR accidents were observed to be highest on the narrowest highways (lane widths of 9 feet) for both highways with and without edge lines, and the highest overall ROR percentage was found on curved segments with lane widths of 9 feet and no edge lines.

For both highways with and without edge lines, over 75 percent of all accidents occur between intersections. Although the proportion of intersection-related accidents was observed to be higher overall of highways with edge lines (24 percent) than without (18 percent), the difference could likely be due to disparities in traffic volume or intersection concentration between highway types. At the same time, slightly higher percentages of intersection-related accidents were observed on curved segments of narrow highways (9-foot lane widths) without edge lines.

Concerning lighting conditions, no significant differences in accident proportions during daylight and darkness were observed between highways with and without edge lines over all analyzed highway classes. At the same time, slightly higher accident frequencies can be noted on curved segments without edge lines during daytime while straight segments have a higher accident frequency at night-time.

The analysis indicated some safety impact of edge lines on curved segments during wet surface conditions. Overall for all highway classes, the percentage of accidents occurring during such conditions increases on curved segments when compared to straight segments for both highways with and without edge lines, but this increase was observed to be higher on highways without edge lines. Although it was observed that on narrow roadways (9-foot lane widths) there are no differences in the proportion of accidents occurring on wet surfaces for straight and curved segments on highways with edge lines, for these types of highways without edge lines curved segments continue to have higher accident frequencies than straight segments. Therefore, it can be concluded that the presence of edge lines on narrow roadways may improve driver performance on curved segments during wet conditions.

The conducted analysis does not indicate any impact of edge-line presence on accident severity.

The predominant crash-supporting factor was identified as speeding (40 percent overall for all highways) followed by failure to yield right-of-way (4 percent), disregarding signs and signals (4 percent), and passing inadequacy (2.7 percent) with little variation between highways with and without edge lines. However, on intersections during night-time, speeding and disregarding signs and signals were noted more frequently on highways without edge lines. Further, comparing daylight and night-time, the speeding factor increased on both highways with and without edge lines during darkness, but this increase was greater on non-edge-striped sections (16 percent) than on edge-striped sections (6 percent).

Therefore, the obtained findings can be summarized as follows: edge-line treatments on rural two-lane roadways may reduce accident frequency with the highest safety impact on curved segments of narrow roadways. Also, edge-line presence shows some positive safety impact during darkness that may be related to better driver perception of path and speed.

5. Future Research

For better understanding of the safety impact of edge lines, the accident statistics analysis should be supported by the deep understanding of driver reaction and responses. With this purpose, several investigations will be performed in the next study phase.

First, the analysis of the impact of edge lines on vehicle speed and lateral position will be conducted. Further research will target the determination of driver performance and psycho-physiological responses under edge-line presence. This will include investigation of driver perception of roadway curvature, advance recognition of adjacent roadways, pedestrians, or animals crossing the roadway, eye recovery after the blinding effect from oncoming vehicle headlights, and stress level in general.

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Appendix A

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
1 – 1	N1	**RECORD-TYPE**	1=Mainlanes 2=Right Frontage 3=Left Frontage 8=Link segment (not used for mileage)
2 – 3	N2	**DISTRICT-ID**	01 – 25
4 – 6	N3	**COUNTY-NUMBER**	001 – 254 State county number, not FIPS county number
7 – 11	N5	**CITY-NUMBER**	00000 – 99999
12 – 18	A7	**SIGNED-HIGHWAY**	
12 – 13	A2	**HIGHWAY-SYSTEM**	IH=Interstate BF=Business FM US=US Highway FM=Farm to Mkt UA=US Alt. RM=Ranch to Mkt UP=US Spur RR=Ranch Road SH=State Highway PR=Park Road SA=State Alt. RE=Rec Road SL=State Loop RP=Rec Rd Spur SS=State Spur FS=FM Spur BI=Business IH RS=RM Spur BU=Business US RU=RR Spur BS=Business State PA=Principal Arterial
14 – 17	N4	**HIGHWAY-NUMBER**	(0001 – 9999)
18 – 18	A1	**HIGHWAY-SUFFIX**	A – Z for Park Roads A – H, J – N, P – Z for Business Routes Blank or A – Z for other highways
19 – 28		**FROM-REFERENCE-MARKER**	
19 – 22	N4	**FROM-REF-MARKER-NBR**	0010 – 9999 for non-IH 0000 – 9999 for IH
23 – 23	A1	**FROM-REF-MARKER-SUF**	Blank, then A – Z
24 – 28	N2.3	**FROM-REF-MARKER-DISP**	00.000 – 99.999
29 – 38		**TO-REFERENCE-MARKER**	
29 – 32	N4	**TO-REF-MARKER-NBR**	(see From Ref Marker Nbr)
33 – 33	A1	**TO-REF-MARKER-SUF**	(see From Ref Marker Suf)
34 – 38	N2.3	**TO-REF-MARKER-DISP**	(see From Ref Marker Disp)
39 – 40	A2	**ROADBED-ID**	CG = Centerline AG = Right Frontage Road XG = Left Frontage Road
41-47	N4.3	**LENGTH-OF-SECTION**	00.001 – 99.999
48 – 48	N1	**HIGHWAY-STATUS**	Not open to traffic: 1=New Route 3=Under construction Open to traffic: 4=Open but with some construction 5=District data input, TPP data needed 6=All data input 7=Emergency closing
49 – 50	N2		
51 – 52	N2	**FUNCTIONAL-SYSTEM**	Rural: Urban: 01=Interstate 11=Prin Arterial (IH) 02=Prin Arterial 12=Prin Arterial

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
			(other Freeway) 06=Minor Arterial 14=Prin Arterial (other) 07=Major Coll 16=Minor Arterial 08=Minor Coll 17=Collector 09=Local 19=Local
53 – 54	N2	**ADMIN-SYSTEM**	01=State (Rural) 02=State (City; 5000 or more) 03=Certified County maintained 04=Not county maintained (private, non-desig) 05=State (City; less than 5000) 06=City(Less than 5000) 07=Other State Agency (Rural) 08=Federal (Rural) 09=Other State (City >= 5000) 10=Other State (City < 5000 11=Federal (City; less than 5000) 12=Federal (City; 5000 or more) 13=City (5000 or more)
55 – 59	N5	**URBAN-AREA-NUMBER**	00000 – 99999 (2 lead zeros)
60 – 60	A1	**SEC-RTE-STATE-TRK-RTE**	0 = Is not a State Truck Route A = Is a State Truck Route
61 – 61	N1	**SEC-RTE-NAT'L-TRK-RTE**	0 = Is not a National Truck Route 1 = Is a National Truck Route
62 – 62	A1	**SEC-RTE-HAZARDOUS-RTE**	0 = Is not a Haz-Mat Route C = Is a Haz-Mat Route
63 – 63	A1	**SEC-RTE-NHS**	0=Not on the NHS 1=On the NHS, not a connector 2-9=Is an intermodal connector
64 – 64	A1	**SEC-RTE-TX-TRUNK-SYSTEM**	0 = Is not a Texas Trunk Route E = Is a State Truck Route
65 – 65	N1	**SEC-RTE-STRAHNET**	0=Is not a Strahnet route 1=Is a Strahnet route
66 – 66	N1	**SEC-RTE-STRAHNET-CONN**	0 = Is not a Strahnet-Connector 1 = Is a Strahnet-Connector
67– 67	A1	**SEC-RTE-NAT’L-FOREST-HWY**	0 = Is not a National Forest Highway H = Is a National Forest Highway
68 – 68	A1	**SEC-RTE-ST-MEMORIAL-HWY**	0 = Is not a State Memorial Highway I = Is a State Memorial Highway
69 – 69	A1	**SEC-RTE-TEXAS-TRAVEL-TRAIL**	0 = Is not a Texas Travel Trail J = Is a Texas Travel Trail
70 – 70	A1	**SEC-RTE-PARKWAY**	0 = Is not a Parkway K = Is a Parkway
71 – 71	A1	**SEC-RTE-BICYCLE-ROUTE**	0 = Is not a Bicycle Route L = Is a Bicycle Route
72 – 72	A1	**SEC-RTE-ADOPT-A-HIGHWAY**	0 = Is not an Adopt a Highway M = Is an Adopt a Highway
73 – 73	A1	**SEC-RTE-URBAN-ROUTE**	0 = Is not a Urban Route N = Is a Urban Route
74 – 74	A1	**SEC-RTE-FEDERAL-AID**	0 = Is not a Federal Aid O = Is a Federal Aid
75 – 75	A1	**SEC-RTE-EVACUATION-RTE**	0 = Is an Evacuation Route P = Is not an Evacuation Route
76 – 84	A9	**SEC-RTE-Q-Y**	Future Expansion

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
85 – 85	A1	**SEC-RTE-Z**	0=Not an Other Secondary Route Z=Is an Other Secondary Route
86 – 87	N2	**GOVT-CONTROL-LEVEL**	01=State Highway Agency 02=County Highway Agency 03=Town Highway Agency 04=Municipal Agency 05=Other State Agency 06=Other Local Agency (ex: Tolls) 07=Federal Agency 08=Other
88 – 99	A12	**HPMS Current ID**	90-93 = Control 94-95 = Section 96 = Identifier: Samples: M=Mainlane, A=Right Frontage, X=Left Frontage Universe: N=NHS, T=Toll, D=Donut, H=HOV, S=Surveillance, Z=HOV & Surv 97-101 = Begin Mpt
100 – 102	N2.1	**PCT-SINGLE-TRK-ADT**	(%-Avg-Daily-Single-Unit-Trucks) 00.0 – 99.9
103 – 105	N2.1	**PCT-COMBO-TRK-ADT**	(%-Avg-Daily-Combo-Unit-Trucks) 00.0 – 99.9
106 – 108	N2.1	**PCT-SINGLE-TRK-DHV**	(%-Peak-Single-Unit-Trucks) 00.0 – 99.9
109 – 111	N2.1	**PCT-COMBO-TRK-DHV**	(%-Peak-Combo-Unit-Trucks) 00.0 – 99.9
112 – 112	N1	**Filler**	Zero fill
113 – 113	N1	**RURAL-URBAN-CODE**	1=Rural (< 5000) 2=Small Urban (5000 – 49,999) 3=Large Urban (50,000 – 199,999) 4=Urbanized (200,000+)
114 – 115	N2	**SPECIAL-SYSTEM**	00 = Is not a STRAHNET route 01 = Is a STRAHNET route 02 = Is a STRAHNET connector
116 – 121	A6	**CONTROL-SECTION**	Format ccccss
122 – 122	N1	**MSA-COUNTY**	1=Is an MSA County 0=Is not an MSA County
123 – 124	N2	**MSA-CLASS-CODE**	01 – 03 = Roadway is not within an MSA County 11 – 13 = Roadway is within an MSA County
125 – 126	A2	**HIGHWAY-DESIGN**	1st char 0 = one-way-pair 1 = one-way 2 = two-way 3 = boulevard 4 = expressway 5 = freeway 2nd char zero or blank = no HOV or Railway or Toll A=with HOV lanes B=with Railways C=Toll Road
127 – 128	N2	**MAINTENANCE-DISTRICT**	01 – 25

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
129 – 131	N3	**METRO-PLANNING-AREA**	000 – 999
132 – 136	N5	**CENSUS-PLACE-NUMBER**	blank or 00000 – 99999
137 – 144	N8	**REF-MARKER-DATE**	Format mmddyyyy
145 – 152	A8	**HIGHWAY-STATUS-DATE**	Format mmddyyyy
153 – 182	A30	**HIGHWAY-STATUS-NOTE**	Text
183 – 184	N2	**MAINTENANCE-FOREMAN**	00 – 30
185 – 186	N2	**MAINTENANCE-SECTION**	00 – 30
187 – 192	N6	**ADT-CURRENT**	000000 – 999999
193 – 196	N4	**ADT-CURRENT-YEAR**	Format yyyy
197 – 202	N6	**ADT-FOR-DESIGN-YEAR**	(Future ADT Year) Format yyyy
203 – 208	N6	**ADT-ADJUST-CURRENT**	000000 – 999999
209 – 212	N4	**ADT-HISTORY-YEAR**	Format yyyy
213 – 266	N54	**ADT-HISTORY-YEAR-1-9**	Format yyyy each
267 – 269	N3	**HP-SHLDR-WIDTH-LEFT**	000 – 999 Width of inside shoulder on divided sections, or width of left shoulder while traveling in descending marker direction
270 – 272	N3	**HP-SHLDR-WIDTH-RIGHT**	000 – 999 Width of outside shoulder on divided sections, or width of right shoulder while traveling in ascending marker direction
273 – 275	N3	**HP-MEDIAN-WIDTH**	000 – 999 Median-Width + both Inside Shoulders
276 – 326	N51	**FILLER**	Zero fill
327 – 329	N3	**ATHWLD-PCT**	000 – 100
330 – 332	N3	**ATHWLD-100lbs**	000 – 999
333 – 336	N4	**DESIGN-YEAR (Future Year)**	Current AADT Year + 20 years
337 – 342	N6	**DESIGN-HOURLY-VOLUME**	000000 – 999999
343 – 345	N3	**D-FACTOR (Directional Distribution)**	000 – 100
346 – 348	N2.1	**TRUCK-AADT-PCT**	00.0 to 99.9
349 – 351	N2.1	**TRUCK-DHV-PCT**	00.0 to 99.9
352 – 354	N2.1	**K-FACTOR**	00.0 to 99.9
355 – 360	N6	**FLEX-18KIP-ESAL**	000000 – 999999
361 – 366	N6	**RIGID-18-KIP-ESAL**	000000 – 999999
367 – 367	N1	**BASE-TYPE**	1=Roadbed Soil 2=Flex Base (Granular) 3=Stabilized Earth or Flex (Granular) 8=Asphalt Base (Hot Mix, Asphalt Concrete) 9=Concrete
368 – 369	N2	**SPEED-LIMIT-MAX**	00 – 75
370 – 371	N2	**SPEED-LIMIT-MINIMUM**	00 – 75
372 – 374	N3	**NUMBER-OF-LANES**	Does not include turning or climbing lanes
375 – 378	N4	**ROW-WIDTH-USUAL**	001 – 999
379 – 382	N4	**SURFACE-WIDTH**	Does not include Shoulder-Widths

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
383 – 386	N4	**ROADBED-WIDTH**	Includes Shoulder-Width and Surface-Widths
387 – 388	N2	**SURFACE-TYPE**	Unpaved: 20=Unimproved road 30=Graded and Drained 40=Soil, Gravel or Stone Low Type Bituminous Surface-treated: 51=Bituminous Surface Treated Intermediate Type Mixed: 52=Mixed Bituminous, < 7" Base & Surface 53=Bituminous Penetration, < 7" Base & Surface High Type Flexible: 61=High Flex-mixed, Bituminous 7" Base & Surf 80=Other (Brick, Block, etc.) High Type Rigid: 71=Plain Jointed Concrete Pavement 72=Reinforced Joint Concrete Pavement 73=Continuous Reinforced Concrete Pavement 74=Bonded Concrete over Concrete 75=Unbounded Concrete over Concrete 76=Concrete over Bituminous High Type Composite: 62=Flexible Over Rigid 7" Base & Surface
389 – 389	N1	**CURB-TYPE-LEFT**	0=None 1=Curb-Surface Drainage Only 2=Curb-Sub-surface Only 3=Overlaid (resurfaced, no longer functions) 4=Overlaid (resurfaced, may or not open)
390 – 390	N1	**CURB-TYPE-RIGHT**	(see Curb-Type-Left)
391 – 391	N1	**DIRECTION-OF-TRAVEL**	1=Ascending Marker Direction 2=Descending Marker Direction 3=Both Directions
392 – 392	A1	**PHYSICAL-ROADBED**	Roadbed source of fields like Surface-Type and Speed-Limit. K=Single Roadbed A=Right Frontage R=Right Mainlane X=Left Frontage L=Left Mainlane
393 – 393	N1	**SHOULDER-TYPE-LEFT**	1=None 2=Surfaced 3=Stabilized-Surfaced with Flex 4=Combination-Surface/Stabilized 5-Earth-with or without turf
394 – 396	N3	**SHOULDER-WIDTH-LEFT**	000 - 999
397 – 398	N2	**SHOULDER-USE-LEFT**	00=No designated use 04=Bus 01=Diagonal Parking 05=Emergency only 02=Parallel Parking 06=Peak only 03=Bicycle 07=Other
399 – 399	N1	**SHOULDER-TYPE-RIGHT**	(See Shoulder-Type-Left)
400 – 402	N3	**SHOULDER-WIDTH-RIGHT**	(See Shoulder-Width-Left)
403 – 404	N2	**SHOULDER-USE-RIGHT**	(See Shoulder-Use-Left)
405 – 408	N4	**ROW-WIDTH-MIN**	0001 - 9999
409 – 414	N6	**LOAD-LIMIT-AXLE**	000000 – 999999
415 – 420	N6	**LOAD-LIMIT-GROSS**	000000 – 999999

Appendix A - TRMEOY File Format

Column Position	Format	Item Name	Further Definitions as needed
421 – 426	N6	**LOAD-LIMIT-TANDEM**	000000 - 999999
427 – 427	N1	**MEDIAN-TYPE**	0=No median 1=Curbed 2=Positive Barrier 3=Unprotected 4=One-way pair
428 – 430	N3	**MEDIAN-WIDTH**	Does not include inside Shoulder Widths
431 – 438	N8	**DATA-DATE**	(Date of data file in the form YYYYMMDD)
439 – 445	N4.3	**FROM-DFO**	0000.000 – 9999.998
446 – 452	N4.3	**TO-DFO**	0000.001 – 9999.999
453 – 461	N9	**FILLER**	Zero fill
462 – 467	N6	**RIA-MILEPOINT-DATE**	in the form YYYYMM

Revisions:
02/12/04 – Updated to include new Secondary-Route-Code “P” and new Highway-Design 2nd byte codes.

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
1 – 1	N1	**RECORD-TYPE**	1=Mainlanes 2=Right Frontage 3=Left Frontage
2 – 3	N2	**DISTRICT-ID**	01 – 25
4 – 6	N3	**COUNTY-NUMBER**	001 – 254 State county number, not FIPS county number
7 – 11	N5	**CITY-NUMBER**	00000 – 99999
12 – 18	A7	**SIGNED-HIGHWAY**	
12 – 13	A2	**HIGHWAY-SYSTEM**	IH=Interstate BF=Business FM US=US Highway FM=Farm to Mkt UA=US Alternate RM=Ranch to Mkt UP=US Spur RR=Ranch Road SH=State Highway PR=Park Road SA=State Alternate RE=Rec Road SL=State Loop RP=Rec Rd Spur SS=State Spur FS=FM Spur BI=Business IH RS=RM Spur BU=Business US RU=RR Spur BS=Business State PA=Principal Arterial
14 – 17	N4	**HIGHWAY-NUMBER**	(0001 – 9999)
18 – 18	A1	**HIGHWAY-SUFFIX**	A – Z for Park Roads A – H, J – N, P – Z for Business Routes Blank or A – Z for other highways
30 – 40	N11	**FILLER**	Zero fill
		REFERENCE-MARKER	
30 – 33	N4	**REF-MARKER-NBR**	0010 – 9999 for non-IH 0000 – 9999 for IH
34 – 34	A1	**REF-MARKER-SUF**	Blank, then A – Z
35 – 35	A1	**REF-MARKER-SIGN**	+ or -
36 – 40	N2.3	**REF-MARKER-DISP**	00.000 – 99.999
41 – 42	A2	**ROADBED-ID**	CG = Centerline AG = Right Frontage Road XG = Left Frontage Road
43 – 49	N4.3	**LENGTH-OF-SECTION**	00.001 – 99.999
50 – 50	N1	**HIGHWAY-STATUS**	Not open to traffic: 1=New Route 3=Under construction Open to traffic: 4=Open but with some construction 5=District data input, TPP data needed 6=All data input 7=Emergency closing
51 – 52	N2	**ROADWAY-MAINT-STATUS**	01=State Maintenance 02=Local Maintenance
53 – 54	N2	**FUNCTIONAL-SYSTEM**	Rural: Urban: 01=Interstate 11=Prin Arterial (IH)

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
			02=Prin Arterial 12=Prin Arterial (other Freeway) 06=Minor Arterial 14=Prin Arterial (other) 07=Major Coll 16=Minor Arterial 08=Minor Coll 17=Collector 09=Local 19=Local
55 – 56	N2	**ADMIN-SYSTEM**	01=State (Rural) 02=State (City; 5000 or more) 03=Certified County maintained 04=Not county maintained (private, non-desig) 05=State (City; less than 5000) 06=City(Less than 5000) 07=Other State Agency (Rural) 08=Federal (Rural) 09=Other State (City >= 5000) 10=Other State (City < 5000 11=Federal (City; less than 5000) 12=Federal (City; 5000 or more) 13=City (5000 or more)
57 – 61	N5	**URBAN-AREA-NUMBER**	00000 – 99999 (2 lead zeros)
62 – 62	A1	**SEC-RTE-STATE-TRK-RTE**	0 = Is not a State Truck Route A = Is a State Truck Route
63 – 63	N1	**SEC-RTE-NAT'L-TRK-RTE**	0 = Is not a National Truck Route 1 = Is a National Truck Route
64 – 64	A1	**SEC-RTE-HAZARDOUS-RTE**	0 = Is not a Haz-Mat Route C = Is a Haz-Mat Route
65 – 65	A1	**SEC-RTE-NHS**	0=Not on the NHS 1=On the NHS, not a connector 2-9=Is an intermodal connector
66 – 66	A1	**SEC-RTE-TX-TRUNK-SYSTEM**	0 = Is not a Texas Trunk Route E = Is a Texas Trunk Route
67 – 67	N1	**SEC-RTE-STRAHNET**	0=Is not a Strahnet route F=Is a Strahnet route
68 – 68	N1	**SEC-RTE-STRAHNET-CONN**	0 = Is not a Strahnet-Connector G = Is a Strahnet-Connector
69 – 69	A1	**SEC-RTE-NAT'L-FOREST-HWY**	0 = Is not a National Forest Highway H = Is a National Forest Highway
70 – 70	A1	**SEC-RTE-ST-MEMORIAL-HWY**	0 = Is not a State Memorial Highway I = Is a State Memorial Highway
71 – 71	A1	**SEC-RTE-TEXAS-TRAVEL-TRAIL**	0 = Is not a Texas Travel Trail J = Is a Texas Travel Trail
72 – 72	A1	**SEC-RTE-PARKWAY**	0 = Is not a Parkway K = Is a Parkway
73 – 73	A1	**SEC-RTE-BICYCLE-ROUTE**	0 = Is not a Bicycle Route L = Is a Bicycle Route
74 – 74	A1	**SEC-RTE-ADOPT-A-HIGHWAY**	0 = Is not an Adopt a Highway M = Is an Adopt a Highway
75 – 75	A1	**SEC-RTE-URBAN-ROUTE**	0 = Is not a Urban Route N = Is a Urban Route
76 – 76	A1	**SEC-RTE-FEDERAL-AID**	0 = Is not a Federal Aid O = Is a Federal Aid
77 – 77	A1	**SEC-RTE-EVACUATION-RTE**	0 = Is an Evacuation Route

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
			P = Is not an Evacuation Route
78 – 86	A9	**SEC-RTE-Q-Y**	Future Expansion
87 – 87	A1	**SEC-RTE-Z**	0=Not an Other Secondary Route Z=Is an Other Secondary Route
88 – 89	N2	**GOVT-CONTROL-LEVEL**	01=State Hwy Agency 05=Other State 02=County Hwy Agency 06=Other Local 03=Town Hwy Agency 07=Federal 04=Municipal Agency 08=Other
90 – 101	A12	**HPMS Current ID**	90-93 = Control 94-95 = Section 96 = Identifier: Samples: Universe: M=Mainlane N=NHS A=Right Frontage T=Toll X=Left Frontage D=Donut H=HOV S=Surveillance Z=HOV & Surv 97-101 = Begin Mpt
102 – 104	N2.1	**PCT-SINGLE-TRK-ADT**	(%-Avg-Daily-Single-Unit-Trucks) 00.0 – 99.9
105 – 107	N2.1	**PCT-COMBO-TRK-ADT**	(%-Avg-Daily-Combo-Unit-Trucks) 00.0 – 99.9
108 – 110	N2.1	**PCT-SINGLE-TRK-DHV**	(%-Peak-Single-Unit-Trucks) 00.0 – 99.9
111 – 113	N2.1	**PCT-COMBO-TRK-DHV**	(%-Peak-Combo-Unit-Trucks) 00.0 – 99.9
114 – 114	N1	**Filler**	Zero fill
115 – 115	N1	**RURAL-URBAN-CODE**	1=Rural (< 5000) 2=Small Urban (5000 – 49,999) 3=Large Urban (50,000 – 199,999) 4=Urbanized (200,000+)
116 – 117	N2	**SPECIAL-SYSTEM**	00 = Is not a STRAHNET route 01 = Is a STRAHNET route 02 = Is a STRAHNET connector
118 – 123	A6	**CONTROL-SECTION**	Format ccccss
124 – 124	N1	**MSA-COUNTY**	1=Is an MSA County 0=Is not an MSA County
125 – 126	N2	**MSA-CLASS-CODE**	01 – 03 = Roadway is not within an MSA County 11 – 13 = Roadway is within an MSA County
127 – 128	A2	**HIGHWAY-DESIGN**	1st char 2nd char 0 = one-way-pair zero or blank 1 = one-way A = with HOV lanes 2 = two-way B = with Railways 3 = boulevard C = Toll Road 4 = expressway 5 = freeway
129 – 130	N2	**MAINTENANCE-DISTRICT**	01 – 25
131 – 133	N3	**METRO-PLANNING-AREA**	000 – 999
134 – 138	N5	**CENSUS-PLACE-NUMBER**	blank or 00000 – 99999
139 – 146	N8	**REF-MARKER-DATE**	Format mmddyyyy
147 – 154	A8	**HIGHWAY-STATUS-DATE**	Format mmddyyyy

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
155 – 184	A30	**HIGHWAY-STATUS-NOTE**	Text
185 – 186	N2	**MAINTENANCE-FOREMAN**	00 – 30
187 – 188	N2	**MAINTENANCE-SECTION**	00 – 30
189 – 194	N6	**ADT-CURRENT**	000000 – 999999
195 – 198	N4	**ADT-CURRENT-YEAR**	Format yyyy
199 – 204	N6	**ADT-FOR-DESIGN-YEAR**	(Future ADT Year) Format yyyy
205 – 210	N6	**ADT-ADJUST-CURRENT**	000000 – 999999
211 – 214	N4	**ADT-HISTORY-YEAR**	Format yyyy
215 – 268	N54	**ADT-HISTORY-YEAR-1-9**	Format yyyy each
269 – 271	N3	**HP-SHLDR-WIDTH-LEFT**	000 – 999 Width of inside shoulder on divided sections, or width of left shoulder while traveling in descending marker direction
272 – 274	N3	**HP-SHLDR-WIDTH-RIGHT**	000 – 999 Width of outside shoulder on divided sections, or width of right shoulder while traveling in ascending marker direction
275 – 277	N3	**HP-MEDIAN-WIDTH**	000 – 999 Median-Width + both Inside Shoulders
278 – 284	N7	**CURVE-ID**	Unique identifier for Normal & Spiral curves
285 – 285	A1	**CURVE-TYPE**	P=Point Curve N=Normal Curve S=Spiral Curve
286 – 290	N5	**CURVE-LENGTH**	00.001 – 99.999
291 – 295	N5	**TS1-LENGTH**	00.001 – 99.999 ** Curve-Type N & S only **
296 – 300	N5	**TS2-LENGTH**	00.001 – 99.999 ** Curve-Type S only **
301 – 307	N7	**CURVE-DEGREES**	** Curve-Type N & S only **
301 – 302	N2	**CD-Degrees**	00 – 89
303 – 304	N2	**CD-Minutes**	00 – 59
305 – 307	N3	**CD-Seconds**	00.0 – 59.9
308 – 316	N9	**DELTA-DEGREES**	
308 – 308	N1	**Delta-Left-Right**	L=Left R=Right
309 – 311	N3	**Delta-Degrees**	000 – 179
312 – 313	N2	**Delta-Minutes**	00 – 59
314 – 316	N3	**Delta-Seconds**	00.0 – 59.9
317 – 328	N51	**FILLER**	Zero fill
329 – 331	N3	**ATHWLD-PCT**	000 – 100
332 – 334	N3	**ATHWLD-100lbs**	000 – 999
335 – 338	N4	**DESIGN-YEAR (Future Year)**	Current AADT Year + 20 years
339 – 344	N6	**DESIGN-HOURLY-VOLUME**	000000 – 999999
345 – 347	N3	**D-FACTOR (Directional Distribution)**	000 – 100

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
348 – 350	N2.1	**TRUCK-AADT-PCT**	00.0 to 99.9
351 – 353	N2.1	**TRUCK-DHV-PCT**	00.0 to 99.9
354 – 356	N2.1	**K-FACTOR**	00.0 to 99.9
357 – 362	N6	**FLEX-18KIP-ESAL**	000000 – 999999
363 – 368	N6	**RIGID-18-KIP-ESAL**	000000 – 999999
369 – 369	N1	**BASE-TYPE**	1=Roadbed Soil 2=Flex Base (Granular) 3=Stabilized Earth or Flex (Granular) 8=Asphalt Base (Hot Mix, Asphalt Concrete) 9=Concrete
370 – 371	N2	**SPEED-LIMIT-MAX**	00 – 75
372 – 373	N2	**SPEED-LIMIT-MINIMUM**	00 – 75
374 – 376	N3	**NUMBER-OF-LANES**	Does not include turning or climbing lanes
377 – 380	N4	**ROW-WIDTH-USUAL**	001 – 999
381 – 384	N4	**SURFACE-WIDTH**	Does not include Shoulder-Widths
385 – 388	N4	**ROADBED-WIDTH**	Includes Shoulder-Width and Surface-Widths
389 – 390	N2	**SURFACE-TYPE**	<u>Unpaved</u>: 20=Unimproved road 30=Graded and Drained 40=Soil, Gravel or Stone <u>Low Type Bituminous Surface-treated</u>: 51=Bituminous Surface Treated <u>Intermediate Type Mixed</u>: 52=Mixed Bituminous, < 7” Base & Surface 53=Bituminous Penetration, < 7” Base & Surface <u>High Type Flexible</u>: 61=High Flex-mixed, Bituminous 7” Base & Surf 80=Other (Brick, Block, etc.) <u>High Type Rigid</u>: 71=Plain Jointed Concrete Pavement 72=Reinforced Joint Concrete Pavement 73=Continuous Reinforced Concrete Pavement 74=Bonded Concrete over Concrete 75=Unbounded Concrete over Concrete 76=Concrete over Bituminous <u>High Type Composite</u>: 62=Flexible Over Rigid 7” Base & Surface
391 – 391	N1	**CURB-TYPE-LEFT**	0=None 1=Curb-Surface Drainage Only 2=Curb-Sub-surface Only 3=Overlaid (resurfaced, no longer functions) 4=Overlaid (resurfaced, may or not open)
392 – 392	N1	**CURB-TYPE-RIGHT**	(see Curb-Type-Left)
393 – 393	N1	**DIRECTION-OF-TRAVEL**	1=Ascending Marker Direction 2=Descending Marker Direction 3=Both Directions
394 – 394	A1	**PHYSICAL-ROADBED**	Roadbed source of fields like Surface-Type and Speed-Limit.

Appendix A - TRM GEO-HINI File Format

Column Position	Format	Item Name	Further Definitions as needed
			K=Single Roadbed A=Right Frontage R=Right Mainlane X=Left Frontage L=Left Mainlane
395 – 395	N1	**SHOULDER-TYPE-LEFT**	1=None 2=Surfaced 3=Stabilized-Surfaced with Flex 4=Combination-Surface/Stabilized 5-Earth-with or without turf
396 – 398	N3	**SHOULDER-WIDTH-LEFT**	000 - 999
399 – 400	N2	**SHOULDER-USE-LEFT**	00=No designated use 04=Bus 01=Diagonal Parking 05=Emergency only 02=Parallel Parking 06=Peak only 03=Bicycle 07=Other
401 – 401	N1	**SHOULDER-TYPE-RIGHT**	(See Shoulder-Type-Left)
402 – 404	N3	**SHOULDER-WIDTH-RIGHT**	(See Shoulder-Width-Left)
405 – 406	N2	**SHOULDER-USE-RIGHT**	(See Shoulder-Use-Left)
407 – 410	N4	**ROW-WIDTH-MIN**	0001 - 9999
411 – 416	N6	**LOAD-LIMIT-AXLE**	000000 – 999999
417 – 422	N6	**LOAD-LIMIT-GROSS**	000000 – 999999
423 – 428	N6	**LOAD-LIMIT-TANDEM**	000000 - 999999
429 – 429	N1	**MEDIAN-TYPE**	0=No median 1=Curbed 2=Positive Barrier 3=Unprotected 4=One-way pair
430 – 432	N3	**MEDIAN-WIDTH**	Does not include inside Shoulder Widths
433 – 440	N8	**DATA-DATE**	(Date of data file in the form YYYYMMDD)
441 – 447	N4.3	**FILLER**	zero fill
448 – 454	N4.3	**DFO**	0000.000 – 9999.999
455 – 474	N20	**FILLER**	Zero fill
475 – 479	N2.3	**MILEPOINT**	Within the Control-Section
480 – 484	N2.3	**RI-MILEPOINT-LENGTH**	Within the Control-Section

Appendix B

DPS Accident Database Record A Sample

LIGHT CONDITION, Column 27

1 - Daylight
2 - Dawn
3 - Darkness-Not Lighted
4 - Darkness-Lighted
5 - Dusk

FIRST HARMFUL EVENT, Column 28

Collision of a motor vehicle with:

1 - Pedestrian
2 - Another motor vehicle in transport
3 - RR Train
4 - Parked car
5 - Pedalcyclist
6 - Animal
7 - Fixed Object
8 - Other Object

Other than collision:

0 - Overturned
- - Other non collision

SEVERITY, Column 29

Coded in accordance with the highest degree of injury suffered in the accident:

1 - Incapacitating injury - not able to walk or drive (A)
2 - Nonincapacitating injury - bump on head, abrasions, minor lacerations (B)
3 - Possible injury - limping, complaint of pain (C)
4 - Fatal (F)
5 - Non-injury (N)

WEATHER, Column 30

1 - Clear (cloudy)
2 - Raining
3 - Snowing
4 - Fog
5 - Blowing dust
6 - Smoke
7 - Other
8 - Sleeting

SURFACE CONDITION, Column 31

1 - Dry
2 - Wet
3 - Muddy
4 - Snowy/Icy

ROADWAY RELATED, Column 36

1 - On roadway
2 - Off roadway on shoulder
3 - Off roadway beyond shoulder

INTERSECTION RELATED, Column 37

1 - Intersection
2 - Intersection related
3 - Driveway access (code type driveway in col. 59 or col. 60)
4 - Non intersection

VEHICLE MOVEMENTS/MANNER OF COLLISION, Columns 40-41

These columns show the manner of collision and vehicular movements in accidents involving collisions between two motor vehicles and vehicular movements in all other accidents.

TWO MOTOR VEHICLES APPROACHING AT AN ANGLE

10 - Both going straight
11 - #1 straight - #2 backing
12 - #1 straight - #2 stopped
13 - #1 straight - #2 right turn
14 - #1 straight - #2 left turn
15 - Both right turn
16 - #1 right turn - #2 left turn
17 - #1 right turn - #2 stopped
18 - Both left turn
19 - #1 left turn - #2 stopped

TWO MOTOR VEHICLES - GOING SAME DIRECTION

20 - Both going straight - rear end
21 - Both going straight - sideswipe
22 - #1 straight - #2 stopped
23 - #1 straight - #2 right turn
24 - #1 straight - #2 left turn
25 - Both right turn
26 - #1 right turn - #2 left turn
27 - #1 right turn - #2 stopped

28 - Both left turn
29 - #1 left turn - #2 stopped

TWO MOTOR VEHICLES - GOING OPPOSITE DIRECTIONS

30 - Both going straight
31 - #1 straight - #2 backing
32 - #1 straight - #2 stopped
33 - #1 straight - #2 right turn
34 - #1 straight - #2 left turn
35 - #1 backing - #2 stopped
36 - #1 right turn - #2 left turn
37 - #1 right turn - #2 stopped
38 - Both left turn
39 - #1 left turn - #2 stopped

TWO MOTOR VEHICLES - OTHER

40 - #1 straight - #2 entering or leaving parking space
41 - #1 right turn - #2 entering or leaving parking space
42 - #1 left turn - #2 entering or leaving parking space
43 - #1 entering or leaving parking space - #2 stopped
44 - Both entering or leaving parking space
45 - Both vehicles backing
46 - All Others

Movement of vehicle in other than motor with motor accidents:

01 - Vehicle going straight
02 - Vehicle turning right
03 - Vehicle turning left
04 - Vehicle backing
05 - Other

OBJECT STRUCK, Columns 42-43

These columns used in conjunction with column 28 (First Harmful Event) and columns 40-41 (Vehicle Movement/Manner of Collision) will give a more detailed picture of the accident. The code in columns 42-43 may indicate either the first or second impact or collision depending on the first harmful event. For example: If column 28 shows collision with a fixed object, then the codes in these columns would indicate the first impact. If column 28 shows collision between two motor vehicles, then these columns may indicate a second impact, or may be used to show vehicle movement or specifically:

00 - No code shown is applicable
01 - Vehicle overturned
02 - Vehicle hit hole in road

03 - Vehicle jack-knifed
04 - Person fell or jumped from vehicle
09 - Vehicle hit train on tracks parallel to road - no crossing
10 - Vehicle hit train moving forward
11 - Vehicle hit train backing
12 - Vehicle hit train standing still
13 - Vehicle hit train - action unknown
20 - Vehicle hit highway sign
21 - Vehicle hit curb
22 - Vehicle hit culvert - headwall
23 - Vehicle hit guardrail
24 - Vehicle hit railroad signal pole or post
25 - Vehicle hit railroad crossing gates
26 - Vehicle hit traffic signal pole or post
27 - Vehicle hit overhead (signal light, wires, signs, etc.)
28 - Vehicle hit work zone barricade, cones, signs or material
29 - Vehicle hit luminaire pole
30 - Vehicle hit utility pole
31 - Vehicle hit mailbox
32 - Vehicle hit tree or shrub
33 - Vehicle hit fence
34 - Vehicle hit house, building or building fixture
35 - Vehicle hit commercial sign
36 - Vehicle hit other fixed object
38 - Vehicle hit work zone machinery or stockpiled materials
39 - Vehicle hit median barrier
40 - Vehicle hit end of bridge (abutment or rail end)
41 - Vehicle hit side of bridge (bridge rail)
42 - Vehicle hit pier or support at underpass, tunnel or overhead sign bridge
43 - Vehicle hit top of underpass or tunnel
44 - Vehicle hit bridge crossing gate
45 - Vehicle hit attenuation device
49 - Vehicle hit by fallen/blowing rocks from a truck
50 - Vehicle hit fallen trees or debris on road
51 - Vehicle hit object from another vehicle in road
52 - Vehicle hit previously wrecked vehicle
54 - Vehicle hit other machinery
55 - Vehicle hit other object
56 - Vehicle hit concrete traffic barrier
57 - Vehicle hit delineator or marker post
58 - Vehicle hit retaining wall
59 - Vehicle hit HOV lane gate
60 - Vehicle hit guard post
61 - Fire hydrant
62 - Ditch (long narrow excavation dug in earth)
63 - Embankment (a raised strip of land or beam)

DEGREE OF CURVE, HIGHWAY NO. 1, Column 57

Whenever an accident location is determined from the RI-1, the degree of curvature of the highway at that location shown in the RI-1 will be coded. All other accidents leave blank.

0 - No curve	6 - 10.0 to 11.9
1 - 0.1 to 1.9	7 - 12.0 to 13.9
2 - 2.0 to 3.9	8 - 14.0 to 15.9
3 - 4.0 to 5.9	9 - 16.0 to 17.9

TOTAL NUMBER OF VEHICLES INVOLVED, Columns 85-86

Enter total number of vehicles involved in the accident, regardless of whether they were in the first impact.

DPS Accident Database Record B Sample

DRIVER AGE, Columns 23-24 and Columns 61-62

Code the driver's age between 00 and 99 years of age. If drivers age cannot be determined, code unknown, ++.

DRIVER RACE AND SEX, Columns 25 and 63

1 - White male	6 - Delete 1-1-97
2 - White female	7 - Other male
3 - Black male	8 - Other female
4 - Black female	+ - Race & sex unknown
5 - Deleted 1-1-97	

CONTRIBUTING FACTORS, Columns 31-32 and Columns 69-70

Columns 31 and 69	Columns 32 and 70
0 - No factor in these columns applies	0 - No factor in these columns applies
1 - Speeding, limit	1 - Following too closely
2 - Speeding, unsafe	2 - Overtake & pass, insufficient clearance
3 - Failed to yield ROW	3 - Passing in no passing zone
4 - Disregard stop sign or light	4 - Other illegal passing
5 - Disregard stop and go signal	5 - No signal or wrong signal of intent
*6 – Cell/Mobile Phone Use	6 - Improper start from a parked position
7 - Improper turn, wide right	7 - Fail to yield ROW to pedestrian
8 - Improper turn, cut corner on left	8 -Improper parking
9 - Improper turn, wrong lane	*9 - Under influence of alcohol
- - Wrong side, not passing	**- - Under influence of drugs
+ - Wrong way on 1 way road	+ - Other factor

NOTE: Cols. 31 & 69 * Priority over 0-5, 7-9, -, +
Cols. 32 & 70 * Priority over 0-8, +; ** Priority over 0-9, +

DRIVER SEVERITY OF INJURY, Columns 34 and 72

1 - "A" type - Incapacitating injury - unable to walk, drive, etc.
2 - "B" type - Nonincapacitating injury - bump on head
3 - "C" type - Possible injury (complaint of pain or momentary unconsciousness)
4 - Killed
5 - Not injured

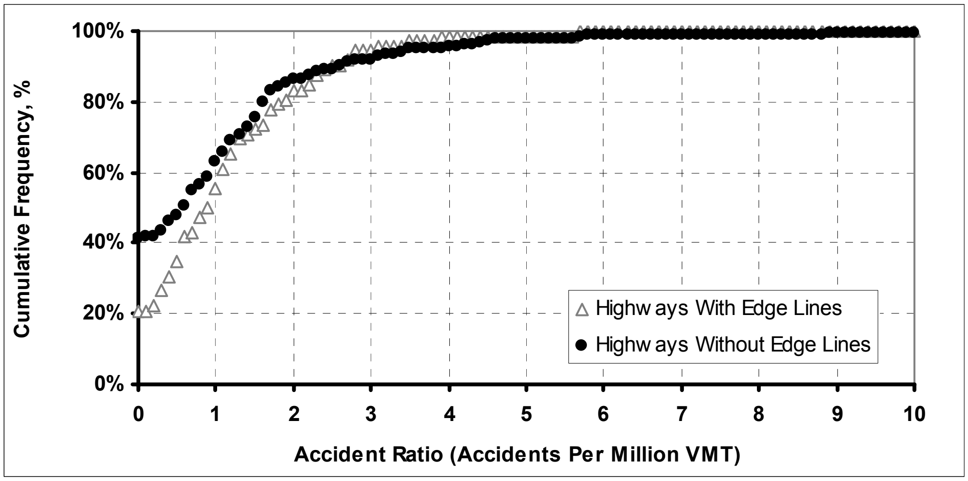
Appendix C

Highways with Different Traffic Lane Widths

Statistical Comparison of Accident Ratios on Highways With Different Lane Widths

Lane Width, ft	Accident Ratio, accidents per million VMT		
	Mean	**Std. Dev.**	**Variance**
Highways With Edge Lines			
9	1.09	1.08	1.16
10	1.06	1.17	1.37
11	1.01	1.10	1.21
Highways Without Edge Lines			
9	1.04	1.83	3.34
10	0.88	1.07	1.13
11	0.94	0.97	0.96

a)



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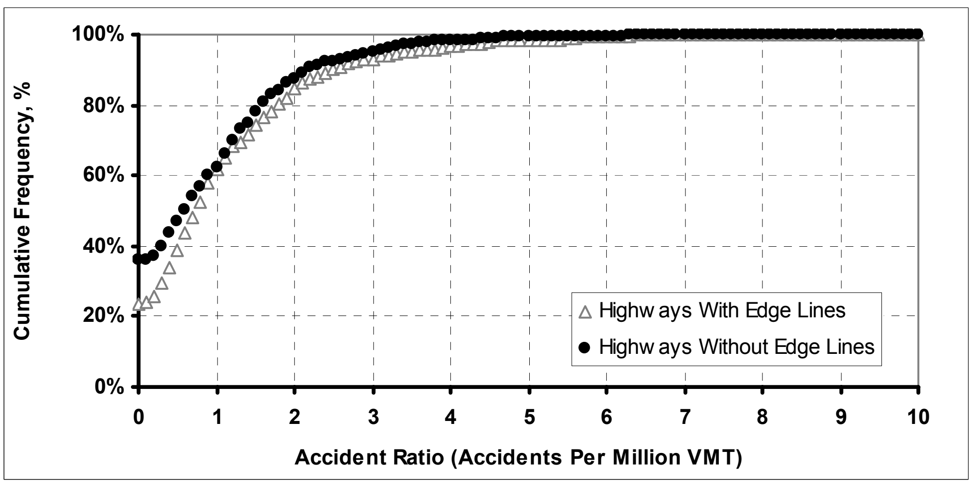

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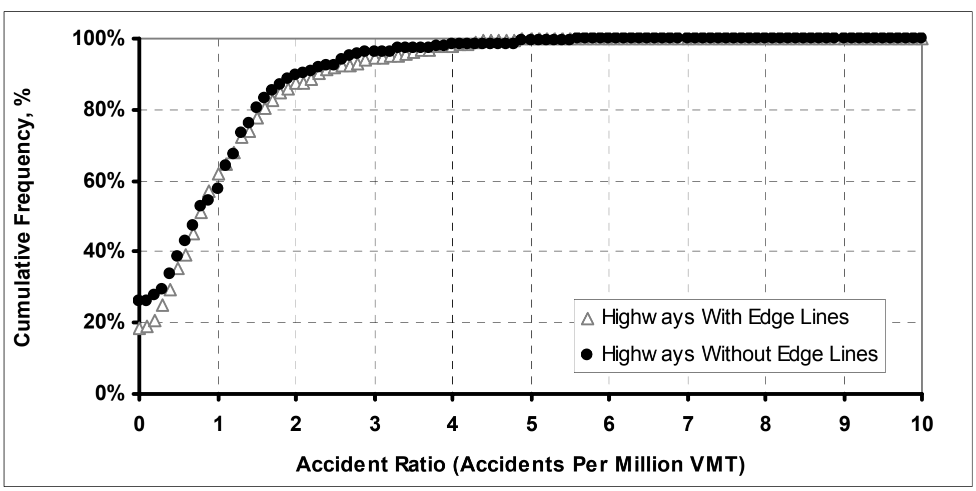


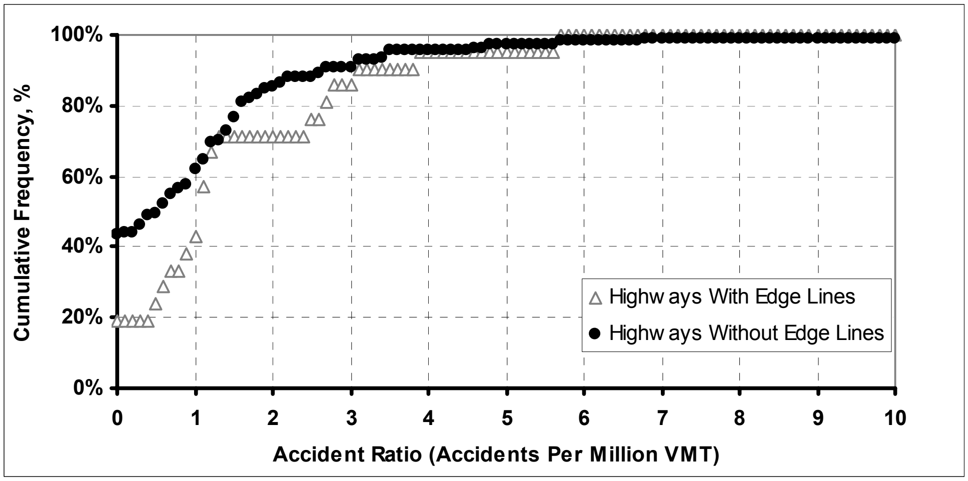
Distribution of Accident Ratios on All Highways
a) Lane Widths of 9 ft b) Lane Widths of 10 ft c) Lane Widths of 11 ft

Highways with Different Shoulder Widths

Statistical Distribution of Accident Ratios by Shoulder Width for All Highways

Lane Width, ft	Shoulder Width, ft	Accident Ratio, accidents per million VMT		
		Mean	Std. Dev.	Variance
Highways With Edge Lines				
9	**0-2**	1.46	1.46	2.12
	3-4	0.89	0.78	0.61
10	**0-2**	1.07	1.28	1.63
	3-4	1.04	1.06	1.11
11	**0-2**	1.08	1.04	1.09
	3-4	0.83	0.88	0.78
Highways Without Edge Lines				
9	**0-2**	1.09	2.17	4.70
	3-4	0.99	1.59	2.52
10	**0-2**	0.93	1.11	1.23
	3-4	0.82	1.00	1.01
11	**0-2**	1.00	0.96	0.92
	3-4	0.71	1.04	1.08

a)



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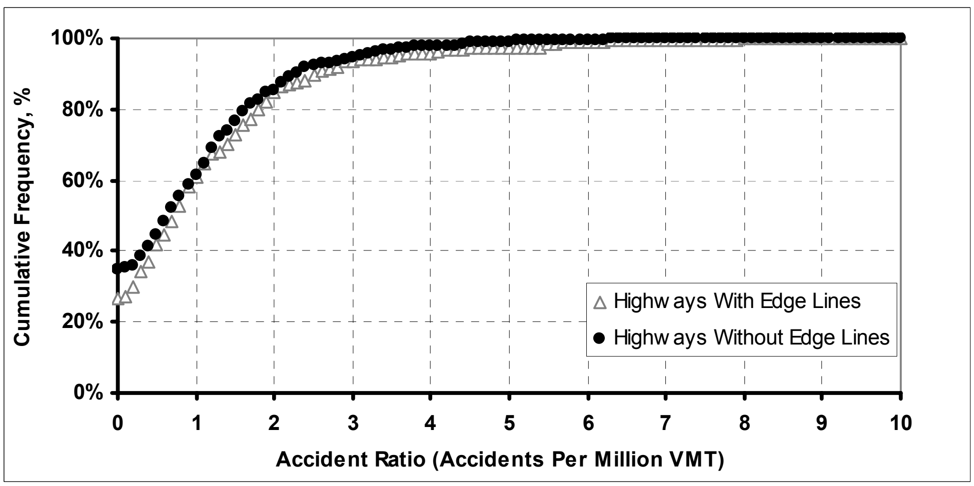

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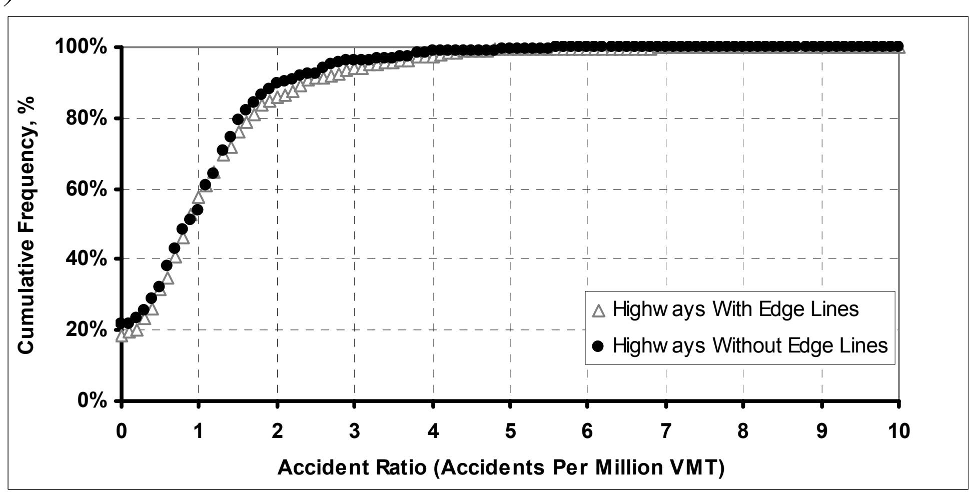
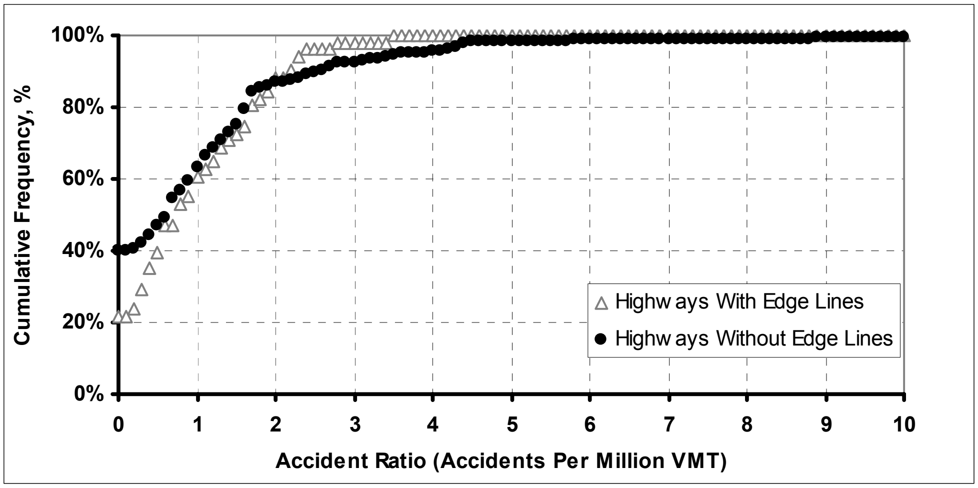


Distribution of Accident Ratios on All Highway Sections with Shoulder Widths of 0-2 ft
a) Lane Widths of 9 ft   b) Lane Widths of 10 ft   c) Lane Widths of 11 ft

a)



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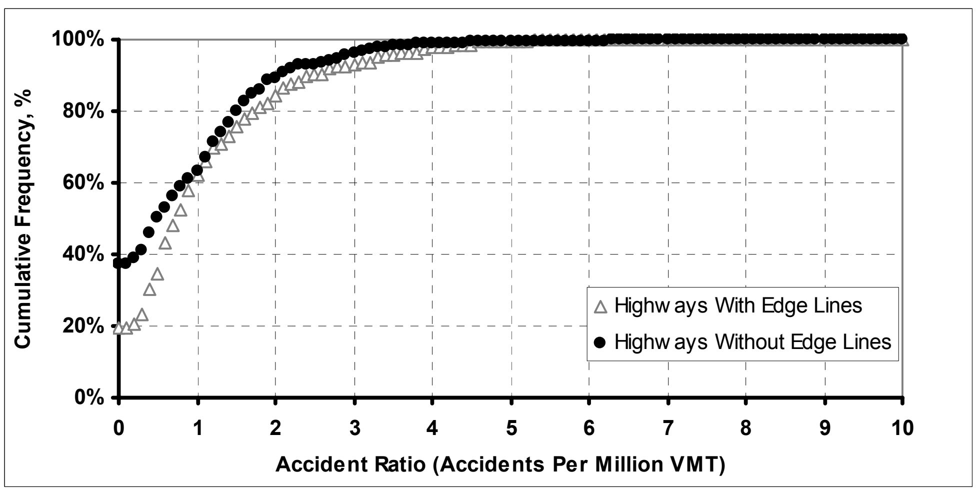
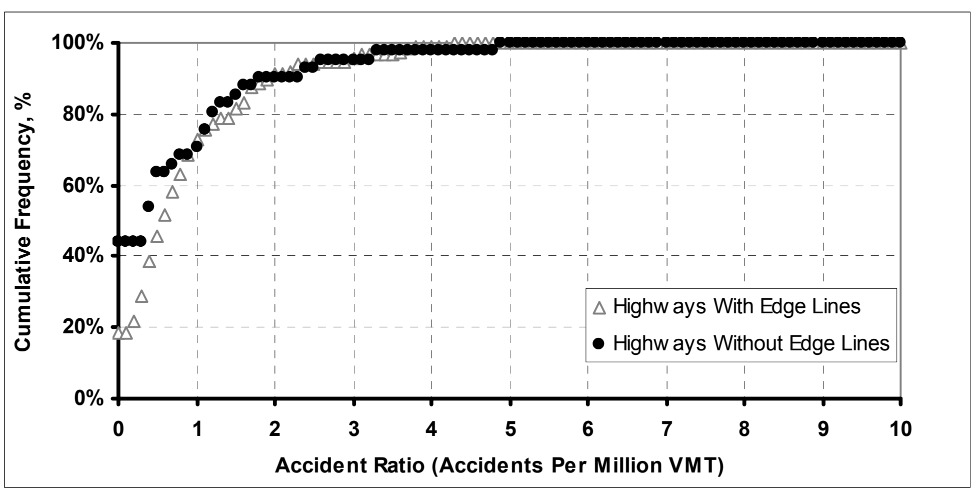


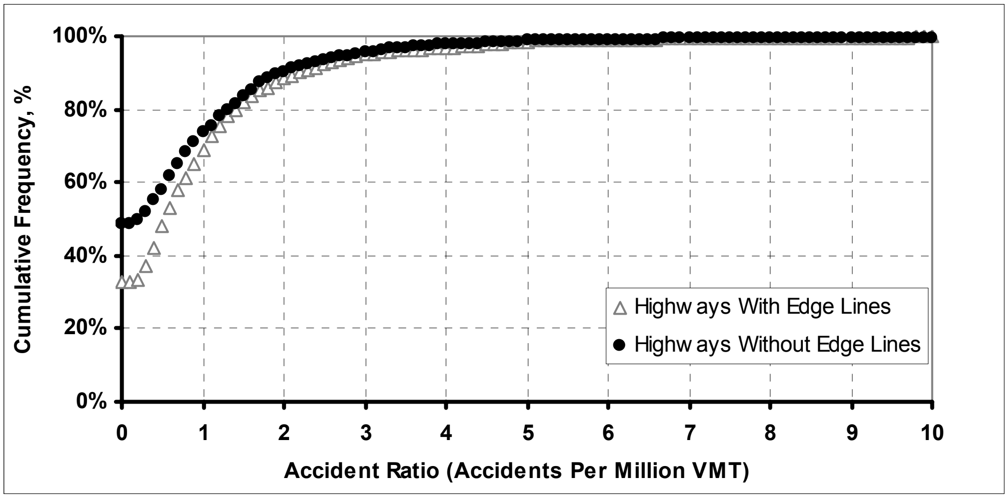
c)



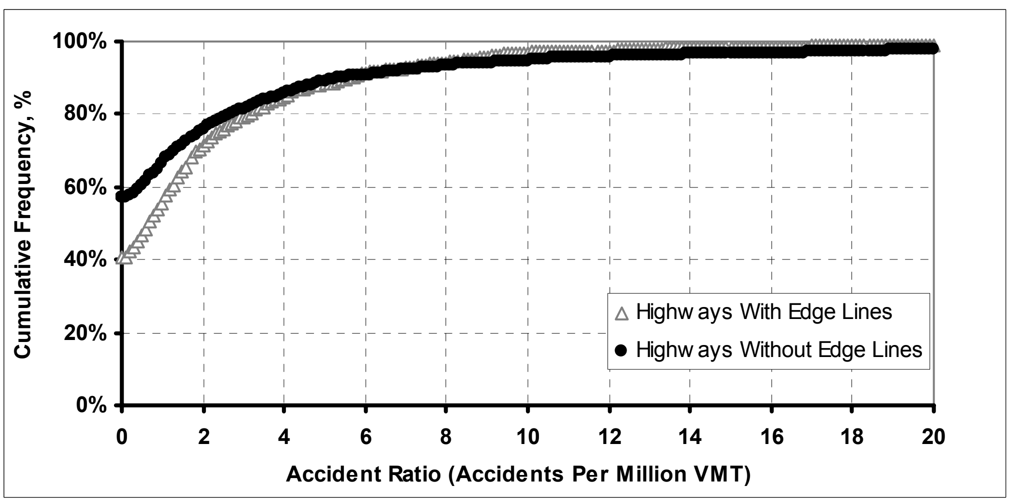
Distribution of Accident Ratios on All Highway Sections with Shoulder Widths of 3-4 ft
a) Lane Widths of 9 ft b) Lane Widths of 10 ft c) Lane Widths of 11 ft

Curved and Straight Highway Segments

a)



b)

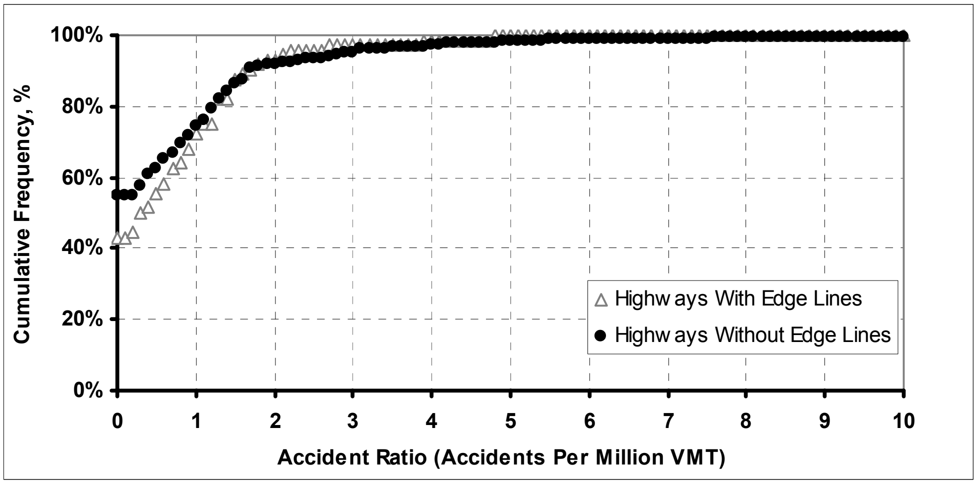


Distribution of Accident Ratios on All Sections
a) Straight Segments b) Curved Segments

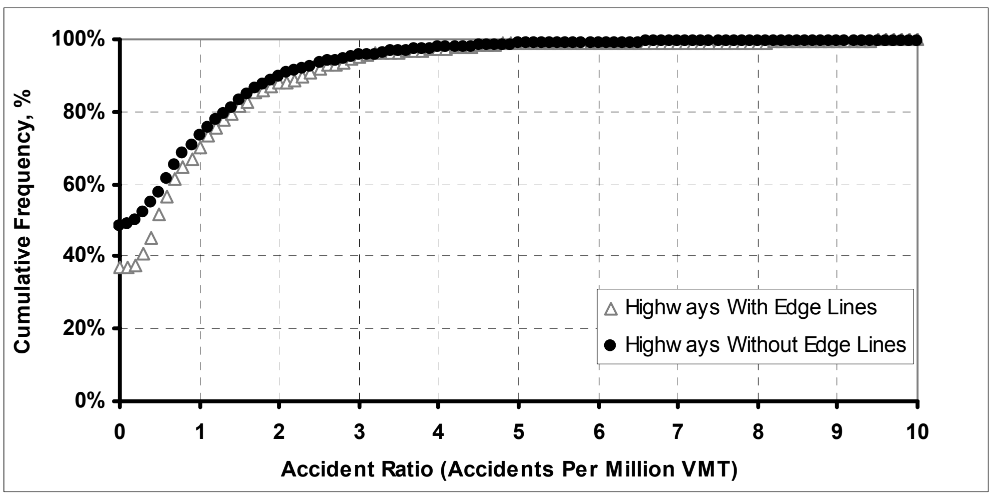
Statistical Characteristics of Accident Ratio Distribution on All Highways by Curvature and Lane Width

Curved	Lane Width, ft	Accident Ratio, accidents per million VMT		
		Mean	**Std. Dev.**	**Variance**
Highways With Edge Lines				
Straight	**9**	0.68	0.91	0.83
	10	0.86	1.28	1.57
	11	1.17	3.82	14.62
Curved	**9**	2.92	4.69	22.00
	10	1.93	3.14	9.83
	11	2.30	7.63	58.16
Highways Without Edge Lines				
Straight	**9**	0.81	2.86	8.19
	10	0.92	5.65	31.98
	11	0.94	3.17	10.03
Curved	**9**	3.05	7.83	61.38
	10	2.20	8.12	65.93
	11	2.77	6.48	42.01

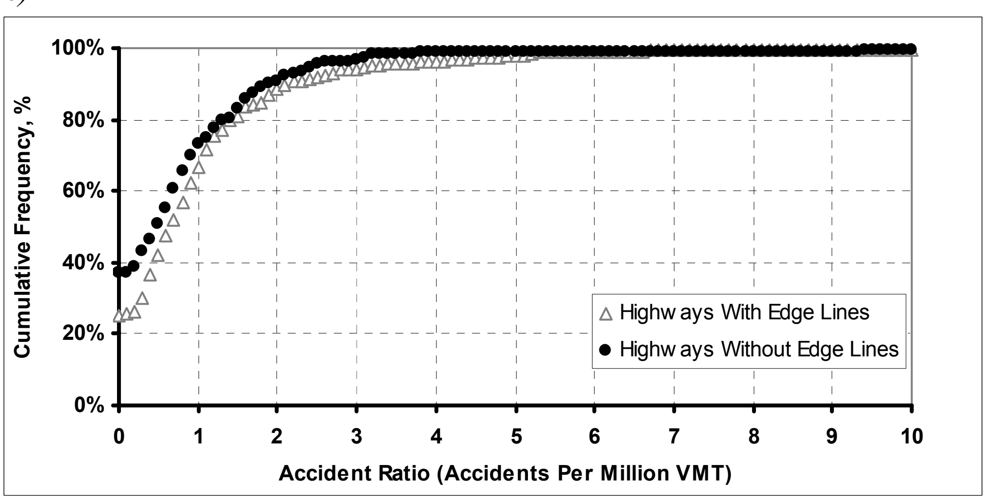
a)



b)

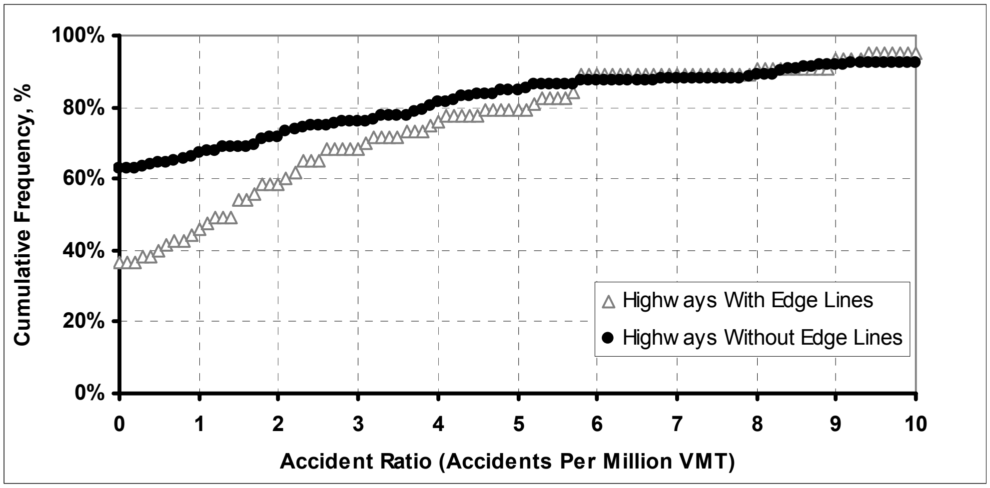


c)

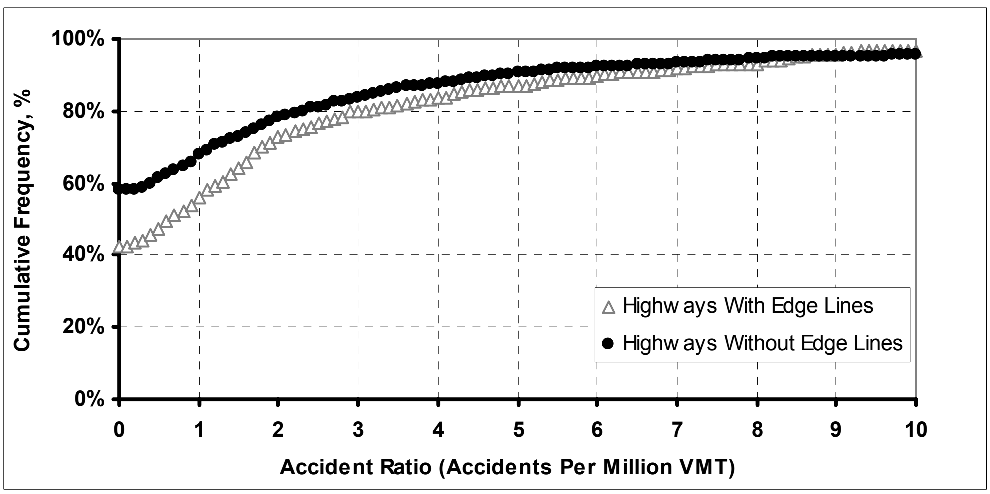


Distribution of Accident Ratios on All Sections on Straight Segments
a) Lane Width of 9 ft b) Lane Width of 10 ft c) Lane Width of 11 ft

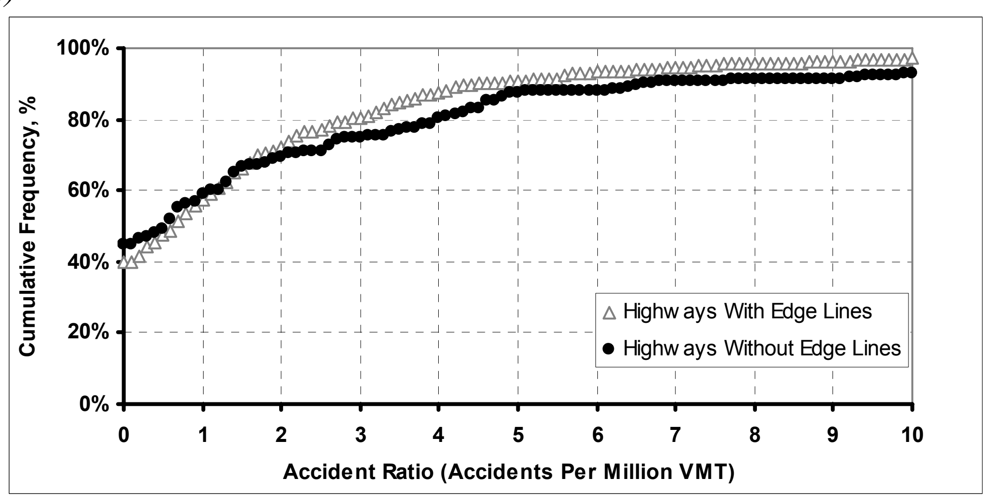
a)



b)



c)



Distribution of Accident Ratios on All Sections on Straight Segments
a) Lane Width of 9 ft b) Lane Width of 10 ft c) Lane Width of 11 ft