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ACCIDENTS ON SECONDARY HIGHWAYS AND COUNTER-MEASURERS PHASE I

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16. Abstract

The Southeastern states have some of the highest overall traffic collision rates in the United States. Collision rates on secondary highways in the region are particularly high compared to other regions and compared to higher functional classes in the Southeast. This report presents the results from Phase I of the study, focusing on the analysis of collisions.

The overall goals of this study are to examine the factors that influence collisions on secondary roadways and to recommend effective countermeasures. This report presents Phase I results that related to the effects of environmental, roadway, vehicle and driver factors on secondary road collisions in the Southeastern United States. The report presents:

- The opinions of officials in the region's state highway and safety agencies on the common secondary road problems and countermeasures.
- A detailed analysis of collision and roadway data from six representative counties: two each in Kentucky, North Carolina and Tennessee.
- An analysis of statewide collision data using the quasi-induced exposure method to examine the impact of driver and vehicle characteristics in Kentucky and North Carolina.

The factors influencing collisions were analyzed with a view to determine promising countermeasures for reducing collision frequency and injury severity. Phase II of the project will focus on developing a methodology for identifying effective countermeasures.

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Phase I Final Report:

Accidents on Secondary Highways and Counter-Measures

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ABSTRACT

The goal of this study was to examine the factors that influence collisions on secondary roadways. The secondary roads examined in this study were two-lane two-way highways. This report presents Phase I results that related to the effects of environmental, roadway, vehicle and driver factors on secondary road collisions in the Southeastern United States. The report presents:

- The opinions of officials in the region's state highway and safety agencies on the common secondary road problems and countermeasures. A carefully designed survey was used to obtain the perceptions of state highway and safety officials.
- A detailed analysis of collision and roadway data from six representative counties: two each in Kentucky, North Carolina and Tennessee. Contingency tables were to analyze the effects of environmental, roadway and vehicle factors on collision frequency, type and injury severity.
- Analysis of statewide collision data to examine the impact of driver and vehicle characteristics in Kentucky and North Carolina. The quasi-induced exposure method was used to analyze the effects of driver and vehicle factors on collisions.

The factors influencing collisions were analyzed with a view to determine promising countermeasures for reducing collision frequency and injury severity. Phase II of the project will focus on developing a methodology for identifying effective countermeasures.

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The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views and opinions of the STC, the USDOT, North Carolina State University, University of North Carolina at Chapel Hill, University of Kentucky or University of Tennessee at Knoxville. The authors assume full responsibility for the accuracy of the data and conclusions presented in this paper.

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CHAPTER 1. INTRODUCTION

The Southeastern states have some of the highest overall traffic collision rates in the United States. Collision rates on secondary highways in the region are particularly high compared to other regions and compared to higher functional classes in the Southeast.(1) The Southeastern Transportation Center, a United States Department of Transportation-sponsored University Transportation Center, initiated a study of the collision patterns and potential countermeasures on secondary highways in the region. This report presents the results from Phase I of the study, focusing on the analysis of collisions. The ultimate goal was to identify countermeasures that can be applied system-wide.

RESEARCH ISSUES

The research questions related to secondary road collisions during Phase I included:

- How do various highway and safety agencies in the Southeastern United States view problems on secondary roads and what do they perceive as efficient countermeasures?
- What are the characteristics of collisions on secondary roads?
- How do roadway, environmental, vehicle and driver factors influence collisions on secondary roadways?

Answers to some of these questions will help in designing effective countermeasures.

GOALS, OBJECTIVES AND METHODS

The overall goal of Phase I was to study the factors that influence collisions on secondary roadways. The secondary roads examined in this study were two-lane two-way highways. More specific objectives and methods used to address the objectives are given below.

Literature Review

Some studies have examined the safety issues involving low-volume two-lane roads. The objective of this portion of the study was to conduct a thorough literature review and synthesis of previous work. The purpose of the literature review was to obtain guidance on collision causes and potential countermeasures and to identify gaps in our knowledge regarding secondary road collisions.

The research team focused the review on references particularly relevant to rural and suburban secondary highways. The team also focused on studies presenting results from credible scientific experiments and results relating collisions to some measure of exposure.

On-line sources such as the Transportation Research Information Service (TRIS), UnCover, and Compendex were searched. Team members also conducted manual searches of their various university libraries and utilized professional contacts. The literature review painted a complex picture of collision patterns on low volume rural and suburban secondary highways. As with many literature reviews, this one raised more questions than answers.

Survey of Highway and Safety Officials

To identify an appropriate project scope, a method for communication with state Department of Transportation officials was developed. The intent was to make the research more meaningful to those in the field and help the project team focus on specific issues. To gather the opinions of transportation and highway safety professionals in the Southeast regarding secondary highway safety, the team conducted a structured "fax-out, fax-back" survey. The team wrote and distributed a written questionnaire. The questionnaire had three questions: one on highway factors, one on collision types, and one on driver/vehicle factors. Each question provided a list of 8 to 12 items and asked respondents to rank the three most important collision causes or types and the three causes or types of collisions that are most efficient to fix. The team sent the questionnaire to officials in the eight Southeastern states: generally the state traffic or safety engineer, the state design engineer, the governor's highway safety representative and the commander of the highway patrol.

Collision Databases

To analyze the effects of roadway and environmental factors on collisions, the team needed accurate and detailed collision databases. Although the collision data record management systems of State DOTs have improved significantly in recent years, accurate data on secondary roads was frequently unavailable. The objective was to compile reliable databases of collisions on secondary roads. The project team obtained 1993-1995 data on secondary road collisions from:

- Kentucky, from the Kentucky Department of Transportation
- North Carolina, from FHWA's Highway Safety Information System
- Tennessee, from the Tennessee Department of Transportation

The three databases used in this project met many of the criteria developed by the research team for selection. The key criterion was quality, which was construed as an unchanged reporting form throughout the period, consistent reporting across areas, and more than 80 percent of the collisions successfully located (i.e. mileposted). Furthermore, the team wanted to select counties with at least some legal alcohol sales, and a sample size of collisions from a county to be at least 1,000. Some of the other criteria included: variety in terrain and traffic volumes (particularly low volumes), representation of both rural and suburban areas, large numbers of collisions with many variables related to each collision and a low reporting threshold, ideally less than $1,000. Two counties from each of the three state databases were selected based on these criteria.

Though no counties in the states met all of the above criteria, two counties meeting most of them were selected. For North Carolina, Wake County was chosen because it met the sample size requirements, has liberal alcohol sales laws and only 11 percent of its collisions are not mileposted. Robeson County was also selected because it met the sample size requirement, allows some alcohol sales and less than 7 percent of its collisions are not mileposted. For Kentucky, Fayette and Pike counties were selected. Both met the sample size requirements and for counties with a larger number of collisions, they had among the lowest percentage of missing or un-mileposted data. The two counties represent very different terrain and character, with Fayette being urban in character and Pike being mountainous and rural. Finally, Fayette has liberal alcohol sales laws while Pike County allows some alcohol sales. Using the same criteria of data quality and quantity, geographic location and alcohol sales laws, the team selected Hamilton and Montgomery Counties in Tennessee for analysis.

To analyze the effects of driver and vehicle factors on collisions, separate collision databases were used. The induced exposure methodology was appropriate for the analysis. The induced exposure methodology required a significantly larger sample than the six county samples in the three states. Therefore, the research team used statewide collision databases for Kentucky and North Carolina in exploring the impacts of driver and vehicle characteristics on collisions.

IDENTIFICATION OF FACTORS RELATED TO COLLISIONS

Roadway, Environmental and Vehicle Factors

A key purpose of this project was the analysis of collision frequency, type and injury severity on two-lane secondary roads. The analysis of vehicle, roadway and environmental factors in the six selected counties was divided into two sections, the first focusing on collisions traditionally associated with intersections and the second focusing on those traditionally associated with segments. Secondary roads were defined according to Average Annual Daily Traffic (AADT) levels, with the threshold of 5,000 AADT selected. All collisions that occurred in the selected counties between 1993 and 1995 on two-lane roads with AADT less than 5,000 vehicles were included in the final database. It should be noted that the AADT threshold applies to segments where collisions occurred and not entire routes. Also note that for Fayette and Pike counties (Kentucky) all rural and local roads were assumed to have AADT less than 5,000. The Tennessee collision data for two-lane roadways obtained from the Tennessee Department of Transportation did not have the AADT variable. Therefore, the condition of AADT less than 5,000 could not be applied to the Tennessee data. The implication is that the Tennessee roadways in the database contained some roads with higher AADT.

The team explored the effects of several roadway and environmental factors on collisions. Specifically, the importance of collision locations, road geometry, type of vehicles involved, time of occurrence and weather on collisions were explored. Collisions were characterized by their type, i.e., whether single vehicles (head-on, sideswipe, rear-end, angle, etc.), injury severity (whether the collision involves property damage only, injuries or fatalities). Using contingency table analysis, the study identified patterns and similarities among the collisions that occurred in the six selected counties. The team conducted an in-depth analysis of roadway, environmental and vehicle factors as they related to intersection-type collisions (rear-end, angle, backing) and segment-type collisions (single vehicle ran off the road, head-on and sideswipe).

Driver and Vehicle Factors

To identify the impacts of driver and vehicle factors on collisions, the team used the induced exposure method. The quasi-induced exposure technique develops relative collision propensities for disaggregated collision data. With this method, one can determine the inherent collision risk for different groups of drivers in many different geometric, roadway and environmental conditions. The first step in this type of analysis was to divide the collision data into three basic groups: 1) drivers in single-vehicle collisions, 2) drivers at-fault in two-vehicle collisions, and 3) drivers not-at-fault in two-vehicle collisions. Collisions involving two at-fault drivers, no at-fault drivers or three or more vehicles are disregarded in the data analysis. The next step in the analysis was to compute the relative accident involvement ratio (RAIR) for drivers involved in both single and two-vehicle collisions. For single ($RAIR_s$) and two-vehicle ($RAIR_m$) collisions, the RAIR of a particular group of drivers is defined as follows:

$$RAIR_s = \frac{\text{Fraction of a given class of drivers/vehicles in single-vehicle collisions}}{\text{Fraction of a given class of not-responsible drivers/vehicles in single-vehicle collisions}}$$

$$RAIR_m = \frac{\text{Fraction of a given class of responsible drivers/vehicles in two-vehicle collisions}}{\text{Fraction of a given class of not-responsible drivers/vehicles in two-vehicle collisions}}$$

The RAIR can then be used as a measure of relative collision propensity for different groups of drivers. Once the team established relative collision risks for sets of drivers and for roadway conditions, potential countermeasures were identified to help reduce the collisions occurring on the secondary roads examined here.

Structure of the Report

This report documents the project findings arranged into chapters. Chapter 2 provides the literature review and synthesis. Chapter 3 discusses the survey results of highway and safety professionals in Southeastern states. Chapter 4 provides an overview of collision and roadway data from six representative counties in Kentucky, North Carolina and Tennessee (two in each state). Chapter 5 discusses results of contingency table analysis of collisions typically associated with intersections and driveways in the four selected North Carolina and Tennessee counties. Chapter 6 provides contingency analysis of collisions typically associated with segments in the four selected North Carolina and Tennessee counties. Chapter 7 presents results from the induced exposure methodology to examine the effects of driver and vehicle factors on collisions. Finally, Chapter 8 lists the conclusions from the study and discusses ideas for Phase II of the project.

CHAPTER 2. LITERATURE REVIEW

INTRODUCTION

An important part of this research project was a review of the extensive existing literature on secondary highway safety. For a particular variable or factor related to safety on secondary highways, the team searched the literature trying to answer questions like the following:

* Are collisions involving this factor a large component of the problem on secondary highways?
* What types of collisions are typically associated with this factor on secondary highways?
* Do collisions involving this factor tend to occur at certain times of the day, days of the week, etc.?
* At what types of locations do collisions involving this factor tend to occur?
* Are there effective countermeasures for collisions associated with this factor?

The research team found literature using online indexes such as TRIS and UnCover, manual library searches, and professional contacts. The team reviewed the literature critically, reporting below only the most scientific study results and the most relevant research to the topic.

OVERALL COLLISION STATISTICS

Two-lane, two-way roads make up 80 percent of the roadway network in the United States. Also, 90 percent of these secondary highways have traffic volumes less than 1,000 vehicles per day.(2) Even though these roads carry low traffic volumes, available information indicates that they have higher collision rates than other highways. While all roadways had a collision rate of approximately 99 collisions per 100 million vehicle-miles of travel (VMT) for 1992, the collision rate for secondary roads was almost twice as high for the same period, 188 collisions per 100 million VMT.(3) During the same period, higher fatality rates were observed on secondary roads, 2.33 collisions per 100 million VMT, than all roadways, 1.56 collisions per 100 million VMT.

In 1996, 41,907 people were killed and 3,511,000 were injured in motor vehicle collisions on roadways in the United States.(4) Traffic fatalities are the leading cause of death among people between the ages of 6 and 27 in this country.(4) Traffic fatality rates are especially alarming in rural areas and in the Southeastern United States. According to the National Highway Traffic Safety Administration (NHTSA) (5), only 38 percent of the total vehicle miles traveled in 1995 were on rural roads, but 59 percent of all traffic fatalities were on these roads. Although most collisions occur in urban areas, most fatal collisions occur in rural areas because vehicle speeds tend to be higher than urban traffic.

Recent statistics indicate an increase in the number of traffic fatalities in Southeastern states. For example, in 1996, there were 1,574 fatalities in Georgia, 1,493 in North Carolina, 1,143 in Alabama and 930 in South Carolina, increases of 6, 3, 3 and 6 percent over 1995 totals, respectively. Other Southeastern states, Tennessee, Kentucky and Florida, experienced no change or slight decreases from 1995 to 1996.(6) This research effort aims to identify collision trends based on the information contained in collision reports filed by police, and then suggest countermeasures to make secondary highways safer, particularly in the Southeastern United States.

Truck-Involved Collisions

Trucks on secondary highways continue to be a topic of intense debate guided by few facts. For example, a bill introduced in the North Carolina House of Representatives recently would allow longer and wider trucks (up to 70 feet long and 8.5 feet wide) on all North Carolina state highways.(7) Trucks of that size are currently allowed on most two-lane highways in North Carolina only for pick-ups and deliveries and to obtain services. The debate over the bill centered on economic development versus safety, but the data cited in newspaper accounts by safety proponents were not particularly relevant to secondary highways.

The literature provides some clues about large truck safety on secondary highways. However, because researchers have typically focused attention in large truck safety on freeways and on highways in urban industrial areas, the literature does not fully answer the questions raised above. Lyles et al. (8) analyzed large truck accident frequencies and rates (per mile driven) in Michigan and concluded that trucks are involved only about five percent of all reported collisions, truck collisions tend to be more severe, and truck collisions tend to involve multiple vehicles more often than non-truck collisions. In terms of rates, Lyles et al. found that truck collision rates were much higher on county and local roads than state and interstate routes, and highest on rural county or local roads at night. Other researchers have found that truck-involved collisions on rural two-lane roads are more likely to be severe than on any other class of roadway.(9) Vallette et al. (10) conducted a comprehensive analysis of a six-state data base and found that truck collisions on rural non-freeways occur primarily on weekdays (87 percent of all collisions) and during daytime (60 percent of all collisions between 6:00 p.m. and 6:00 a.m.). The Vallette et al. data showed 36 percent of rural non-freeway collisions were single-vehicle, with about half of those being run-off-road collisions. Angle, rear-end, and sideswipe were all prominent multi-vehicle collision types.

The literature suggests several highway factors are related to truck safety on secondary highways. Zegeer et al. (11) conducted operational tests of large trucks over rural secondary highways which showed that vehicles encountering opposite-direction large trucks on roads with narrower lanes, with narrower shoulders, or with horizontal curves slowed down more and encroached on the edge line more often. Vallette et al. (10) found that truck collisions were more frequent on vertical down grades than up grades on rural non-freeways and that about 34 percent of large truck collisions occurred on horizontal curves. Vallette et al. and Lohman et al. (12), looking at truck data from North Carolina in 1973, both found almost half of large truck-involved collisions were at intersections or driveways, but Vallette et al. further noted that only 23 percent of rural non-freeway collisions were intersection-related. Miaou et al. (13) explored relationships between truck collisions and geometric design features such as horizontal curvature, grades, shoulder width and AADT, for rural two-lane roadways.

Using 1993 FARS data, Braver et al. (14) found that head-on collisions, and collisions in which a vehicle defies a traffic control device, are the most frequent truck-car fatal collision types, accounting for 61 percent of all fatal collisions. They found that slippery roads, curves and hillsides increased the likelihood of fatal collisions. Braver et al. also suggest countermeasures aimed at preventing fatal collisions.

The literature on driver characteristics in truck-involved collisions is scarce. In a report to the North Carolina Governor's Highway Safety Program, Duncan and Reinfurt (15) qualitatively analyzed focus group discussions of passenger car and heavy truck drivers who had been in recent collisions. The focus groups revealed that passenger car drivers, while concerned about collisions with heavy trucks, were largely unaware of the visibility, maneuvering and acceleration/deceleration limitations of heavy trucks. Furthermore, most car drivers do not drive in a way that accounts for the specific roadway and environmental conditions that make these limitations especially problematic for trucks. In the same report, a survey of driver educators showed that unsafe passing maneuvers, close following distances and limited visibility are the most frequent concerns mentioned by driver educators about heavy trucks and cars sharing the road.

Bridges

Many researchers through the years have identified bridges as elements of special concern on secondary highways. Researchers have concentrated on bridge width as an important variable. After reviewing the literature, Mak (16), for the Transportation Research Board, and Spring and Hummer (17), for the STC, both concluded that the model assembled by Turner (18) is the best available for bridge width. Turner's recommended model is:

$$Y = 0.50 - 0.061(RW) + (0.0022)RW^2$$

where Y is the number of bridge-related collisions per million vehicles and RW is the bridge width relative to roadway width, in feet. The equation was derived from a sample of 2,800 collisions at

2,100 bridges on two-lane, two-way rural roads in Texas during a four-year period. An R^2 value of 0.81 showed that the equation fit the data quite well.

Abed-Al-Rahim and Johnston (19) developed a bridge-related collision prediction model from a sample of over 2,000 collisions in North Carolina. Their model used a log transformation and had terms for average daily traffic, bridge length, and bridge width relative to an acceptable width. The model had an R^2 value of 0.33 and applied to all areas and all functional classes of roadway, even though the authors indicated a desire to develop separate models for rural areas and for secondary highways. Like the Turner model given above, and many other models mentioned in this chapter, this model is subject to criticism for assuming that collisions are normally distributed rather than Poisson distributed.

Several researchers have attempted to combine the effects bridge width and other variables in a bridge safety index. Ivey et al. (20) produced the most widely known bridge safety index to date, which is the sum of ten individual factors, three of which relate to bridge width. Mak (16) points out that the Ivey, et al. index was developed subjectively based on "engineering judgement" and that subsequent research in Texas and elsewhere (see Ghandi, et al. (21)) added more terms to the index and placed the index on a more sound statistical basis. Murthy and Sinha (22) subsequently developed an index with three groups of factors (bridge, approach roadway, and environment) using fuzzy sets.

Lighting

There is some potential for fixed roadway lighting to be an effective countermeasure on secondary highways. A recent study by Hummer, et al. (23) found from a sample of Minnesota highways that unlit rural intersections can expect about 18 to 27 percent of their collisions at night. Unlit rural roadway sections experienced about 23 to 28 percent of their collisions at night. In addition, Zegeer et al. (24) found that compared to the full sample of rural two-lane roads, low-volume roads had a higher percentage of nighttime, no-lighting collisions (39.0% vs. 31.1%).

The relevant research on the effects of fixed roadway lighting is older and relates only to intersections. A before and after study of 47 rural intersections in Iowa by Walker and Roberts (25) found an overall 52 percent reduction in the rate of collisions at night per entering vehicle. The researchers noted particular improvements at more complex intersections: intersections with channelization, intersections where a primary route turned, and intersections with four legs. As the authors provided no reason that the 47 sites were chosen for lighting, some of the collision reduction documented this uncontrolled before and after study is likely due to regression to the mean.

Lipinski and Wortman (26) studied the effects of lighting on collisions at rural intersections in Illinois. The sample included 263 lighted intersections and 182 unlighted intersections that had characteristics similar to the lighter intersections. They found that the rate of night collisions per entering vehicle was 45 percent lower for the lighted intersections. More convincing was the finding that the night to total collision ratio was 22 percent lower for the lighted intersections.

Collisions with Animals

The relatively sparse literature on this topic shows that collisions with animals are a large and growing problem on secondary highways, but the collisions are rarely severe for humans. A study of collision data from five states (Illinois, Maine, Michigan, Minnesota, and Utah) using FHWA's Highway Safety Information System (HSIS) showed a rise from 21,500 reported animal collisions in 1985 to 36,300 in 1991.(27) North Carolina data show a rise from 2,900 reported collisions in 1986 to 6,000 in 1991 to almost 12,000 animal collisions in 1996.(28) The HSIS study showed that less than 0.1 percent of reported animal collisions resulted in a fatality to a motor vehicle occupant while only two to ten percent resulted in a reported injury. In North Carolina in 1996, animal collisions resulted in three human fatalities, about 1,000 human injuries, and about 10,000 to 15,000 animal fatalities. Most of the animals involved in reported collisions are deer.

Two-lane rural roads are by far the most likely scenes for animal collisions. The HSIS study computed an average animal collision rate of 0.48 per million vehicle miles for two-lane rural roads versus 0.12 for multilane rural roads and about 0.05 for urban roads.

The HSIS study and the North Carolina data show that reported animal collisions are high in October and December and peak in November. In Michigan, for example, the HSIS study documented that October had over 9,000 reports (over six years), November over 14,000, and December about 7,000, while no other month recorded more than 5,000 reports.

The HSIS study briefly reviews countermeasures that have been attempted through the years for animal collisions. Those mentioned include warning signs, roadside vegetation management, animal control measures, reflective devices, and deer whistles. The study characterizes these attempts as enjoying "varying degrees of success" and "mixed results".

Unpaved Roads

Zegeer, et al. (24) recently studied the safety of unpaved roads relative to paved roads as part of a larger project for the NCHRP. They developed collision models based on data from three states (including North Carolina) from 170 sections of unpaved roads and 600 sections of comparable paved road. They concluded that, all else being equal, below an ADT of 250 there was no important difference in collision rates, but between ADT values of 250 and 400 unpaved roads experienced about 50 percent more related collisions. Above an ADT of 400 the difference appeared to decrease, although the sample size of unpaved roads became too small to analyze thoroughly.

Effect of Resurfacing

The effects of roadway resurfacing on the safety of rural two-lane highways are controversial in part because they may not be positive. Indeed, NCHRP project 17-9(2) is underway to shed additional light on this area. In the meantime, the most credible work to this point has been done by Cleveland (29) and by Hauer, et al. (30). Cleveland conducted a thorough review of the literature on this topic for TRB in 1987. After examining dozens of studies, many of which were methodologically flawed, he concluded that for resurfacing projects selected due to pavement structure or ride quality on rural highways, all collisions will increase in the first year by an average of five percent and will increase through the life of the project by an average of three percent. He wrote that these increases are composed of increases in collisions on dry pavements (i.e., up 10 percent in the first year and six percent overall) and somewhat offset by decreases in collisions on wet roads (down 15 percent in the first year and seven percent overall). Cleveland also found that there would be a small increase in collision severity after resurfacing a rural two-lane highway, on the order of ten percent more injuries and fatalities per collision.

Hauer, et al. (30) studied two types of resurfacing projects in the State of New York: 82 projects with resurfacing only and 55 projects with resurfacing and limited remedies for safety and operational problems. They assembled about 13 years of collision data per site, including about 70 months of collision data after project completion at most project sites. Hauer et al. used the Empirical Bayes approach with a large comparison and reference group (525 sites) to overcome regression to the mean and other uncontrolled factors. Table 2.1 shows that the effects of resurfacing were more important than Cleveland estimated. Table 2.1 also shows that the addition of limited safety and operational improvements to resurfacing projects help them a great deal.

TABLE 2.1. Effects of resurfacing projects on safety estimated by Hauer, et al.(30)

Project Type	**Location Type**	**Time Following Project [months]**	**Change in Collision Frequency [%]**
Resurfacing only	Intersection	0-12	+35
		13-32	+0
		33-70	-23
	Segment	0-30	+21
		40-63	+0
		64-70	Decline (unknown %)
Resurfacing and limited other improvements	Intersection	0-70	-29
	Segment	0-70	+0

Same-Direction Passing Collisions

The FHWA recently examined this issue using five years of collision data from three states in the HSIS.(31, 32) The major conclusion drawn was that passing collisions are relatively rare. On two-lane rural roads, passing collisions were about two percent of the total number of collisions. The researchers also found that passing collisions are somewhat more severe than other collisions, that head-on collisions account for only a small portion (i.e., only about six percent in the two states with available data) of passing-related collisions, and that about 90 percent of passing collisions occurred within passing zones.

Vertical Alignment

Vertical alignment is one of the major areas of decision for the designer of a highway and is one of the most costly elements to update later should the original design prove unsafe. However, the available information on the relationship between safety and vertical alignment for two-lane secondary highways is scarce.

Glennon (33) reviewed the literature for TRB in the late 1980's. He found that the multivariate models relating highway elements to collisions to that point had not produced reliable measures of the effects of vertical alignment. This has not changed during the past ten years. Glennon did find consistency among several smaller studies on three points relating to vertical alignment, namely:

1. Grade sections have higher collision rates than level sections,
2. Steep grades have higher collision rates than mild grades, and
3. Downgrades have higher collision rates than upgrades.

Brinkman and Perchonok, for FHWA (34), confirm the third point. They also show that collisions on downgrades or vertical curves are more severe than collisions on upgrades or level sections.

Most of the research attention in the area of safety and vertical alignment lately has focused on the interaction between crest vertical curves, sight distance, and collisions. Olson, et al. (35) examined ten matched pairs of vertical curves on two-lane rural roads in Michigan, where one member of the pair had a sight distance restriction and one member did not. They found that there were significantly more collisions at the sites with sight distance restrictions over a five-year period. Meanwhile, Fambro, et al. (36) concluded the opposite in a more recent study in Texas using regression analysis. Fitzpatrick, et al. (37) tried to rectify the opposing conclusions by pointing out that there may be threshold values of sight distance above which increases do not contribute appreciably to collision frequencies.

Glennon (33) made several relevant points on the interaction between sight distance, crest vertical curves, and safety. First, Glennon pointed out that lengthening vertical curves to improve sight distances at the crest would sometimes generate other sections of roadway where the sight distance is reduced. Not only is curve flattening expensive, he wrote, but it might be counterproductive. Second, Glennon used a set of hypothetical collision rate estimates for various hazards to show that lengthening vertical curves to increase sight distance is only cost-effective with high ADT levels and significant hazards (i.e., sharp horizontal curves, intersections, narrow bridges, etc.) within the restricted sight distance area. Fambro, et al. (36) and Fitzpatrick, et al. (37) agreed with this second point following their analyses.

The conclusion of a recent major review for NCHRP (38) was that Neuman, et al. (39) have produced "the best known relationship" between sight distance and collision frequency for crest vertical curves on two-lane rural highways. The model is:

$$N = (AR_h)(L)(V) + (AR_h)(L_r)(V)(Far)$$

where N is the collision frequency on the highway segment containing the curve, AR_h is the average collision rate for the highway or for highway segments like the one being analyzed, L is the segment length, V is the traffic volume on the segment, L_r is the length of the sight distance restriction, and

Far is the hypothetical collision rate factor for the curve and hazards on it. The model needs to be calibrated so that it does not rely on those hypothetical factors any longer, but the professional consensus seems to be that the form is sound. Calibration of the model to arrive at a set of those factors would require a large research effort.

Horizontal Alignment

The literature is quite consistent in finding that curved segments of two-lane rural highways have higher collision rates than tangent segments. A literature synthesis for FHWA (40) notes that the rates for curved sections are 1.5 to four times those of tangent sections depending on the study. Collisions on curves also tend to be more severe than collisions on tangent sections.(41)

Sharpness of the horizontal curve, as typically measured by the degree of curve, is almost universally recognized as being important in predicting collision frequency. However, several authors have perceived a threshold of sharpness below which collision rates do not change much. Krammes, et al. (42) identified four degrees as this breakpoint after analyzing 1,100 curve sites in three states, while Lin (43) noted a breakpoint somewhere between three degrees and nine degrees after analyzing 155 curves in New York. Curve length and traffic volume are factors also widely recognized as related to collision experience in curves.

Besides sharpness, length, and traffic volume, the FHWA synthesis (40) listed many factors which may affect the number of collisions on a given rural two-lane horizontal curve, such as:

* Spiral or other transition curves. Glennon, et al. (44) and Zegeer, et al. (41) conclude that there are small positive safety effects from spiral transition curves, although Stewart and Chudworth (45) concluded otherwise after a small study in the U.K.

* Superelevation. Zegeer, et al. (41) found a "small but significant" effect on collisions due to substandard superelevation on curves and Zador, et al. (46) found more deficiencies in superelevation

at curves that were fatal collision sites than other curves. However, Lin (43) doubts that raising superelevation is an effective way to reduce collisions.

* Cross section elements such as lane width and shoulder width (discussed below under the heading "Cross-Section Elements").

* Roadside elements (discussed below under the heading "Roadside Elements").

* Sight distance. Glennon, in a literature review for TRB (47), concluded "clearing trees or other minor obstructions from the inside of sight-restricted horizontal curves appears to be cost-effective for almost all highways."

* Vertical alignment. As noted earlier in the section headed "Vertical Alignment", the most important effect here is likely a horizontal curve beginning just beyond a vertical curve in a location providing the drivers little sight distance to it.

* Consistent curve design. Krammes, et al. (42) have recently studied the consistency between horizontal curves along a rural road. Their analysis of categories of curves grouped by the required speed reduction showed that the mean collision rate increased approximately linearly as the required mean speed reduction increased.

* Presence/distance from the curve to the nearest intersection, driveway, bridge, etc. This interaction remains basically unquantified. As noted earlier in the section on "Vertical Alignment", though, there is reason to suspect that curves with limited sight distances only start to cause more collisions in the presence of one of these features.

* Pavement friction. This effect is not well known.

* Traffic control. Glennon (33) reviewed this factor for TRB and found some operational and collision effects from improved signing and delineation.

Clearly, developing models to predict collisions on horizontal curves involving all these factors is an impossible task. However, several authors have made credible attempts to model collisions on horizontal curves using the most important factors. Glennon, et al. (44) developed an equation that discriminated between curve segments with a high number of recorded collisions and segments with a low number of recorded collisions. Their equation included terms for degree of curve, length of curve, roadside rating (based in turn on sideslope steepness, average clear zone, and density of roadside hazards), pavement skid resistance, and shoulder width. The equation correctly classified 76 percent of the high-collision curves and 60 percent of the low-collision curves from a sample of 330 curves. Glennon, et al. also calibrated a collision prediction model:

$$A = (AR_s)(L)(V) + 0.0336(D)(V)$$

where A is the collision frequency on a segment containing a curve, AR_s is the average collision rate on comparable straight segments, L is the segment length in miles and L is greater than the length of the curve, V is the traffic volume in millions of vehicles, and D is the degree of curve.

In a recent review for NCHRP, McGee, et al. (38) call the model developed by Zegeer, et al. (41) the "best available" for predicting collisions on horizontal curves. The first two terms of their model look like the Glennon, et al. model above. Zegeer, et al. added other terms for presence of a spiral and for roadway width. Zegeer, et al. calibrated the model using a database of 10,900 curves on two-lane roads in Washington state which had other curves nearby (i.e., non-isolated curves). The researchers also calibrated a model for curves with tangents on each side (i.e., isolated curves). The pseudo R^2 value for the model for non-isolated curves was 0.35, which indicates that there is much still unexplained about collisions on curves. McGee, et al. (38) suggest that roadside elements, vertical alignment, and the presence of intersections and driveways are other important factors which should be included in an improved model.

Lane Width and Shoulder Width

There is little doubt that, generally, wider lanes and wider shoulders should mean fewer collisions on secondary highways. The more challenging question has been how much safety benefit can an agency expect for each increment of widening when considering interactions with many other factors (such as those discussed in the previous sections of this chapter). Three relatively recent efforts with reasonably defensible sample sizes and study designs stand out in attempting to answer that question.

In 1987, Zegeer, et al. (48) analyzed a database of almost 4,000 miles of rural two-lane roads from seven states, including detailed data on the roadside condition of the sampled sections. The researchers used multiple log-linear regression analysis to fit a model explaining collisions related to the cross-section elements. The recommended model had terms for ADT, lane width, paved shoulder width, unpaved shoulder width, roadside hazard rating, and terrain. The R^2 value was 0.46, indicating that much of the variation in the collision data was unexplained. The model results, summarized in Table 2.2, showed that widening lanes was more effective than widening paved shoulders and that widening paved shoulders was more effective than widening unpaved shoulders. The Zegeer, et al. model has been criticized through the years for assuming that collisions are normally distributed rather than Poisson distributed and for combining all the data from seven diverse states into one database.

TABLE 2.2. Collision reductions predicted by the recommended Zegeer, et al. (48) model.

	Percent reduction in related collisions		
Amount of widening [ft]	**Lane**	**Paved shoulder**	**Unpaved shoulder**
1	12	8	7
2	23	16	13
3	32	22	19
4	40	29	25
6	N/A	40	35
8	N/A	49	43

Note: N/A means 'Not Applicable'

In 1994, Zegeer, et al. (24) examined a database of 4,100 miles of rural two-lane roads with ADT less than 2,000 from four states, including part of the seven state database from 1987. The researchers used analysis of covariance to explore lane and shoulder widths while accounting for a number of other factors like state, terrain, roadside hazard rating, and number of driveways. Table 2.3 shows some of their key results. They concluded that, for paved roads, lane widths greater than ten feet are safer than ten-foot lane widths. They also concluded that for lane widths over nine feet, shoulders wider than five feet enhance safety. They speculate that eight and nine-foot wide lanes reduce speeds which, in turn, reduces collision frequency.

TABLE 2.3. Collision rates for various combinations of lane and shoulder widths for low volume paved rural roads.(24)

Lane width [ft]	Shoulder width [ft]	Collisions per million vehicle miles
8 and 9	All	1.66
10	0-4	2.41
	5+	1.43
11-12	0-2	1.87
	3+	1.31
13+	0-4	1.57
	5+	0.76

Bared and Vogt (49) have produced the most recent important model of the effects of cross section elements on the safety of rural two-lane roads. Their negative Binomial model form, theoretically more sound than the Zegeer models described above, described about 65 percent of the variation in the data. However, Bared and Vogt used a smaller sample (700 miles) of data from only one state (Minnesota) to calibrate their model. Their recommended model predicted non-intersection collisions using ADT, lane width, shoulder width, roadside hazard rating, driveway density, a horizontal curve index, and a vertical curve index. Their model showed that widening shoulders would have a greater marginal effect on safety than the same amount of lane widening.

Roadside Elements

Several authors have provided the distribution of reported collisions with roadside objects. Viner (50) reported most harmful event data from the National Accident Sampling System for all roadways while Mak (51) analyzed first harmful event data from the General Estimates System for all roadways. Viner reported that overturns are the events that cause the most monetary loss, followed by collisions with trees, utility poles, embankments, guardrails, ditches, culverts, bridge rails, and luminaire supports. In terms of number of fatal or severe injuries, Mak found collisions with posts and poles first, followed by overturns and collisions with trees. Data on roadside object struck for secondary highways are scarce, however. Zegeer, et al. (48) examined the fixed object reportedly struck in over 5,000 collisions on rural and urban two-lane road sections with ADT under 4,000 in six states. They found that trees were the most frequently struck object, followed by guardrail, utility poles, signs, and mailboxes. Over half the collisions were reported with other obstacles.

The Roadside Design Guide, published by the American Association of State Highway and Transportation Officials (AASHTO), is the primary source of help for designers and analysts choosing countermeasures for collisions on roadsides (52). The Guide articulates a forgiving roadside philosophy, which includes the following general options for reducing a roadside hazard:

* Remove the obstacle.
* Redesign the obstacle so that it can be safely traversed.
* Relocate the obstacle.
* Reduce the impact severity by using a breakaway device.
* Shield the obstacle.
* Delineate the obstacle.

The Guide suggests clear zones, which are lateral distances from travel lanes free of potentially harmful obstacles and slopes, based on ADT, sideslope ratio, and design speed, as shown in Figure 2.1. Note that the values in Figure 2.1 should be adjusted if applied to the outsides of horizontal curves.

The Roadside Design Guide (52) also provides the best available model for predicting the cost-effectiveness of roadside countermeasures. The model is quite detailed, including an equation predicting encroachments and a large set of severity indices for various object and slope combinations. The model has been criticized because it is so detailed that it is cumbersome to apply

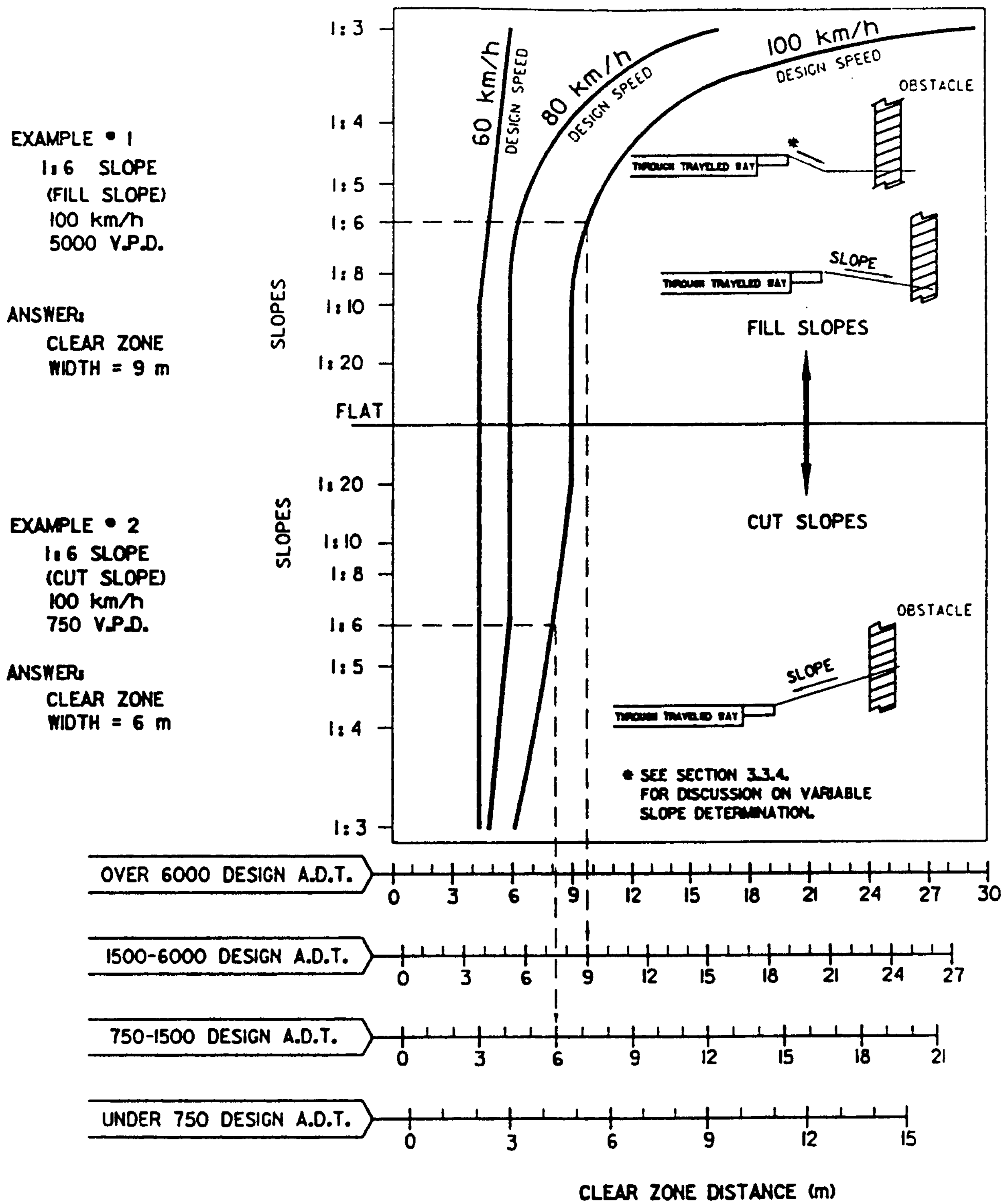

FIGURE 2.1. AASHTO-recommended clear zones.(52)

on sections or at large numbers of spots. Some have also criticized the model because the encroachment equation and severity indices have not been well validated.

Researchers have attempted to address the perceived weaknesses of the Roadside Design Guide model recently. Turner and Hall (53) synthesized the extensive recent work on more valid severity indices for roadside objects, while Sicking, et al. (54) have offered a new approach using kinematic analysis. Meanwhile, Stephens (55) provided a way that agencies can quickly apply parts of the Roadside Design Guide model to choose low-cost guardrail countermeasures.

Besides the model from the Roadside Design Guide focusing on particular spots, agencies can use some of the models described in previous parts of this chapter to predict the effects on roadside collisions on longer road sections. The equation from Glennon et al. (44), which attempted to separate horizontal curves by hazardousness included a term for roadside rating based on sideslope steepness, average clear zone, and density of roadside hazards. The models from Zegeer, et al. (48) and Bared and Vogt (49), predicting collisions due to cross-section elements, each included a term for roadside hazard rating. The rating was from one through seven, with one for low collision frequency and severity and seven for high collision frequency and severity. Using the Zegeer, et al. recommended model, a reduction in roadside hazard rating of one, two and three points would lead to 19, 34, and 47 percent reductions, respectively, in collisions related to cross-section elements. Zegeer, et al. also developed models based on the average roadside lateral recovery distance and the average sideslope steepness of the sections.

Several researchers have developed models predicting collisions with particular fixed objects. Zegeer, et al. (41) used a portion of the seven-state two-lane road database from Zegeer, et al. (48), which included some urban roads, to develop models for seven types of objects. Table 2.4 shows some results from these individual models, for objects less than 30 feet from the roadway. Unfortunately, the proportion of the variation in the data explained by the models was not high, ranging from 0.37 for the utility pole model to 0.25 for the guardrail model to less than 0.16 for the other five models. Zegeer and Parker (56) have also published a model of utility pole collisions for the FHWA.

TABLE 2.4. Results from models of individual obstacle models developed by Zegeer, et al.(41)

Object type	Percentage reduction in collisions						
	Added distance object is moved from road [ft]						
	2	**4**	**6**	**8**	**10**	**12**	**15**
Guardrails	26	45	60	70	78	NF	NF
Utility poles	25	44	58	69	77	82	89
Trees	15	28	39	49	57	63	71
Fences/Gates	14	25	35	44	52	NF	NF
Mailboxes, culverts or signs	10	19	26	34	40	NF	NF

Note: "NF" means that it is generally not feasible to move the object the specified distance.

INTERSECTIONS

A study of both three-arm and four-arm intersections by Leong (57) revealed that the presence of traffic signals at four-arm intersections reduced collision frequency but made little difference at three-arm intersections. However, the presence of narrow-curbed medians reduced collisions at three-arm intersections. Overall, three-arm intersections had a lower number of collisions than four-arm intersections with similar traffic controls. This suggests that intersections with characteristics that slow traffic or reduce the potential for conflicts have fewer collisions than intersections without these characteristics.

Bonneson and McCoy (58) found that the annual collision frequency for two-way, stop-controlled intersections on rural highways increased non-linearly with increasing major and minor road volumes. McCoy et al. (59) report on guidelines at access points on urban two-lane roadways. They provide guidelines that define the design hour traffic volumes for which the benefits of right turn lanes exceed their costs (including collision cost reduction). Bared and Vogt (49) provide details of important intersection design variables on two-lane rural roads. The key design factors include: traffic volumes, horizontal and vertical alignment, speed limits, roadside hazard ratings, weather conditions, channelization on the main road, intersection angle and the number of driveways within 250 feet of the intersection.

New Methods in Safety Analysis

The previous sections in this chapter have summarized the best available research on the safety of various elements of secondary highways. There has also been recent research on identifying sites and choosing countermeasures that could be applied to secondary highways. This review briefly summarizes three areas of new research into the processes of safety analysis: identifying promising (as opposed to hazardous) sites, conducting road safety audits, and using expert systems.

Several authors have recognized that the conventional method of identifying hazardous locations is flawed. The conventional method requires large sets of collision data which makes it reactive rather than proactive, vulnerable to the many errors in the data, expensive to perform every year, subject to regression-to-the-mean biases, and likely to identify sites with no obvious cost-effective remedy. One response to these flaws has been a focus on finding correctable collision patterns.(60, 61) The most exciting research along these lines for secondary highways is from Hauer (62) who proposed five criteria for finding promising sites:

1) where proven countermeasures would work,
2) where newly opened sites are performing more poorly than expected,
3) where safety has suddenly deteriorated,
4) where the collision rate is unacceptably high, and
5) where the collision rate is higher than expected.

The key to Hauer's proposed method is that agencies would only need to check Criterion 3 each year, reducing the reliance on collision data. Analysts would only check Criteria 4 and 5 every few years, and check Criterion 2 only when a new roadway opened. Criterion 1 would provide sites already matched with potential countermeasures. Hauer's promising site method is based in sound logic, requires fewer data than conventional methods, and matches sites to countermeasures more efficiently than conventional methods.

The road safety audit has developed in the U.K., Australia, and New Zealand within the past ten years and is just gaining attention in the U.S.(63) The idea behind road safety audits is that experts review operating highways or highway projects at any stage of development looking specifically for ways in which road-user safety may be improved. The key feature distinguishing an audit from standard design and operation practices is that independent professionals conduct the audit. The audit is a formal process resulting in a written report from the auditors and requiring a written response from the highway designers or operators. Auditors in Australia and New Zealand use checklists of safe design and operation practices that are similar to American references such as the Roadside Design Guide (52) and checklists from the literature.(64, 65) The FHWA (63) reports that some Australian highway agencies audit identified hazardous sites while others attempt to audit a pre-determined portion of the highway network each year. Agencies have reported greater benefits than costs with road safety audits, although convincing scientific evidence is lacking.

A final area of promising developments in the process of safety studies that could be applied to secondary highways is the use of expert systems. The vast body of knowledge the safety engineer must bring to bear on the problem of deciding whether and how to remedy a certain spot or section would seem to be a natural application for an expert system. Indeed, checklists, such as those mentioned in the previous paragraph, are a typical beginning point for the development of an expert system. Increasingly powerful and inexpensive computers and a wide distribution of good geographic databases also make the application seem feasible. Several researchers have taken on the challenge of developing an expert system for highway safety. For example, Spring and Hummer (17) completed a pilot study recently for STC trying to apply engineering expertise within a geographic information system to the task of identifying hazardous sites. The most mature highway safety expert system to date was developed in the U.K. by Wu and Heydecker.(66) In testing with a collision database, their system distinguished between sites with some similar characteristics, which nonetheless experienced different types of collisions.

SUMMARY

There is a rich literature related to the safety of secondary highways. After a critical review of this literature, it is apparent that the profession knows a great deal about which elements make up a large component of the safety problem on secondary highways, whether there are effective countermeasures for collisions associated with various elements, and other key questions. Some of the important findings from the review included:

* Truck-involved collisions and passing-related collisions are both relatively rare on secondary highways.
* Lighting rural intersections and paving rural roads have the potential to reduce collisions at some locations.
* Resurfacing a rural two-lane road will cause collisions to rise in the first few years following the project, while resurfacing, accompanied by low-cost safety improvements, will reduce collisions.
* Collisions with animals are a large and growing problem on secondary highways, but the collisions are rarely severe for humans.
* Credible models exist for predicting collisions on two-lane roads associated with cross-section elements, horizontal curves, and narrow bridges.
* Models exist for predicting collisions on two-lane roads related to vertical curves and roadside elements, but professionals will have difficulties applying them.
* Restricted sight distance becomes a safety problem primarily when it is in combination with another element requiring driver attention, such as an intersection or horizontal curve.
* A number of factors influence collision frequency at intersections on two-lane highways.
* New methods to identify sites and countermeasures in a safety program have been developed recently which could be of great help on secondary highways.

CHAPTER 3. EXPERT OPINION

INTRODUCTION

An important part of Phase I of the project was gathering the opinions of transportation and highway safety professionals in the Southeast regarding secondary highway safety. The main purpose of this activity was to gather information from people who are not usually represented in the published literature. The research team was interested in the opinions of engineers and police officers who make decisions about safety on actual highways every day or work at actual collision scenes every day. The research team also wanted opinions specific to the Southeast region, rather than the U.S. as a whole.

The team attempted to gather opinions from four officials in each of the eight STC states. These generally included the state traffic or safety engineer, the state design engineer, the governor's highway safety representative, and the commander of the highway patrol. In three states, one person assumed more than one of these roles or the office was vacant, so the list of potential respondents actually included 29 names. The research team was only interested in expert professional opinion, so it did not conduct a larger survey.

QUESTIONNAIRE FORMAT

After considering several possible ways of gathering opinions, the team wrote and distributed via fax a written questionnaire. The team considered other formats, particularly telephone interviews. However, the team was concerned that interviews may be biased by the opinions of the interviewer, would require the respondent to remember a lot of information during the interview, and may not provide quantifiable results. The team was also concerned about not being able to reach busy potential respondents by telephone. The team considered e-mail, but rejected it since not all potential respondents had addresses.

After several drafts, including one that was reviewed by the entire project team at its meeting in Knoxville in May 1997, the researchers settled on the questionnaire in the Appendix. The questionnaire had three questions: one on collision types, one on highway-related collision causes, and one on collision causes related to drivers and vehicles. The team believed that brevity was important in encouraging responses. Each question provided a list of 8 to 12 items and asked respondents to rank the three most important collision causes or types and the three most efficient causes or types to fix. This dual list provided important information, as very important factors may not necessarily be the easiest to fix. The items were listed in no particular order. Following each question, the team asked for information on studies the agency had performed on those items.

The team made an initial telephone call to the office of the respondent to confirm the identity of the person in the office, to establish the willingness to receive the questionnaire, and to obtain the fax number. The team then sent the questionnaire via fax. For those not responding to the first fax after about four weeks, the team sent another fax. In all, the team received 20 responses, 19 of which were at least partially usable. The responses were from a variety of those offices contacted and included at least one from each state. South Carolina was the only state to return all four questionnaires sent. Table 3.1 shows the states and offices of the respondents.

TABLE 3.1. States and offices of questionnaire respondents

State	Number of Respondents
Alabama	2
Florida	2
Georgia	1
Kentucky	2
Mississippi	3
North Carolina	3
South Carolina	4
Tennessee	3
Total	20
Office	**Number of Respondents**
State Design Engineer	7
State Traffic Engineer	5
Governor's Highway Safety Rep.	2
Highway Patrol Commander	6
Total	20

RESULTS

Table 3.2 shows, for each item in the list for each question, the number of respondents who ranked that item first, second, or third most important. For example, Part A of Question 1 asked about the most important highway related collision causes, and eight respondents ranked sight distance as most important, two respondents ranked sight distance as second most important, and one respondent ranked sight distance as third most important. Table 3.2 also shows an overall score for each item, computed as three times the number of first place responses plus two times the number of second place responses plus the number of third place responses.

The research team was pleased to note the low number of "other" responses. This likely indicates that the respondents thought the list of items offered for each question was complete. The questionnaire results reveal some strong trends among the opinions of professionals. The next few paragraphs discuss the results for each question separately.

Question 1: Highway-Related Causes. The question on highway causes produced more variety in responses than the other questions. The scores were more evenly distributed than the other two questions, and the high score (29) for Question 1 was less than the high scores (45 and 40) for Questions 2 and 3, respectively. No single response achieved an overall score over 30 for Part A on frequency or Part B on efficiency. In addition, the standard deviations of the overall scores for Question 1, 9.3 and 6.7 for Parts A and B, respectively, were lower than the standard deviations of the overall scores for other questions.

Sight distance, roadside clearance to objects, shoulder widths and surfaces, and intersection and driveway control were the responses cited as most frequent highway-related causes of collisions on secondary highways, in that order. None of the respondents thought fixed street lighting or bridge widths and barriers ranked in the top three highway related causes. Despite the vast sums spent on pavement maintenance on secondary highways, the respondents do not see pavement condition as a frequent cause of collisions.

The pattern on most efficient causes to fix was much different from the pattern in Part A. In fact, the correlation coefficient between the overall scores for Part A and Part B was only 0.59, much lower than for the other questions (0.94 and 0.98 for Questions 2 and 3, respectively). Shoulder width and surfaces rose to be scored as the most efficient item to improve to reduce collisions.

In Part B, sight distance fell into a tie for second in overall score with signs and pavement markings. In fact, signs and pavement markings had a noteworthy pattern of responses. The respondents barely acknowledged that item as a frequent highway cause in Part A, but three respondents cited it as the most efficient highway cause to improve in Part B. Roadside clearance fell from an overall score of 24 in Part A to 11 in Part B, with respondents apparently feeling that it is not very efficient to clear roadsides on secondary highways.

Question 2: Collision Type. The respondents overwhelmingly chose single vehicle as the collision type that was most frequent on secondary highways. Rear-end, angle, turning, and night were the collision types cited as the next most frequent on secondary highways. After these five, the overall scores for other items in Part A dropped to near zero. In fact, the standard deviation for the overall score in Part A was relatively high at 12.9.

The respondents also cited single vehicle as the most efficient collision to treat, but by a lesser margin than in Part A. Turning collisions finished as the second most efficient collision type to treat, but the collective professional opinion was that rear-end and angle collisions are not so efficient to fix on secondary highways. In fact, besides single vehicle and turning collisions, there was no consensus on other collision types that are generally efficient to try to reduce. The standard deviation for the overall scores in Part B was relatively low at 8.0.

Question 3: Driver and Vehicle Causes. For this question, there was a very strong correlation between the responses for most frequent causes and most efficient causes to treat (a correlation coefficient of 0.98 between Part A and Part B). The drunk driver cause emerged as a convincing first place for both parts of the question. The respondents indicated overaggressive drivers, inexperienced drivers, and fatigued drivers, in that order, as the next most frequent collision causes and most efficient causes to treat. It is interesting that inexperienced drivers scored much higher than did older drivers. The vehicle causes on the list, defective vehicles and poorly maintained vehicles, trailed the other causes.

TABLE 3.2. Summary of questionnaire responses

		Number of Respondents							
		Part A (Frequency)				Part B (Efficiency)			
	Item	1st	2nd	3rd	Score*	1st	2nd	3rd	Score*
Question #1	Sight distance	8	2	1	29	3	1	3	14
	Side-slopes	0	2	0	4	0	1	1	3
	Shoulder widths and surfaces	2	3	4	16	4	3	6	24
	Horizontal alignments	1	2	3	10	1	1	2	7
	Pavement condition	0	1	1	3	0	3	1	7
	Intersection/driveway control	2	2	3	13	2	2	0	10
	Roadside clearance	3	6	3	24	2	2	1	11
	Lane widths	2	0	2	8	2	2	0	10
	Vertical alignments	0	0	2	2	0	1	2	4
	Signs and pavement markings	0	0	1	1	4	1	0	14
	Fixed street lighting	0	0	0	0	0	0	0	0
	Bridge widths and barriers	0	0	0	0	0	0	1	1
	Other	1	1	1	6	0	0	0	0
Question #2	Single vehicle accidents	13	2	2	45	9	2	0	31
	Angle accidents	2	5	1	17	1	2	4	11
	Turning accidents	2	1	5	13	3	1	3	14
	Large truck accidents	0	0	0	0	0	1	0	2
	Bicycle accidents	0	0	1	1	0	0	0	0
	Night accidents	0	5	1	11	0	3	2	8
	Hit animal accidents	0	0	2	2	1	0	1	4
	Head-on accidents	0	1	1	3	0	1	0	2
	Rear-end accidents	2	5	3	19	1	2	2	9
	Pedestrian accidents	0	0	1	1	0	1	1	3
	Rail-crossing accidents	0	0	0	0	0	1	3	5
	Wet pavement accidents	0	0	2	2	1	2	0	7
	Other	0	0	0	0	2	0	0	6
Question #3	Drunk drivers	8	5	6	40	7	7	2	37
	Drugged drivers	1	2	3	10	1	2	2	9
	Older drivers	1	0	1	4	0	0	3	3
	Defective vehicles	0	0	0	0	0	2	0	4
	Fatigued drivers	1	5	2	15	2	2	1	11
	Overly aggressive drivers	7	1	4	27	5	0	4	19
	Inexperienced drivers	1	6	4	19	3	3	2	17
	Poorly maintained vehicles	0	0	1	1	0	0	1	1
	Other	1	1	0	5	1	1	1	6

* The overall score was computed as three times the number of first place responses plus two times the number of second place responses plus the number of third place responses.

Note: The column sums for each question do not necessarily equal 19 (the number of usable responses) because some respondents skipped a response while others provided more than one response.

CHAPTER 4. COLLISION DATA OVERVIEW

INTRODUCTION

This chapter provides a general overview of collisions on two-lane roads in rural and suburban areas in the Southeast U.S. Collision data from secondary highways in selected counties in North Carolina, Kentucky and Tennessee between 1993 and 1995 were used in the analysis.

DATABASE

The collision data analyzed were obtained from the FHWA Highway Safety Information System (HSIS), the Kentucky Department of Transportation (DOT) and the Tennessee DOT. These databases were selected because they met many of the criteria developed by the research team. The important criterion were data quality, a variety of terrain, representation of both rural and suburban areas, a large number of collisions with many variables related to each collision, and a low collision reporting threshold, ideally less than $1,000. Other important considerations were that the collision reporting forms were unchanged during the study period, and the data were as free of error and bias as possible.

The team selected two counties from each of the three states based upon more specific criteria developed by the research team. The first criteria was that the counties should allow at least some legal alcohol sales laws to eliminate potential biases introduced by 'dry' counties. The second was a maximum of 80 percent of the reported collisions were successfully located (i.e.,mileposted). The third criteria guaranteed that at least 1,000 collisions must have occurred in each county for adequate sample size.

For North Carolina, Wake County was chosen because it has liberal alcohol sales laws, only 11 percent of its collisions are un-mileposted and it met the sample size requirement. Robeson County was also selected because it allows some legal alcohol sales, less than 7 percent of its collisions are un-mileposted and it met the sample size requirement. Similarly, the team choseFayette and Pike Counties in Kentucky and Hamilton and Montgomery Counties in Tennessee.

Although the counties selected from the three states were based upon the same criteria, they differed in population, household income, employment rate and other factors. For example, Wake County, NC, and Fayette County, KY, are urban and located in rolling terrain. Montgomery County, TN, is predominantly urban and located in mountainous terrain. Hamilton County, TN, is in rolling terrain and contains a large military base. Robeson County, NC, is rural in character and is located on the coastal plain, while Pike County, KY, is rural and located in mountainous terrain. Table 4.1 details important differences in the demographics of the selected counties.

With 423,380 residents, Wake County is the most populous of the six counties. The population is almost one-and-a-half times greater than Hamilton, two times greater than Fayette, four times greater than Robeson and Montgomery and six times greater than Pike County. Approximately 25 percent of the people in Robeson and Pike Counties live below the poverty level, and the smallest percentage of people living below the poverty line, 8.4 percent, is in Wake County. Wake County had the highest median household income, $36,222, and the lowest unemployment rate, 3.5 percent, followed by Fayette, Hamilton, Montgomery and Robeson. The lowest median household income and highest unemployment rate is in Pike County.

For the purposes of this study, secondary roads were defined according to AADT, with an upper threshold of 5,000 vehicles. All collisions that occurred in Wake and Robeson Counties in North Carolina and Fayette and Pike Counties in Kentucky between 1993 and 1995 on two-lane roads with AADT less than 5,000 vehicles were included in the databases for North Carolina and Kentucky. All collisions in Hamilton and Montgomery counties were included, irrespective of AADT. This implies that urban highways are more likely to be included in Tennessee, compared to North Carolina and Kentucky. Relatively speaking, the quality of the North Carolina data obtained from HSIS is expected to be better than the Kentucky and Tennessee data obtained from the DOTs.

There are several noteworthy differences between the databases, which in the analyses lead to slight differences in interpretations between the states. Collision severity was coded differently in each state. North Carolina provided the most detailed description of severity with five groups: K (Fatal), A (Severe injury), B (Minor injury), C (Complaint of an injury), and O (No injury). Kentucky breaks down collision severity into fatal and non-fatal. Tennessee has three categories, fatal, injury and no injury. In all three states, the severity of a collision is coded as the most severe injury of any person involved. The data also varies in the coding of vehicles, collision types, accident location and weather conditions. Therefore, the 'other' category includes different categories in different states. Through the study period, the collision reporting threshold was $400 in Tennessee and $500 in Kentucky and North Carolina.

ANALYSIS AND RESULTS

Overall Collision Frequency

Although the collision types, or first harmful events, were coded slightly differently across the states, they are presented jointly in Table 4.2 to provide an overview of the data. There were 5,169, 7,494 and 21,886 collisions between 1993 and 1995 in the selected counties in North Carolina, Kentucky and Tennessee, respectively. In the North Carolina counties, the most frequent collisions were run-off road (34.3%), rear-end (15.8%) and angle (15.4%) collisions. In Kentucky, rear-end (19.7%), hit object (15.8%) and angle (14.7%) collisions were the most frequent. In Tennessee, angle (32.3%), rear-end (22.6%) and sideswipe (8.3%) collisions were the most frequent. The Kentucky and Tennessee data had a large number of collisions coded as 'other'. In Tennessee, 94.1 percent of these were single-vehicle; however, in Kentucky, only 6.8 percent of the 'other' collisions were single-vehicle collisions. Table 4.3 shows that most collisions on two-lane roads involve two or more vehicles: 58 percent in North Carolina, 78 percent in Kentucky and 70 percent in Tennessee. Considering the relatively low volume of traffic, it is interesting that collisions involving more than one vehicle were more common than single-vehicle incidents.

Vehicle Type

Tables 4.4, 4.5 and 4.6 shows the relationship between collision type and vehicle type in all three states. Due to differences in reporting, it is difficult to study trends across states; however, rear-end and angle collision collisions were relatively frequent in all six counties. In North Carolina, left turn and run-off road collisions were also frequent. Kentucky reports high numbers of hit object and sideswipe collisions. For passenger cars, rear-end and angle collisions were over-represented, except rear-end collisions in Tennessee, which are under-represented. Although relatively infrequent, motorcycle collisions were more likely to be run-off road and hit objects in North Carolina, and were more likely to be single-vehicle collisions in Kentucky. In Tennessee, light trucks were over-represented in rear-end collision types. Overall, despite their largely rural nature, two-lane roads frequently had collisions that involved other vehicles.

Roadway Geometry

The relationship between collision type and roadway geometry confirmed what the team expected. Tables 4.7, 4.8 and 4.9 show that on curve and curve/grade combinations, ran off road collisions were over-represented in North Carolina, single-vehicle, hit object and sideswipe collisions were over-represented in Kentucky, and 'other' (mostly single-vehicle) collisions in Tennessee were over-represented. Rear-end collisions were more likely to have occurred on straight grades in all three states. Angle collisions usually occurred on straight roads, where they were also over-represented.

Collision Locations

Tables 4.10, 4.11 and 4.12 present data on collision location and collision type. The Kentucky data seemed to be suspect because nearly all angle and rear-end collisions were coded as occurring on segments as opposed to intersections. In North Carolina, single-vehicle collisions, coded as run-off road or hit object, seemed to occur frequently at bridges and locations coded as 'other'. Angle and turning collisions were over-represented at intersections, and angle collisions occurred most frequently at intersections, as expected. Rear-end collisions were over-represented at driveways, but they were at the expected level at intersections. In Tennessee, angle and rear-end collisions occurred with the greatest frequency at non-intersection locations, but were over-represented at intersections. Bridges and underpasses in Tennessee appear to be problematic for rear-end collisions. Out of 108 bridge collisions, 40 were rear-end, and out of 34 underpass collisions, 12 were rear-end.

Weather Conditions

Adverse weather conditions include rain, snow, ice and fog, and 36.2 percent, 50.8 percent and 49.7 percent of the collisions occurred in these conditions in North Carolina, Kentucky and Tennessee, respectively. Adverse weather can increase the possibility of sideswipe collisions because vehicles are more likely to skid on wet or icy pavements, and also increase the possibility of rear-end collisions due to reduced visibility and longer braking distances. Tables 4.13, 4.14 and 4.15 show that rainy weather was associated with an increase in rear-end and single-vehicle collisions in North Carolina, and rear-end and sideswipe collisions in Kentucky and Tennessee. In clear weather, angle collisions were over-represented in all three states. Snowy weather increased the likelihood of single-vehicle and hit object collisions in all three states.

Time of Day

Tables 4.16, 4.17 and 4.18 show the collision patterns associated with the time of day. There is a peak in the number of collisions between 7 a.m. and 8 a.m. in North Carolina. Most collisions occurred during the afternoon hours. For example, 40.3 percent, 42.7 percent and 42.7 percent of all the collisions occurred between 2 p.m. and 8 p.m. in North Carolina, Kentucky and Tennessee, respectively. Rear-end and angle collisions were among the most frequent and over-represented collisions between 2 p.m. and 8 p.m. in all three states. Relatively high traffic volumes are expected during these times. Single-vehicle collisions (ran-off-road and hit object in North Carolina, single vehicle and hit object in Kentucky and 'other' in Tennessee) were more likely to occur during night hours, 8 p.m. to 6 a.m.

Collision Severity

A study of collision type and severity showed that single-vehicle collisions resulting in fatalities were over-represented in all three states, as shown in Tables 4.19, 4.20 and 4.21. Single-vehicle collisions were usually coded as 'run-off road' in North Carolina, 'hit object' or 'single-vehicle' in Kentucky, and as 'other' in Tennessee. Although multi-vehicle collisions were more frequent, single-vehicle collisions were more likely to be associated with fatalities.

Roadway Geometry

Tables 4.22, 4.23 and 4.24 contain information about vehicle involvement and roadway geometry, and a statistically significant relationship was found in all three states. Single-vehicle collisions occurred more frequently than expected on curved and grade/curve roadways in all three states. Multi-vehicle collisions were more likely to occur on straight and grade/straight roadways in North Carolina and Kentucky. An exception to this trend occurred in Tennessee, where single-vehicle involvement was also more frequent than expected on grade/straight roads.

Weather Conditions

Tables 4.25, 4.26 and 4.27 show relationships between vehicular involvement and weather conditions. For the most part, in adverse weather conditions, single-vehicle collisions were over-represented. In clear weather, collisions involving two vehicles were over-represented in Tennessee and North Carolina. In Tennessee, collisions involving three vehicles were also over-represented in clear weather.

ANALYSIS OF COLLISION SEVERITY

Vehicle Type

Tables 4.28 and 4.29 show the relationship between the most severe injury in a collision and the vehicle type in North Carolina and Tennessee. There were only 28 fatal collisions reported in the Kentucky dataset, and no breakdown of 'non-fatal' collisions, so the team did not provide tables showing the Kentucky data throughout this section. Passenger car collisions were under-represented in fatal collisions in North Carolina and Tennessee and in the more severe injury classes in North Carolina. Truck involvement in fatal collisions occurred more often than expected in North Carolina and Tennessee. The Tennessee data provide further distinctions between truck types, and indicate that light and heavy truck collisions were over-represented. Motorcycle collisions were also more likely to be fatal than expected in North Carolina and Tennessee. Furthermore, motorcycles were greatly under-represented in the 'no injury' class in both states with only five observed and 33 expected in North Carolina, and 42 observed and 195 expected in Tennessee.

Roadway Geometry

Tables 4.30 and 4.31 show relationships between collision severity and road geometry in North Carolina and Tennessee. The Kentucky data indicates that roadway geometry and injury severity were statistically independent. Although more collisions occurred on straight roads than other types of roads, 66 percent in North Carolina and 48 percent in Tennessee, curve and curve/grade combinations were the most likely to result in injury collisions. Property damage only (PDO) and Class C injury collision were over-represented on straight roads.

Collision Locations

Relationships between collision severity and collision location are shown in Tables 4.32 and 4.33. In Tennessee, fatal and injury collisions were over-represented at intersections. In North Carolina, injury collisions were over-represented at intersections, but fatal injuries were slightly under-represented.

Weather Conditions

Tables 4.34 and 4.35 indicate that in North Carolina and Tennessee, clear weather collisions were slightly more likely to be injurious than collisions during adverse weather. The relationships observed were consistent with the theory that suggests severity should be relatively low in adverse weather because of reduced speeds, longer headways and more careful driving. It is expected that collision rates increase in adverse weather.(67) However, the team did not have the adverse weather exposure data to conduct such an analysis.

Time of Day

Tables 4.36 and 4.37 show relationships between collision severity and time of day in North Carolina and Tennessee. Fatalities in both states, and Class A and B injuries in North Carolina, were over-represented at night between 8 p.m. and 7 a.m.

SUMMARY

This chapter analyzed collisions involving passenger cars and other vehicles on two-lane roadways in the six counties selected from North Carolina, Kentucky and Tennessee. The two-lane roadways of the counties in North Carolina and Kentucky had an AADT less than 5,000 vehicles, but the AADT for two-lane roadways in the Tennessee counties was not available. The 1993-1995 North Carolina HSIS collision and inventory data, Kentucky DOT data, and Tennessee DOT data for two-lane roads were used for analysis.

Trucks and motorcycles seemed to be the most problematic in fatal collisions. Collisions involving passenger cars were the most frequent among all vehicle types, as expected by exposure. They were also slightly over-represented in collisions involving three or more vehicles for all three states. Single-vehicle collisions were more likely to occur on curve and curve/grade combinations than expected, and they seemed to be more likely to result in injury than expected. Out of all collisions, 36 percent, 51 percent and 59 percent collisions occurred in adverse weather in North Carolina, Kentucky and Tennessee, respectively. Rain seemed to be most problematic among adverse weather conditions, and snow increased the likelihood of single-vehicle and hit object collisions in all three states.

A summary of the key findings from this analysis is presented here. This summary is intended to point out similarities in collisions and injury severity among all three states.

- Run-off road and other single-vehicle collisions were over-represented along curves.
- Multi-vehicle collisions were over-represented at intersections.
- Rain results in an over-representation of rear-end, single-vehicle and sideswipe accidents.
- Passenger cars were over-represented in rear-end and angle collisions.
- Motorcycle collisions were more often single-vehicle collisions than expected.
- Trucks were over-represented in two-vehicle collisions.

- Trucks and motorcycles were over-represented in collisions that resulted in fatalities, while passenger cars were under-represented in fatal collisions.
- Curves resulted in more injury collisions than straight road segments.
- Collisions that occurred at intersections resulted in more injuries, but fewer fatalities, than collisions that occurred along segments.
- Clear weather collisions were more injurious than collisions that occurred in adverse weather.
- Night collisions were over-represented among fatal collisions.
- Single-vehicle collisions are over-represented among fatal collisions, and are also over-represented at night, and at bridges, underpasses, railroad crossings and along road segments.

TABLE 4.1. Demographics of the six counties, 1990 data

County	Population	Median Household Income	Unemployment	Below Poverty
Wake (NC)	423,380	$36,222	3.5 %	8.4 %
Robeson (NC)	105,179	$19,716	8.9 %	24.1 %
Fayette (KY)	225,366	$28,056	3.8 %	14.1 %
Pike (KY)	72,583	$17,468	10.2 %	25.4 %
Hamilton (TN)	285,536	$26,523	5.9 %	13.1 %
Montgomery (TN)	100,498	$25,568	8.0 %	12.8 %

TABLE 4.2. Collision type, or first harmful event, by county

Collision Type	Number of Collisions (Percent of Total)		
	Wake & Robeson (NC)	Fayette & Pike (KY)	Hamilton & Montgomery (TN)
Angle	798 (15.4%)	1,101 (14.7%)	7,077 (32.3%)
Head-on	52 (1.0%)	83 (1.1%)	915 (4.2%)
Rear-end	817 (15.8%)	1,478 (19.7%)	4,951 (22.6%)
Left turn	764 (14.8%)	---	---
Right turn	121 (2.3%)	---	---
Sideswipe	137 (2.7%)	1,062 (14.2%)	1,818 (8.3%)
Overturn	20 (0.4%)	---	---
Hit object	557 (10.8%)	1,184 (15.8%)	---
Backing	91 (1.8%)	---	---
Opposite	---	149 (2.0%)	---
Run-off road	1,771 (34.3%)	---	---
Single-vehicle	---	420 (5.6%)	---
Not stated	---	---	115 (0.5%)
Other	41 (0.8%)	2,017 (26.9%) *	7,010 (32.0%) *
Total	5,169 (100%)	7,494 (100%)	21,886 (100%)

* In Kentucky, there were 137 single-vehicle type collision coded as 'other', and in Tennessee, there were 6,596 single-vehicle collisions coded as 'other'.

TABLE 4.3. Number of vehicles involved in collisions

Number of Vehicles	Number of Vehicles Involved (Percent of Total)		
	Wake & Robeson (NC)	Fayette & Pike (KY)	Hamilton & Montgomery (TN)
1	2,173 (42.0%)	1,664 (22.2%)	6,598 (30.2%)
2	2,810 (54.4%)	5,502 (73.4%)	14,131 (64.6%)
3	167 (3.2%)	290 (3.9%)	1,028 (4.7%)
4	13 (0.3%)	31 (0.4%)	118 (0.5%)
5	3 (0.1)	6 (0.1%)	11 (0.1%)
6	2 (0.0%)	1 (0.0%)	1 (0.0%)
7	0 (0.0%)	0 (0.0%)	0 (0.0%)
8	1 (0.0%)	0 (0.0%)	1 (0.0%)
Total	5,169 (100%)	7,494 (100%)	21,886 (100%)

TABLE 4.4. Collision type by vehicle type in North Carolina

Collision Type	Vehicle Type					Total
	Car	Truck	Bus	Motorcycle	Bicycle	
Rear-end	1,311 (1,298)	371 (376)	13 (9)	5 (16)	0 (1)	1,700
Angle	1,249 (1,223)	345 (354)	4 (8)	3 (15)	0 (1)	1,601
Left turn	1,153 (1,159)	348 (336)	6 (8)	9 (14)	1 (1)	1,517
Right turn	177 (182)	60 (53)	1 (1)	0 (2)	0 (0)	238
Run-off road	1,464 (1,434)	374 (415)	5 (10)	33 (18)	1 (1)	1,877
Backing	113 (130)	51 (38)	6 (1)	0 (2)	0 (0)	170
Sideswipe	181 (205)	82 (59)	3 (1)	2 (3)	0 (0)	268
Head-on	80 (81)	23 (24)	3 (1)	0 (1)	0 (0)	106
Overturn	8 (19)	9 (6)	0 (0)	8 (0)	0 (0)	25
Hit object	458 (457)	123 (132)	0 (3)	15 (6)	2 (0)	598
Other	27 (34)	16 (10)	1 (0)	1 (0)	0 (0)	45
Total	6,221	1,802	42	76	4	8,145

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 4.5. Collision type by vehicle type in Kentucky

Collision Type	Vehicle Type						Total
	Car	Truck	Bus	Motorcycle	Not stated	Other	
Rear-end	1,360 (1,239)	63 (68)	7 (10)	4 (11)	33 (135)	11 (16)	1,478
Angle	1,042 (923)	19 (50)	8 (7)	2 (8)	24 (100)	6 (12)	1,101
Opposite	135 (125)	3 (7)	0 (1)	0 (1)	10 (14)	1 (2)	149
Hit object	978 (993)	61 (54)	9 (8)	14 (8)	105 (108)	17 (13)	1,184
Sideswipe	932 (891)	53 (49)	8 (7)	5 (8)	55 (97)	9 (12)	1,062
Head-on	80 (70)	2 (4)	0 (1)	1 (1)	0 (8)	0 (1)	83
Single-vehicle	363 (352)	30 (19)	0 (3)	13 (3)	8 (38)	6 (5)	420
Other	1,394 (1,691)	111 (92)	18 (14)	14 (14)	448 (184)	32 (22)	2,017
Total	6,284	342	50	53	683	82	7,494

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 4.6. Collision type by vehicle type in Tennessee

Collision Type	Vehicle Type								Total
	Car	Light truck	Medium truck	Heavy truck	Motorcycle	Bus	Bicycle	Other	
Rear-end	7,114 (7,286)	3,157 (2,776)	89 (84)	155 (193)	22 (77)	41 (45)	12 (38)	132 (223)	10,722
Angle	10,184 (9,723)	3,408 (3,704)	91 (112)	200 (258)	73 (103)	56 (61)	88 (50)	208 (297)	14,308
Sideswipe-same	1,102 (1,196)	432 (456)	26 (14)	81 (32)	11 (13)	13 (8)	6 (6)	89 (36)	1,760
Sideswipe-opposite	1,277 (1,303)	460 (496)	23 (15)	58 (35)	8 (14)	12 (8)	1 (7)	78 (40)	1,917
Head-on	1,249 (1,219)	425 (465)	9 (14)	18 (32)	18 (13)	11 (8)	23 (6)	41 (37)	1,794
Top of vehicle	3 (3)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4
Not indicated	110 (119)	45 (45)	3 (1)	4 (3)	3 (1)	1 (1)	1 (1)	8 (3)	175
Other	5,109 (5,299)	2,034 (2,019)	60 (61)	178 (141)	142 (56)	29 (33)	4 (27)	242 (162)	7,798
Total	26,148	9,962	301	694	277	163	135	798	38,480

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 4.7. Collision type by roadway geometry in North Carolina

Collision Type	Roadway Geometry					Total
	Straight	Curve	Grade / Straight	Grade / Curve	Not stated	
Rear-end	638 (543)	43 (143)	120 (75)	16 (55)	0 (1)	817
Angle	649 (530)	66 (140)	60 (73)	22 (54)	1 (1)	798
Left turn	618 (508)	56 (134)	71 (70)	18 (52)	1 (1)	764
Right turn	101 (80)	3 (21)	16 (11)	1 (8)	0 (0)	121
Run-off road	771 (1,177)	644 (310)	110 (162)	245 (120)	1 (1)	1,771
Backing	78 (61)	5 (16)	8 (8)	0 (6)	0 (0)	91
Sideswipe	81 (91)	26 (24)	13 (13)	17 (9)	0 (0)	137
Head-on	26 (35)	13 (9)	5 (5)	8 (4)	0 (0)	52
Overturn	14 (13)	2 (4)	3 (2)	1 (1)	0 (0)	20
Hit object	425 (370)	44 (98)	66 (51)	21 (38)	1 (0)	557
Other	34 (27)	4 (7)	2 (4)	1 (3)	0 (0)	41
Total	3,435	906	474	350	4	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.8. Collision type by roadway geometry in Kentucky

Collision Type	Roadway Geometry					Total
	Straight	Curve	Grade / Straight	Grade / Curve	Not stated	
Rear-end	820 (722)	86 (181)	472 (401)	96 (168)	4 (6)	1,478
Angle	551 (538)	63 (135)	393 (299)	93 (125)	1 (4)	1,101
Opposite	89 (73)	16 (18)	37 (40)	7 (17)	0 (1)	149
Hit object	487 (579)	229 (145)	275 (321)	186 (134)	7 (5)	1,184
Sideswipe	429 (519)	205 (130)	223 (288)	201 (121)	4 (4)	1,062
Head-on	18 (41)	33 (10)	6 (23)	26 (9)	0 (0)	83
Single-vehicle	135 (205)	154 (51)	41 (114)	86 (48)	4 (2)	420
Other	1,134 (986)	132 (247)	586 (547)	155 (229)	10 (8)	2,017
Total	3,663	918	2,033	850	30	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.9. Collision type by roadway geometry in Tennessee

Collision Type	Roadway Geometry					Total
	Straight	Curve	Grade / Straight	Grade / Curve	Not stated	
Rear-end	2,973 (2,400)	207 (397)	1,204 (833)	234 (514)	333 (808)	4,951
Angle	4,019 (3,430)	215 (567)	831 (1,190)	149 (735)	1,863 (1,154)	7,077
Sideswipe-same	534 (427)	31 (71)	171 (148)	50 (91)	94 (144)	880
Sideswipe-opposite	325 (455)	104 (75)	44 (158)	26 (98)	439 (153)	938
Head-on	354 (444)	95 (73)	55 (154)	41 (95)	370 (149)	915
Top of vehicle	1 (1)	0 (0)	0 (0)	0 (0)	1 (0)	2
Not indicated	48 (56)	11 (9)	27 (19)	17 (12)	12 (19)	115
Other	2,354 (3,397)	1,091 (562)	1,348 (1,178)	1,757 (728)	458 (1,143)	7,008
Total	10,608	1,754	3,680	2,274	3,570	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.10. Collision type by collision location in North Carolina

Collision Type	Location							Total
	Bridge	Underpass	Driveway	Intersection	Interchange	RR Xing	Other	
Rear-end	13 (16)	0 (0)	180 (129)	253 (273)	2 (1)	4 (2)	365 (395)	817
Angle	2 (15)	0 (0)	73 (126)	655 (267)	1 (1)	0 (2)	67 (386)	798
Left turn	0 (15)	0 (0)	260 (121)	433 (255)	1 (1)	0 (2)	70 (370)	764
Right turn	0 (2)	0 (0)	29 (19)	73 (40)	1 (0)	0 (0)	18 (59)	121
Run-off road	54 (34)	0 (2)	197 (281)	225 (592)	1 (2)	3 (5)	1,291 (857)	1,771
Sideswipe	13 (3)	1 (0)	15 (22)	10 (46)	1 (0)	0 (0)	97 (66)	137
Head-on	2 (1)	0 (0)	4 (8)	13 (17)	0 (0)	0 (0)	33 (25)	52
Overturn	1 (0)	0 (0)	0 (3)	11 (7)	0 (0)	0 (0)	8 (10)	20
Hit object	14 (11)	1 (0)	17 (88)	31 (186)	0 (1)	5 (1)	489 (269)	557
Other	1 (1)	0 (0)	6 (7)	6 (14)	0 (0)	0 (0)	28 (20)	41
Total	100	2	819	1,727	7	13	2,501	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.11. Collision type by collision location in Kentucky

Collision Type	Location			Total
	Roadway	Intersection	Other	
Rear-end	1,467 (1,166)	11 (242)	0 (70)	1,478
Angle	1,099 (869)	2 (180)	0 (52)	1,101
Opposite	149 (118)	0 (24)	0 (7)	149
Hit object	450 (934)	727 (194)	7 (56)	1,184
Sideswipe	1,051 (838)	10 (174)	1 (50)	1,062
Head-on	82 (66)	1 (14)	0 (4)	83
Single-vehicle	96 (331)	324 (69)	0 (20)	420
Other	1,519 (1,592)	151 (330)	347 (96)	2,017
Total	5,913	1,226	355	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.12. Collision type by collision location in Tennessee

Collision Type	Location						Total
	Non-intersection	**Intersection**	**RR Xing**	**Bridge**	**Underpass**	**Other**	
Rear-end	3,010 (3,565)	1,881 (1,347)	5 (4)	40 (24)	12 (8)	3 (2)	4,951
Angle	4,505 (5,096)	2,550 (1,926)	3 (6)	15 (35)	1 (11)	3 (3)	7,077
Sideswipe-same	641 (634)	226 (240)	0 (1)	7 (4)	4 (1)	2 (0)	880
Sideswipe-opposite	782 (675)	149 (255)	2 (1)	5 (5)	0 (2)	0 (0)	938
Head-on	711 (659)	199 (249)	0 (1)	3 (5)	2 (1)	0 (0)	915
Not stated	88 (83)	25 (31)	0 (0)	2 (1)	0 (0)	0 (0)	115
Other	6,023 (5,048)	926 (1,908)	8 (6)	36 (35)	15 (11)	2 (3)	7,010
Total	15,760	5,956	18	108	34	10	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.13. Collision type by weather condition in North Carolina

Collision Type	Weather					Total
	Clear	Cloudy	Rain	Snow	Other	
Rear-end	506 (521)	136 (136)	159 (141)	2 (5)	11 (12)	817
Angle	566 (509)	131 (133)	90 (138)	2 (5)	11 (12)	798
Left turn	568 (487)	109 (127)	80 (132)	1 (4)	6 (13)	764
Right turn	81 (77)	18 (20)	20 (21)	1 (1)	1 (2)	121
Run-off road	951 (1,130)	326 (294)	425 (306)	20 (10)	49 (31)	1,771
Backing	63 (58)	20 (15)	7 (16)	0 (1)	1 (2)	91
Sideswipe	93 (87)	14 (23)	28 (24)	1 (1)	2 (2)	137
Head-on	29 (33)	10 (9)	11 (9)	0 (0)	2 (1)	52
Hit object	392 (355)	89 (93)	66 (96)	2 (3)	8 (10)	557
Other	48 (39)	5 (10)	8 (11)	0 (0)	0 (1)	61
Total	3,297	858	894	29	91	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.14. Collision type by weather condition in Kentucky

Collision Type	Weather					Total
	Clear	Cloudy	Rain	Snow	Other	
Rear-end	702 (727)	406 (405)	305 (255)	52 (56)	13 (35)	1,478
Angle	561 (542)	306 (302)	201 (190)	30 (42)	3 (26)	1,101
Opposite	74 (73)	42 (41)	30 (26)	2 (6)	1 (4)	149
Hit object	572 (583)	306 (324)	193 (204)	65 (45)	48 (28)	1,184
Sideswipe	498 (523)	309 (291)	200 (183)	43 (41)	12 (25)	1,062
Head-on	31 (41)	19 (23)	24 (14)	7 (3)	2 (2)	83
Single-vehicle	239 (207)	82 (115)	78 (73)	11 (16)	10 (10)	420
Other	1,011 (993)	582 (552)	262 (348)	76 (77)	86 (47)	2,017
Total	3,688	2,052	1,293	286	175	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.15. Collision type by weather condition in Tennessee

Collision Type	Weather					Total
	Clear	Cloudy	Rain	Snow	Other	
Rear-end	2,471 (2,492)	1,602 (1,594)	779 (681)	19 (31)	80 (153)	4,951
Angle	3,733 (3,562)	2,319 (2,279)	868 (974)	27 (44)	130 (218)	7,077
Sideswipe-same	525 (443)	265 (283)	77 (121)	2 (6)	11 (27)	880
Sideswipe-opposite	474 (472)	303 (302)	139 (129)	8 (6)	14 (29)	938
Head-on	422 (461)	303 (295)	166 (126)	9 (6)	15 (28)	915
Not stated	37 (58)	21 (37)	7 (16)	0 (1)	50 (4)	115
Other	3,353 (3,538)	2 (1)	975 (964)	72 (44)	2,608 (2,463)	7,010
Total	11,015	7,048	3,011	137	675	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.16. Collision type by time of day in North Carolina

Collision Type	Time of Day (Military Time)				Total
	0000-0559	0600-1259	1300-1859	1900-2359	
Rear-end	39 (110)	299 (258)	404 (329)	75 (120)	817
Angle	45 (108)	307 (252)	390 (322)	56 (117)	798
Left turn	38 (103)	300 (241)	362 (308)	64 (112)	764
Right turn	9 (16)	43 (38)	57 (49)	12 (18)	121
Run-off road	394 (239)	464 (559)	562 (714)	351 (259)	1,771
Backing	6 (12)	35 (29)	40 (37)	10 (13)	91
Sideswipe	13 (19)	51 (43)	59 (55)	14 (20)	137
Head-on	6 (7)	18 (16)	22 (21)	6 (8)	52
Overturn	1 (3)	9 (6)	7 (8)	3 (3)	20
Hit object	141 (75)	95 (176)	164 (225)	157 (82)	557
Other	6 (6)	10 (13)	17 (17)	8 (6)	41
Total	698	1,631	2,084	756	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.17. Collision type by time of day in Kentucky

Collision Type	Time of Day (Military Time)				
	0000-0559	0600-1259	1300-1859	1900-2359	Total
Rear-end	38 (127)	588 (541)	726 (626)	116 (174)	1,468
Angle	34 (95)	466 (404)	520 (468)	78 (130)	1,098
Opposite	7 (13)	51 (55)	74 (63)	16 (18)	148
Hit object	221 (100)	358 (424)	387 (491)	186 (137)	1,152
Sideswipe	24 (91)	393 (388)	548 (450)	89 (125)	1,054
Head-on	2 (7)	35 (31)	42 (35)	4 (10)	83
Single-vehicle	91 (36)	116 (152)	125 (176)	81 (49)	413
Other	221 (169)	706 (719)	721 (833)	305 (232)	1,953
Total	638	2,713	3,143	875	7,369

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.18. Collision type by time of day in Tennessee

Collision Type	Time of Day (Military Time)				
	0000-0559	0600-1259	1300-1859	1900-2359	Total
Rear-end	309 (659)	1,694 (1,538)	2,619 (2,114)	327 (639)	4,949
Angle	486 (941)	2,543 (2,196)	3,356 (3,019)	683 (912)	7,068
Sideswipe-same	109 (117)	310 (272)	357 (374)	100 (113)	876
Sideswipe-opposite	98 (125)	288 (291)	433 (401)	119 (121)	938
Head-on	131 (122)	238 (284)	392 (391)	154 (118)	915
Top of vehicle	0 (0)	1 (1)	1 (1)	0 (0)	2
Not Indicated	19 (15)	35 (36)	43 (49)	18 (15)	115
Other	1,757 (931)	1,681 (2,172)	2,133 (2,986)	1,420 (902)	6,991
Total	2,909	6,790	9,334	2,821	21,854

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.19. Collision type by severity in North Carolina

Collision Type	Severity					Total
	PDO	Class C	Class B	Class A	Fatal	
Rear-end	362 (372)	368 (262)	69 (133)	17 (40)	1 (10)	817
Angle	276 (363)	302 (256)	163 (130)	50 (39)	7 (10)	798
Left turn	356 (348)	268 (245)	109 (125)	27 (37)	4 (9)	764
Right turn	78 (55)	26 (39)	15 (20)	1 (6)	1 (2)	121
Run-off road	670 (807)	544 (568)	404 (289)	116 (86)	37 (22)	1,771
Backing	69 (41)	18 (29)	2 (15)	2 (4)	0 (1)	91
Sideswipe	78 (62)	33 (44)	16 (22)	8 (7)	2 (2)	137
Head-on	6 (24)	12 (17)	16 (9)	13 (3)	5 (1)	52
Overturn	6 (9)	2 (6)	7 (3)	4 (1)	1 (0)	20
Hit object	437 (254)	76 (179)	31 (91)	10 (27)	3 (7)	557
Other	16 (19)	10 (13)	10 (7)	3 (2)	2 (1)	41
Total	2,354	1,659	842	251	63	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.20. Collision type by severity in Kentucky

Collision Type	Severity		Total
	Non-Fatal	Fatal	
Rear-end	1,478 (1,474)	0 (4)	1,478
Angle	1,099 (1,098)	2 (3)	2,001
Head-on	82 (83)	1 (0)	83
Sideswipe	1,061 (1,059)	1 (3)	1,062
Hit object	1,175 (1,181)	9 (3)	1,184
Opposite	149 (149)	0 (0)	149
Single-vehicle	417 (419)	3 (1)	420
Other	2,012 (2,011)	5 (6)	2,017
Total	7,473	21	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.21. Collision type by severity in Tennessee

Collision Type	Severity			Total
	PDO	Injury	Fatal	
Rear-end	3,562 (3,466)	1,385 (1,461)	4 (25)	4,951
Angle	5,017 (4,954)	2,031 (2,088)	29 (35)	7,077
Sideswipe-same	788 (616)	91 (260)	1 (4)	880
Sideswipe-opposite	762 (653)	173 (277)	3 (5)	938
Head-on	461 (640)	431 (270)	23 (5)	915
Top of vehicle	2 (1)	0 (1)	0 (0)	2
Not indicated	85 (81)	27 (34)	3 (1)	115
Other	4,640 (4,903)	2,322 (2,070)	46 (35)	7,008
Total	15,317	6,460	109	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.22. Number of vehicles involved by roadway geometry in North Carolina

# Vehicles	Roadway Geometry					Total
	Straight	Curve	Grade / Straight	Grade / Curve	Not stated	
1	1,108 (1,444)	653 (381)	161 (199)	249 (147)	2 (2)	2,173
2	2,186 (1,867)	235 (493)	290 (258)	97 (190)	2 (2)	2,810
3	125 (111)	18 (29)	21 (15)	3 (11)	0 (0)	167
4	11 (9)	0 (2)	1 (1)	1 (1)	0 (0)	13
5	2 (2)	0 (1)	1 (0)	0 (0)	0 (0)	3
6	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	2
8	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1
Total	3,435	906	474	350	4	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.23. Number of vehicles involved by roadway geometry in Kentucky

# Vehicles	Roadway Geometry					Total
	Straight	**Curve**	**Grade / Straight**	**Grade / Curve**	**Not stated**	
1	661 (813)	392 (204)	324 (451)	273 (189)	14 (7)	1,664
2	2,820 (2,689)	494 (674)	1,616 (1,493)	556 (624)	16 (22)	5,502
3	161 (142)	28 (36)	83 (79)	18 (33)	0 (1)	290
4	15 (15)	4 (4)	10 (8)	2 (4)	0 (0)	31
5	5 (3)	0 (1)	0 (2)	1 (1)	0 (0)	6
6	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1
Total	3,663	918	2,033	850	30	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.24. Number of vehicles involved by roadway geometry in Tennessee

# Vehicles	Roadway Geometry					Total
	Straight	**Curve**	**Grade/Straight**	**Grade/Curve**	**Not stated**	
1	2,137 (3,196)	1,089 (528)	1,319 (1,109)	1,811 (685)	237 (1,075)	6,593
2	7,830 (6,849)	634 (1,133)	2,182 (2,376)	434 (1,468)	3,051 (2,305)	14,131
3	569 (500)	29 (83)	147 (173)	26 (107)	260 (168)	1,031
4	63 (57)	2 (10)	29 (20)	2 (12)	22 (19)	118
5	7 (5)	0 (1)	3 (2)	1 (1)	0 (2)	11
6	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1
8	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1
Total	10,608	1,754	3,680	2,274	3,570	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.25. Number of vehicles involved by weather condition in North Carolina

# of Vehicles	Weather							Total
	Clear	Cloudy	Rain	Snow	Fog / Smog	Sleet / Hail	Not stated	
1	1,249 (1,386)	384 (361)	464 (376)	20 (12)	49 (33)	6 (3)	1 (2)	2,173
2	1,936 (1,792)	447 (466)	385 (486)	9 (16)	27 (42)	2 (4)	4 (3)	2,810
3	102 (107)	23 (28)	40 (29)	0 (1)	2 (3)	0 (0)	0 (0)	167
4	7 (8)	4 (2)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	13
5	2 (2)	0 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	3
6	1 (1)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2
8	0 (1)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
Total	3,297	858	894	29	78	8	5	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.26. Number of vehicles involved by weather condition in Kentucky

# of Vehicles	Weather							Total
	Clear	Rain	Snow	Fog / Smog	Sleet / Hail	Cloudy	Not stated	
1	860 (819)	279 (287)	76 (64)	17 (7)	15 (9)	393 (456)	24 (22)	1,664
2	2,690 (2,708)	947 (949)	196 (210)	15 (24)	20 (31)	1,559 (1,507)	75 (73)	5,502
3	121 (143)	59 (50)	12 (11)	1 (1)	5 (2)	92 (79)	0 (4)	290
4	13 (15)	7 (5)	2 (1)	0 (0)	1 (0)	7 (9)	1 (0)	31
5	3 (3)	1 (1)	0 (0)	0 (0)	1 (0)	1 (2)	0 (0)	6
6	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
Total	3,688	1,293	286	33	42	2,052	100	7,494

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.27. Number of vehicles involved by weather condition in Tennessee

# of Vehicles	Weather							Total
	Clear	Cloudy	Fog	Rain	Snow	Other	Not stated	
1	3,140 (3,318)	2,096 (2,123)	109 (53)	947 (907)	68 (41)	38 (26)	195 (124)	6,593
2	7,270 (7,112)	4,603 (4,551)	60 (114)	1,897 (1,944)	63 (89)	45 (56)	193 (265)	14,131
3	543 (519)	312 (332)	8 (8)	141 (142)	6 (7)	4 (4)	17 (19)	1,031
4	53 (59)	35 (38)	0 (1)	24 (16)	0 (1)	0 (1)	6 (2)	118
5	8 (6)	2 (4)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	11
6	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
8	0 (1)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1
Total	11,015	7,048	177	3,011	137	87	411	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.28. Severity by vehicle type in North Carolina

Severity	Vehicle Type					Total
	Car	Truck	Bus	Motorcycle	Bicycle	
PDO	2,742 (2,748)	834 (796)	13 (19)	5 (34)	4 (2)	3,598
Class C	2,172 (2,113)	565 (612)	16 (14)	14 (26)	0 (1)	2,767
Class B	957 (980)	283 (284)	11 (7)	32 (12)	0 (1)	1,283
Class A	287 (309)	93 (89)	2 (2)	22 (4)	0 (0)	404
Fatal	63 (71)	27 (21)	0 (1)	3 (1)	0 (0)	93
Total	6,221	1,802	42	76	4	8,145

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 4.29. Severity by vehicle type in Tennessee

Severity	Vehicle Type								Total
	Car	Light truck	Medium truck	Heavy truck	Bus	Motorcycle	Bicycle	Other	
PDO	18,199 (18,381)	7,284 (7,003)	218 (212)	515 (488)	105 (115)	42 (195)	7 (95)	678 (561)	27,048
Injury	7,853 (7,651)	2,626 (2,915)	83 (88)	170 (203)	58 (48)	227 (81)	125 (40)	117 (234)	11,259
Fatal	96 (116)	52 (44)	0 (1)	9 (3)	0 (1)	8 (1)	3 (1)	3 (3)	171
Total	26,148	9962	301	694	163	277	135	798	38,478

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 4.30. Severity by roadway geometry in North Carolina

Severity	Roadway Geometry					Total
	Straight	Curve	Grade/Straight	Grade/Curve	Not stated	
PDO	1,614 (1,564)	354 (413)	237 (216)	147 (159)	2 (2)	2,354
Class C	1,146 (1,103)	263 (291)	142 (152)	107 (112)	1 (1)	1,659
Class B	496 (560)	204 (148)	73 (77)	68 (57)	1 (1)	842
Class A	145 (167)	68 (44)	15 (23)	23 (17)	0 (0)	251
Fatal	34 (42)	17 (11)	7 (6)	5 (4)	0 (0)	63
Total	3,435	906	474	350	4	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.31. Severity by roadway geometry in Tennessee

Severity	Roadway Geometry					Total
	Straight	Curve	Grade/Straight	Grade/Curve	Not stated	
PDO	7,509 (7,424)	1,145 (1,228)	2,665 (2,576)	1,497 (1,592)	2,501 (2,499)	15,317
Injury	3,059 (3,131)	593 (518)	992 (1,086)	765 (671)	1,051 (1,054)	6,460
Fatal	40 (53)	16 (9)	23 (18)	12 (11)	18 (18)	109
Total	10,608	1,754	3,680	2,274	3,570	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.32. Severity by location type in North Carolina

Severity	Location								Total
	Bridge	Underpass	Driveway	Intersection	Interchange	RR Xing	Not stated	Other	
PDO	47 (46)	2 (1)	352 (373)	689 (787)	7 (3)	5 (6)	1 (1)	1,251 (1,139)	2,354
Class C	26 (32)	0 (1)	304 (263)	631 (554)	0 (2)	5 (4)	0 (0)	693 (802)	1,659
Class B	19 (16)	0 (0)	123 (133)	300 (281)	0 (1)	1 (2)	0 (0)	399 (407)	842
Class A	7 (5)	0 (0)	34 (40)	89 (84)	0 (0)	1 (1)	0 (0)	120 (121)	251
Fatal	1 (1)	0 (0)	6 (10)	18 (21)	0 (0)	1 (0)	0 (0)	37 (31)	63
Total	100	2	819	1,727	7	13	1	2,500	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.33. Severity by location type in Tennessee

Severity	Location							Total
	Non-intersection	Intersection	RR Xing	Bridge	Underpass	Ramp	Not stated	
PDO	11,213 (11,030)	3,983 (4,168)	9 (13)	75 (76)	28 (24)	8 (6)	1 (1)	15,317
Injury	4,481 (4,652)	1,931 (1,758)	9 (5)	32 (32)	6 (10)	1 (3)	0 (0)	6,460
Fatal	66 (79)	42 (30)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	109
Total	15,760	5,956	18	108	34	9	1	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.34. Severity by weather condition in North Carolina

Severity	Weather							Total
	Clear	Cloudy	Rain	Snow	Fog / Smog	Sleet / Hail	Not stated	
PDO	1,478 (1,502)	412 (391)	417 (407)	16 (13)	23 (36)	5 (4)	3 (2)	2,354
Class C	1,076 (1,058)	247 (275)	299 (287)	8 (9)	27 (25)	2 (3)	0 (1)	1,659
Class B	533 (537)	140 (140)	144 (146)	3 (5)	19 (13)	1 (1)	2 (1)	842
Class A	166 (160)	48 (42)	26 (43)	2 (1)	9 (4)	0 (0)	0 (0)	251
Fatal	44 (40)	11 (11)	8 (11)	0 (0)	0 (1)	0 (0)	0 (0)	63
Total	3,297	858	894	29	78	8	5	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.35. Severity by weather condition in Tennessee

Severity	Weather							Total
	Clear	Cloudy	Fog	Rain	Snow	Other	Not stated	
PDO	7,630 (7,709)	4,896 (4,933)	135 (124)	2,164 (2,107)	97 (96)	81 (61)	314 (288)	15,317
Injury	3,323 (3,251)	2,119 (2,080)	39 (52)	838 (889)	39 (40)	6 (26)	96 (121)	6,460
Fatal	62 (55)	33 (35)	3 (1)	9 (15)	1 (1)	0 (0)	1 (2)	109
Total	11,015	7,048	177	3,011	137	87	411	21,886

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.36. Collision severity by time of day in North Carolina

Severity	Time of Day (Military time)				Total
	0000-0559	0600-1259	1300-1859	1900-2359	
PDO	313 (318)	772 (743)	909 (949)	360 (344)	2,354
Class C	184 (224)	539 (524)	724 (669)	212 (243)	1,659
Class B	137 (114)	254 (266)	333 (340)	118 (123)	842
Class A	47 (34)	59 (79)	92 (101)	53 (37)	251
Fatal	17 (9)	7 (20)	26 (25)	13 (9)	63
Total	698	1,631	2,084	756	5,169

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 4.37. Collision severity by time of day in Tennessee

Severity	Time of Day (Military Time)				Total
	0000-0559	0600-1259	1300-1859	1900-2359	
PDO	2,035 (2,036)	4,700 (4,751)	6,628 (6,531)	1,929 (1,974)	15,292
Injury	848 (859)	2,067 (2,005)	2,667 (2,756)	871 (833)	6,453
Fatal	26 (15)	23 (34)	39 (47)	21 (14)	109
Total	2,909	6,790	9,334	2,821	21,854

Note: A cell entry is the observed number of collisions (expected number of collisions)

CHAPTER 5. INTERSECTION AND DRIVEWAY COLLISIONS

INTRODUCTION

Using methods presented in the previous chapter, intersection-type collisions for North Carolina and Tennessee were explored in an attempt to understand the associated factors. Several collision types are typically associated with intersections. In North Carolina, these include right turn, left turn, rear-end, angle and backing collisions. Collisions involving pedestrians, bicycles or mopeds that occurred at intersections or driveways were also included. The Tennessee data included all rear-end collisions, all angle collisions and multi-vehicle collisions that occurred at intersections.

An important secondary objective in this chapter was to explore the involvement of heavy vehicles in intersection-type collisions. The need for this analysis was based on the literature and results presented in the previous chapter. The heavy truck analysis was only performed using North Carolina data, due to the focus on secondary roads with AADT less than 5,000 vehicles.

ANALYSIS AND RESULTS

Vehicle Type

Tables 5.1 and 5.2 show the relationship between intersection-type collisions and vehicle type in both states. In North Carolina, trucks were over-represented in left turn, right turn and backup collisions. In Tennessee, cars were slightly over-represented in angle collisions, but under-represented in rear-end collisions. Light and medium trucks were under-represented in angle collisions, but over-represented in rear-end collisions. Heavy trucks were also under-represented in angle collisions, but they were also under-represented in rear-end collisions. Angle collisions were problematic for motorcycles and bicycles in Tennessee.

Roadway Geometry

Relationships between intersection-type collisions and roadway characteristics are presented in Tables 5.3 and 5.4. As expected, the majority of intersection-type collisions occurred on straight roadways. In North Carolina, 80 percent of the intersection-related collisions occurred on straight roadway, as did 58 percent of the intersection-related collisions in Tennessee. These tables show that in both states, rear-end collisions were over-represented on straight roadways with grades.

Collision Location

Table 5.5 shows that 55 percent of the intersection-type collisions in North Carolina occurred at intersections, and 23 percent occurred at driveways. Table 5.6 shows that 59 percent of the intersection-type collisions, including rear-end and angle, occurred away from intersections in Tennessee. In North Carolina, rear-end collisions were under-represented at intersections, and angle collisions were over-represented. Driveways were problematic for left turn and backing collisions because the observed numbers of these collisions exceed the expected values. Where detailed information is available in the data, rear-end collisions were found to be problematic at bridges and underpasses in both states.

Weather Conditions

Tables 5.7 and 5.8 show the majority of intersection-type collisions occurred in clear or cloudy weather in both states. In North Carolina, 2,221 (84.9%) of the collisions occurred in clear or cloudy conditions, as did 10,725 (84.1%) of the collisions in Tennessee. Collisions in adverse weather conditions (rain, snow, ice and fog) account for the remainder. In both states, rear-end collisions were over-represented in rain, and angle collisions were under-represented. In clear weather, the opposite trend was evident.

Time of Day

Tables 5.9 and 5.10 show that few intersection-type collisions occurred at night, between 8 p.m. and 7 a.m. In both states, the hours between 2 p.m. and 8 p.m. included the highest percentage of collisions of the time blocks studied. In North Carolina and Tennessee, 48.5 percent and 49.5 percent of the intersection collisions occurred during these hours, respectively. In both states, rear-end collisions were slightly over-represented between 2 p.m. and 8 p.m.

Collision Severity

Tables 5.11 and 5.12 show that most intersection-type collisions resulted in property damage only (PDO). In North Carolina, 44 percent of the intersection collisions resulted in no injury and 38 percent resulted in a Class C injury. In Tennessee, 71 percent of the collisions resulted in no injury. Angle collisions resulted in more fatalities than expected in both states, and more serious injuries in North Carolina, while rear-end collisions were over-represented in PDO collisions in both states.

COLLISIONS INVOLVING HEAVY VEHICLES

Overall Collision Frequency

For the North Carolina data, heavy vehicles were defined as trucks, including two-axle, three-axle, four-axle and tractor trailer trucks, recreational vehicles and buses. Table 5.13 shows that 233 (8.9%) of the intersection collisions involved one or more heavy vehicles. Almost all (95.3%) intersection collisions involving at least one heavy vehicle were two-vehicle collisions, and another 3.4 percent involved three vehicles. Most of these multi-vehicle collisions involved a heavy vehicle colliding with one or more passenger cars.

Weather Conditions

Table 5.13 presents an analysis of heavy vehicle involved collisions and weather conditions, and shows that 87 percent of heavy vehicle involved collisions occurred during clear or cloudy conditions.

Only 12 percent of heavy vehicle collisions occurred in the rain compared to 14 percent for passenger car only collisions. This suggests that heavy vehicle drivers may be more experienced and better able to avoid collisions in adverse weather.

Time of Day

Table 5.14 shows that 90 percent of heavy vehicle involved collisions occurred between 7 a.m. and 8 p.m. Passenger car only collisions were somewhat more likely to occur at night, with 332 collisions (14.2%) between 8 p.m. and 7 a.m. compared to only 24 (10.3%) collisions involving heavy vehicles.

Roadway geometry

Table 5.15 presents information about intersection-related collisions and roadway geometry, as reported by the police officer. Of the heavy vehicle-involved intersection collisions, 73 percent occurred on straight, level roads, 21 percent occurred on grades, hillcrests or sags and 8 percent occurred on curved roads. Overall, heavy vehicle involved collisions and passenger car only collisions occurred at their expected frequencies for each of the different roadway geometries.

Collision Location

Table 5.16 shows that 73 percent of the intersection-type collisions involving heavy vehicles occurred at intersections and driveways. Also, 78 percent of collisions involving only passenger cars occurred at intersections or driveways.

Collision Severity

Table 5.17 shows that the collisions involving at least one heavy vehicle were slightly more severe than passenger car only collisions. This is similar to findings by Lyles et al.(68) Compared to collisions involving only passenger cars, collisions involving a heavy vehicle resulted in more Class A injuries than expected. However, heavy vehicle involved collisions at intersections resulted in a greater number of PDO collisions than expected, and passenger car only collisions resulted in more Class C injuries than expected. A consistent trend was not identifiable in these data.

Collision Type

Table 5.18 is an analysis of the collision type by vehicle type in North Carolina. It shows that of the 233 collisions involving heavy vehicles, 67 (28.8%) were left turn, 62 (26.6%) were rear-end, 56 (24.0%) were angle, 25 (10.7%) were right turn and 21 (9.0%) were backing collisions. Relative to passenger car only intersection collisions, heavy vehicles were involved in left turn collisions at the same rate, but were more likely to be involved in right turn and backing collisions, as illustrated by the differences in actual and expected frequencies in Table 5.18. However, heavy vehicles were less likely to be involved in rear-end and angle collisions. This shows that more heavy vehicles were involved than expected in right turn and backing collisions, highlighting the need for countermeasures.

Speed Limit

Table 5.19 shows that 72.1 percent of the collisions involving heavy vehicles occurred on roads with a 55 mile per hour (mph) speed limit. However, the frequency of heavy vehicle-involved collisions at this speed, 168, was less than the expected value, 184. Surprisingly, 50 heavy vehicle involved collisions occurred on roads with a 35 mph speed limit which was more than expected, while fewer passenger car only collisions than expected occurred at this speed limit. This suggests that intersections on lower speed limit roads might have been more of a problem for heavy vehicles than for passenger cars.

Day of Week

The data in Table 5.20 show that 92.7 percent of collisions involving heavy vehicles occurred on weekdays, and only 7.3 percent occurred on the weekends. Each weekday contains 16.3 percent to

21.0 percent of the collisions involving heavy vehicles. This can be explained by exposure because heavy vehicles were more likely to be traveling during the week. These results are supported by the findings of Vallette et al.(69) In North Carolina, passenger car only intersection collisions were found to be most frequent (19.3%) on Fridays.

SUMMARY

This chapter analyzed intersection-type collisions in North Carolina and Tennessee, and examined the data for trends related to environmental and locational factors. The intersection-type collisions involving heavy vehicles were explored in detail. Overall trends of intersection-type collisions include the following:

- Rear-end collisions were over-represented on straight roadways, bridges, underpasses and railway crossings.
- Driveways were problematic for left turn and backing collisions.
- Rear-end collisions were more likely to occur in rain than angle collisions.
- Rear-end collisions were over-represented between 2 p.m. and 8 p.m.
- Fatalities were over-represented for angle collisions.

Collisions involving a heavy vehicle at intersections were most frequently rear-end, left turn and angle, and left turn and angle collisions occurred less frequently for heavy vehicles relative to passenger cars. Heavy vehicles had a greater propensity to be involved in right turn and backing collisions compared to passenger cars. Right turn, left turn, rear-end, angle and backing collisions involving at least one heavy vehicle occurred most often at intersections, followed by no special location and private driveways. Possible countermeasures to address these problems include:

- Where significant truck traffic exists, adding right turn lanes should be considered.
- Insure that enough turning space exists on the road for the heavy vehicle to complete a right turn. One way to increase space available for heavy vehicles making right turns is to move back the stop line for left turn lanes (if they exist) on the mainline. More in-depth study of right turn options at intersections is needed.
- Widening lanes near intersections to increase turning space and measures to improve visibility at private driveways.

TABLE 5.1. Collision type by vehicle type in North Carolina

Collision Type	Vehicle Type				Total
	Car	Truck	Bus	Motorcycle	
Rear-end	1,311 (1,299)	371 (383)	13 (10)	5 (7)	1,700
Angle	1,249 (1,224)	345 (361)	4 (9)	3 (7)	1,601
Left turn	1,153 (1,159)	348 (342)	6 (9)	9 (7)	1,517
Right turn	177 (182)	60 (54)	1 (1)	0 (1)	238
Backing	113 (130)	51 (38)	6 (1)	0 (1)	170
Other	16 (25)	10 (7)	1 (0)	6 (0)	33
Total	4,019	1,185	31	23	5,259

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 5.2. Collision type by vehicle type in Tennessee

Collision Type	Vehicle Type								Total
	Car	Light truck	Medium truck	Heavy truck	Motorcycle	Bus	Bicycle	Other	
Rear-end	7,114 (7,385)	3,157 (2,810)	89 (77)	155 (164)	22 (44)	41 (43)	12 (43)	132 (156)	10,722
Angle	10,184 (9,854)	3,408 (3,750)	91 (103)	200 (219)	73 (59)	56 (58)	88 (57)	208 (209)	14,308
Other	965 (1,024)	385 (390)	11 (11)	50 (23)	14 (6)	10 (6)	6 (6)	46 (22)	1,487
Total	18,263	6,950	191	405	109	107	106	386	26,517

Note: A cell entry is the observed number of vehicles involved (expected number of vehicles)

TABLE 5.3. Collision type by roadway geometry in North Carolina

Collision Type	Roadway Geometry					Total
	Straight	Curve	Grade/Straight	Grade/Curve	Not Stated	
Rear-end	638 (657)	43 (55)	120 (86)	16 (18)	0 (1)	817
Angle	649 (641)	66 (54)	60 (84)	22 (18)	1 (1)	798
Left turn	618 (614)	56 (52)	71 (81)	18 (17)	1 (1)	764
Right turn	101 (97)	3 (8)	16 (13)	1 (3)	0 (0)	121
Backing	78 (73)	5 (6)	8 (10)	0 (2)	0 (0)	91
Other	18 (20)	4 (2)	1 (3)	2 (1)	0 (0)	25
Total	2,102	177	276	59	2	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.4. Collision type by roadway geometry in Tennessee

Collision Type	Roadway Geometry					Total
	Straight	Curve	Grade/Straight	Grade/Curve	Not Stated	
Rear-end	2,973 (2,874)	207 (177)	1,204 (824)	234 (154)	333 (922)	4,951
Angle	4,019 (4,109)	215 (253)	831 (1,177)	149 (220)	1,863 (1,318)	7,077
Other	410 (419)	34 (26)	86 (120)	13 (22)	179 (135)	722
Total	7,402	456	2,121	396	2375	12,750

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.5. Collision type by location in North Carolina

Collision Type	Location						Total
	Bridge	Driveway	Intersection	Interchange	RR Xing	Other	
Rear-end	13 (5)	180 (185)	253 (450)	2 (2)	4 (2)	365 (173)	817
Angle	2 (5)	73 (181)	655 (440)	1 (2)	0 (2)	67 (169)	798
Left turn	0 (4)	260 (173)	433 (421)	1 (2)	0 (2)	70 (162)	764
Right turn	0 (1)	29 (27)	73 (67)	1 (0)	0 (0)	18 (26)	121
Backing	0 (1)	38 (21)	17 (50)	0 (0)	1 (0)	35 (19)	91
Other	0 (0)	13 (6)	11 (14)	0 (0)	1 (0)	0 (5)	25
Total	15	593	1,442	5	6	555	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.6. Collision type by location in Tennessee

Collision Type	Location							Total
	Non-intersection	Intersection	RR Xing	Bridge	Underpass	Ramp	Other	
Rear-end	3,010 (2,918)	1,881 (2,001)	5 (3)	40 (21)	12 (5)	2 (2)	1 (0)	4,951
Angle	4,505 (4,171)	2,550 (2,860)	3 (4)	15 (31)	1 (7)	3 (3)	0 (1)	7,077
Other	0 (426)	722 (292)	0 (1)	0 (3)	0 (1)	0 (0)	0 (0)	722
Total	7,515	5,153	8	55	13	5	1	12,750

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.7. Collision type by weather condition in North Carolina

Collision Type	Weather							Total
	Clear	Cloudy	Rain	Snow	Fog / Smog	Sleet / Hail	Not Stated	
Rear-end	506 (563)	136 (130)	159 (112)	2 (2)	11 (8)	2 (1)	1 (1)	817
Angle	566 (550)	131 (127)	90 (109)	2 (2)	8 (8)	0 (1)	1 (1)	798
Left turn	568 (527)	109 (122)	80 (105)	1 (2)	5 (8)	0 (1)	1 (1)	764
Right turn	81 (83)	18 (19)	20 (17)	1 (0)	1 (1)	0 (0)	0 (0)	121
Backing	63 (63)	20 (15)	7 (13)	0 (0)	1 (1)	0 (0)	0 (0)	91
Other	20 (17)	3 (4)	2 (3)	0 (0)	0 (0)	0 (0)	0 (0)	25
Total	1,804	417	358	6	26	2	3	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.8. Collision type by weather condition in Tennessee

Collision Type	Weather							Total
	Clear	Cloudy	Rain	Snow	Fog	Not Indicated	Other	
Rear-end	2,471 (2,558)	1,602 (1,607)	779 (671)	19 (19)	26 (23)	42 (60)	12 (13)	4,951
Angle	3,733 (3,656)	2,319 (2,297)	868 (960)	27 (27)	30 (33)	80 (86)	20 (19)	7,077
Other	383 (373)	217 (234)	82 (98)	2 (3)	3 (3)	33 (9)	2 (2)	722
Total	6,587	4,138	1,729	48	59	155	34	12,750

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.9. Collision type by time of day in North Carolina

Collision Type	**Time of Day (Military Time)**				**Total**
	0000-0659	**0700-1359**	**1400-1959**	**2000-2359**	
Rear-end	39 (44)	299 (308)	404 (396)	75 (68)	817
Angle	45 (43)	307 (301)	390 (387)	56 (67)	798
Left turn	38 (42)	300 (288)	362 (370)	64 (64)	764
Right turn	9 (7)	43 (46)	57 (59)	12 (10)	121
Backing	6 (5)	35 (34)	40 (44)	10 (8)	91
Other	5 (1)	3 (9)	15 (12)	2 (2)	25
Total	142	987	1,268	219	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.10. Collision type by time of day in Tennessee

Collision Type	**Time of Day (Military Time)**				**Total**
	0000-0659	**0700-1359**	**1400-1959**	**2000-2359**	
Rear-end	309 (340)	1,694 (1,728)	2,619 (2,449)	327 (433)	4,949
Angle	486 (486)	2,543 (2,468)	3,356 (3,497)	683 (618)	7,068
Other	80 (50)	210 (252)	327 (357)	104 (63)	721
Total	875	4,447	6,302	1,114	12,738

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.11. Collision type by severity in North Carolina

Collision Type	Severity					Total
	PDO	Class C	Class B	Class A	Fatal	
Rear-end	362 (359)	368 (310)	69 (114)	17 (30)	1 (4)	817
Angle	276 (351)	302 (302)	163 (112)	50 (30)	7 (4)	798
Left turn	356 (336)	268 (289)	109 (107)	27 (28)	4 (4)	764
Right turn	78 (53)	26 (46)	15 (17)	1 (5)	1 (1)	121
Backing	69 (40)	18 (35)	2 (13)	2 (3)	0 (1)	91
Other	8 (11)	9 (10)	8 (4)	0 (1)	0 (0)	25
Total	1,149	991	366	97	13	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.12. Collision type by severity in Tennessee

Collision Type	Severity			Total
	PDO	Injury	Fatal	
Rear-end	3,562 (3,533)	1,385 (1,403)	4 (15)	4,951
Angle	5,017 (5,051)	2,031 (2,005)	29 (22)	7,077
Other	520 (515)	196 (205)	6 (2)	722
Total	9,099	3,612	39	12,750

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.13. Vehicle type by weather condition in North Carolina

Vehicle Type	Weather Condition							Total
	Clear	Cloudy	Rain	Snow	Fog / Smog	Sleet / Hail	Not Indicated	
Heavy Vehicle Involved	174 (161)	29 (37)	27 (32)	0 (1)	3 (2)	0 (0)	0 (0)	233
Car Only	1,603 (1,613)	376 (373)	327 (320)	6 (5)	22 (23)	2 (2)	3 (3)	2,339
Other	27 (30)	12 (7)	4 (6)	0 (0)	1 (0)	0 (0)	0 (0)	44
Total	1,804	417	358	6	26	2	3	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.14. Vehicle type by time of day in North Carolina

Vehicle Type	Time of Day (Military Time)				Total
	0000-0659	0700-1359	1400-1959	2000-2359	
Heavy Vehicle Involved	11 (13)	112 (88)	97 (113)	13 (20)	233
Car Only	129 (127)	869 (883)	1,138 (1,134)	203 (196)	2,339
Other	2 (2)	6 (17)	33 (21)	3 (4)	44
Total	142	987	1,268	219	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.15. Roadway geometry by vehicle type in North Carolina

Roadway Geometry	Vehicle Type			Total
	Heavy Vehicle Involved	Car Only	Other	
Straight, Level	170 (171)	1,706 (1,711)	38 (32)	1,914
Straight, Crest	10 (12)	128 (123)	0 (2)	138
Straight, Grade	26 (25)	248 (247)	2 (5)	276
Straight, Sag	8 (5)	42 (45)	0 (1)	50
Curve, Level	15 (13)	134 (135)	2 (3)	151
Curve, Crest	0 (2)	17 (16)	1 (0)	18
Curve, Grade	4 (5)	54 (53)	1 (1)	59
Curve, Sag	0 (1)	8 (7)	0 (0)	8
Not Stated	0 (0)	2 (2)	0 (0)	2
Total	233	2339	44	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.16. Vehicle type by location in North Carolina

Vehicle Type	Location						Total
	Bridge	Driveway	Intersection	Interchange	RR Xing	Other	
Heavy Vehicle Involved	5 (1)	55 (53)	116 (128)	0 (0)	0 (1)	57 (49)	233
Car Only	10 (13)	516 (530)	1,313 (1,289)	5 (5)	6 (5)	489 (496)	2,339
Other	0 (0)	22 (10)	13 (24)	0 (0)	0 (0)	9 (9)	44
Total	15	593	1,442	5	6	555	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.17. Vehicle type by collision severity in North Carolina

Vehicle Type	Severity					Total
	PDO	Class C	Class B	Class A	Fatal	
Heavy Vehicle Involved	125 (102)	62 (88)	32 (33)	12 (9)	2 (1)	233
Car Only	1,013 (1,027)	916 (886)	318 (327)	81 (87)	11 (12)	2,339
Other	11 (19)	13 (17)	16 (6)	4 (2)	0 (0)	44
Total	1,149	991	366	97	13	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.18. Collision type by vehicle type in North Carolina

Collision Type	Vehicle Type			Total
	Heavy Vehicle Involved	Car Only	Other	
Rear-end	62 (73)	742 (731)	13 (14)	817
Angle	56 (71)	738 (714)	4 (13)	798
Left turn	67 (68)	679 (683)	18 (13)	764
Right turn	25 (11)	96 (108)	0 (2)	121
Backing	21 (8)	68 (81)	2 (2)	91
Other in Road	2 (1)	9 (11)	1 (0)	12
Hit Moped	0 (0)	0 (5)	5 (0)	5
Hit Parked Car	0 (1)	7 (7)	1 (0)	8
Total	233	2,339	44	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.19. Vehicle type by speed limit in North Carolina

Vehicle Type	Speed Limit						Total
	20 mph	25 mph	35 mph	45 mph	50 mph	55 mph	
Heavy Vehicle Involved	2 (0)	2 (2)	50 (35)	10 (11)	1 (1)	168 (184)	233
Car Only	3 (5)	18 (18)	337 (351)	113 (110)	7 (7)	1,861 (1,849)	2,339
Other	0 (0)	0 (0)	5 (7)	0 (2)	0 (0)	39 (35)	44
Total	5	20	392	123	8	2,068	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 5.20. Vehicle type by day of week in North Carolina

Vehicle Type	Day of Week							Total
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
Heavy Vehicle Involved	38 (32)	49 (35)	40 (33)	49 (36)	40 (45)	11 (31)	6 (21)	233
Car Only	310 (317)	335 (352)	325 (329)	350 (361)	452 (450)	339 (316)	228 (214)	2,339
Other	7 (6)	10 (7)	3 (6)	5 (7)	11 (9)	3 (6)	5 (4)	44
Total	355	394	368	404	503	353	239	2,616

Note: A cell entry is the observed number of collisions (expected number of collisions)

CHAPTER 6. ANALYSIS OF SEGMENT-RELATED COLLISIONS

INTRODUCTION

This chapter is an analysis of collision data from 1993-1995 on segments of two-lane secondary highways in North Carolina and Tennessee. Two counties were studied as representative counties in each state. In North Carolina, Wake and Robeson counties were selected, and in Tennessee, Hamilton and Montgomery counties were chosen. Collision data from Fayette and Pike counties in Kentucky were also analyzed in other chapters, but due to a variety of problems, these data were not analyzed in this chapter.

The counties selected for analysis have met a list of criteria to insure consistency in the data. Ideally, a low reporting threshold for PDO collisions was favored. The reporting thresholds for filing a collision report in North Carolina and Tennessee were $500 and $400, respectively. The other important considerations included a large sample size, variation in demographics, variation in alcohol sales laws and a small percentage of un-mileposted collisions. Each of the factors was favorable for these counties, and the report form did not change substantially during the three-year period in question.

There were many variables that define a secondary road, but for this study, the AADT was considered the most important. Traffic volume appears to be an appropriate variable because collision rates are more dependent on it than other factors. The research team defined a secondary highway as one with 5,000 vehicles per day or less. The North Carolina database consists of all reported collisions in the Highway Safety Information System (HSIS) database on two-lane highways with an AADT of 5,000 vehicles or less. The Tennessee collision data was obtained by the research team from the Tennessee DOT. The Tennessee data did not include AADT, so those data are from all two-lane highways.

The selected collisions were divided into intersection-related and segment-related because these categories tend to have different types of collisions and require different countermeasures.

Segment-related collisions include all run-off road, animal, head-on, overturn and sideswipe collisions, and pedestrian, bicycle and 'other' collisions reported as not occurring at intersections. This classification split the collision data roughly in half, and the North Carolina State University (NCSU) portion of the team studied the segment collisions. During the three-year study period, a total of 2,862 segment related collisions occurred on two-lane secondary roads in the two North Carolina counties, and 9,049 collisions occurred on two-lane highways in the two Tennessee counties.

To draw conclusions from the data, contingency tables were generated based on factors related to the collisions. For each combination of factors in consideration, the total number of collisions that involve all of the factors were counted and presented in contingency tables. Trends and patterns were observed with two comparison methods. To determine if a specific collision type is a problem, the team calculated the relative frequencies of all collisions by dividing the actual number of collisions by the total number of collisions. Also, the expected value for any cell in a table was computed as the cell row total multiplied by the cell column total and divided by the table grand total. The expected values were then compared to the actual frequencies to highlight deviance.

GENERAL TRENDS IN THE DATA

Khattak and Hummer (70) completed an overview of collision characteristics from the North Carolina database. The factors they studied include time, roadway conditions, weather, light and alcohol involvement. The results from this preliminary work gave a rough breakdown of the factors that influence various collision types, and led to subsequent studies.

Among the fundamental data fields on any collision report form are the month, day, year and time of the collision. This information revealed interesting and useful trends in the collision data. Table 6.1 is a count of the total number of collisions in each month for the years 1993-1995. If the collisions in the North Carolina counties were evenly distributed, 239 collisions, or 8.3 percent, would occur each month. The three months with the most collisions are November, December and October, with 11.0 percent, 10.1 percent and 9.4 percent of the collisions, respectively. This is most likely due to darkness, poor weather, increased animal activity and the heavy traffic volumes during the holiday season. By contrast, April accounts for only 6.2 percent of the collisions, making it by far the safest month to travel.

In the two Tennessee counties, it is interesting to note that the number of collisions in each month was fairly uniform compared to North Carolina. The range of collisions has a low of 689 (7.6%) in April, and a peak of 846 (9.3%) in May. The range in North Carolina is 177 (6.2%) in April to 314 (11.0%) in November. In Tennessee, the months with the highest percentage of collisions were October, December and January with 8.8 percent, 8.8 percent and 8.7 percent of the collisions, respectively.

Table 6.2 shows a count of the number of collisions for each day of the week. If evenly distributed in North Carolina, each day would have had 409 collisions, or 14.3 percent of the total. Note that Friday and Saturday were well above the average with 16.4 percent and 16.6 percent, respectively. This can be expected due to an increase in travel associated with social activity and weekend trips. On the other hand, Tuesday and Wednesday had only 11.7 percent and 12.5 percent of the total, indicating an opposite trend. The data from Tennessee were remarkably similar to the North Carolina data, and the same trends were evident.

When the 24-hour day was grouped into three-hour blocks, as in Table 6.3, more trends in the data became apparent. Each block should contain an average of 12.5 percent of the collisions, but this was not the case. In North Carolina, the hours between 3:00 p.m. and midnight were above the average. The morning rush hour had the next highest percentage of collisions, but it was still less than the 12.5 percent average. In Tennessee, the hours between noon and 11:59 p.m. contained 5,519 (61.0%) of the collisions. Note the peak between 3:00 p.m. and 5:59 p.m. with 1,647 (18.2%) of the collisions.

The first three tables do not illuminate any surprising conclusions, but they contain valuable information. The next three tables also summarize important basic facts about the databases. Table 6.4 describes the weather conditions at the time of the collision. For North Carolina, the weather was clear or cloudy for 76.2 percent of the collisions, raining for 20.6 percent and snowing or icing for 3.0 percent of the collisions. The corresponding percentages for Tennessee are clear or cloudy 82.5 percent, raining 14.7 percent and snowing or icing 0.9 percent.

Table 6.5 shows the percentage of collisions in North Carolina in daylight is roughly equal to the percentage during darkness, 46.4 percent to 47.2 percent, respectively. However, the distribution was different in Tennessee. Over half (53.5%) of the reported collisions occurred in daylight, but only 41.5 percent in darkness. In North Carolina, only 43 (1.5%) of the collisions occurred on segments with street lights on, but 1,885 (21.5%) of the collisions had the same conditions in Tennessee, probably due to the inclusion of collisions on higher-volume roads in the Tennessee database.

Table 6.6 is a count and relative frequency of each collision type in the North Carolina database. The three most common collision types were run off road right, run off road left and hit animal with 45.0 percent, 21.8 percent and 14.7 percent of the total, respectively. Table 6.7 is a count and relative frequency of the collision types in Tennessee. The three most common collision types in Tennessee were run off road and hit fixed object, sideswipe (opposite direction), and sideswipe (same direction) with 43.7 percent, 9.7 percent and 8.4 percent of the collisions, respectively.

There are distinct differences in the relative frequencies of collision types in North Carolina compared to Tennessee. Run off the road collisions accounted for 70.5 percent of the collisions in North Carolina, but only 58.9 percent in Tennessee. Animal collisions are 14.7 percent of the North Carolina collisions, but only 4.1 percent in Tennessee. Finally, 4.8 percent of the North Carolina collisions are described as sideswipes, but 18.1 percent of the collisions in Tennessee are coded as sideswipes.

The relationship between severity and light conditions is presented in Table 6.8. Property damage only and fatal collisions were over-represented in darkness, and Class C and Class B injury collisions were over-represented in daylight. Table 6.9 counts the Tennessee collisions by severity and light. Most of the totals agree closely with the expected values, except for the fatal collisions. As in North Carolina, the number of fatal collisions was less than expected in daylight, and more than expected in darkness.

Table 6.10 shows the severity of each collision type in North Carolina. Run off road to the right collisions tend to have more minor injuries than expected, while run off road to the left had more injuries and fatalities than expected. Collisions involving pedestrians, bicycles and mopeds were very severe with injuries in all 52 cases, including 12 fatalities. Further work is warranted in this area to reduce the number of these very severe collisions. Animal collisions were numerous, but generally resulted in fewer injuries and fatalities than expected. Head-on collisions were rare, but tend to be devastating events. Out of the 52 head-on collisions, five resulted in at least one fatality. Sideswipes were more frequent than head-on collisions, but resulted in fewer serious injuries and deaths than expected.

Table 6.11 is the severity of collision types in Tennessee. There were 3,953 run off the road and hit fixed object collisions, which accounts for 43.7 percent of all segment collisions in Tennessee. These collisions resulted in more injuries and fatalities than expected. As in North Carolina, head-on and hit bicycle or pedestrian collisions tended to be more severe than expected. Finally, sideswipes and animal collisions tended to be less severe than expected.

Tables 6.12 and 6.13 are counts of collision types by light conditions in North Carolina and Tennessee, respectively. The trends seen in these tables are remarkably similar. In both states, head-on and sideswipe collisions occurred much more frequently in daylight than expected. Also, animal collisions occurred far less frequently than expected in daylight. On the other hand, head-on and sideswipe collisions were extremely under-represented, and animal collisions were grossly over-represented, in darkness.

COLLISIONS INVOLVING HEAVY VEHICLES

Many researchers have studied collisions involving heavy vehicles on urban freeways, but little is known about the extent of these collisions on rural and suburban two-lane highways. The NCSU portion of the study team examined the North Carolina data to evaluate the contributing factors and potential countermeasures. For this study, heavy vehicles included buses, recreational vehicles and large trucks. The team found that these vehicles were not involved in a large proportion of collisions on rural two-lane highways. Compared to passenger car only collisions on segments, the first harmful event in collisions involving heavy vehicles was more often 'sideswipe' and less often 'run off road' and 'hit animal'.

The researchers sought to answer several questions about heavy vehicle collisions. First, the team determined what types of collisions on secondary highways involve heavy vehicles. Then, the team studied these collisions to find out if heavy vehicles were over-represented in the database, and if their collisions occurred more often at certain times and places.

Of the 2,862 collisions in the segment-related collision database, only 154 (5.4%) involved one or more heavy vehicles. Table 6.14 summarizes the most harmful injury in the collision by the type of vehicle involved. It shows that collisions involving heavy vehicles were generally slightly less severe than expected when compared to passenger car only collisions. Single heavy vehicle collisions included no fatalities and a lower percentage of Class B injury collisions than single-vehicle passenger car collisions. Overall, heavy vehicle collisions resulted in Class C injury collisions less often than passenger car only collisions.

The first harmful events for heavy vehicle collisions and those for passenger car collisions show some significant differences. Table 6.15 shows that collisions involving heavy vehicles were less likely than collisions involving only passenger cars to be 'ran off road' or 'hit animal'. Meanwhile, collisions involving heavy vehicles were more likely than expected to be 'sideswipe'. 'Overturn' and 'hit other object' collision types also appeared more often than expected for heavy vehicles.

The North Carolina data showed that heavy vehicles were involved primarily during the weekdays and during the daytime hours. Only 6 percent of the heavy vehicle collisions occurred on Saturday, and only 3 percent on Sunday, but the weekdays varied from 13 percent to 23 percent each.

The hours between 6:00 a.m. and 6:00 p.m. contained 77 percent of the heavy vehicle collisions, but only 55 percent of collisions involving only passenger cars. The distribution of heavy vehicle collisions during these times was relatively even.

ANIMAL COLLISIONS

Collisions involving animals on secondary highways accounted for 421 (14.7%) of the collisions in the North Carolina database. Only run off road right (45.0%) and run off road left (21.8%) collisions occurred more frequently. Fortunately, Table 6.10 shows that animal collisions were far less severe than expected. Out of 421 collisions, 360 (85.5%) resulted in no injuries to the driver or passengers, and only one collision resulted in a human fatality. Although animal collisions were not particularly dangerous, an excellent topic for further study is to find effective countermeasures that will reduce the number of these collisions.

The animal collisions were studied in more detail to determine if certain factors influence the number or severity of these collisions. Table 6.12 shows that 306 (72.7%) of the 421 animal collisions occurred in the dark, and only 90 (21.4%) in daylight. This suggests that a lack of visibility, or increased animal movements, are problems that lead to a large percentage of animal collisions.

A closer look at the data indicated that animal collisions do not follow any strong trends based on the factors on the collision report. For example, Table 6.16 shows that animal collisions were slightly over-represented on grades with shoulder widths less than 6 feet, and on level roads with shoulder widths greater than 8 feet. Wide shoulders give drivers an opportunity to avoid an animal in the road, but the data indicated that more animal collisions occurred than expected on the roads with the widest shoulders. Table 6.17 shows that there was not a clear trend relating the surface width of the roadway, the shoulder width and the number of animal collisions. We might expect the combination of a wide roadway and a wide shoulder to result in fewer animal collisions than expected, but this was not the case.

RUN-OFF THE ROAD COLLISIONS

As noted earlier and as shown in Table 6.6, run off the road was the most common collision type, accounting for 2,017 (70.5%) of the 2,862 reported segment-related collisions in the North Carolina database. When these collisions were crossed against roadway geometry factors, some interesting patterns emerged. Table 6.18 relates the road character and the lighting conditions for run off the road to the right collisions. The clear trend in this data was that more collisions occurred on level road in the dark and on grades in daylight than expected. Conversely, fewer of these collisions occurred on level road in the daylight and on curves in the dark than expected. Table 6.19 shows a weaker trend among the run off the road to the left collisions. The only notable feature of this table is that more run off the road to the left collisions occurred on curves in the dark than expected.

Tables 6.20 and 6.21 contain very interesting patterns involving road character and right shoulder width for run off the road to the right and left collisions, respectively. The number of collisions was higher than expected on grades with narrow shoulders and lower than expected on level roads with narrow shoulders. However, in both cases, the trend reverses at a shoulder width of six feet. This suggests that wider shoulder widths on grades are effective in reducing the number of run off the road collisions. The team analyzed the impact of lighting conditions on the tables discussed in this paragraph, and found that the same trends were present in daylight and in dark conditions.

EFFECTS OF ROADWAY GEOMETRY

On a collision report form, the road geometry is coded in categories such as horizontal and vertical alignment, surface width and shoulder width. The project team tried to determine if one of these factors, or a combination of two or more factors, resulted in recognizable trends among specific collision types.

When road alignment was studied, many important findings became evident. Table 6.22 counts the number of each collision type in North Carolina and the expected value by the horizontal alignment of the roadway. Overall, 1,718 (60.1%) of all collisions occurred on straight roads, and 1,142 (39.9%) were on curves. Run off the road right and left collisions accounted for 66.8 percent of all collisions, and they occurred much more often than expected on curves. This suggests the need for more or better countermeasures on curved roadways to reduce the number of run off the road incidents. On the other hand, every other collision type occurred less frequently than expected on curves. For instance, 89.5 percent of the animal collisions, 68.6 percent of the sideswipe collisions and 88.6 percent of the run off the road straight collisions occurred on straight roadways.

Animal collisions were well over-represented on straight roads, and under-represented on curved segments. The animal collisions occurred slightly more frequently than expected on level segments as opposed to grades. These results suggest that straight, level roads are good targets for countermeasures against animal collisions.

Table 6.23 describes the vertical alignment of the roadway at the collision site for each collision type in North Carolina. No collision type is particularly over-represented in Table 6.23. Run off the road right collisions were slightly over-represented on grades, by a margin of 258 reported collisions to 238 expected. In other words, it appears the horizontal alignment of the roadway has a much more pronounced influence on the different collision type than the vertical alignment.

Table 6.24 counts the North Carolina collision types and their expected values by the surface width of the roadway. Few patterns are very strong in this table. The two notable comparisons involve the run off the road right and sideswipe collisions. Run off the road to the right collisions were slightly over-represented on the narrowest surface widths. Sideswipe collisions, surprisingly, were over-represented on the widest surface widths.

Table 6.25 reveals a couple of notable trends when the North Carolina collisions were grouped by right shoulder width. Run off the road to the right and left were under-represented for shoulder widths greater than 8 feet. Also, sideswipe collisions occurred more often than expected on narrow shoulder widths. Both of these conclusions match prior expectations, and point to roadway conditions that are possible countermeasures against these types of collisions.

SUMMARY

A general analysis of segment-related collisions from secondary highways in North Carolina and Tennessee showed that collisions were more common during autumn, on weekends, and during later afternoons and evenings. 'Run-off road' and 'hit animal' were the most frequent collision types, but 'head-on' and 'hit pedestrian or bicycle' collisions were relatively more severe.

In general, collisions involving heavy vehicles in North Carolina were not as common or severe as expected. Heavy vehicle collisions associated with segments were more often 'sideswipe' and less often 'ran off road' and 'hit animal' than passenger car only collisions. Potential countermeasures include reviewing passing criteria and increasing lane widths and bridge widths to avoid sideswipes.

Animal collisions were the third most frequent collision type in the North Carolina database, accounting for 14.7 percent of the reported collisions. However, analyzing possible contributing factors to these collisions yielded few recommendations. Animal collisions appear to be random incidents because road characteristics, such as lane width and shoulder width, seem to have little effect on the number of these collisions. Animal collisions were over-represented in darkness, so additional warning signs and lighting might reduce the number of collisions if known trouble spots can be identified.

Run off the road collisions accounted for more than 50 percent of the segment-related collisions in North Carolina and Tennessee, so countermeasures focused on these collisions have a lot of potential benefit. The results of the analysis indicated that wider shoulders on graded sections of roadway might be effective in the reduction of collisions. Also, roadway geometry and lighting conditions are important factors.

More run off the road collisions occurred on curves than expected, so effective countermeasures are needed in these areas. Based on the North Carolina collision data, the horizontal alignment of the roadway has a larger influence on the number of each collision type than the vertical alignment. As expected, run-off road collisions were under-represented on segments with wide shoulders, while sideswipe collisions were over-represented on segments with narrow shoulders.

TABLE 6.1. Monthly variation of collisions in North Carolina (70) and Tennessee

Month	North Carolina		Tennessee	
	Collisions	Percentage	Collisions	Percentage
January	222	7.8	785	8.7
February	213	7.4	716	7.9
March	228	8.0	717	7.9
April	177	6.2	689	7.6
May	215	7.5	846	9.3
June	226	7.9	738	8.2
July	250	8.7	718	7.9
August	221	7.7	741	8.2
September	238	8.3	743	8.2
October	269	9.4	800	8.8
November	314	11.0	763	8.4
December	289	10.1	793	8.8
Total	2,862	100.0	9,049	100.0

TABLE 6.2. Daily variation of collisions in North Carolina (70) and Tennessee

Day of Week	North Carolina		Tennessee	
	Collisions	Percentage	Collisions	Percentage
Sunday	420	14.7	1,212	13.4
Monday	391	13.7	1,240	13.7
Tuesday	334	11.7	1,169	12.9
Wednesday	358	12.5	1,130	12.5
Thursday	414	14.5	1,297	14.3
Friday	470	16.4	1,514	16.7
Saturday	475	16.6	1,485	16.4
Total	2,862	100.0	9,049	100.0

TABLE 6.3. Hourly variation of collisions in North Carolina (70) and Tennessee

Hour of Day	North Carolina		Tennessee	
	Collisions	Percentage	Collisions	Percentage
0000 – 0259	312	10.9	1,123	12.4
0300 – 0559	259	9.0	551	6.1
0600 – 0859	344	12.0	927	10.2
0900 – 1159	248	8.7	929	10.3
1200 – 1459	328	11.5	1,271	14.0
1500 – 1759	425	14.8	1,647	18.2
1800 – 2059	482	16.8	1,316	14.5
2100 – 2359	464	16.2	1,285	14.2
Total	2,862	100.0	9,049	100.0

TABLE 6.4. Weather conditions at time of collisions in North Carolina (70) and Tennessee

Weather	North Carolina		Tennessee	
	Collisions	Percentage	Collisions	Percentage
Clear	1,685	58.9	4,383	50.0
Cloudy	494	17.3	2,855	32.5
Rain	589	20.6	1,293	14.7
Snow/Ice	84	3.0	82	0.9
Other	10	0.3	161	1.8
Total	2,862	100.0	8,774	100.0

Note: 275 of the Tennessee collisions did not have weather coded

TABLE 6.5. Light conditions at time of collisions in North Carolina (70) and Tennessee

Light	North Carolina		Tennessee	
	Collisions	Percentage	Collisions	Percentage
Daylight	1,327	46.4	4,689	53.5
Dusk	63	2.2	239	2.7
Dawn	75	2.6	195	2.2
Dark, Street Lights	43	1.5	1,885	21.5
Dark, Unlit	1,352	47.2	1,757	20.0
Total	2,862	100.0	8,765	100.0

Note: 284 of the Tennessee collisions did not have light coded

TABLE 6.6. Count of collision types in North Carolina (70)

Collision Type	Collisions	Percentage
Run-off the road...		
to the Right	1,288	45.0
to the Left	624	21.8
Straight	105	3.7
Animal	421	14.7
Vehicle hits...		
Pedestrian/bicycle/moped	52	1.8
Parked car/fixed object/other object	129	4.5
Sideswipe	137	4.8
Head-on	52	1.8
Overturn	20	0.7
Other	34	1.2
Total	2,862	100.0

TABLE 6.7. Count of collision types in Tennessee

Collision Type	Collisions	Percentage
Run-off the road and...		
Hit fixed object	3,953	43.7
Overturn	644	7.1
Other	729	8.1
Animal	370	4.1
Vehicle hits bicycle or pedestrian	189	2.1
Sideswipe...		
Opposite direction	877	9.7
Same direction	761	8.4
Head-on	748	8.3
Overturn in roadway	63	0.7
Miscellaneous and Other	715	7.9
Total	9,049	100.0

TABLE 6.8. Severity of collision by light conditions in North Carolina

Severity	Light Conditions				Total
	Daylight	Dusk / Dawn	Street Light	Dark	
PDO	615 (670)	70 (70)	21 (22)	737 (682)	1,443
Class C	368 (317)	26 (33)	7 (10)	282 (323)	683
Class B	251 (236)	28 (25)	11 (8)	219 (241)	509
Class A	73 (76)	11 (8)	3 (2)	77 (78)	164
Fatal	20 (28)	3 (3)	1 (1)	37 (29)	61
Total	1,327	138	43	1,352	2,860

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.9. Severity of collision by light conditions in Tennessee

Severity	Light Conditions				Total
	Daylight	Dusk/Dawn	Street Light	Dark	
PDO	3,203 (3,207)	284 (297)	1,307 (1,289)	1,200 (1,202)	5,994
Injury	1,464 (1,452)	147 (134)	569 (584)	535 (544)	2,715
Fatal	22 (30)	3 (3)	9 (12)	22 (11)	56
Total	4,689	434	1,885	1,757	8,765

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.10. Severity of collision types in North Carolina

Collision Type	Severity					Total
	PDO	Class C	Class B	Class A	Fatal	
Run off Road, Right	568 (650)	352 (307)	279 (229)	71 (74)	18 (27)	1,288
Run off Road, Left	282 (315)	171 (149)	118 (111)	37 (36)	16 (13)	624
Run off Road, Straight	44 (53)	24 (25)	27 (19)	7 (6)	3 (2)	105
Overturn	6 (10)	2 (5)	7 (4)	4 (1)	1 (0)	20
Other in Road	17 (17)	5 (8)	6 (6)	4 (2)	2 (1)	34
Hit Pedestrian/Bicycle	0 (26)	14 (12)	14 (9)	12 (3)	12 (1)	52
Hit Parked Vehicle	19 (14)	4 (7)	4 (5)	0 (2)	1 (1)	28
Animal	360 (213)	42 (100)	13 (75)	5 (24)	1 (9)	421
Hit Fixed Object	26 (20)	9 (10)	2 (7)	3 (2)	0 (1)	40
Hit Other Object	38 (31)	15 (15)	7 (11)	1 (3)	0 (1)	61
Head-on	6 (26)	12 (12)	16 (9)	13 (3)	5 (1)	52
Sideswipe	79 (69)	33 (33)	16 (24)	7 (8)	2 (3)	137
Total	1,445	683	509	164	61	2,862

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.11. Severity of collision types in Tennessee

Collision Type	Severity			Total
	Fatal	Injury	PDO	
Head-on	8 (5)	343 (230)	397 (514)	748
Sideswipe, opposite direction	3 (5)	149 (269)	725 (602)	877
Sideswipe, same direction	1 (5)	68 (234)	692 (523)	761
Hit Bicycle or Pedestrian	3 (1)	184 (58)	2 (130)	189
Animal	0 (2)	19 (114)	351 (254)	370
Overturn in Road	0 (0)	31 (19)	32 (43)	63
Run off road and overturn	3 (4)	309 (198)	332 (442)	644
Run off road and hit fixed object	37 (24)	1,335 (1,214)	2,581 (2,715)	3,953
Run off road and Other	1 (5)	203 (224)	525 (501)	729
Miscellaneous and Other	0 (4)	138 (220)	577 (491)	715
Total	56	2,779	6,214	9,049

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.12. Collision type by light conditions in North Carolina

Collision Type	Light Conditions				Total
	Daylight	Dusk / Dawn	Street Light	Dark	
Run off Road, Right	691 (598)	61 (62)	16 (19)	520 (609)	1,288
Run off Road, Left	275 (290)	33 (30)	11 (9)	305 (295)	624
Run off Road, Straight	17 (48)	4 (5)	3 (2)	80 (49)	104
Overturn	16 (9)	1 (1)	0 (0)	3 (9)	20
Other in Road	18 (16)	3 (2)	0 (1)	13 (16)	34
Hit Pedestrian/Bicycle	22 (24)	4 (3)	2 (1)	24 (25)	52
Hit Parked Vehicle	13 (13)	1 (1)	2 (0)	12 (13)	28
Animal	90 (195)	19 (20)	6 (6)	306 (199)	421
Hit Fixed Object	21 (19)	0 (2)	1 (1)	18 (19)	40
Hit Other Object	33 (28)	2 (3)	0 (1)	26 (29)	61
Head-on	36 (24)	3 (3)	0 (1)	13 (25)	52
Sideswipe	95 (63)	7 (7)	2 (2)	32 (64)	136
Total	1,327	138	43	1,352	2,860

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.13. Collision type by light conditions in Tennessee

Collision Type	Light Conditions				Total
	Daylight	Dusk / Dawn	Street Light	Dark	
Head-on	459 (396)	44 (37)	177 (159)	61 (149)	741
Sideswipe, opposite direction	613 (468)	48 (43)	153 (188)	60 (175)	874
Sideswipe, same direction	532 (406)	29 (38)	154 (163)	44 (152)	759
Hit Bicycle or Pedestrian	140 (101)	10 (9)	31 (40)	7 (38)	188
Animal	103 (195)	29 (18)	54 (78)	178 (73)	364
Overturn in Road	31 (32)	3 (3)	13 (13)	12 (12)	59
Run off road and overturn	315 (333)	30 (31)	64 (134)	214 (125)	623
Run off road, hit fixed object	1,759 (2,042)	186 (189)	961 (821)	911 (765)	3,817
Run off road and Other	321 (375)	27 (35)	155 (151)	198 (141)	701
Miscellaneous and Other	416 (342)	28 (32)	123 (137)	72 (128)	639
Total	4,689	434	1,885	1,757	8,765

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.14. Collision severity (most harmful injury) by vehicle type for segment related collisions in North Carolina

Vehicle Types	Severity					Total
	PDO	Class C	Class B	Class A	Fatal	
Truck (single vehicle)	43 (36)	16 (17)	8 (12)	3 (3)	0 (1)	70
Truck & Truck	5 (6)	4 (3)	2 (2)	1 (1)	0 (0)	12
Truck & Car	30 (26)	6 (12)	8 (9)	6 (2)	1 (1)	51
Heavy Truck Involved	**84 (80)**	**30 (37)**	**26 (27)**	**12 (7)**	**2 (3)**	**154**
Car (single vehicle)	1,211 (1,185)	552 (554)	398 (395)	89 (109)	31 (38)	2,281
Car & Car	116 (149)	78 (69)	49 (49)	30 (14)	13 (5)	286
Passenger Car Only	**1,327 (1,333)**	**630 (623)**	**447 (444)**	**119 (123)**	**44 (43)**	**2,567**
Total (bold rows only)	1,411	660	473	131	46	2,721

Note: A cell entry is the observed number of collisions (expected number of collisions)
Note: Collisions involving buses and RV's are included in the 'Heavy Truck Involved' row, but are not shown separately

TABLE 6.15. First harmful event by vehicle type (excluding hit pedestrian/bicycle/moped) in North Carolina

Collision Type	Vehicle Type		Total
	Heavy Truck	Car Only	
Run off Road, Right	55 (69)	1,196 (1,182)	1,251
Run off Road, Left	17 (33)	592 (576)	609
Run off Road, Straight	1 (6)	103 (98)	104
Overturn	8 (1)	4 (11)	12
Other in Road	4 (2)	29 (31)	33
Hit Parked Vehicle	6 (1)	15 (20)	21
Hit Animal	3 (23)	412 (392)	415
Hit Fixed Object	6 (2)	34 (38)	40
Hit Other Object	10 (3)	46 (53)	56
Head-on	4 (3)	47 (48)	51
Sideswipe	35 (7)	89 (117)	124
Total	149	2,567	2,716

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.16. Road character and right shoulder width conditions at animal collision sites in North Carolina

Road Character	Right Shoulder Width				Total
	0-3 ft.	4-5 ft.	6-7 ft.	8-9 ft.	
Straight, Level	5 (5)	92 (98)	88 (90)	71 (63)	256
Straight, Grade	1 (1)	24 (18)	16 (16)	6 (12)	47
Curve, Level	0 (0)	7 (10)	11 (9)	7 (6)	25
Curve, Grade	1 (0)	7 (5)	4 (4)	0 (3)	12
Total	7	130	119	84	340

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.17. Surface width and right shoulder width conditions at animal collision sites in North Carolina

Surface Width	Right Shoulder Width				Total
	0-3 ft.	4-5 ft.	6-7 ft.	8-9 ft.	
LE 18 ft.	1 (3)	47 (49)	59 (43)	19 (32)	126
19-20 ft.	2 (4)	76 (63)	36 (56)	49 (41)	163
21-22 ft.	5 (1)	18 (25)	27 (22)	14 (16)	64
23-24 ft.	0 (0)	0 (4)	2 (4)	9 (3)	11
Total	8	141	124	91	364

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.18. Roadway character and light conditions for run off the road right collisions in North Carolina

Road Character	Light Conditions				Total
	Daylight	Dusk / Dawn	Street Light	Dark	
Straight, Level	238 (249)	15 (22)	5 (6)	205 (187)	463
Straight, Crest	12 (9)	1 (1)	1 (0)	2 (6)	16
Straight, Grade	48 (40)	9 (4)	2 (1)	16 (30)	75
Straight, Sag	16 (13)	1 (1)	0 (0)	7 (10)	24
Curve, Level	235 (250)	28 (22)	6 (6)	197 (188)	466
Curve, Crest	15 (14)	1 (1)	0 (0)	11 (11)	27
Curve, Grade	107 (98)	4 (9)	2 (2)	70 (74)	183
Curve, Sag	20 (18)	2 (2)	0 (0)	11 (13)	33
Total	691	61	16	519	1,287

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.19. Roadway character and light conditions for run off the road left collisions in North Carolina

Road Character	Light Conditions				Total
	Daylight	Dusk / Dawn	Street Light	Dark	
Straight, Level	129 (124)	19 (15)	4 (5)	130 (138)	282
Straight, Crest	9 (7)	0 (1)	0 (0)	6 (7)	15
Straight, Grade	21 (15)	1 (2)	2 (1)	10 (17)	34
Straight, Sag	6 (5)	1 (1)	0 (0)	4 (5)	11
Curve, Level	77 (81)	7 (10)	3 (3)	97 (90)	184
Curve, Crest	2 (4)	1 (0)	0 (0)	5 (4)	8
Curve, Grade	26 (36)	4 (4)	2 (1)	50 (40)	82
Curve, Sag	5 (4)	0 (0)	0 (0)	3 (4)	8
Total	275	33	11	305	624

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.20. Road character and right shoulder width for run off the road right collisions in North Carolina

Road Character	Right Shoulder Width				Total
	0-3 ft.	4-5 ft.	6-7 ft.	8-9 ft.	
Straight, Level	25 (24)	118 (144)	191 (178)	71 (60)	405
Straight, Crest	1 (1)	7 (5)	4 (7)	3 (2)	15
Straight, Grade	1 (4)	44 (26)	19 (32)	9 (11)	73
Straight, Sag	2 (1)	13 (8)	5 (10)	2 (3)	22
Curve, Level	22 (26)	133 (155)	214 (192)	68 (66)	437
Curve, Crest	3 (2)	13 (10)	8 (12)	3 (4)	27
Curve, Grade	14 (11)	82 (64)	68 (79)	16 (27)	180
Curve, Sag	2 (2)	12 (11)	13 (14)	4 (6)	31
Total	70	422	522	176	1,190

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.21. Road character and right shoulder width for run off the road left collisions in North Carolina

Road Character	Right Shoulder Width				Total
	0-3 ft.	4-5 ft.	6-7 ft.	8-9 ft.	
Straight, Level	14 (16)	80 (86)	114 (111)	42 (36)	250
Straight, Crest	2 (1)	8 (5)	3 (7)	2 (2)	15
Straight, Grade	2 (2)	17 (11)	9 (15)	5 (5)	33
Straight, Sag	0 (1)	7 (3)	2 (4)	0 (1)	9
Curve, Level	9 (11)	48 (60)	87 (77)	30 (25)	174
Curve, Crest	2 (1)	4 (3)	1 (4)	1 (1)	8
Curve, Grade	8 (5)	33 (27)	34 (35)	4 (12)	79
Curve, Sag	1 (1)	2 (3)	5 (4)	0 (1)	8
Total	38	199	255	84	576

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.22. Collision type by horizontal alignment in North Carolina

Collision Type	Horizontal Alignment		Total
	Straight	Curve	
Run off Road, Right	578 (773)	709 (514)	1,287
Run off Road, Left	342 (375)	282 (249)	624
Run off Road, Straight	93 (63)	12 (42)	105
Overturn	17 (12)	3 (8)	20
Other in Road	29 (20)	5 (14)	34
Hit Pedestrian/Bicycle	48 (31)	4 (21)	52
Hit Parked Vehicle	28 (17)	0 (11)	28
Hit Animal	376 (252)	44 (168)	420
Hit Fixed Object	31 (24)	9 (16)	40
Hit Other Object	51 (37)	10 (24)	61
Head-on	31 (31)	21 (21)	52
Sideswipe	94 (82)	43 (55)	137
Total	1,718	1,142	2,860

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.23. Collision type by vertical alignment in North Carolina

Collision Type	Vertical Alignment		Total
	Level	Grade	
Run off Road, Right	929 (949)	258 (238)	1,187
Run off Road, Left	466 (465)	116 (117)	582
Run off Road, Straight	93 (84)	12 (21)	105
Overturn	16 (16)	4 (4)	20
Other in Road	25 (23)	4 (6)	29
Hit Pedestrian/Bicycle	43 (40)	7 (10)	50
Hit Parked Vehicle	23 (19)	1 (5)	24
Hit Animal	322 (313)	70 (79)	392
Hit Fixed Object	30 (30)	7 (7)	37
Hit Other Object	47 (46)	11 (12)	58
Head-on	30 (34)	13 (9)	43
Sideswipe	98 (102)	30 (26)	128
Total	2,122	533	2,655

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.24. Collision type by surface width in North Carolina

Collision Type	Surface Width					Total
	LE 18 ft.	19-20 ft.	21-22 ft.	23-24 ft.	25+ ft.	
Run off Road, Right	447 (411)	490 (505)	218 (224)	112 (121)	21 (27)	1,288
Run off Road, Left	198 (199)	232 (245)	122 (108)	62 (59)	10 (13)	624
Run off Road, Straight	31 (34)	47 (41)	15 (18)	11 (10)	1 (2)	105
Overturn	6 (6)	8 (8)	1 (3)	4 (2)	1 (0)	20
Other in Road	9 (11)	16 (13)	4 (6)	2 (3)	3 (1)	34
Hit Pedestrian/Bicycle	11 (17)	28 (20)	6 (9)	3 (5)	4 (1)	52
Hit Parked Vehicle	8 (9)	11 (11)	4 (5)	2 (3)	3 (1)	28
Hit Animal	126 (134)	168 (165)	79 (73)	46 (40)	2 (9)	421
Hit Fixed Object	9 (13)	13 (16)	11 (7)	3 (4)	4 (1)	40
Hit Other Object	19 (19)	27 (24)	9 (11)	5 (6)	1 (1)	61
Head-on	12 (17)	23 (20)	12 (9)	4 (5)	1 (1)	52
Sideswipe	38 (44)	59 (54)	16 (24)	15 (13)	9 (3)	137
Total	914	1,122	497	269	60	2,862

Note: A cell entry is the observed number of collisions (expected number of collisions)

TABLE 6.25. Collision type by right shoulder width in North Carolina

Collision Type	Right Shoulder Width				Total
	0-3 ft.	4-5 ft.	6-7 ft.	8-9 ft.	
Run off Road, Right	69 (71)	422 (424)	523 (499)	176 (196)	1,190
Run off Road, Left	38 (35)	199 (205)	255 (241)	84 (95)	576
Run off Road, Straight	2 (6)	28 (36)	50 (42)	21 (17)	101
Overturn	1 (1)	9 (6)	2 (7)	5 (3)	17
Other in Road	4 (2)	7 (11)	14 (13)	7 (5)	32
Hit Pedestrian/Bicycle	5 (3)	17 (18)	20 (21)	8 (8)	50
Hit Parked Vehicle	4 (2)	10 (9)	9 (11)	3 (4)	26
Hit Animal	8 (22)	141 (130)	126 (153)	91 (60)	366
Hit Fixed Object	5 (2)	12 (13)	15 (15)	4 (6)	36
Hit Other Object	5 (3)	21 (21)	18 (24)	14 (10)	58
Head-on	4 (3)	17 (17)	20 (20)	6 (8)	47
Sideswipe	12 (7)	50 (43)	46 (50)	12 (20)	120
Total	157	933	1,098	431	2,619

Note: A cell entry is the observed number of collisions (expected number of collisions)

CHAPTER 7. DRIVER AND VEHICLE FACTORS

INTRODUCTION

This chapter presents an analysis of driver and vehicle factors involved in collisions on secondary highways conducted by the University of Kentucky (UK) portion of the project team. The findings presented here were based on a collision analysis using the quasi-induced exposure technique. The relationships were developed using a database of collisions from two Southeastern U.S. states, Kentucky and North Carolina. For both collision databases, three years of collisions are used, 1993 to 1995, and only collisions on two-lane, two-way roads with an AADT of less than 5,000 vehicles are considered.

METHODOLOGY

Quasi-Induced Exposure Method

The quasi-induced exposure method allows for determining relative collision involvement for specific characteristics of the driving population, such as driver age and gender, as well as vehicle characteristics, such as vehicle age and type. These groups of interest can then be linked to other collision related parameters, such as time of day, speed limit, road surface, lane width, shoulder width, and degree of curvature to identify the factors that contributed to collisions. Collision rates disaggregated into such categories are useful metrics for establishing the relative safety among groups and provide invaluable direction for policy development aimed at improving highway safety. Although computerized databases yield sufficiently accurate estimates of the frequencies of collisions sub-divided by many of these characteristics, correspondingly accurate estimates of collision exposure are often difficult or impossible to make. Moreover, investigators disagree about which exposure measure is most appropriate for each specific application. The traditional methods are based on estimating the amount of vehicle-miles traveled by multiplying the AADT by the length of the roadway. However, the use of VMT's calculated in this manner prohibit the development of exposure metrics for other variables of interest such as specific times of day, driver and vehicle characteristics, as well as the geometric features discussed above.

To overcome some of the problems and limitations in estimating exposure by driver and vehicle type from exogenous values such as travel distance, drivers licensed, and vehicles registered, methods have been developed that derive exposure estimates from the collision database itself. These techniques are coming into more widespread use, and have recently been validated against more conventional techniques.(71) The induced exposure techniques have been developed specifically to obtain first-order approximations of relative travel by different classes of road users, and are acceptable surrogates for vehicle-miles of travel when estimates are made for conditions (facility type and time) during which the mix of road users is relatively constant. The approach is ideal for application to low-volume roads where the assumption with respect to facility type is valid.

The extent of collision hazard also depends on the driving environment including factors such as facility type, time of day, and climatic conditions. In highly aggregated analyses, exposure estimates are biased toward conditions under which multi-vehicle collisions are more frequent for example, during the high volume conditions of rush hour travel. In addition, confounding factors, such as time of day and collision location, can mask the exposure of specific driver/vehicle classes and lead to inaccurate estimates. For instance, younger drivers will more likely be found on urban roads during nighttime on weekends than on rural roads during daytime on weekdays. To avoid such bias, and to assure that exposure estimates closely reflect presence on the roadway, disaggregated analysis is necessary. Therefore, disaggregation of the collision data was implemented in this study to account for these confounding effects.

One final interactive effect which has not received adequate prior attention is the differences over time among the types of drivers and vehicles that use different elements of the roadway system(72) For example, it is reasonable to assume that younger drivers are more likely to comprise a larger proportion of the driving population on local streets during weekend nights than on interstates during rush hour periods. These kinds of differences are not accurately represented by traditional aggregate exposure metrics, such as total VMT, because of the difficulty in collecting the large amount and variety of necessary data. The use of induced exposure can provide an alternative means to achieve this stratification of data over location and time, and as a result, can reflect the differences in driver/vehicle characteristics for each such combination.

Relative Collision Rates

To proceed with the collision analysis, collision propensities for different driver and vehicle characteristics are required. The measure of the collision propensity used in the quasi-induced exposure methodology is the relative accident involvement ratio (RAIR) defined as the ratio of the percentage of at-fault drivers/vehicles for a given set of characteristics to the percentage of not-at-fault drivers/vehicles for the same set of conditions. Therefore, to determine both the collision proneness and the collision exposure, the driver/vehicle for each collision should be categorized into one of the following three basic groups: 1) drivers/vehicles of single-vehicle collisions, 2) drivers/vehicles at-fault in two-vehicle collisions, and 3) drivers/vehicles not at-fault in two-vehicle collisions. Collisions involving two at-fault drivers, no at-fault drivers or three or more vehicles are disregarded in this type of data analysis, since they could introduce a bias. Also, these groups of collisions constitute only about 7 percent of the total number of collisions.

Given this basic categorization, single- and multi-vehicle collision rates are computed. For single-vehicle collisions, the collision rate is defined as the ratio of drivers/vehicles in single-vehicle collisions for a given set of conditions to drivers/vehicles of the same set of conditions of the not responsible drivers/vehicles in two-vehicle collisions. This ratio will be denoted as RAIRs in the following. For two-vehicle collisions, the ratio is defined as described above (ratio of driver/vehicle at-fault to the driver/vehicle not-at-fault) and will be noted as RAIRm. These ratios are used as a measure of relative collision propensity for different groups of drivers and vehicles, and values greater than 1.0

indicate a higher likelihood of collision involvement for that group.

As stated above, the quasi-induced exposure method allows for developing an accurate means for identifying risk factors most likely to be associated with rural road collisions. These factors may include driver age and gender groups, vehicle type and age groups, and geometric characteristics. Moreover, using the risk factors identified, countermeasures can be developed aiming to reduce the large number of collisions occurring on secondary highways. Such countermeasures may include education of certain driving populations, enforcement of traffic laws, and correction of roadway hazards that lead to rural road collisions.

DATA COMPILATION

A set of criteria that define the secondary, low-volume roads to be included in this research were defined by the research team of the University of Kentucky (UK), North Carolina State University (NCSU), and the University of North Carolina (UNC). The collision databases of Kentucky and North Carolina were used for this chapter, and a common three-year period, 1993-1995, was chosen for collisions occurring on two-lane, two-way, non-interstate roads with an AADT of less than 5,000 vehicles. The Kentucky database, used in the quasi-induced exposure analysis, consisted of collisions occurring in all counties in Kentucky within the criteria defined. It was compiled using three sources of data: 1) the Kentucky State Police Collision Database, 2) the Highway Inventory System (HIS) geometric information, and 3) the state AADT data. The UNC team provided a similar database to the UK team, from FHWA's HSIS, for collisions occurring in the entire state of North Carolina. These two data sets formed the basis for the quasi-induced analysis.

Table 7.1 shows the considerable difference in the number of collisions that occurred in each state during the three-year time period. The lower number of collisions in Kentucky is attributed to the fact that geometric information is not readily available for all roadways. The geometric data found in the Highway Inventory System (HIS) file was available only for state-maintained roads, so the number of usable collision records was greatly reduced. The state-maintained roadway system makes up only 23,700 of Kentucky's 72,900 statewide roadway miles, so it appears that this process omits the majority of the roadway system in Kentucky. Unfortunately, the non-state-maintained roads are typically the county and city secondary roads that are important to this study. However, 84 percent of the highway travel in Kentucky occurs on the state-maintained system. So, while the HIS matching process does eliminate a large portion of the roadway mileage, most of the travel is retained.

TABLE 7.1. Number of collisions occurring in each state between 1993 and 1995

	Kentucky	**North Carolina**
Single-Vehicle Collisions	32,452	53,379
Two-Vehicle Collisions	24,186	42,196
Total	56,638	95,575

As shown in Table 7.1, the number of collisions in the Kentucky database is only about 60 percent of the number of collisions in the North Carolina database. However, the Kentucky sample size is adequate for completing a quasi-induced exposure analysis. Most of the roads in North Carolina are state-maintained, so the matching of geometric data presented less of a problem for the North Carolina data. An examination of the split between single- and two-vehicle collisions between the two states indicates that both states have approximately the same ratios. Single-vehicle collisions make up 57 percent of the total Kentucky collisions and 56 percent of the total North Carolina collisions.

RESULTS

The RAIR analysis technique was used to evaluate disaggregated groups of data from collisions that occurred on rural roads in Kentucky and North Carolina. The analyses considered the independent variables of driver age, driver gender, vehicle type, and vehicle year and how they were affected by a number of confounding factors, such as speed limit, shoulder and lane width, curvature class and roadway volume. The North Carolina and Kentucky databases do not include all of the same data elements, so it was impossible to perform a complete analysis of all of variables for both states. Similarly, while conclusions may be drawn about collision trends within each state, it was not always possible to compare one confounding variable trend in one state with the same variable trend in the other state. The results for each independent variable are presented in the following sections of the report, with comparisons where possible. Statistical tests were performed using logistic regression using a 95 percent confidence interval.

Driver Age

The independent variable of driver age was considered for both Kentucky and North Carolina collision data. Drivers were grouped in seven age groups using ten-year intervals, and the oldest group of drivers included those ages 75 and above. The single-vehicle collision ratios, shown in Figure 7.1, indicate that a direct trend of decreasing collision risk with increasing driver age is observed for both states. Drivers under the age of 25 have a higher collision ratio than any other group of drivers, so these drivers are more likely to be involved in an collision on secondary roads than any age group of drivers. Also, middle-aged drivers are less likely to be involved an collision, and a small increase in collision risk is seen in drivers over 75 years for single-vehicle collisions.

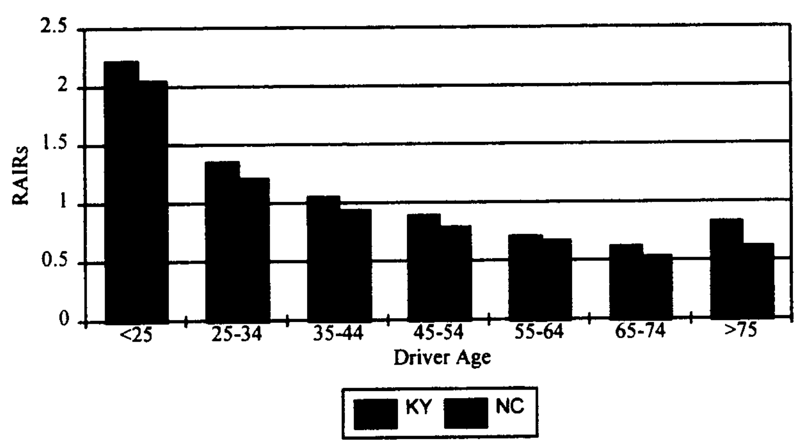

FIGURE 7.1: Single-vehicle accident ratios by driver age

Figure 7.2 shows a general U-shaped curve for the ratio (RAIRm) of two-vehicle collisions for both Kentucky and North Carolina data. This trend is typical of an age-related distribution of two-vehicle collisions, where younger and older drivers experience higher involvement ratios compared to middle-aged drivers. These findings were statistically significant with respect to age indicating a higher likelihood for younger and older drivers to be involved in collisions in rural, secondary roads compared to drivers between 35 and 64 years of age.

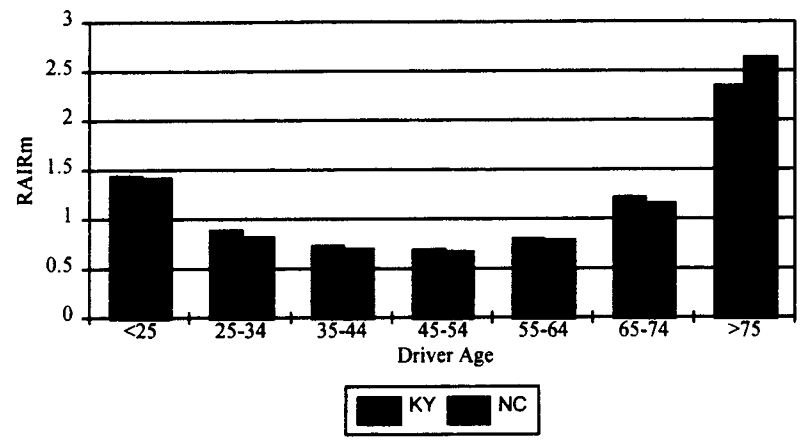

FIGURE 7.2: Two-vehicle accident ratios by driver age

The independent variable of driver age was also evaluated by several confounding factors such as speed limit, lane width, shoulder width, curvature, and AADT. The general trends of the age analysis conformed to prior trends, and to maintain adequate sample sizes, the drivers were grouped in four age groups when considering these confounding variables. Speed limit data were available only for North Carolina. By examining these data for the single-vehicle collisions in Figure 7.3, one can observe that, in general, higher speeds lead to larger ratios. In other words, drivers tend to be involved in more collisions when driving on roads with higher posted speed limits. The statistical test showed that age differences are greater for higher speeds, confirming the observations noted for these data. Also, younger drivers have the highest ratios at any speed limit when compared to other age groups, and they exhibit the highest ratio for collisions on roads with speed limits over 45 mph.

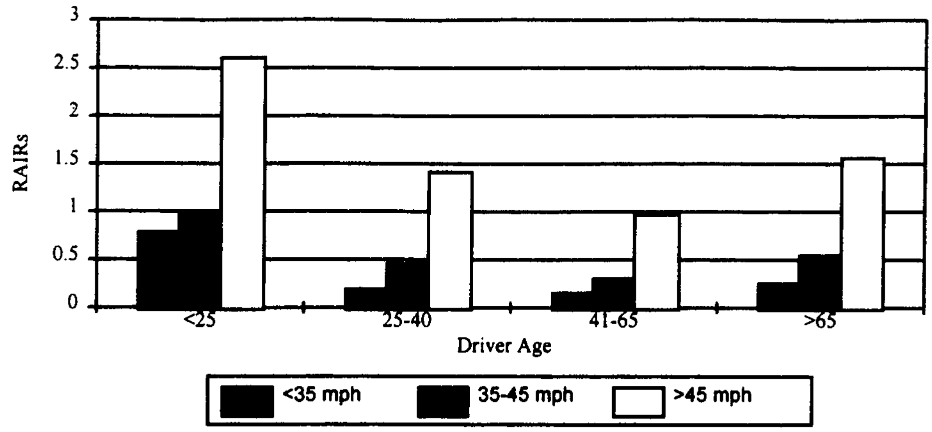

FIGURE 7.3: Single-vehicle accident ratios by driver age and road speed limit (NC data)

Figure 7.4 shows the general U-shaped trends for the two-vehicle collisions versus the speed limits on North Carolina roads. The large age differences noted for the higher speed limits in the single-vehicle collisions were absent from these data, and the statistical tests showed that speed limit had no effect within any age group. The age differences were also noted here, but they were independent of the posted speed limit of the roadway. Therefore, it could be concluded that the speed limit does not have a significant effect on two-vehicle collisions, but it contributes to single-vehicle collisions of younger drivers.

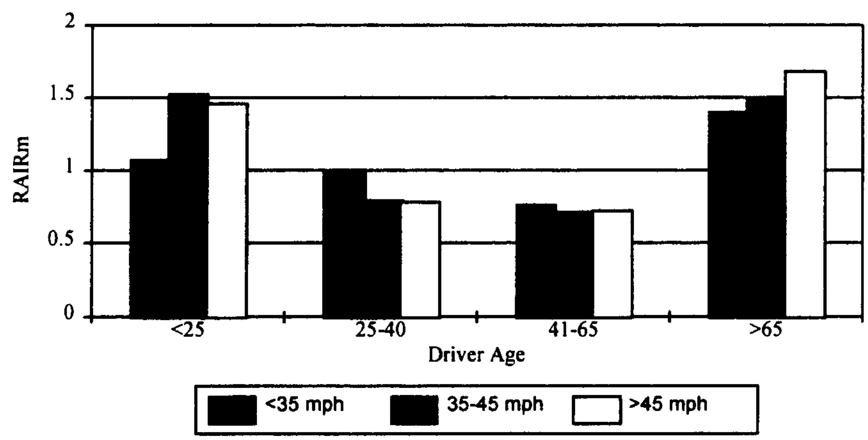

FIGURE 7.4: Two-vehicle accident ratios by driver age and speed limit (NC data)

A number of geometric data were also evaluated for rural secondary roads in Kentucky. The corresponding data for the North Carolina data set were not available for evaluation. Figure 7.5

demonstrates the RAIRs for three categories of lane width and four driver age groups. Three classes of lane width were used in the analysis, and the data in Figure 7.5 indicate that the collision propensity decreases as the lane width increases. This trend is expected, since wider pavement provides drivers with a greater margin of error regarding vehicle placement. Younger drivers had the highest ratios in the narrowest lanes, indicating that lane width is more of a contributing factor for these drivers than other age groups.

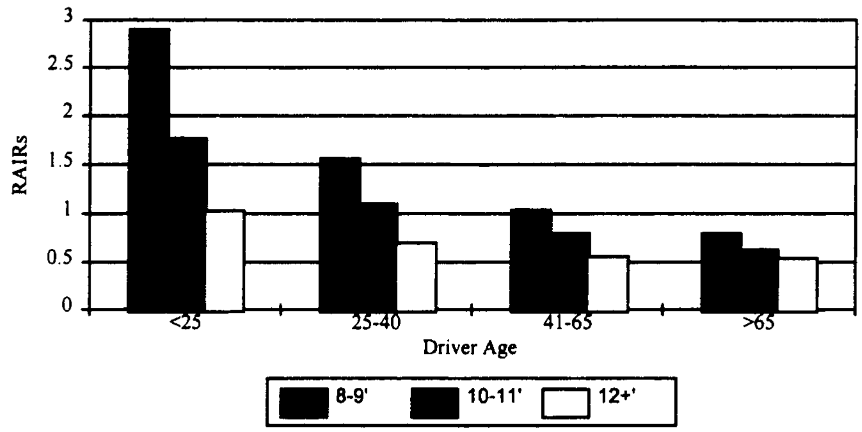

FIGURE 7.5: Single-vehicle accident ratios by driver age and lane width (KY data)

The ratios of multi-vehicle collisions shown in Figure 7.6 indicate that the age differences were slightly greater for wider lanes where older drivers had higher collision ratios than younger drivers. These differences were attributed primarily to the age differences as opposed to the lane width because within each age group, the lane width did not have a statistically significant contribution to the collision ratios. Thus, for rural, secondary roads, lane width is much less of a contributing factor in two-vehicle collisions.

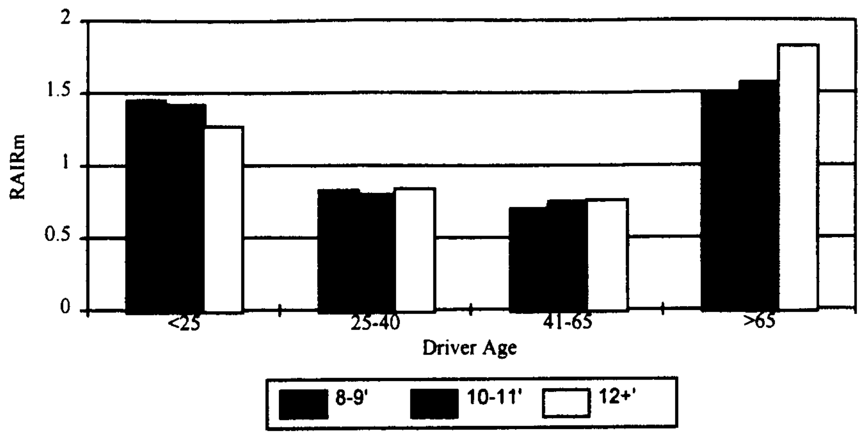

FIGURE 7.6: Two-vehicle accident ratios by driver age and lane width (KY data)

The effect of shoulder width on the collision propensities of drivers was examined using only the Kentucky data because the North Carolina data were not available. In general, the ratios for single-vehicle collisions indicate that drivers experience lower ratios for shoulders less than one foot wide and more than five feet wide. This finding, statistically significant for all age groups except the oldest drivers, does not conform to prior expectations where the collision risk should decrease with increasing shoulder width. A possible explanation for such a trend may be that drivers are more cautious on roads with no shoulders, but drive in a more careless manner on roads with shoulders two to five feet wide. Also, roads with shoulders wider than five feet showed no statistical age differences, indicating an adequate level of safety level for such roads. The statistics indicate that there are age differences for all shoulder widths where younger drivers are more likely to be involved in a single-vehicle collision. Furthermore, these differences diminish with increasing age.

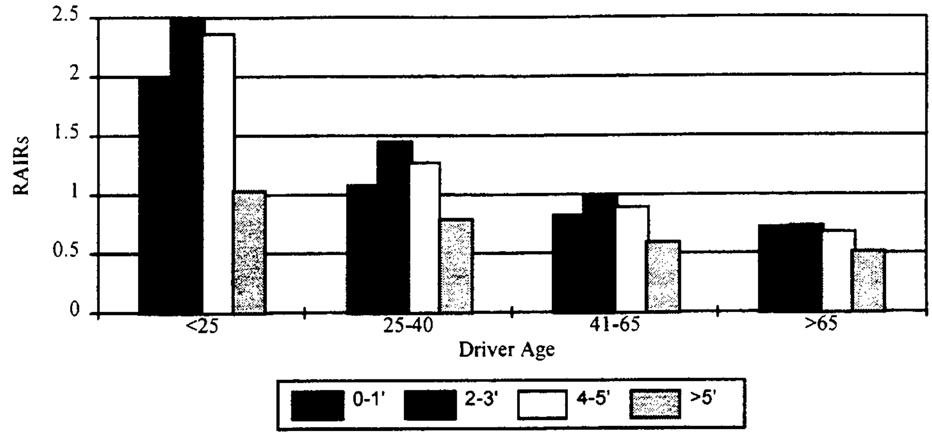

FIGURE 7.7: Single-vehicle accident ratios by driver age and shoulder width (KY data)

Even though age differences are noted for two-vehicle collisions, as shown in Figure 7.8, these differences are independent of the shoulder width. Within each age group of drivers, no statistical differences are noted for any of the four categories of shoulder width. This suggests that this factor does not have a significant contribution to two-vehicle collisions, and is contrary to single-vehicle collision ratio trends.

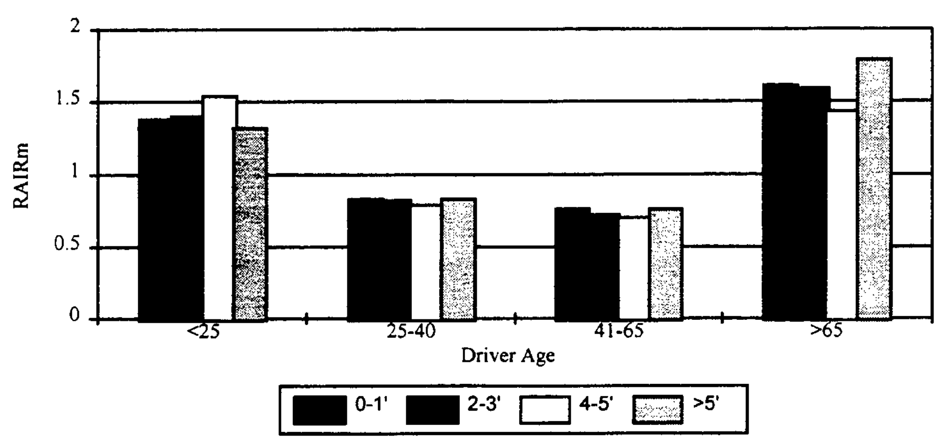

FIGURE 7.8: Two-vehicle accident ratios by driver age and shoulder width (KY data)

The relationship between driver age and the degree of roadway curvature was also examined. The degree of curvature is lower for smooth curves and higher for sharp curves. The first category used in this analysis includes basically straight segments of roadway, and the other three categories represent increasing levels of sharpness. The data for single-vehicle collisions in Figure 7.9 represent a mixture of prior expectations and unconventional results. While it is expected that straight segments will have lower ratios than curved segments, the sharpest curves had significantly lower ratios compared to the other two categories of curves. In addition, the proportional relationship between sharpness of curve and collision ratios is noted for the transition from the straight segments to curves, but is not present for the sharpest curves. As for the shoulder width, a possible explanation may be that the 19+ degrees curves are sharp enough to demand closer attention by the driver. The general age differences are noted here as well. Younger drivers have larger ratios compared to older drivers. Also, older drivers seem to have more problems negotiating sharper curves than younger drivers, resulting in higher collision ratios.

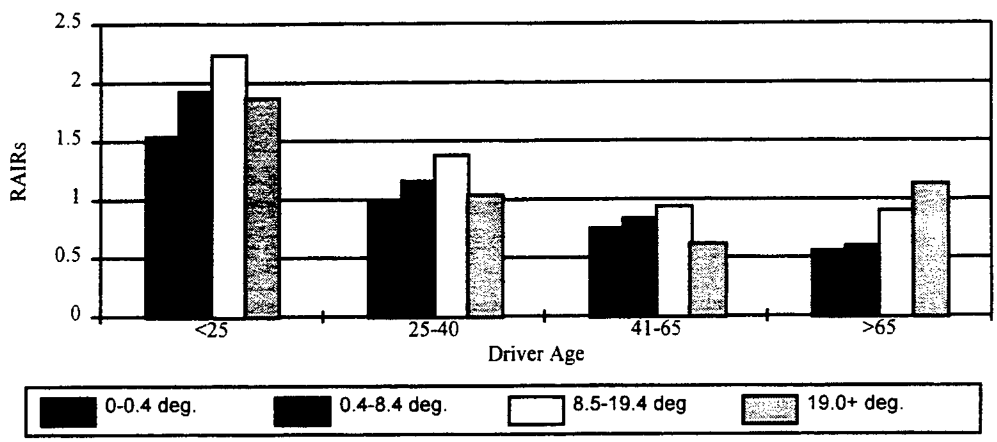

FIGURE 7.9: Single-vehicle accident ratios by driver age and degree of curvature (KY data)

The analysis of the two-vehicle collision ratios versus the degree of curvature in Figure 7.10 showed no statistical differences except in the oldest age group. The differences in the various degrees of curvature for the older group of drivers are opposite to intuitive expectations. The sharper the curve, the lower the ratio, with the exception of the sharpest curves where an increase is noted. It is possible that older drivers are more careful as the curves become sharper, but they may have a problem dealing with the sharpest curves.

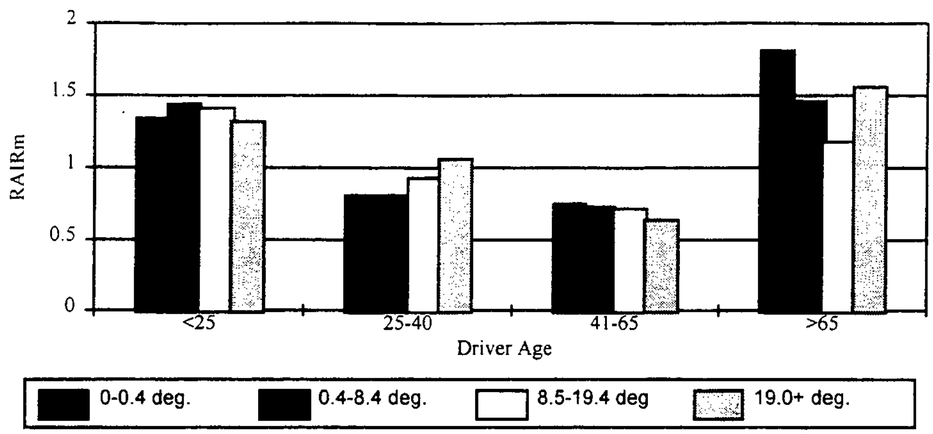

FIGURE 7.10: Two-vehicle accident ratios by driver age and degree of curvature (KY data)

The effect of the traffic volume on the secondary roads on the collision propensities was then examined. Only the North Carolina data were used because the Kentucky database has small sample sizes when split into five AADT categories. The single-vehicle data, in Figure 7.11, are consistent with expectations. As the traffic volume increases, the single vehicle collision propensity decreases and the propensity to be involved in a multi-vehicle collision increases. Age differences are noted here as well and slight differences for the AADT are present. Larger traffic volumes lead to lower ratios, most likely due to increased attention while driving. These differences were more obvious for the younger drivers compared to the older drivers.

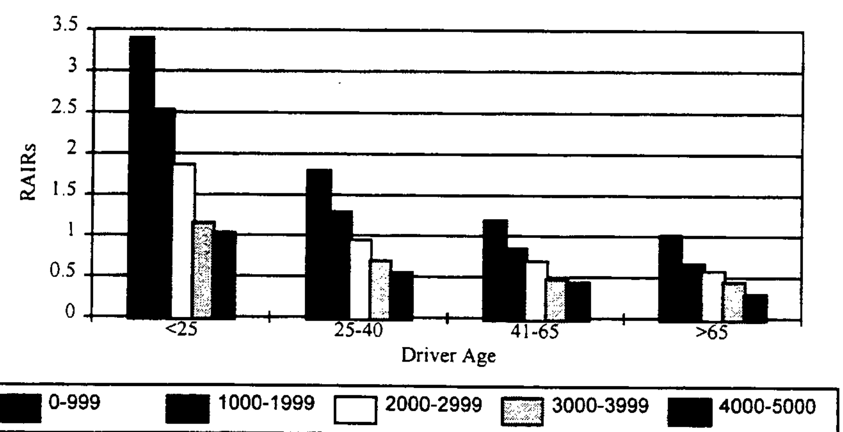

FIGURE 7.11: Single-vehicle accident ratios by driver age and AADT (NC data)

Even though age differences are present for the two-vehicle collisions, Figure 7.12 shows that no statistical differences were observed among the traffic volume categories. However, differences were noted for the older drivers with respect to traffic volumes, where higher involvement rates were observed for roads with an AADT range between 1,000 and 4,000 vehicles. One possible explanation for this trend is increased driver attention on roads with higher traffic volumes.

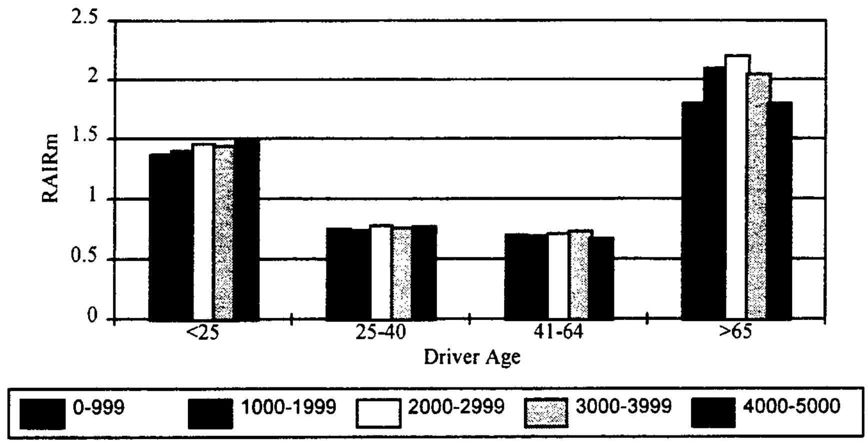

FIGURE 7.12: Two-vehicle accident ratios by driver age and AADT (NC data)

The time of the collision was another factor of interest in the analysis of collisions on secondary highways. Figure 7.13 shows that in single-vehicle collisions, younger drivers had significantly higher collision ratios for nighttime collisions compared to collisions during the day. Also, time differences were noted for all drivers, indicating that a single-vehicle collision is more likely to occur at night.

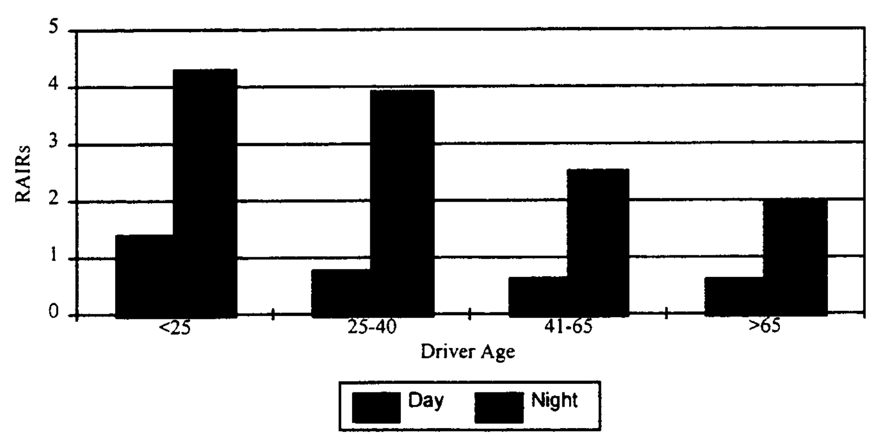

FIGURE 7.13: Single-vehicle accident ratios by driver age and time of accident

Figure 7.14 shows that all age groups showed lower collision ratios for nighttime collisions in two-vehicle collisions. This trend was expected because larger traffic volumes are frequently encountered during the day. The significantly higher ratio of younger drivers for single-vehicle collisions at night was also expected.

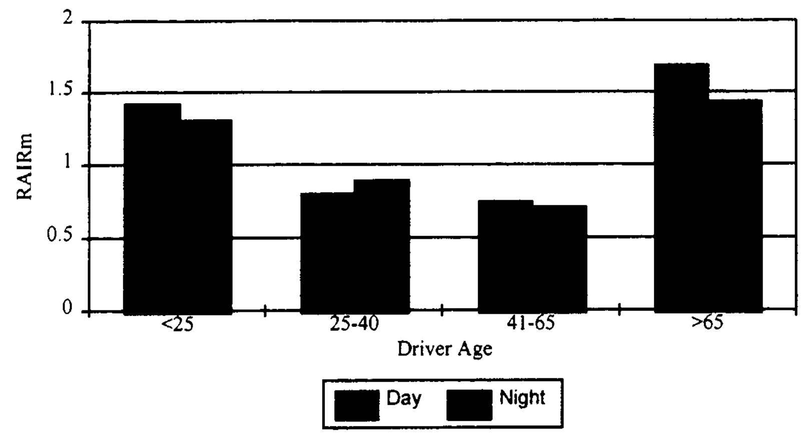

FIGURE 7.14: Two-vehicle accident ratios by driver age and time of accident

Driver Gender

The gender of the driver was another independent variable of concern in this research effort, and can provide additional information about the factors contributing to collisions. The data for Kentucky and North Carolina were used in this analysis. In general, the single-vehicle data indicate that females have lower collision involvement ratios than males as shown in Figure 7.15. This trend is true for both states, but women in North Carolina had a lower collision propensity than women in Kentucky. To further explore this relationship, additional personal information about the drivers involved such as socio-economic status, driving record or other personal information would be required. Similar trends were also noted for two-vehicle collision ratios where males have higher involvement ratios than females, and North Carolina female drivers had lower ratios than Kentucky female drivers.

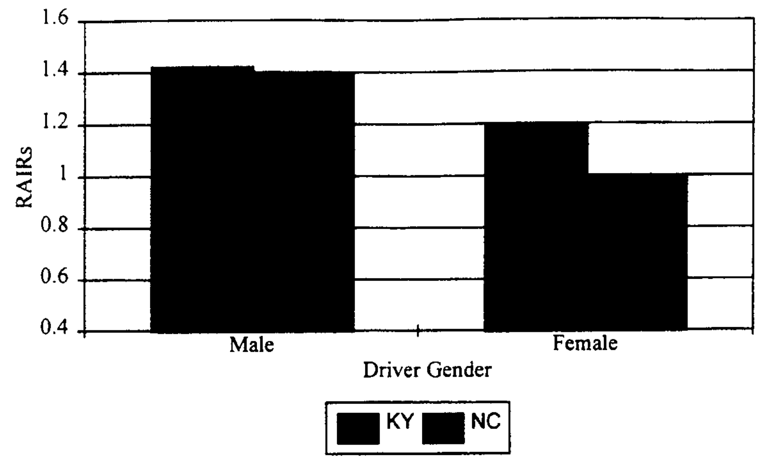

FIGURE 7.15: Single-vehicle accident ratios by driver gender

The relationship between the age and gender of the driver was examined using data from both states. Figure 7.16 indicates that age and gender differences exist for single-vehicle collisions, and are more profound for the younger drivers than any other age group. In general, females tend to have collision rates lower than males with respect to single-vehicle collisions on secondary, rural roads.

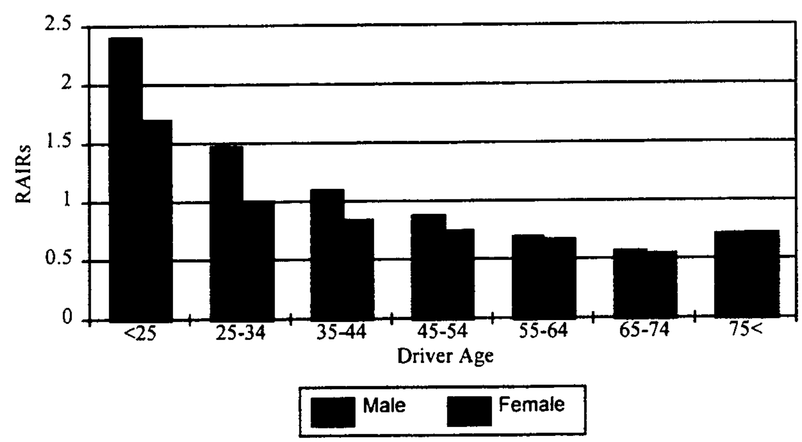

FIGURE 7.16: Single-vehicle accident ratios by driver gender and age

Similar age and gender differences were also noted in two-vehicle collisions, as shown in Figure 7.17. Three general trends were noted: 1) younger males had higher RAIR than younger females, 2) older females had higher RAIR than older males, and 3) there are no statistically significant gender differences between middle-aged drivers. These findings are consistent with previous research, and demonstrate that the gender and age factors are no different on low-volume, secondary roads than other roadways.

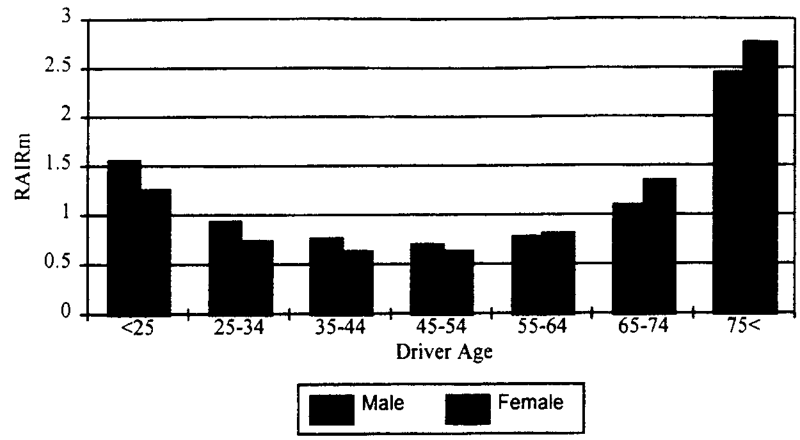

FIGURE 7.17: Two-vehicle accident ratios by driver gender and age

The same factors described previously in the driver age analysis were also considered here, and the results followed the general patterns established earlier. In general, female drivers tend to have lower collision ratios than males for both single- and multi-vehicle collisions. These differences were statistically significant for all variables tested: roadway speed limit, lane width, shoulder width, degree of curvature and AADT. These differences were especially profound for single-vehicle collisions, where males tend to have much higher collision ratios.

Vehicle Age

Over the past decades, significant improvements have been made in the motor vehicle industry with respect to vehicular safety. A number of new safety devices have been introduced, such as anti-lock brakes and third brake lights, which may contribute to collision reduction. It is reasonable to assume that older vehicles lack recent safety technologies and may pose a serious safety problem. Also, given the rural nature of the southeast, and low-income levels, it is likely that a larger fleet of older vehicles may be encountered in rural areas in this part of the country.

An analysis was completed by first grouping the vehicle age into four categories. Collisions involving vehicles more than 25 years old accounted for only 1 percent of the total in Kentucky and 3 percent in North Carolina. In both states, 56 percent of the vehicles were between 5 and 14 years old, and 30 percent of the Kentucky collisions and 32 percent of the North Carolina collisions involved vehicles less than 5 years old. Even though the vehicle age distribution is approximately the same for both states, the collision propensities for single-vehicle collisions, shown in Figure 7.18, indicate different trends. While there is little difference by vehicle age for the Kentucky data, except for the very old vehicles, the North Carolina data show an increase in single-vehicle collision involvement as the vehicle fleet becomes younger. One explanation for the stability of the Kentucky data and the increase of the collision involvement of North Carolina data could be that drivers change their safety margin. One can hypothesize that the driver sets the level of safety and risk level based on the vehicle. Upon purchasing a newer vehicle with additional safety margins, the acceptable level of safety and risk increases and he or she tends to drive in a more risk-prone manner. The conditions under which single-vehicle collisions occurred were likely more conducive to taking chances and testing the limits of the accepted safety and risk level set by the driver.

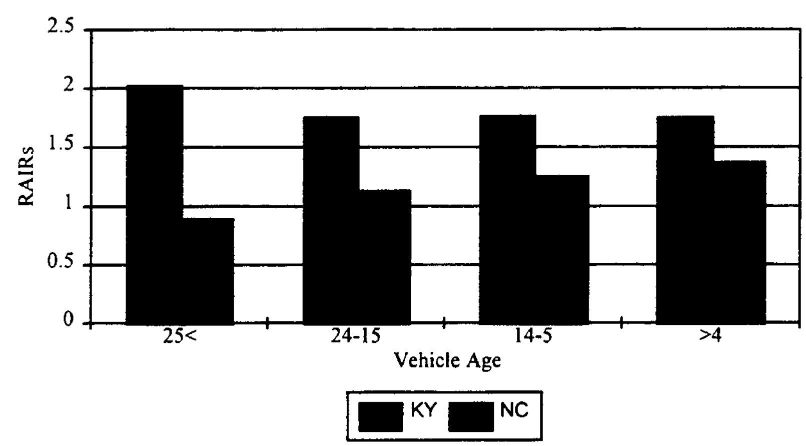

FIGURE 7.18: Single-vehicle accident ratios by vehicle age

The hypothesis stated above is further supported by the two-vehicle collision ratios of the vehicle age, as shown in Figure 7.19. The data indicate that involvement decreases as the vehicles become newer. These differences were statistically significant for the North Carolina data, but not for the Kentucky data. This trend conforms to prior expectations where newer vehicles generally have a safer collision trend than older vehicles.

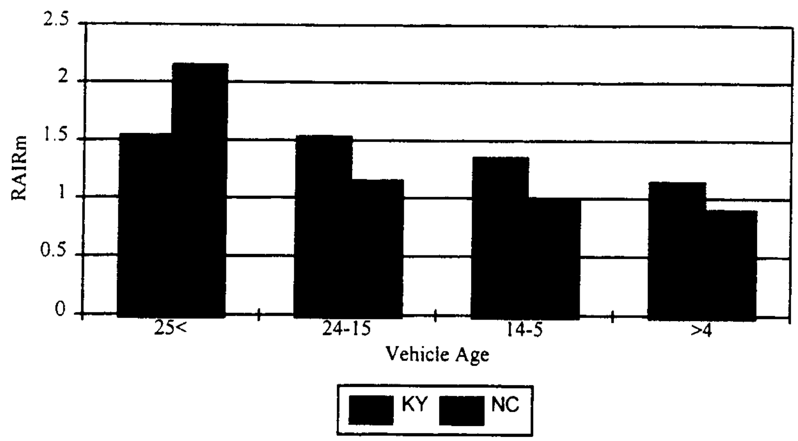

FIGURE 7.19: Two-vehicle accident ratios by vehicle age

The next analysis examined the relationship between driver age and vehicle age, shown in Figure 7.20. The single-vehicle data showed that the most dangerous combination was a young driver with a new vehicle. The middle-aged drivers did not show any significant differences by vehicle age, but older drivers had an improving safety trend with newer vehicles. These trends were somewhat consistent with prior expectations. Younger drivers have significantly higher collision ratios with older vehicles as well, which may attributed to inexperience and risk-taking behavior. Even though it is expected that newer vehicles will improve the overall safety levels, it was reasonable to assume that drivers with the most driving experience were more capable of capitalizing on such improvements, and it is encouraging to detect this pattern in these data.

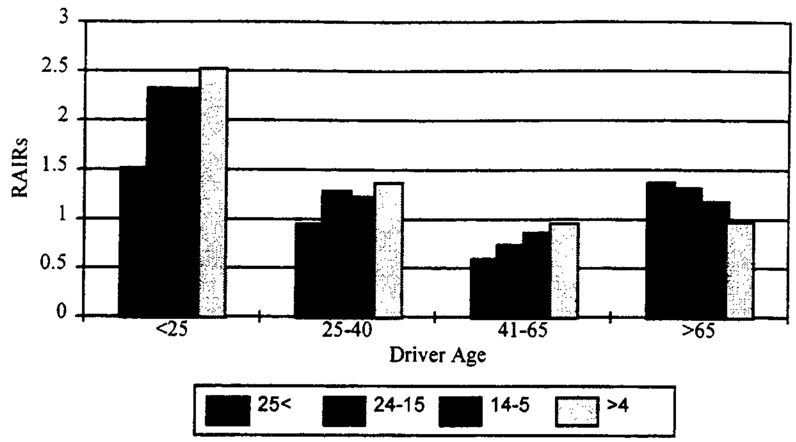

FIGURE 7.20: Single-vehicle accident ratios by driver age and vehicle age

The two-vehicle collision ratios showed the general U-shaped distribution across driver ages as expected in Figure 7.21. Younger and older drivers had differences with respect to vehicle age, where both groups exhibited an improving trend with newer vehicles. The trend for older drivers was consistent with the trend observed for single-vehicle collisions, but the improving trend of younger drivers may be attributed to a different driving manner. Younger drivers may be more cautious with new vehicles when other vehicles are present. A number of other confounding variables tested with vehicle age did not produce any significant results.

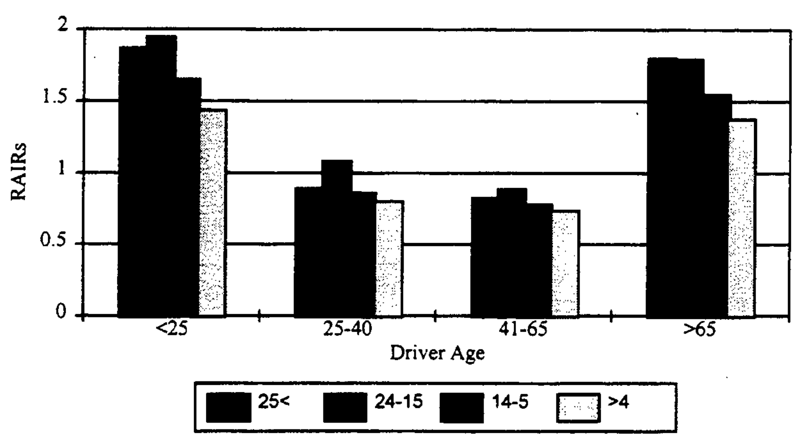

FIGURE 7.21: Two-vehicle accident ratios by driver age and vehicle age

Vehicle Type

Vehicle type was also of concern in analyzing collision data. Previous research indicated that passenger cars and heavy vehicles have different characteristics and varied collision involvement(71) The analysis performed was based only on North Carolina data because the Kentucky data showed that almost all vehicles involved (85%) were passenger cars, and no other vehicle type produced a sample large enough to be statistically acceptable. The collision ratios for North Carolina data, in Figure 7.22, indicate that passenger cars are more likely to be involved in single-vehicle collisions. On the other hand, larger vehicles exhibited a higher propensity to be involved in two-vehicle collisions. These trends agree with prior expectations because larger vehicles were more likely to hit other vehicles on narrow secondary roads, but smaller vehicles were more likely to be involved in single-vehicle collisions. No other trends were examined using this variable due to sample size limitations.

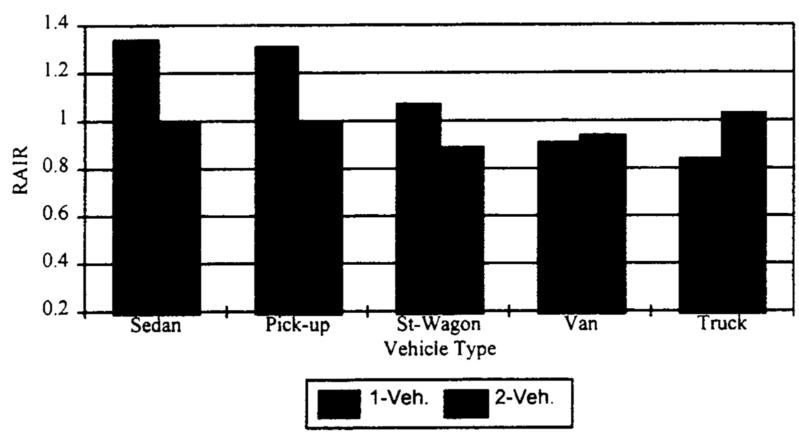

FIGURE 7.22: Accident ratios by vehicle type (NC data)

SUMMARY

The relative collision propensity of drivers, grouped by age and gender, and vehicles, grouped by age and type, was examined. The primary results have been presented in this chapter. The analysis was performed using the quasi-induced exposure technique that identified driver and vehicle groups that were most at risk of being involved in a collision on secondary, rural, low-volume roads. Specific findings and conclusions include the following:

1. In general, the collision trends observed for secondary roads in Kentucky and North Carolina were similar to trends observed on other roads. The only significant difference was the higher collision ratios of younger drivers, particularly for single-vehicle collisions.
2. Young drivers, under the age of 25, had higher collision ratios for single-vehicle collisions than any other group of drivers.
3. The general trend of age differences was noted for collisions on secondary roads. Middle-aged drivers were safer than younger drivers who were safer than older drivers.
4. For single-vehicle collisions, the differences among age groups were larger for collisions that occurred at night and on roadways with high speed limits, narrow lanes, both narrow and wide shoulder widths, sharp curves and low-volume roads. In general, younger drivers were the least safe age group under all of these conditions.
5. The data showed that drivers tend to drive more carefully on roads with no shoulder or with sharp curves than on less dangerous segments. These data indicate that drivers may drive safer in adverse traffic environments, but they drive less carefully in safer environments.
6. Single- and two-vehicle collision analysis showed that older drivers were less safe than younger and middle-aged drivers on roads with sharp curves.
7. For two-vehicle collisions, driver age differences were present and stronger than the roadway speed limit, lane and shoulder width and roadway curvature. The data analyzed show that these factors did not significantly affect the occurrence of two-vehicle collisions on secondary, low-volume roads.
8. Female drivers were safer than male drivers. Younger female drivers were safer than younger male drivers, but older male drivers were safer than older female drivers. Female drivers from North Carolina had lower collision ratios than their Kentucky counterparts.
9. Newer vehicles were more likely to be involved in single-vehicle collisions and were more likely to be driven by younger drivers.

10. Older drivers were more likely to benefit from the increased safety levels of newer vehicles.

11. Larger vehicles were more likely to hit other vehicles on narrow secondary roads, and smaller vehicles were more likely to be involved in single-vehicle collisions.

Based on these findings, a series of potential countermeasures are possible to improve the traffic safety of secondary, low-volume roads. Most of the findings indicated that younger drivers had higher collision ratios in all traditional geometric features of such roads: sharp curves, narrow lanes, no shoulders, and high speed limits. Driver education is a reasonable countermeasure for improving the safety of these drivers. Specific programs that focus on the problems of secondary roads, and their potential for single-vehicle collisions, are required to increase the awareness of young drivers. However, experience is an important factor in improving driving habits and learning safe driving techniques. Unfortunately, there is not much that safety engineers can do in this area. This is a problem that young drivers face, and will continue to face, while driving in any roadway.

Most of the countermeasures should focus on addressing the issue of single-vehicle collisions because more than half of the collisions on secondary roads involve only one vehicle. Short-term solutions should focus on increased driver education and lowering speeds on certain roadway segments. Long-term solutions include geometric improvements such as increasing lane and shoulder widths and eliminating sharp curves.

A number of socio-economic characteristics may explain some of the problems on secondary roads. Obviously, older vehicles are less safe than newer vehicles, and the age of the vehicle is closely tied to a variety of social factors. The data here showed that the age of the vehicle is inversely proportional to the single-vehicle collision involvement and directly proportional to two-vehicle collision involvement. While newer vehicles have many safety features compared to older vehicles, this could reduce the safety margins set by the driver. This is particularly true for younger drivers in single-vehicle collisions. These facts could also be presented within a driver education program, where the potential perils of new vehicles could be demonstrated. Older vehicles present the opposite problem, where antiquated vehicles still drive on secondary, low volume roads. Vehicle inspection programs may be an effective countermeasure, where vehicles with safety-related deficiencies could be identified.

The second phase of this research will identify additional countermeasures using socio-economic and driver characteristics. These variables could further explain and substantiate the trends presented here. The quasi-induced exposure method used here will assist in determining the target groups for such countermeasures, defined by geography, demographics, personal characteristics and roadway characteristics.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The states in the Southeastern United States have some of the highest collision and fatality rates in the country. The main goal of this study was to examine the factors that influence collisions on secondary highways in these states. The database included reported collisions in two counties in North Carolina, Tennessee and Kentucky, which occurred between 1993 and 1995 on roads with AADT up to 5,000 vehicles. Contingency tables were developed from the data for various factors, and the actual numbers of collisions were compared to the expected numbers of collisions to identify important factors and draw conclusions.

The first step was to complete a review of the extensive available literature. It is clear that the profession knows a great deal about which factors contribute most to collisions, and which countermeasures are most effective against specific problems. The key findings from the literature review include:

- Collisions involving heavy trucks are rare, but collisions involving animals is a growing problem, even though humans are rarely injured in these collisions.
- Models exist for predicting collisions on two-lane roads given certain roadway characteristics, but these models are not widely accepted.
- Many factors influence collision frequency on segments and at intersections on two-lane highways.
- Lighting and paving rural roads are potentially effective countermeasures.

A general overview of the collision databases of all three states is presented in Chapter 4. A summary of the important findings include:

- Collisions that occurred at intersections resulted in more injuries, but fewer fatalities, than collisions that occurred along segments.
- Rear-end, single-vehicle and sideswipe collisions were over-represented in the rain.
- Heavy trucks and motorcycles were over-represented in collisions that resulted in fatalities.
- Single-vehicle collisions were over-represented among fatal collisions, and also at night, at bridges, underpasses and along segments.

Chapter 5 presents the analysis of intersection- and driveway-related collisions. Collision types that are typically associated with intersections and driveways include turning, backing, rear-end and angle collisions. The notable trends in these data were:

- Rear-end collisions were over-represented on straight segments, bridges and underpasses.
- Driveways were problematic for turning and backing collisions.
- Angle collisions were over-represented among fatal collisions.

Chapter 6 summarizes the analysis of segment-related collisions. These collisions include: run-off the road, animal, head-on overturn and sideswipes. Many factors were analyzed, and the conclusions were:

- Collision frequency is highest during autumn, on weekends and in the late afternoon or evening hours.
- Most of the collisions were 'run-off road', so countermeasures focusing on these collisions have great potential benefit.
- A significant percentage of the collisions were 'hit animal', but these appeared to be fairly random and it may be difficult to recommend effective countermeasures.
- Collisions were over-represented on curves, and in all three states, the horizontal alignment of the roadway had a larger influence on the collisions than the vertical alignment.

Chapter 7 explored the quasi-induced exposure method to determine if certain driver or vehicle classes had higher collision propensities than others. The quasi-induced exposure method is powerful and easy to use with the collision databases. The key findings were:

- In general, younger and older drivers were over-involved in all collisions, and middle-aged drivers were the safest age group.
- Female drivers were slightly safer then male drivers.
- Newer vehicles were more likely to be involved in single-vehicle collisions, and were more likely to be driven by younger drivers.
- Larger vehicles were more likely to be involved in multi-vehicle collisions than smaller vehicle classes.

Many interesting and useful conclusions were reached during the Phase I research effort. The next step is to complete Phase II of the project, which concentrates on identifying hazardous sites and recommending effective countermeasures.

RECOMMENDATIONS

Phase I of this project had the objective of understanding the important characteristics of collisions on secondary highways in the Southeastern U.S. The project team conducted a literature review, surveyed highway safety professionals in the region, and analyzed collision data from three states. The collision data analysis included detailed breakdowns by highway-related variables and examinations of driver and vehicle variables using quasi-induced exposure methods.

Despite the wealth of data analyzed during Phase I, summarized in previous sections of this report, no particular countermeasure idea emerged to demand the attention of the project team for Phase II. There were obviously many excellent countermeasure possibilities, but each of the possibilities applied to a small niche in the overall secondary highway safety problem. In other words, the project team did not identify a 'magic bullet' within current technologies and funding levels. Instead, the team realized that there was good potential for reducing the number of collisions on secondary highways in the near term by better matching the large number of possible countermeasures to sites with the greatest potential for collision reduction. The current site identification and countermeasure selection methods are reactive rather than proactive, use outmoded formulae, and require data that are scarce and often erroneous. As noted in Chapter 2, new equations and new data collection technologies have made better countermeasure selection methods possible.

The project team therefore recommends a three-part strategy to investigate new site identification and countermeasure selection methods during Phase II. These three parts met with favorable comments during presentations to the Tennessee DOT in November 1997 and to the North Carolina DOT in December 1997. First, UK will delve deeper into the quasi-induced exposure method for identifying over-involved driver and vehicle groups to identify specific countermeasures. To be more specific than Phase I, they will attempt to merge other data, such as census data or driver license data, with the existing demographic and vehicle data in the collision databases. Second, STC will issue an RFP for an examination of the "sites with promise" identification method proposed by Professor Ezra Hauer in Transportation Research Record 1542.(62) Professor Hauer's method would seem to fit the situation on Southeastern secondary highways quite well, but an examination is needed to show whether state DOTs can use it with current data and institutional arrangements. Finally, the NCSU and UNC portions of the project team will test the efficiency and effectiveness of locating promising sites and choosing countermeasures using only roadway inventory data.

Using only roadway inventory data to identify promising sites and countermeasures has several apparent advantages over the conventional methods using collision data. First, the team can directly apply the knowledge of countermeasures gained during Phase I, and state DOTs can keep refining the method as they gain new knowledge on countermeasure effectiveness. Second, the roadway inventory method does not use collision data, which are quite unreliable for many secondary highways. Third, roadway inventory data collection methods are improving rapidly with new technology, such that state DOTs should have good inventory data routinely available soon, even for secondary highways. Finally, the inventory method is proactive, seeking to find and eliminate potential collision sites before they experience collisions.

Developing the algorithms for the inventory method will require a major effort. The method will begin with a list of countermeasures in certain situations and their expected costs and collision reduction effectiveness. The team will derive this list from the results summarized in the previous chapters, particularly the literature reviewed in Chapter 2. The algorithm will search the inventory database for actual sites matching those described on the list. After some potential countermeasure sites are identified, the algorithm will recommend an optimum mix of projects providing the highest collision reduction within the budget. The project team will need to keep the algorithms manageable by emphasizing simpler countermeasures with more certain collision reductions found by using high-quality inventory data elements. The NCSU and UNC portions of the project team will discuss the details of the plan for Phase II in a work plan document for STC.

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APPENDIX. SURVEY QUESTIONNAIRE

Survey of Safety Professionals in STC States

Name: ______________________________ Date: ________________________

Title: ______________________________ Phone No: ________________________

Organization: ______________________________

North Carolina State University is conducting this survey of safety professionals as part of a larger research project for the Southeastern Transportation Center (STC) regarding accidents on secondary highways and countermeasures. The eight states represented by the STC (KY, TN, NC, SC, GA, AL, MS and FL) have indicated that secondary highway safety is a major concern in the southeastern region of this country.

Frankness in your answers to these questions is very important. Therefore, we will not directly quote you or report individual responses.

Comparisons of answers will not be made between states. This is not a competition and we hope that you will answer the questions with that in mind.

Lastly and most importantly, please limit your responses to two-lane rural and suburban secondary highways. We are not interested in the entire roadway system in your state in general.

QUESTION 1 - please use the following list to answer A), B) and C):

Sight distance	Roadside clearance to trees, poles and other roadside objects
Side-slopes	Lane widths
Shoulder widths and surfaces	Vertical alignments
Horizontal alignments	Signs and pavement markings
Pavement condition	Fixed street lighting
Intersection and driveway control	Bridge widths and barriers

A) List the top three most frequent causes of accidents on two-lane rural and suburban secondary highways in your state.

1) ______________________________

2) ______________________________

3) ______________________________

B) Improvements to which of these roadway items is the most efficient in reducing the frequency of accidents on two-lane rural and suburban secondary highways in your state?

1) ______________________________

2) ______________________________

3) ______________________________

C) Has your agency or department conducted any studies regarding these or any other highway features as the causes of two-lane rural and suburban secondary highway accidents or the effects of improvements to these roadway items? If so, would it be possible for us to obtain a copy of the report(s)?

Survey of Safety Professionals in STC States (page 2)

QUESTION 2 - please use the following list to answer A), B) and C):

Single vehicle accidents	Hit animal accidents
Angle accidents	Head-on accidents
Turning accidents	Rear-end accidents
Large truck accidents	Pedestrian accidents
Bicycle accidents	Rail-crossing accidents
Night accidents	Wet pavement accidents

A) List the top three most frequent types of accidents on two-lane rural and suburban secondary highways in your state.

1) ____

2) ____

3) ____

B) Providing countermeasures for which of these types of accidents is the most efficient in reducing the frequency of accidents on two-lane rural and suburban secondary highways?

1) ____

2) ____

3) ____

C) Has your agency or department conducted any studies regarding these or any other types of accidents or countermeasures for accidents on two-lane rural and suburban secondary highways? If so, would it be possible for us to obtain a copy of the report(s)?

Survey of Safety Professionals in STC States (page 3)

QUESTION 3 - please use the following list to answer A), B) and C):

Drunk drivers	Fatigued drivers
Drugged drivers	Overly aggressive drivers
Older drivers	Inexperienced drivers
Defective vehicles	Poorly-maintained vehicles

A) List the top three most frequent driver/vehicle causes of accidents on two-lane rural and suburban secondary highways in your state.

1) ____________________

2) ____________________

3) ____________________

B) Providing countermeasures for which of these types of causes is the most efficient in reducing the frequency of accidents on two-lane rural and suburban secondary highways?

1) ____________________

2) ____________________

3) ____________________

C) Has your agency or department conducted any studies regarding these or any other types of driver/vehicle causes or countermeasures for these causes of accidents on two-lane rural and suburban secondary highways? If so, would it be possible for us to obtain a copy of the report(s)?

ANY OTHER COMMENTS?

Thank you for participating in this survey. Please fax your completed form to Dr. Joseph Hummer at (919) 515-7908 or mail your completed form to Dr. Joseph Hummer, Department of Civil Engineering, North Carolina State University, Raleigh, NC 27695-7908.