Identification of Severe Crash Factors and Countermeasures in North Carolina - Final Report

Prepared for the North Carolina Department of Transportation

By the UNC Highway Safety Research Center

August 2001

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/NC/2001-003		

4. Title and Subtitle	5. Report Date
Identification of Severe Crash Factors and Countermeasures in North Carolina – Final Report	August, 2001
	6. Performing Organization Code
7. Author(s) Huang, H.F., Schneider, R.J., Zegeer, C.V., Khattak, A.J., Amerlynck, V.J., and Lacy, J.K.	8. Performing Organization Report No.
9. Performing Organization Name and Address University of North Carolina Highway Safety Research Center 730 Airport Road, Bolin Creek Center Chapel Hill, NC 27599-3430	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 1999-1442-01
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Analysis Group 1 South Wilmington Street Raleigh, NC 27601	13. Type of Report and Period Covered Final Report May 1, 1999 – August 2001 14. Sponsoring Agency Code 1999-11

15. Supplementary Notes

Pat Strong and Mike Stanley were the N.C. DOT Contract Managers. The UNC Department of City and Regional Planning was a subcontractor to HSRC.

16. Abstract

This report examines the roadway, crash, vehicle, individual, and environmental factors that are associated with fatal and serious injury crashes in North Carolina between 1993 and 1997. The initial analysis identifies road classifications, geographic characteristics, and time trends related to severe crashes using Highway Safety Information Systems (HSIS) segment and crash data. HSIS system highways in North Carolina include the state primary and major secondary routes. Non-HSIS roads include local streets and minor secondary streets. Both HSIS and non-HSIS data are used in the more detailed section of the study to analyze the severe crash factors on all HSIS highways, two-lane urban HSIS highways, two-lane rural HSIS highways, urban non-HSIS routes, and rural non-HSIS routes.

In this report, a test of the standard error of a binomial proportion is used to find the statistical significance of the roadway, crash, vehicle, individual, and environmental factors related to severe crashes. The initial analysis shows that urban and rural two-lane roads are associated with the highest crash severity, mountain counties have the highest proportion of severe crashes, and crash severity remained stable for some of the most severe crash types. Factors associated with significantly high crash severity on all roadway types include curve, run-off-road, utility pole, tree, head-on, pedestrian, bicycle, darkness, and alcohol use. The final section of the report recommends countermeasures that can be used to reduce the incidence of fatal and serious injury crashes associated with these factors.

17. Key Words:	18. Distribution Statement
crashes, fatal and severe injury, countermeasures, crash factors	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	151	

Form DOT F 1700.7 (8-72)

IDENTIFICATION OF SEVERE CRASH FACTORS AND COUNTERMEASURES IN NORTH CAROLINA

For the North Carolina Department of Transportation

By the University of North Carolina Highway Safety Research Center

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August 2001

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ABSTRACT

This report examines the roadway, crash, vehicle, individual, and environmental factors that are associated with fatal and serious injury crashes in North Carolina between 1993 and 1997. The initial analysis identifies road classifications, geographic characteristics, and time trends related to severe crashes using Highway Safety Information Systems (HSIS) segment and crash data. Both HSIS and non-HSIS data are used in the more detailed section of the study to analyze the severe crash factors on all HSIS highways, two-lane urban HSIS highways, two-lane rural HSIS highways, urban non-HSIS routes, and rural non-HSIS routes. In this section, a test of the standard error of a binomial proportion is used to find the statistical significance of the roadway, crash, vehicle, individual, and environmental factors related to severe crashes. The initial analysis shows that urban and rural two-lane roads are associated with the highest crash severity, mountain counties have the highest proportion of severe crashes, and crash severity remained stable for some of the most severe crash types. Factors associated with significantly high crash severity on all roadway types include curve, run-off-road, utility pole, tree, head-on, pedestrian, bicycle, darkness, and alcohol use. The final section of the report recommends countermeasures that can be used to reduce the incidence of fatal and serious injury crashes associated with these factors.

INTRODUCTION

The eight Southeastern States in FHWA's Region IV have been ranked among the highest nationally in terms of fatal crash rates in recent years. These eight states include North Carolina, Alabama, Florida, Georgia, Kentucky, Mississippi, Tennessee, and South Carolina. These eight states accounted for approximately 25 percent of the nation's total fatalities in 1995 and a fatality rate about 20 percent above the national mean[1].

In 1995, North Carolina ranked 9th of the 50 states in terms of total highway-related deaths, with 1,418 people killed. The fatality rate of 1.9 (people killed per 100 million vehicle miles of travel) ranked North Carolina 20th nationally[1]. In response to these trends in traffic fatalities, the North Carolina DOT and other state DOT's in Region IV have expressed an interest in further studying fatal crash causes and possible countermeasures.

This report summarizes the findings of a study on the contributing factors and characteristics of fatal and serious crashes in North Carolina. This is the final report of a two-phase study commissioned by the North Carolina DOT as part of the FHWA's Region IV Fatal Study. The study analyzed data from two sources:

(1) The 1993-1997 Redbook Accident Files database, which contains data on all reported crashes in North Carolina:

  a) The Highway Safety Information System (HSIS) database, a subset of the Redbook Accident Files, was used to examine both fatal and serious injury crashes in North Carolina and to take a more detailed look at severe injury crash factors on two-lane urban and two-lane rural roadways. This database contains approximately 40 percent of crashes reported in North Carolina.

  b) The non-HSIS crashes from the Redbook database were used to supplement and strengthen findings from the preliminary HSIS analysis and to examine severe crash factors on urban and rural roadways. This database represents the remaining 60 percent of crashes reported in North Carolina.

(2) The 1993-1997 Fatal Analysis Reporting System (FAR) data through the Critical Analysis Reporting Environment (CARE) database, which contains only fatal crashes, was used to compare North Carolina crash characteristics with the Southeast as a whole (eight states including North Carolina).

The report consists of a review of previous crash factor studies, an overview of the analysis structure, and three main parts. Part I summarizes the findings of an initial analysis of North Carolina crashes using the HSIS database. Part II is a more detailed examination of the significant severe crash factors identified in Part I. Specifically, it looks at severe crash factors on two-lane urban and two-lane rural HSIS highways and urban and rural non-HSIS routes. Part III suggests possible countermeasures to reduce the occurrence of the most significant severe crash factors in North Carolina. Appendix A compares fatal crashes in North Carolina with those in the Southeast as a whole using CARE data.

REVIEW OF LITERATURE

A. PREVIOUS CRASH FACTOR STUDIES

This report describes an in-depth analysis of the roadway, crash, vehicle, individual and environmental factors that contribute to severe injury crashes in North Carolina. Though limited previous research is available which has examined severe crash factors at this level of detail for a single state, the topic of factors contributing to crashes has been addressed. Earlier studies by Tessmer, Zegeer, *et al.*, Leaf *et al.*, and Stamatiadis, *et al.* have compared fatal crash characteristics on urban and rural roadways throughout the country, general crash factors by roadway class in eight states, crash types on a major urban beltway, and crash characteristics on low-volume rural roads in Kentucky and North Carolina[2,3,4,5].

Tessmer used Fatal Analysis Reporting System (FARS) data collected between 1975 and 1993 to compare factors that contributed to fatal crashes in rural and urban areas of the United States. The research showed that 40 percent more deaths occurred on rural roadways than on urban roadways, even though the total vehicle miles traveled (VMT) during the study period was almost thirty percent lower on rural roads. Specific factors that were associated with higher numbers of fatalities on rural roads than on urban roads included high speed limits, head-on collisions, alcohol involvement, light and large truck involvement, and lower emergency response times. Factors that contributed to fatalities in urban areas included high speed limits and car, motorcycle, and pedestrian involvement[2].

Crash information from the early 1990s was drawn from the eight-state (California, Illinois, Maine, Michigan, Minnesota, North Carolina, Utah, and Washington) HSIS database by Zegeer, *et al.* to compare crash rates and characteristics by roadway class. Unlike the analysis of nationwide FARS data, this study looked at all crashes, regardless of injury severity. It found that total number of crashes per million vehicle miles were higher on urban streets than on rural roads. In addition, undivided non-freeways and rural two-lane roads had higher crash rates than freeways and divided non-freeways.

This study also identified factors that contributed to crashes by roadway classification:

- Urban freeways: icy weather, rear-end/same direction sideswipe, and fixed object crashes;
- Urban two-lane roads: head-on/opposite direction sideswipe, backing and parking, angle, wet weather, and pedestrian and bicyclist crashes;
- Multi-lane divided and undivided roadways: wet weather, rear-end/same direction sideswipe, angle, and pedestrian crashes;
- Rural freeways: fixed object, animal, rollover, nighttime, and icy pavement;
- Rural two-lane roads: fixed-object, rollover, head-on/opposite direction sideswipe, animal, nighttime, icy pavement;
- Rural multi-lane roads: animal, angle, fixed-object, rollover, injury, icy pavement, and wet weather[3].

Leaf, *et al.* reported that three crash types, stopping/slowing, run-off-road, and sideswipe/cutoff, accounted for 78 percent of all crashes between 1993 and 1996 on the Capital Beltway around Washington D.C. The rate of injury and fatal crashes decreased over this period. The results may be representative of the most common types of crashes on major roadways with high congestion levels[4].

North Carolina and Kentucky were used by Stamatiadis, *et al.* to study factors contributing to crashes on low-volume rural roads. Crash data collected between 1993 and 1995 showed that drivers under the age of 25 are more likely to be involved in single-vehicle crashes than any other group of drivers. Young drivers were often involved in single-vehicle crashes occurring at night, under higher-speeds, narrower lanes, sharper curves, and lower-volume roads. Though older drivers were less safe than younger drivers on roads with sharp curves, drivers as a whole had lower crash rates on roads with no shoulders and roads with sharp curves. Another significant finding was that large vehicles were more likely to hit other vehicles on narrow low-volume roads, but small vehicles were more likely to be involved in single-vehicle crashes[5].

These studies suggest factors that contribute to severe injury crashes include rural areas, undivided and two-lane roads, higher-speed roads, head-on collisions, large vehicles, young drivers, pedestrian and bicycle involvement, and alcohol involvement. This report will examine these and other characteristics to find which are significant in North Carolina.

B. CONTRIBUTION OF THIS STUDY TO THE LITERATURE

In addition to identifying factors that are associated with crashes within North Carolina, this study makes several contributions to the body of crash factor analysis literature. First, unlike other crash factor studies, it specifically analyzes the data with respect to high crash severity. Instead of identifying factors related to crashes in general, the study highlights the unique factors associated with serious injury and fatal crashes on specific classes and types of roadway. Next, it carries the process of safety improvement past the analysis stage by offering countermeasures that can be used to reduce the types of crashes that are identified through the analysis. For example, instead of simply stating that crashes on curved roadways are a problem because they are often severe, this study suggests that treatments such as flattening curves, widening lanes or shoulders, removing roadside hazards, and flattening sideslope can be made to achieve safety improvements. Finally, the FARS, HSIS, and Redbook Accident Databases were used in the analysis, and a number of different safety treatments are suggested as countermeasures. Thus, this study represents a strategy involving a wide range of crash problems and roadway factors that can lead to a reduction in severe crashes.

ANALYSIS OVERVIEW

The analysis of this study was structured in three phases (Figure 1). The first phase examined severe crashes over a broad geographic area (eight Southeastern States) using a database with relatively few records (FARS/CARE, 47,047 records). As the analysis proceeded, it evaluated a smaller geographic area (North Carolina) with a larger database (North Carolina HSIS, 478,500 records). The final phase of the analysis examined specific parts of the smaller geographic area (urban and rural routes in North Carolina) and used two databases that contained the greatest number of records (North Carolina HSIS and non-HSIS, 1,129,500 total records). The general objective, structure, method, and findings of the study are outlined by the set of boxes below.

Objective: Identify factors associated with fatal and serious injury crashes in North Carolina and recommend appropriate countermeasures to reduce their frequency.

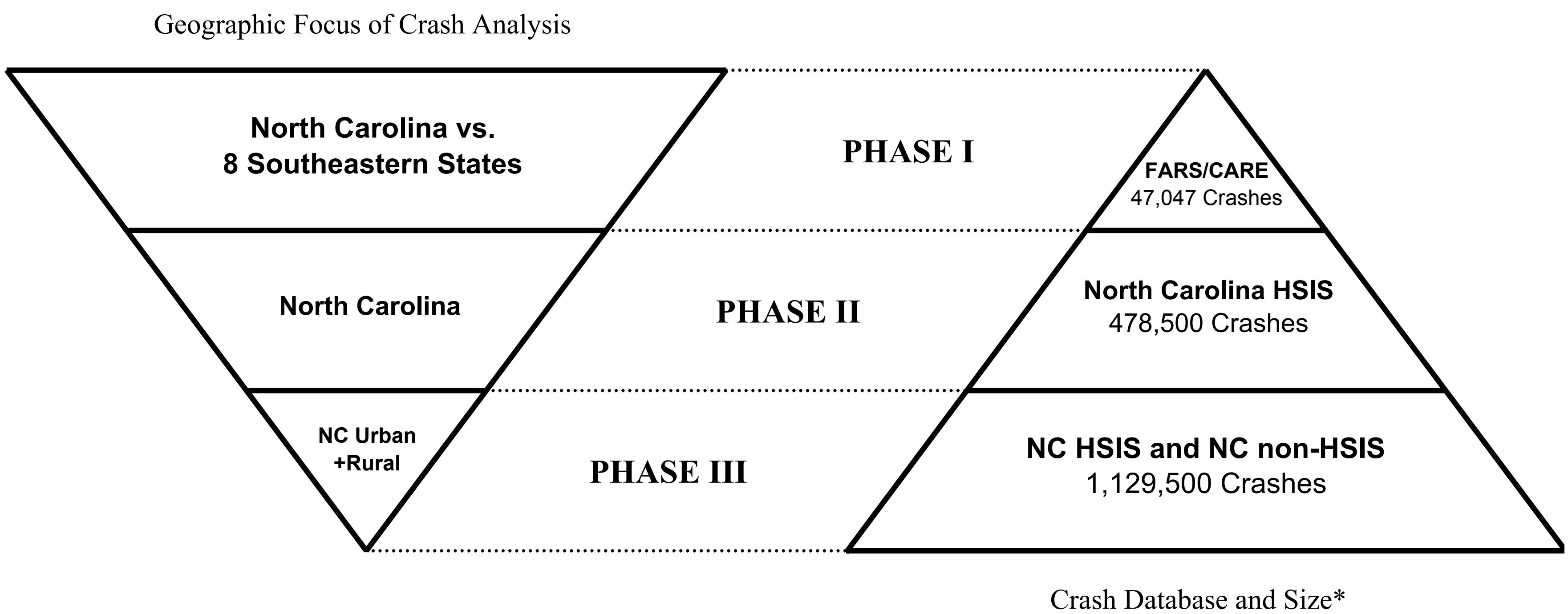
Structure: Examination of eight Southeastern States using FARS/CARE database, North Carolina using HSIS database, and of North Carolina urban and rural roadways using HSIS and non-HSIS databases to find *roadway*, *crash*, *vehicle*, *individual*, and *environmental* factors that influence crash rates and severity.

Method: Crash and segment files of HSIS database are queried to identify road classifications, geographic characteristics, and time trends related to severe crashes in Part I; databases containing crashes on all HSIS, two-lane urban HSIS, two-lane rural HSIS, urban non-HSIS, and rural non-HSIS roadways are queried and tested using the standard error of a binomial proportion to identify significant severe crash factors in Part II.

Findings: Factors associated with a high incidence of fatal and serious injury crashes in North Carolina include:

- Urban and rural two-lane roadways
- Curves
- Run-off-road (utility pole and tree)
- Head-on
- Pedestrian
- Bicycle
- Motorcycle
- Alcohol
- Mountains
- Darkness

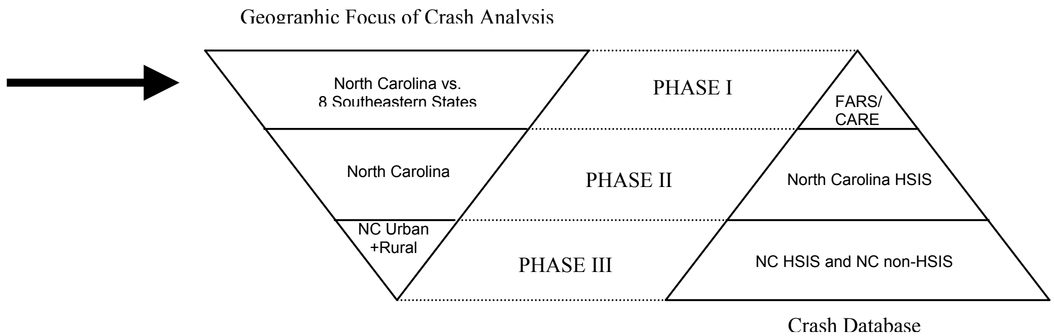
Figure 1. Structure of severe crash analysis



*All crash data used in this study were collected between 1993 and 1997

PART I INITIAL ANALYSIS OF NORTH CAROLINA CRASHES

A. COMPARISON OF NORTH CAROLINA WITH THE SOUTHEAST AS A WHOLE



The study began by examining how fatal crashes in North Carolina compared with other states. To do this, the state was compared to the eight Southeastern States (including North Carolina) in FHWA Region IV using the Critical Analysis Reporting Environment (CARE) database. The following variables were analyzed: roadway function class, first harmful event, manner of collision, relation to junction, relation to roadway, traffic flow, number of travel lanes, speed limit, roadway alignment, roadway profile, roadway surface condition, traffic control device, light condition, atmospheric condition, body type, rollover, vehicle maneuver, most harmful event, violations charged, driver factors, restraint system, alcohol involvement, and injury severity. Findings from the comparison of North Carolina with the Southeast are summarized below. A more detailed explanation of this CARE data analysis is presented in Appendix A.

It is important to note that the CARE analyses do not indicate *why* some factors are over-represented, and why other factors are underrepresented. For example, the fact that two-lane roads are over-represented in North Carolina can mean simply that North Carolina has more two-lane roads than the other Southeastern States. It can also mean that two-lane roads are more dangerous in North Carolina than in the other Southeastern States.

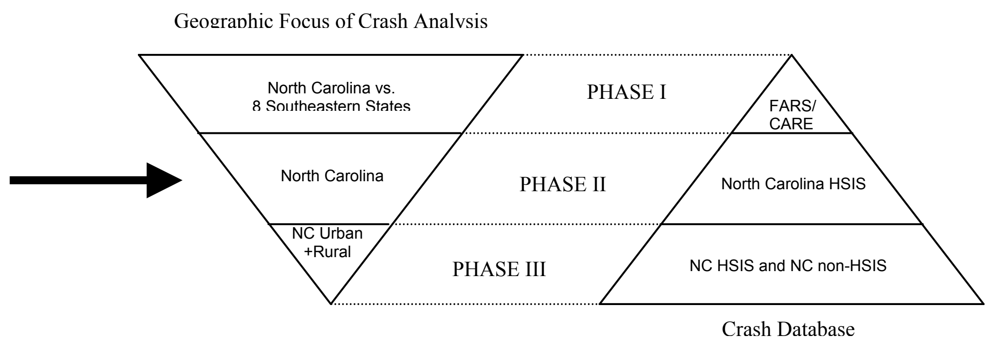
The following factors are over-represented in terms of fatal crashes in North Carolina compared to the eight Southeastern States as a whole:

- Roadway Function Class: Rural local roads, rural minor collectors, rural major collectors, and urban local roads.
- Manner of Collision: Head-on crashes.
- Relation to Roadway: Roadside, shoulder, and outside right-of-way.
- Trafficway Flow: Fatal crashes were over-represented on undivided roads and on divided roads that had medians with barriers (that include barriers shielding bridge piers and other obstacles in the median).

- Number of Travel Lanes: Two-lane roads.
- Roadway Alignment: Curves.
- Roadway Profile: Sag, level, and hillcrest.
- Most Harmful Event: Tree, vehicle in transport – other, and immersion were among the most harmful events.
- Violations Charged: Alcohol/drugs and speeding.

Findings from this examination were used to check consistency with the analysis of factors associated with severe injury crashes within North Carolina in Phase II and Phase III.

B. NORTH CAROLINA CRASH FACTORS



Introduction

This section of the study is an overview of the findings from a general analysis of the HSIS database, which is a subset of crashes occurring on state highways (containing approximately 40 percent of total crashes in North Carolina). It examines crash trends between 1993 and 1997, types of crashes, and roadway, individual, vehicle, and environmental conditions associated with severe injury crashes in North Carolina. Its findings were used to guide Phase III, a more detailed analysis of urban and rural crashes on HSIS and non-HSIS routes, which is presented in Part II. Further details of this section of analysis are provided in Appendix C.

Method

The effects of roadway, crash, environmental, vehicle, and individual factors on fatal and severe crashes in North Carolina were analyzed using crash and inventory data. The analysis included examining distributions of variables, descriptive statistics, bivariate statistics, and time trends. The KABCO injury scale used on the North Carolina police reports was used in this study. The investigating officer determines the level of injury: the most severe category is "fatal" (K); the next most severe category is "incapacitating injury" (A); the next most severe category is "non-incapacitating injury" (B); and the least severe category is "possible injury" (C). The last category is "no injury'' (O). For most of the analyses, the category "K" and category "A" were grouped together to represent severe injuries. Categories "B," "C," and "O" represent relatively non-severe injuries or no injuries. Crashes were categorized according to the worst injury in the crash. Crash data were analyzed at the roadway segment level and the crash level. The measures of injury severity used in the analysis included:

- Segment level:

The following two measures were used:
1. Worst fatal and serious injury (K+A) crash rates. (K+A injury crashes per million vehicle miles).
2. Relative severity of crashes (K+A injury crashes divided by total crashes).

- Crash level:

The following two measures were used:
1. Worst injury in a crash.
2. Total numbers of injuries.

General hypotheses regarding expected distributions and relationships are presented in Appendix C and an examination of the data for statistical evidence is presented later in the report. More specific hypotheses regarding relationships between specific variables are presented along with the data analysis.

Data Description

The North Carolina 1993-1997 Highway Safety Information System (HSIS) crash data and 1994 HSIS inventory data were used for this part of the analysis. HSIS data, which include all injury and all non-injury crashes causing more than $1000 property damage for crashes reported in 1996-1997 and $500 property damage in 1993-1995, come from approximately 34,800 miles of the 92,000 total miles of roadway in the state. These 34,800 miles have been entered into a computer mileposting system, so crashes can be linked to them. Because there are no county-maintained roadways in North Carolina, most of the state's rural roadways are included in this study.

The data were analyzed using two files: a roadway segment file and a crash file. They contained 38,170 road segments and 478,450 crashes, respectively. The variables in the database are as follows:

- ***Segment File***

    Injury variables
    Total number of K crashes (crash in which at least one person was killed).
    Total number of A crashes (crash in which nobody was killed but at least one person sustained incapacitating, "A", injury).
    Total number of B crashes (crash in which worst injury is non-incapacitating, "B", injury).
    Total number of C crashes (crash in which worst injury was coded as "C," or "possible injury").
    Total number of O crashes (crashes without injury).
    Roadway characteristics
    Section length, AADT, surface width, left and right shoulder width and type, median type and width, number of lanes, speed limit, access control, surface type, rural/urban classification and roadway classification.

Crash characteristics
Number of vehicles in crash.

- ***Crash File***

    Injury variables
    Most severe injury in a crash measured on KABCO scale.
    Number of injuries in a crash.
    Roadway factors
    Number of lanes, type of traffic control, location type (bridge etc.), speed limit, road character, road configuration, road defect or under construction, type of road surface, surface condition.
    Crash factors
    Number of vehicles, pedestrian involved, bicyclist involved, motorcycle involved, fire (in any of the vehicles), impact speed (for up to 3 vehicles), contributing factors (27 flags), alcohol involvement.
    Vehicle factors
    Vehicle type (for up to 3 vehicles), number of vehicles in which airbags are present divided by total number of vehicles, number of vehicles in which airbags deployed divided by total number of vehicles, number of occupants in all vehicles.
    Driver/Individual factors
    Driver sex (for up to 3 drivers), driver age (for up to 3 drivers), driver restraint (for up to 3 drivers), alcohol involvement.
    Environmental factors
    Time of day, day of week, light or dark, weather, time of year (accident date), development type, city population.

<u>Steps</u>

Two levels of analysis were performed:

The segment-level analysis:

- Computed and compared the rates of fatal and serious crashes by a composite roadway class variable that included road access (freeway, non-freeway), road type (divided, undivided; number of lanes), area type (urban, rural) and surface type (primitive or not).

- Identified North Carolina counties that had higher crash severity and examined whether the high severity counties were spatially clustered.

The crash-level analysis:

- Compared trends in fatal and serious crashes by roadway class and crash type over five years (1993-1997).

- Examined the distribution of fatal and serious *crashes* and the distribution of fatal and serious *injuries*. The distribution of fatal and serious crashes was examined by the variables listed below:
    - roadway class (e.g., urban freeway, rural 2-lane highway).

- road character (curve, grade, straight).
- crash type (e.g., run-off-road and head-on).
- light condition.
- weather.
- alcohol involvement.

- Reported crash severity associated with the following roadway, crash, vehicle, individual, and environmental characteristics:
  - roadway class.
  - road character.
  - crash type.
  - motorcycle involved.
  - large truck involved.
  - alcohol involvement.
  - driver age.
  - light condition.
  - weather.

Analysis Results

Road Segments

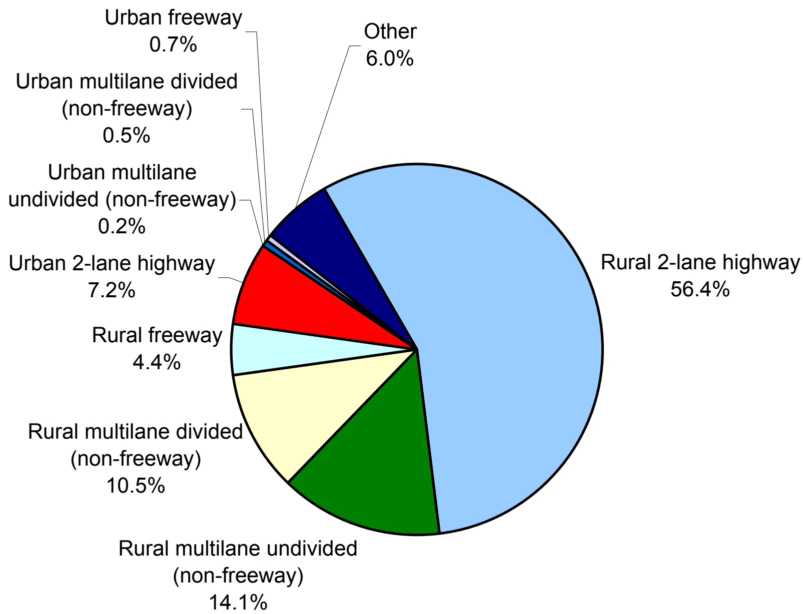
The following are key findings from the crash severity analysis of crashes on North Carolina HSIS route segments.

- ***Rural and urban two-lane roads and rural multilane undivided roads had proportionally more severe crashes than other roadway classes.***
  Most of the segments in the database were rural two-lane highways (N=27,425) and the majority of crashes as well as the majority of severe crashes occurred on such roads (Figure 2). When controlling for exposure (AADT and segment length), the same picture appeared. The severe crash rate (number of K+A crashes per million vehicle miles) was highest for urban two-lane roads (0.13), followed by rural two-lane roads (0.12) and rural multilane undivided roads (0.09) (Figure 3). The overall crash rates were reasonable and consistent with North Carolina crash rates reported in earlier studies[3].

- ***Rural and urban two-lane roads were associated with high crash severity.***
  The proportion of severe crashes ([K+A]/[K+A+B+C+O]) was also high for rural and urban two-lane roadways. 5.9 percent of all crashes on rural two-lane roads and 6.2 percent of crashes on urban two-lane roads were K+A. While rural two-lane roadways have been the focus of studies and are known to be problematic[3,6,7], this preliminary analysis has identified urban two-lane roads as a good candidate for further exploration of severe crashes in North Carolina.

Figure 2. Distribution of all HSIS crashes and severe HSIS crashes by roadway classification

Distribution of all HSIS crashes
(total # of crashes = 478,160)



Distribution of HSIS K+A crashes
(Total # of crashes = 24,714)

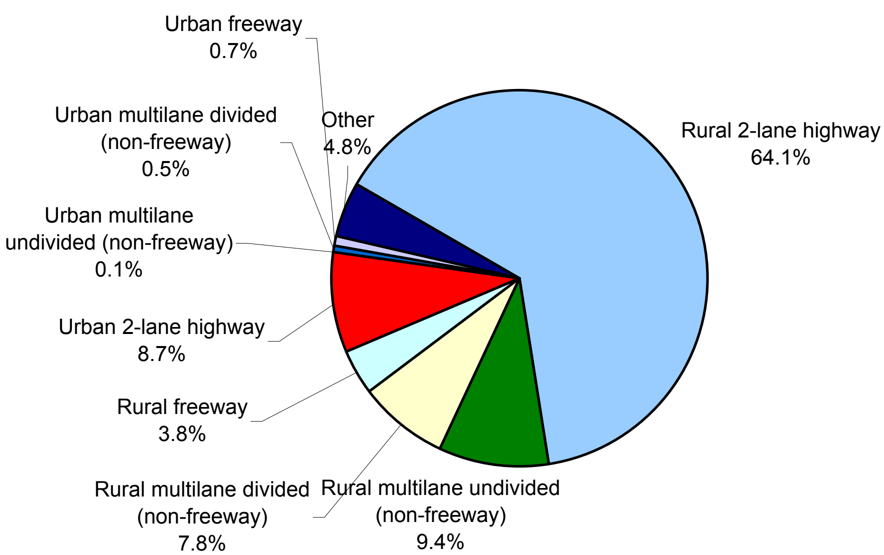


Figure 3. Crash rates by roadway type

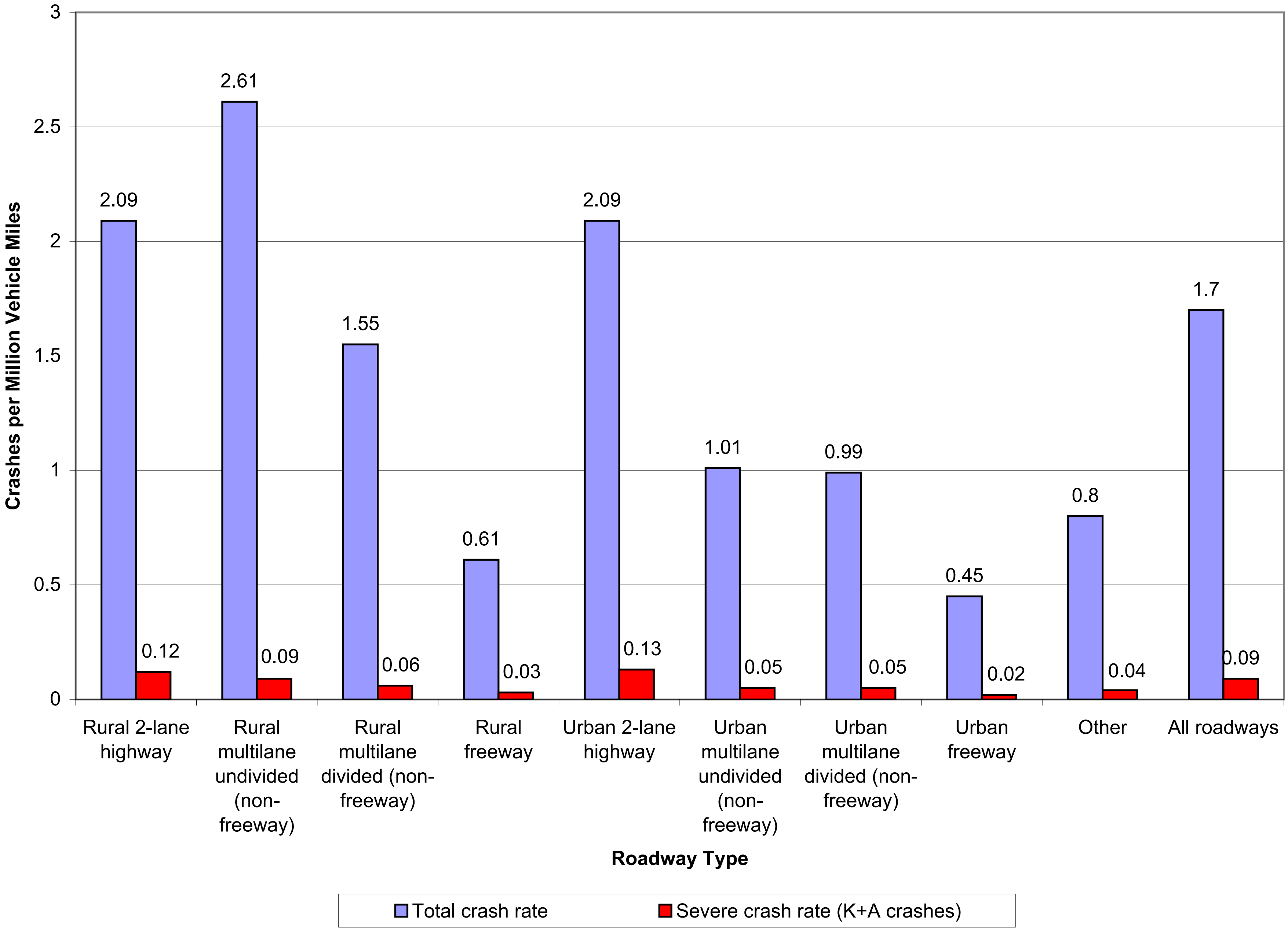
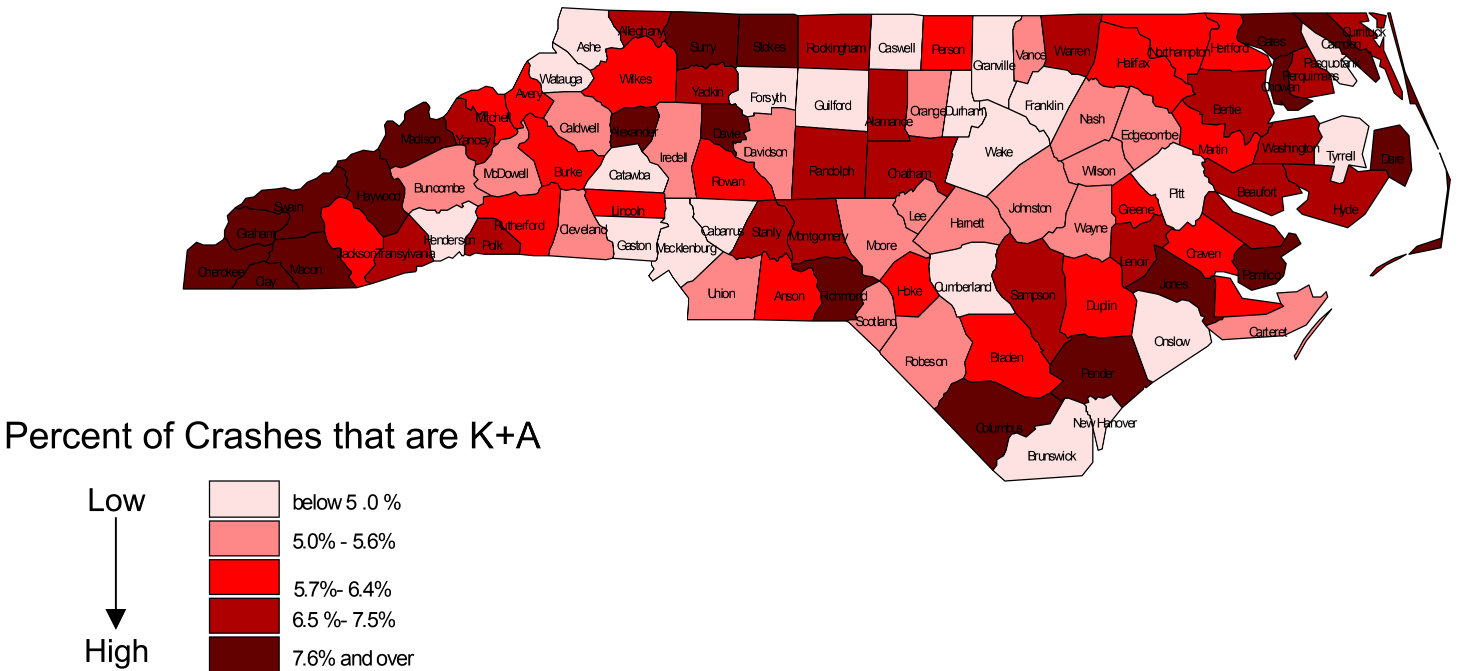


Figure 4. Overall crash severity by county (1993-1997)



SOURCE: Highway Safety Information System

Map produced by
Highway Safety Research Center
University of North Carolina at Chapel Hill
August 1999

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- ***Irrespective of roadway class, high crash severity was concentrated in the mountain counties.***
  Crash severity was measured by dividing the number of crashes in which the worst injury was K or A by the total number of crashes. Higher crash severity is clustered in the mountain counties of North Carolina (Figure 4).

- ***The mountain counties had the highest crash severity when looking only at crashes on rural two-lane roads. Even when taking into account only crashes on urban two-lane roads, the counties with the highest injury severity were in the Western half of the state.***
  The former analysis was repeated for the two types of roads that appeared to be problematic in our former analysis: rural and urban two-lane roads. The same counties as in Figure 4 seem problematic, as shown by crash severity on urban two-lane roads (Figure 5). Note that not all counties have urban two-lane roads. Interestingly, the most dangerous urban two-lane roads were also in the Western half of the state.

Crashes

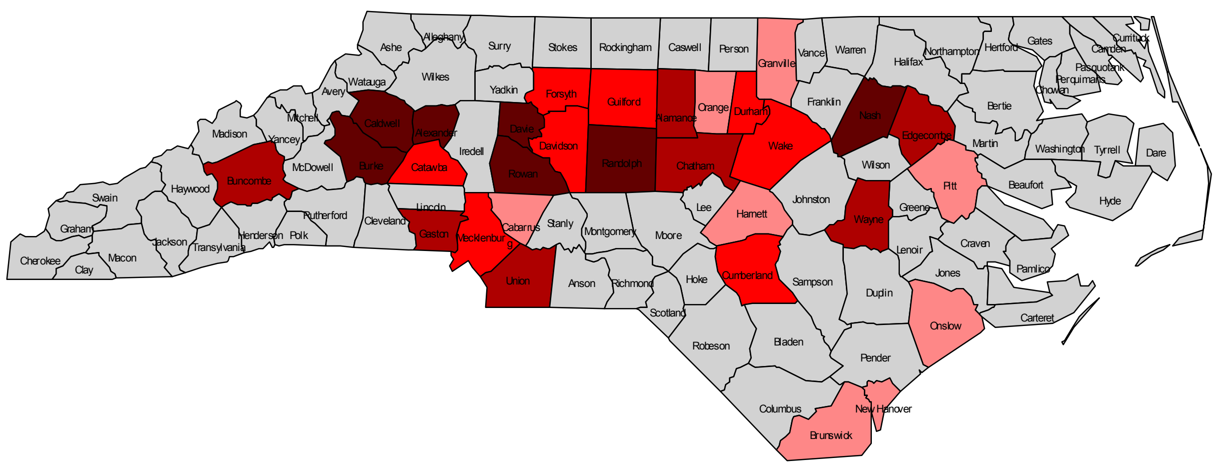
The crash and vehicle files of the HSIS database were merged to explore the impacts of roadway, crash, vehicle, driver/individual, and environmental crash factors. Trends in injury severity, factors associated with severe injury, number of injuries, multi-vehicle vs. single-vehicle crashes and analysis of various crash types are presented. There may have been some fluctuations due to the change in the reporting threshold effective January 1, 1996. This change was applicable statewide; however, there may have been more impact in the counties that have higher proportions of property damage only crashes.

Time Trends

The injury severity distribution of crashes as well as the distribution of crashes by crash type and roadway class were analyzed for each of the five study years. The crash types are: (1) run-off-road (divided into fixed hit object, overturn and other); (2) head-on; (3) rear-end/sideswipe (4) angle or turning; (5) pedestrian; (6) hit animal; (7) braking, backing or parking; and (8) train. Crash types are discussed in more detail later in this report.

- ***In general, crash severity decreased slightly between 1993 and 1997***.
  In line with the increasing trend in automobile travel, police-reported crashes on the North Carolina state-maintained system increased between 1993 and 1995. A moderate decrease in the number of crashes followed between 1995 and 1997. The number of crashes in the North Carolina HSIS database was at its lowest in 1993 with 88,651 crashes and at its highest in 1995 with 99,915 crashes. The percent of fatal or serious crashes decreased over the five-year study period (Figure 6). In 1993, 6.36 percent of crashes were fatal or serious while in 1997, only 4.64 percent of crashes were severe. This can be due to improved roadway conditions, better vehicle technology (e.g., restraints and airbags), shorter emergency response times, driver education and changes in social norms (e.g., driving while drunk is increasingly socially unacceptable), and stricter enforcement policies (e.g., NC's Click It or Ticket). Consistent with the above segment level analysis, rural and urban two-lane roadways had relatively high crash severity, though the crash severity on these roadways was decreasing. Interestingly, rural multilane divided roadways seemed relatively stable in terms

Figure 5. Crash severity on urban two-lane roads by county (1993-1997)



Percent of Crashes that are K+A
of all crashes on Urban Two-Lane Roads

Low

High

- NO URBAN 2 LANE ROADS
- 3.0% - 4.8%
- 5.6% - 6.5%
- 6.8% - 7.6%
- 8.0% - 15.1%

SOURCE: Highway Safety Information System

Map produced by
Highway Safety Research Center
University of North Carolina at Chapel Hill
August 1999

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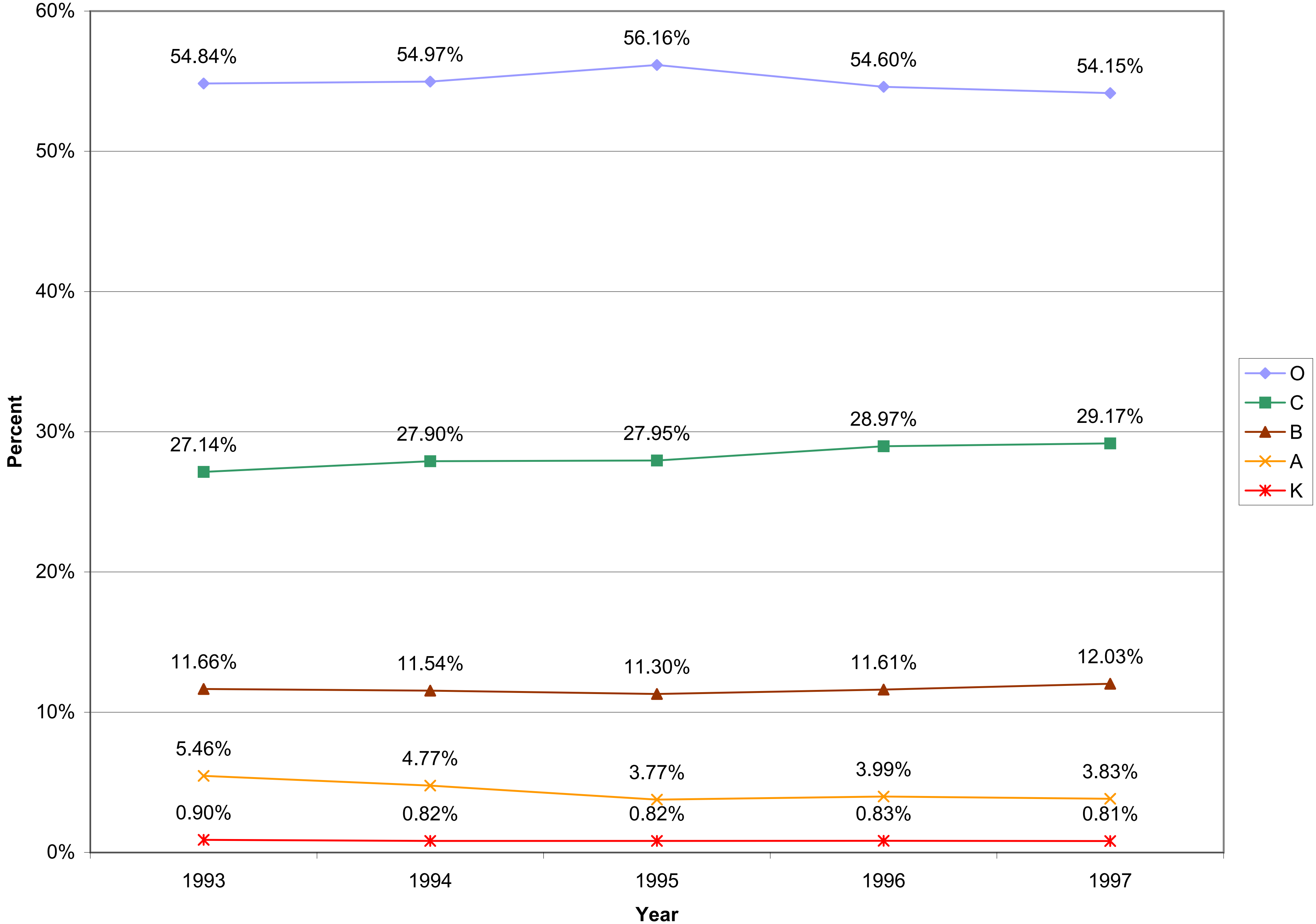

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20%
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3.77%
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0.90%
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0.82%
0.83%
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1993
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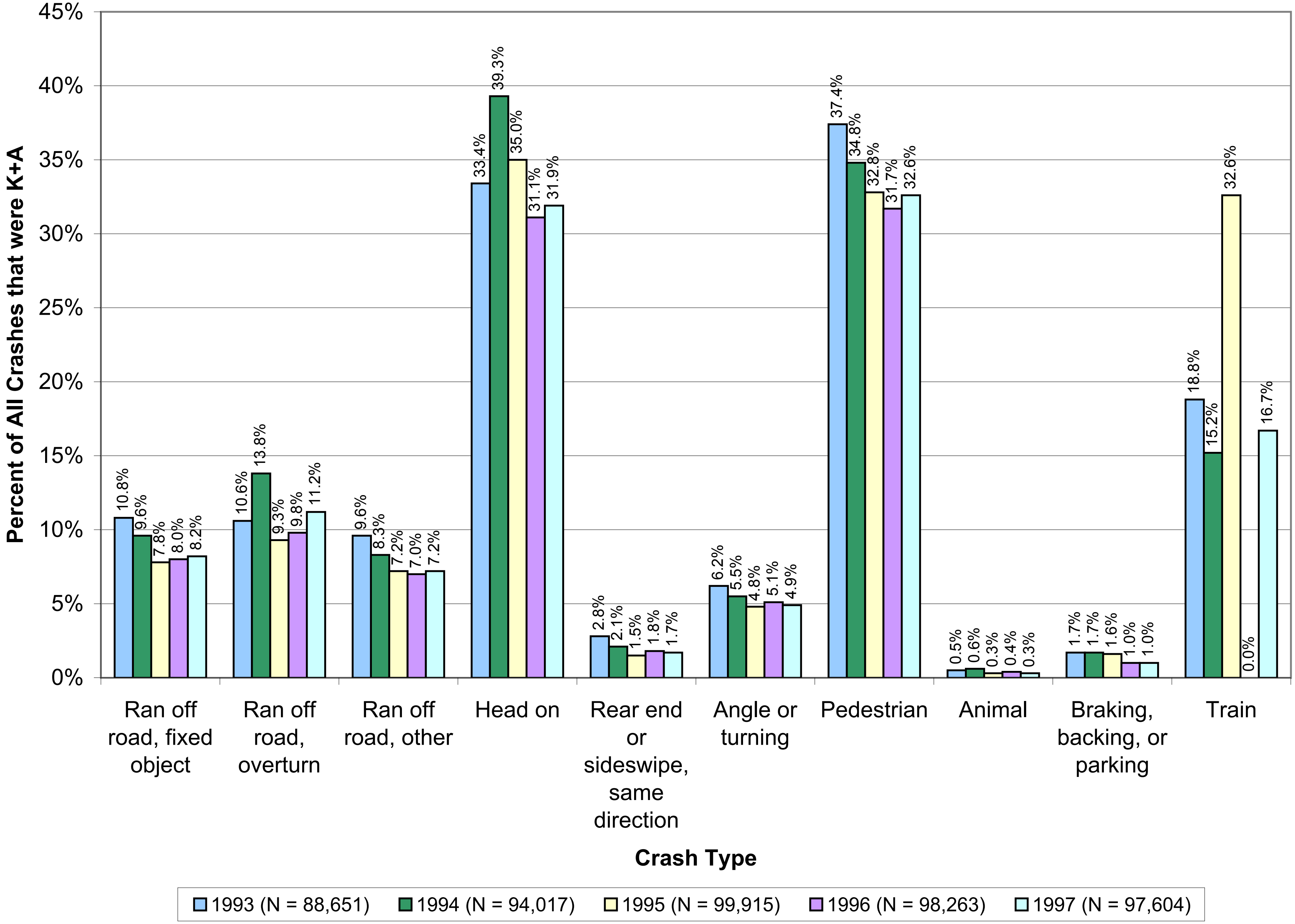
A
K

Figure 7. Trends in injury severity by crash type (1993-1997)



of fatal or serious injury crashes and no particular trend was discernable on urban multilane divided roadways.

- ***Although crash severity for most crash types decreased between 1993 and 1997, crash severity remained stable for some of the most severe crash types.***
  Head-on crashes, pedestrian crashes, and run-off-road crashes had consistently high percentages of fatal or serious crashes (Figure 7). For most collision types, the percent of fatal or severe crashes decreased over 1993-1997. However, the trend in head-on and run-off-road, overturn collisions was relatively stable over 1993-1997. Both types had a peak of high injury severity in 1994 but had more or less the same injury severity in 1997 as they had in 1993. The percentages for train crashes were less informative due to the very small number of such crashes in the database, ranging from 36 crashes in 1997 to 48 crashes in 1993.

- ***The proportion of high severity crash types remained stable or decreased.***
  There were proportionally more rear-end/side swipe crashes and animal crashes in 1997 than in 1993 (Figure 8). Angle or turning crashes, braking, backing and parking crashes, and pedestrian crashes represented a smaller share of the crashes in 1997 than they did in 1993. Other crash types remained more or less stable over time. Thus, while crash types that were generally not severe, such as rear-end/side swipe and animal crashes are increasing, high severity crashes such as run-off-road and pedestrian crashes were remaining stable or are decreasing. A partial explanation for this trend is that high severity crash types were being transferred to low-severity crash types due to roadway improvements or vehicle technology.

Factors associated with severe injury crashes

Fatal (K) and serious (A) crashes made up 24,735 of the 478,450 crashes in the database. Thus, overall 5.2 percent of the crashes were severe (K+A). Crashes with the following characteristics had severity that was noticeably higher than the overall, 5.2 percent severity; they were thus more likely to be severe than the average crash:

- 5.9 percent of crashes that took place on **rural two-lane roads** and 6.2 percent of the crashes that took place on **urban two-lane roads** were fatal or serious.
- Crashes on **curved roadway sections** were more likely to be severe than crashes on straight roads. Further, 11.3 percent of crashes on curved-level road sections were K+A, and 9.0 percent of crashes on curved-graded road sections, 7.9 percent of crashes on curved, bottom roads and 7.3 percent of crashes on curved-hill crest road sections were K+A.
- Crashes that involved a **motorcycle** were more likely to be severe than other crashes. Results showed that 29.1 percent of crashes that involve a motorcycle were K+A (Figure 9). The increased injury severity for crashes involving pedestrians and bicyclists is discussed under crash type.
- Over 1.4 percent of all crashes that involved a **large truck** were fatal (Figure 9), while only 0.8% of all crashes were fatal.
- 17.4 percent of the crashes **involving alcohol and drugs** were severe.

Figure 8. Trends by crash type, as a percent of all crashes for given year (1993-1997)

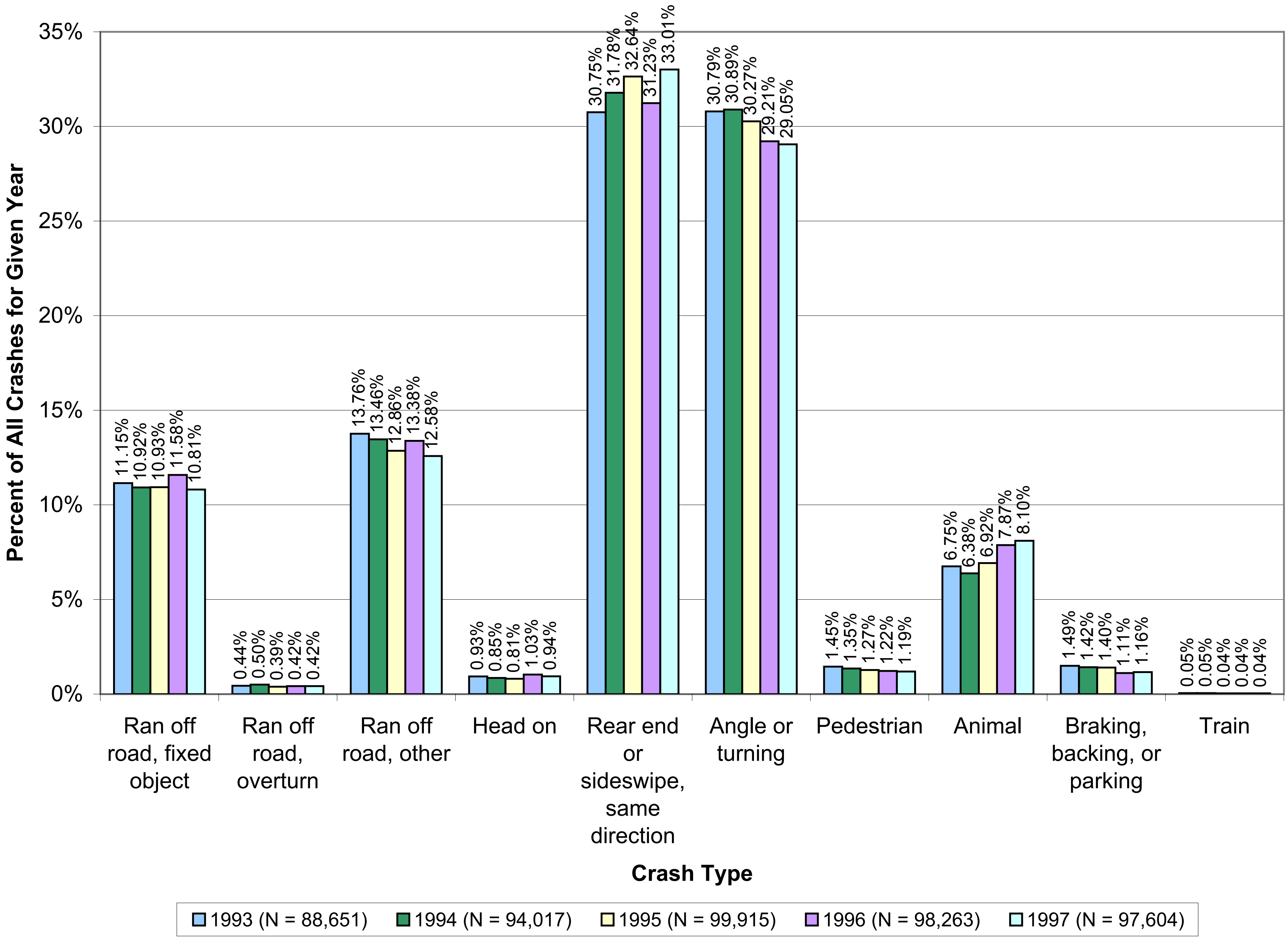
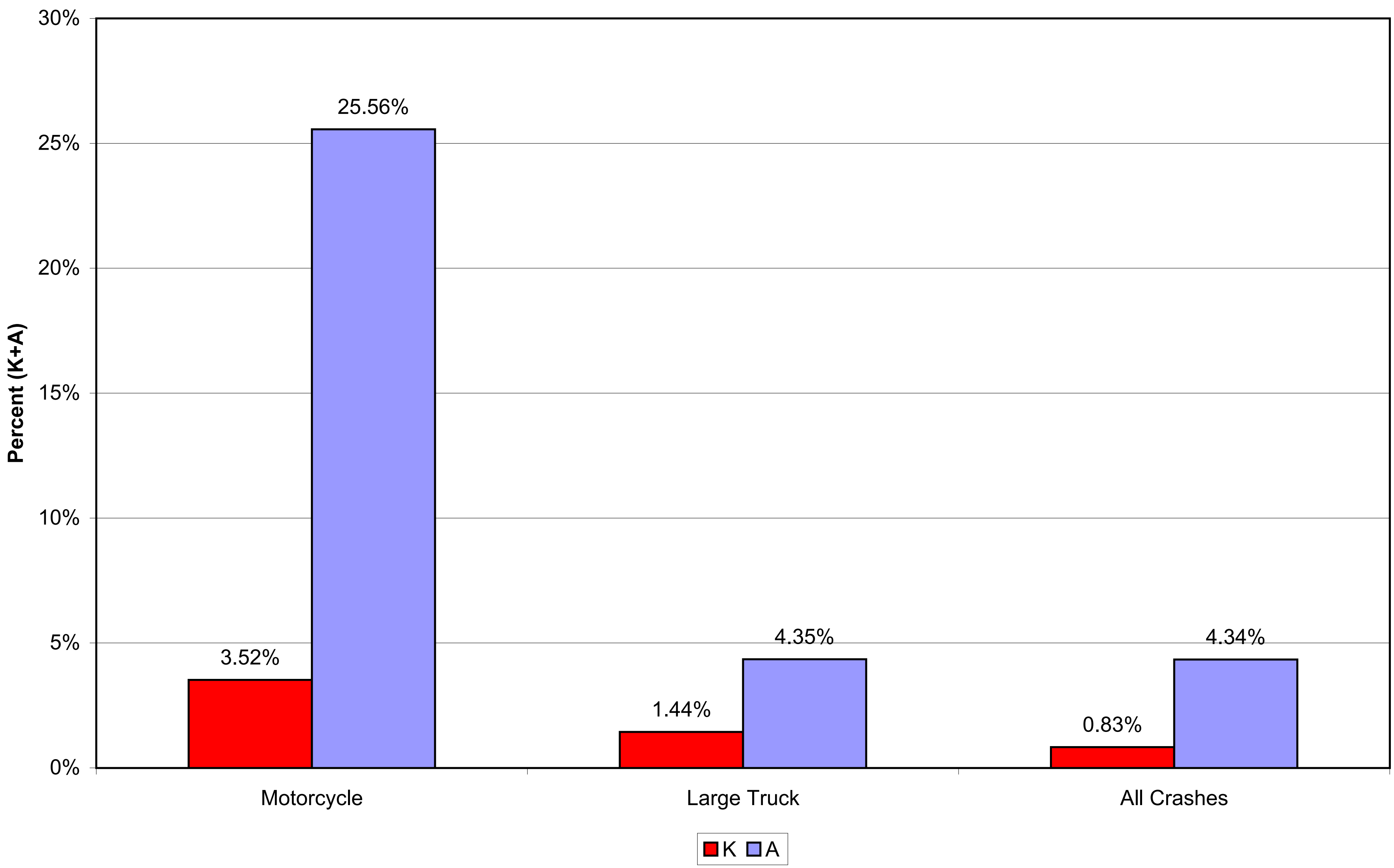


Figure 9. Crashes involving motorcycles and large trucks that are serious or fatal



- Crashes involving one or more young driver (less than 21) or one or more old driver (65 or older) were about as likely to be severe as other crashes. 5.3 percent of crashes involving young drivers and 5.0 percent involving elderly drivers were severe. However, the percent of fatalities was higher for **drivers 65 and older** (1.1 percent) than for younger drivers (0.8 percent).

- 7.0 percent of crashes that took place during **darkness on roads without street lighting** were fatal or serious. In contrast, crashes during darkness on roads *with* street lighting were not especially severe (5.1 percent were K+A). This may imply that street lighting can enhance visibility and provide information to reduce the effect of darkness on injury severity. However, it might simply indicate that lighting was more often present on lower-speed urban streets compared to higher-speed rural roads with less lighting. Also, it was possible that emergency response to crashes that occur in unlit and dark areas (at night) were slower than in other conditions, exacerbating unattended injuries.

- 6.1 percent of crashes that took place during **fog** were fatal or serious. However, only a very small percentage of crashes (1.3 percent) took place during fog. Crashes during sleet or hail (3.3 percent), snow (3.4 percent), or rain (4.1 percent) were all less likely to be severe than other crashes, perhaps due to lower-speed collisions during inclement weather conditions.

Number of injuries by roadway class

When measuring injury severity by the number of injuries, the same picture appears as when taking into account only the worst injury in each crash. The 478,450 crashes that took place in North Carolina between 1993 and 1997 caused 354,394 injuries. Nearly ten percent of these injuries were fatal or serious (K+A). Over 64 percent of all K+A injuries took place on rural two-lane roads, 9.0 percent on rural multilane undivided roads, and 8.7 percent on urban two-lane roads. This distribution of injuries is very similar to the distribution of crashes by roadway class.

Multi-vehicle vs. Single-vehicle crashes

Of the 478,450 crashes in the database, 148,053 (30.9 percent) were single-vehicle crashes while the remaining 330,397 crashes (69.1 percent) involved more than one vehicle. This section examines the association between single-vehicle crashes, other factors, and injury severity .

- ***Curved road segments were especially dangerous for single-vehicle crashes.***
  A larger proportion of single-vehicle crashes occurred on curved road segments (34.3 percent) compared with other crashes (only 10.0 percent of the multi-vehicle crashes occurred on curved roads). In addition, single-vehicle crashes on curved road segments had higher severity (%K+A) than other crashes on curved roads.

- ***Single-vehicle crashes, on average, were more severe than multi-vehicle crashes.***
  The analysis showed that 6.3 percent of the single-vehicle crashes were K+A while only 4.7 percent of the multi-vehicle crashes were K+A.

- ***Proportionally more of the single-vehicle crashes occurred on rural two-lane roads than other crashes.***
  Almost 70 percent of the single-vehicle crashes occurred on rural two-lane roads, while only half of the multi-vehicle crashes took place on such roads.

- ***Surprisingly, nighttime single-vehicle crashes on unlit roads were less severe than daytime single-vehicle crashes.***
  Only 5.9 percent of the single-vehicle crashes that occurred during darkness on unlit roads were K+A while 6.8 percent of the daylight single-vehicle crashes were severe. One explanation for this is that more than one-third of the single-vehicle crashes that took place at night on unlit roads were caused by an animal getting on the road. This type of crash generally causes minor or no injuries.

Crash type versus injury severity and roadway/other crash characteristics

The distribution of total crashes and the distribution of K+A crashes for each crash type is shown by Figure 10. Distributions are shown across severity, roadway class, roadway character, number of lanes, alcohol involvement, light condition, and weather condition. The percent of K+A crashes for each crash type across the same roadway, crash, and environment characteristics is shown in Figure 11. The crash types are: (1) run-off-road (divided into hit fixed object, overturn and other); (2) head-on; (3) rear-end/sideswipe; (4) angle or turning; (5) pedestrian; (6) hit animal; (7) braking, backing or parking; and (8) train. The "pedestrian" crash type includes bicycle crashes.

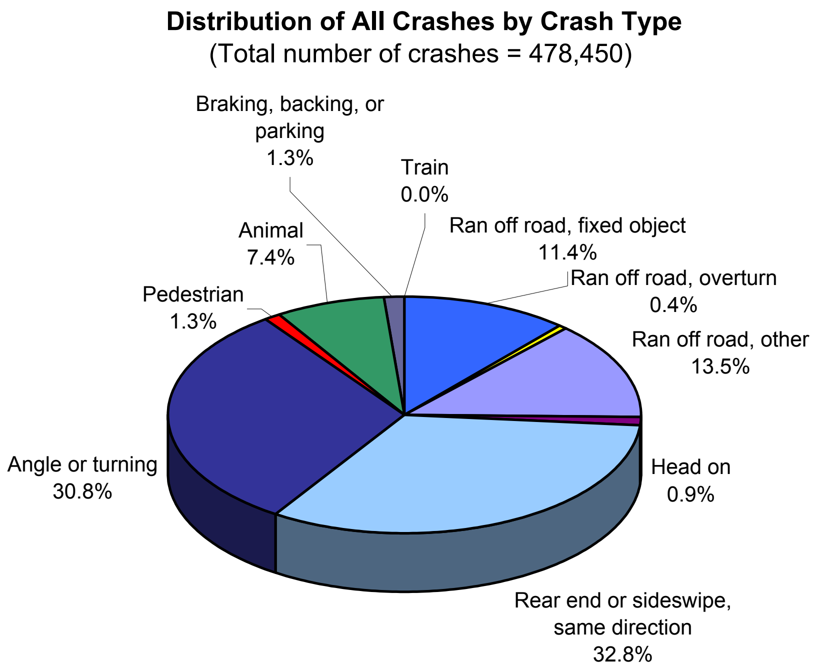
Some of the key findings of this analysis revealed that:

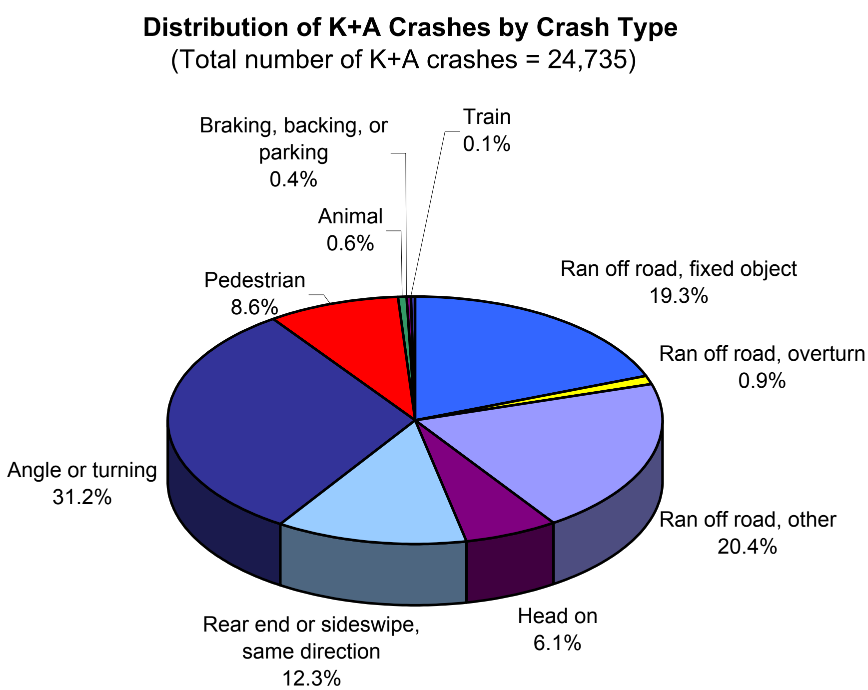
- ***More than two-thirds of the severe crashes (K+A) were either run-off-road or angle or turning crashes. Almost three-fourths of the fatal crashes (K) were either head-on or run-off-road crashes.***
  The largest number of severe crashes are run-off-road crashes (9,828 or 39.7 percent) and angle or turning crashes (7,579 or 31.2 percent) (Figure 10). Head-on crashes accounted for only 6.1 percent of the K+A crashes but accounted for 32.0 percent of the fatal crashes while run-off-road crashes and angle and turning crashes accounted for 42.1 percent and 24.3 percent of the fatal crashes, respectively.

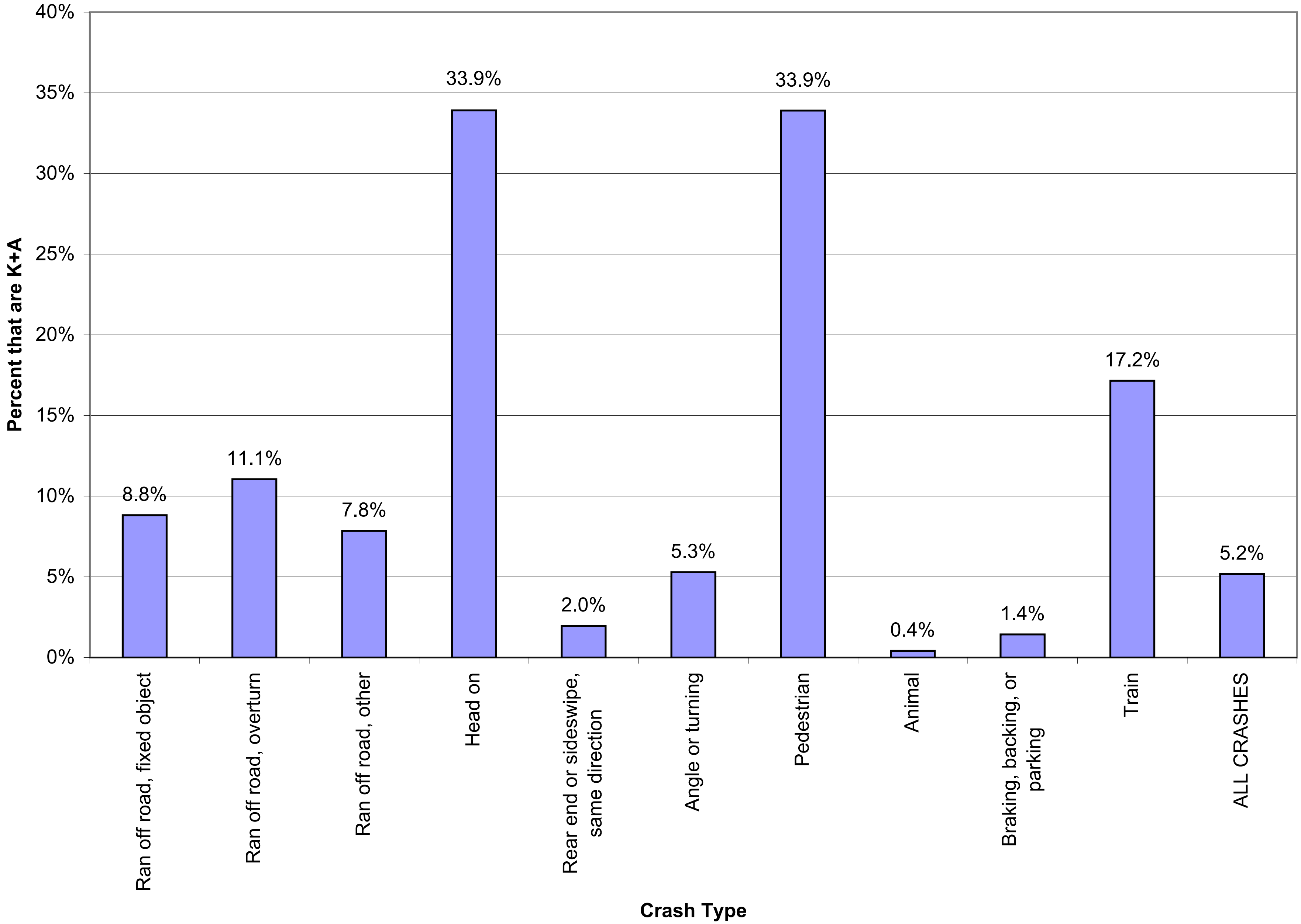
- ***Head-on, pedestrian, train, and run-off-road crashes were very likely to be severe***.
  Some crash types have higher percentages of K and A injury than others. Especially severe were head-on crashes (33.9 percent are K+A), pedestrian crashes (33.9 percent), train crashes (17.2 percent), run-off-road, overturn crashes (11.0 percent), run-off-road, hit fixed object crashes (8.8 percent), and run-off-road, other crashes (7.8 percent) (Figure 12).

- ***The vast majority of serious ran-off- road, other, head-on, animal and backing, braking, and parking crashes occurred on two-lane roads.***
  The majority of crashes (total and serious) occur on two-lane roads. Some crash types, such as "other" run-off-road crashes, head-on crashes, animal crashes, train crashes, occurred almost solely (80 percent or more) on two-lane roads. In addition, more than 80 percent of the serious backing, braking and parking crashes, a low-severity crash type, occurred on two-lane roads.

Figure 10. Distribution of all HSIS and severe HSIS crashes by crash type

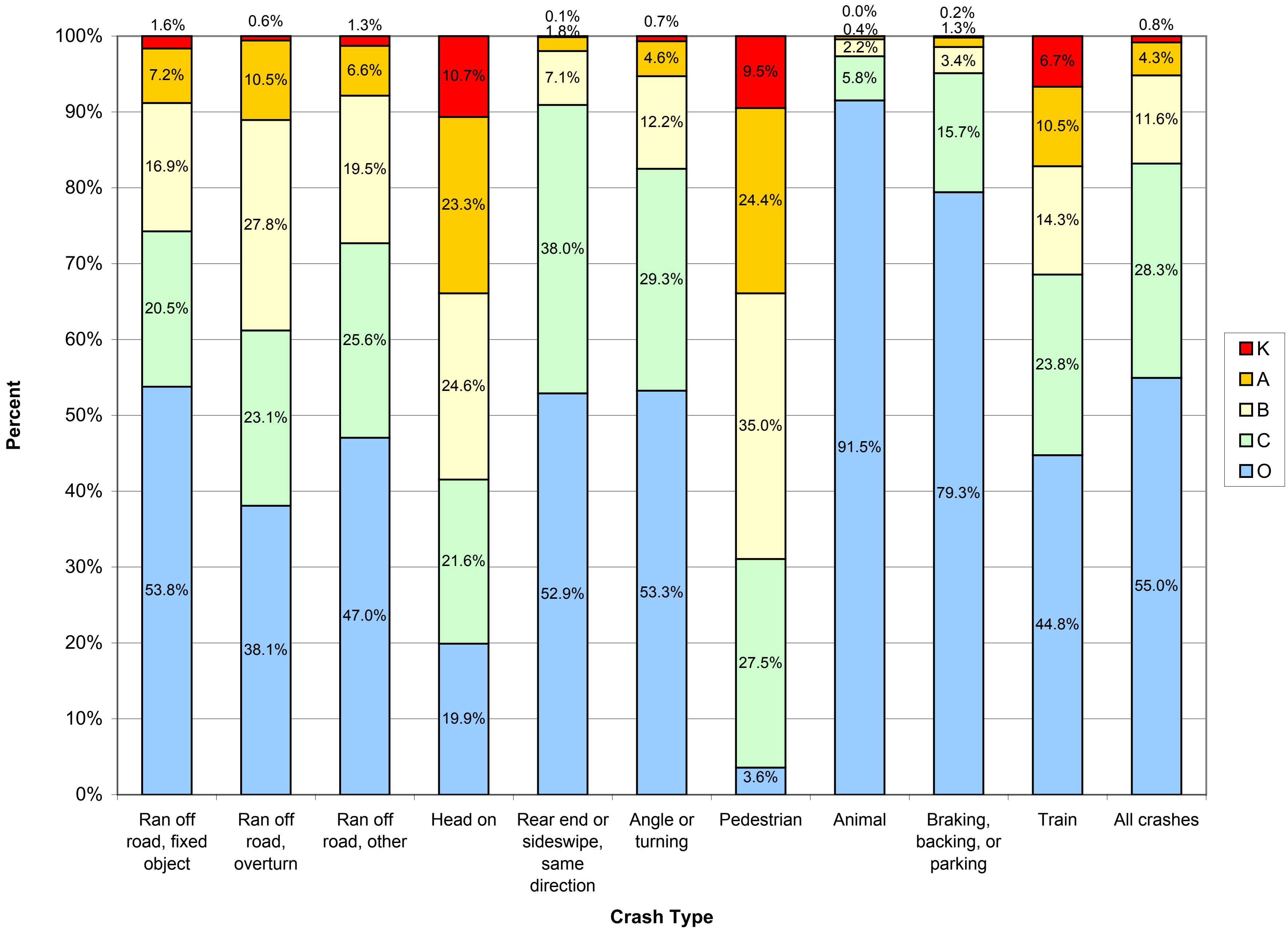






Percent that are K+A
40%
35%
30%
25%
20%
15%
10%
5%
0%
8.8%
11.1%
7.8%
33.9%
2.0%
5.3%
33.9%
0.4%
1.4%
17.2%
5.2%
Ran off road, fixed object
Ran off road, overturn
Ran off road, other
Head on
Rear end or sideswipe, same direction
Angle or turning
Pedestrian
Animal
Braking, backing, or parking
Train
ALL CRASHES
Crash Type

Figure 12. Crash severity by crash type



- ***Run-off-road and head-on crashes were more concentrated on rural two-lane roads than other crash types. In addition, head-on crashes occurring on rural or urban two-lane roads were more likely to be severe than head-on crashes occurring on other types of roads***.
  The majority of crashes (56 percent of total crashes and 64 percent of severe crashes) were on rural two-lane roads, followed by rural multilane undivided and divided highways and urban two-lane roads. Also, 70 percent or more of "other" run-off-road, head-on, animal and train crashes (fatal and serious crashes as well as all crashes) occurred on rural two-lane roads. Rather larger shares of the head-on and run-off-road crashes (fatal and serious crashes as well as all crashes) occurred on urban two-lane roads. Head-on crashes were more likely to be severe when taking place on rural two-lane roads (36.8 percent were K+A) or on urban two-lane roads (35.9 percent were K+A) than when taking place on most other types of roads (in comparison, 33.9 percent of all head-on crashes were K+A).

- ***Run-off-road and head-on crashes were more likely to occur on curved roads than other crash types. In addition, run-off-road and head-on crashes were more likely to be severe on curved roads than on straight roads***.
  Most crashes (total as well as fatal and serious only) took place on straight level roads, more than 40 percent of the run-off-road crashes and almost 40 percent of the head-on crashes occurred on curved roads. Head-on and run-off-road crashes occurring on curved roads were more likely to be severe than if occurring on straight roads.

- ***Pedestrian and head-on crashes involving alcohol lead to fatal or serious injury in half of the cases.***
  As expected, alcohol or drugs increased the possibility of fatality or serious injury—17.4 percent of the crashes involving alcohol and drugs were severe while only 5.2 percent of the total crashes were severe. About half of the pedestrian (49 percent) and head-on (50 percent) crashes that involved alcohol were severe compared with the overall 34 percent K+A for both crash types.

- ***Half of the pedestrian crashes that occurred during darkness on unlit roads were severe.***
  As expected, pedestrian crashes taking place during darkness on unlit roads were particularly severe—49 percent were K+A compared with the 34 percent K+A for all pedestrian crashes. Interestingly, braking, backing and parking crashes, a crash type with a very low overall severity (only 1.4 percent are K+A), were fatal or serious in 7.2 percent of the cases when they occurred in darkness on unlit roads.

- ***More than half of head-on crashes that occurred during fog lead to fatal or serious injury.***
  Only a very small percentage of crashes took place during fog—1.3 percent of all crashes, 1.5 percent of the severe crashes. Some crash types were more likely to occur during fog than others—4.3 percent and 2.4 percent of the serious animal crashes and serious head-on crashes, respectively occurred during fog. Head-on crashes were very likely to be severe when they occurred during fog (52 percent are K+A).

C. CONCLUSIONS OF INITIAL ANALYSIS

Segments

The North Carolina HSIS segment analysis showed that:

- Rural and urban two-lane roads had the highest fatal and serious crash rate. In other words, even when controlling for exposure (AADT and segment length), relatively more K+A crashes occurred on rural and urban two-lane roads than on other roads.

- Rural and urban two-lane roads had higher crash severity than other roads. In other words, if a crash took place on a rural or urban two-lane road, it was more likely to be severe than a crash on another type of road.

- The North Carolina counties with higher crash severity were largely in the mountains.

- Counties with higher crash severity on rural two-lane roads were also located in the mountains of North Carolina. Higher crash severity on urban two-lane roads was found in the western half of the state.

Crashes

The North Carolina HSIS crash analysis showed that:

- Crash severity decreased slightly between 1993 and 1997. However, crash severity remained stable for some of the most severe crash types.

- Crashes on rural or urban two-lane roads, crashes on curved roads, crashes involving alcohol, crashes during darkness on unlit roads, crashes during fog and crashes involving a motorcycle or a large truck were all more likely to be severe than other crashes.

- Single-vehicle crashes, on average, were more severe than multi-vehicle crashes. Proportionally more of the single-vehicle crashes took place on rural two-lane roads than other crashes. Curved roads were especially dangerous for single-vehicle crashes.

- Head-on, pedestrian, run-off-road, and train crashes were very likely to be severe.

- Run-off-road and head-on crashes were more likely to take place on curved roads than other crash types. In addition, run-off-road and head-on crashes were more likely to be more serious on curved roads than on straight roads.

- The following crash characteristics were associated with very high severity (%K+A): pedestrian and head-on crashes involving alcohol lead to fatal or serious injury in half of the cases; half of the pedestrian crashes that took place during darkness on unlit roads were severe; and more than half of head-on crashes that took place during fog lead to fatal or severe injury.

D. NEED FOR MORE IN-DEPTH ANALYSES

The first section of Part I suggested how fatal crashes in North Carolina differed from crashes in the Southeastern FHWA region as a whole. Combining this information with a more detailed analysis of severe crashes led to the following conclusions and suggestions for more in-depth analyses in Part II.

Crash Types Recommended for Further Investigation

- ***Head-on crashes***

Analysis of the CARE database showed that head-on crashes were over-represented in North Carolina between 1993 and 1997. In other words, North Carolina had proportionally more head-on crashes (21 percent of all fatals are head-on crashes in North Carolina) than the Southeast as a whole (15 percent of all fatals are head-on crashes). Based on the subset of North Carolina crashes contained in the HSIS crash and inventory database (meaning crashes on 34,800 miles of state system), head-on crashes were very likely to lead to fatal or serious injury (34 percent of head-on crashes were severe). While head-on crashes accounted for only 6 percent of the total number of severe crashes (K+A), this crash type accounted for 32 percent of the fatal (K) crashes. The detailed analysis of North Carolina crashes in the HSIS database also showed that the vast majority of head-on crashes occurred on two-lane roads and that head-on crashes occurring on two-lane roads were more likely to be severe than head-on crashes occurring on multilane roads. Head-on crashes were also more likely to occur on curved roads than on other crash types and head-on crashes that occurred on curved roads were more likely to be severe than other head-on crashes. Head-on crashes were also particularly likely to be severe when occurring during fog.

- ***Run-off-road crashes***

Another crash type that was very likely to be severe was run-off-road crashes. Analyzing the HSIS database showed that 11 percent of run-off-road, overturn, 9 percent of run-off-road, hit fixed object, and 8 percent of the other run-off-road crashes were severe. As with head-on crashes, run-off-road crashes occurred mostly on two-lane roads and were more likely to be severe if they occurred on such roads. Run-off-road crashes were also more likely to be severe when occurring on curved roadways. In addition, run-off-road crashes accounted for almost 40 percent of the severe (K+A) crashes and 42 percent of the fatal (K) crashes in the 1993-1997 HSIS database. Run-off-road is a crash type that warrants further investigation.

- ***Pedestrian crashes***

A total of 34 percent of the pedestrian crashes in the HSIS database were severe (i.e., K or A injury crashes). Crash severity was likely to increase when alcohol was involved (49 percent are K+A) as well as when the crash took place during darkness on unlit roads (49 percent are K+A). Although pedestrian crashes decreased slightly between 1993 and 1997, in absolute and in relative terms, their severity did not decrease. This particularly dangerous crash type also merits further attention.

Crash Characteristics Recommended for Further Investigation

- ***Rural and urban two-lane roads***

The North Carolina HSIS database showed that rural and urban two-lane roads had higher severe crash rates (number of K+A crashes per million vehicle miles) than other roadway types in North Carolina. In addition, crashes on rural and urban two-lane roads were more likely to be severe than crashes on other roadway types. More investigation is needed to identify factors that make two-lane roads dangerous e.g., shoulder type, curves etc. While rural two-lane roads have been the focus of many studies, this study identified urban two-lane roads as an area of concern.

- ***Rural multilane undivided roads***

The HSIS segment analysis showed a relatively high severe crash rate (0.09 K+A crashes per million vehicle miles) for rural multilane undivided roads. This roadway type ranked first in terms of total crash rate (2.61 crashes per million vehicle miles). More research on crashes on rural multilane undivided highways could point to the reasons for this high incidence of severe crashes.

- ***Curves***

Analysis of the CARE database showed that North Carolina had proportionally more fatal crashes on curves than the Southeast as a whole. This might mean (1) that a larger proportion of North Carolina's roads have curves; (2) that a larger proportion of North Carolina's traffic occur on curved roads; or (3) that North Carolina's curved roads are more dangerous. The HSIS analysis showed that crashes on curves were more likely to be severe than other crashes. Run-off-road and head-on crashes were more likely to take place on curved roads than other crash types. Curve crashes in North Carolina deserve further analysis.

- ***Motorcycles and large trucks***

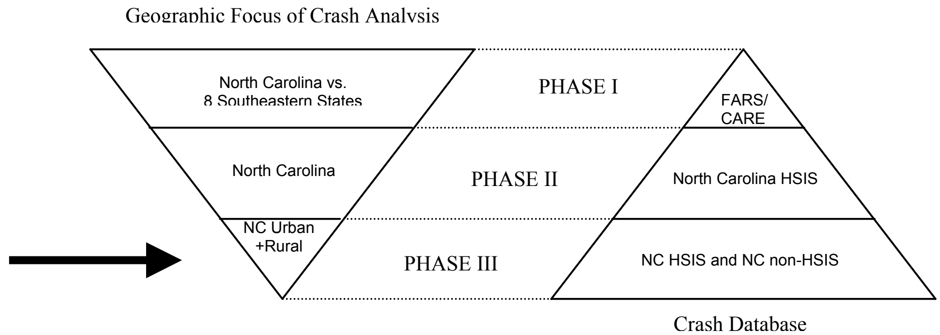
Just as are bicyclists and pedestrians (see "pedestrian crashes" above), motorcyclists are extremely vulnerable. More than a quarter of the crashes that involved motorcyclists were severe (K+A), exceeding the overall 5.2 percent K+A. Crashes involving large trucks were also more likely to result in fatal or serious injury. The vulnerable road users as well as the large trucks are candidates for further research.

- ***Alcohol***

Analyzing the HSIS database showed that 17 percent of all crashes that involved alcohol were severe while only 5 percent of the total number of crashes were severe. Pedestrian crashes and head-on crashes that involved alcohol were severe in about 50 percent of the cases.

Combining the information from this part of the study with the more detailed analysis in Part II will provide a basis for recommended countermeasures for factors associated with severe crashes in North Carolina.

PART II DETAILED COMPARISON OF HSIS AND NON-HSIS ROUTES



A. OBJECTIVE

Phase II used the Highway Safety Information System (HSIS) database to identify the following factors relating to severe crashes in North Carolina:

- Urban and rural two-lane roads
- Rural multilane undivided roads
- Curves
- Head-on
- Run-off-road
- Bicycle and pedestrian
- Motorcycles and large trucks
- Single vehicle involvement
- Alcohol involvement
- Darkness

The HSIS database includes crashes on primary and secondary routes in North Carolina, but contains less than half of all crashes throughout the state. In addition, the HSIS database has been well-analyzed in past studies of crash factors. Therefore, this section includes non-HSIS routes to supplement the analysis. Non-HSIS routes include non-state-owned rural roads, subdivision streets, and minor urban streets. Analysis of both HSIS and non-HSIS crashes give an additional dimension to the analysis by creating a more complete picture of the factors that influence severe crashes, especially on urban and lower class rural roads.

B. APPROACH

Method

The HSIS database contains crash data on 478,450 crashes on major routes in North Carolina between 1993 and 1997. Because two-lane urban and two-lane rural roadways were identified as factors contributing to severe crashes in the preliminary HSIS analysis, it is divided further into 34,629 crashes on urban two-lane highways, 174,048 crashes on rural two-lane highways, and 269,773 crashes on all other HSIS roadways in this section of the report. Severe crashes, represented by the number of K+A crashes in each sample, are evaluated according to roadway, crash, vehicle, driver, and environmental variables. Significant differences between crash factors are found through cross-tabulation techniques.

This sample of HSIS crashes is compared to the non-HSIS database that contains 654,319 crashes. The non-HSIS crashes are divided into 544,878 urban crashes and 107,165 rural crashes. Note that 2276 (0.3 percent) of the records in the non-HSIS database are incomplete because they are not designated as urban or rural. Cross-tabulation techniques are also used on these sets to find the roadway, crash, vehicle, driver, and environmental factors related to severe crashes in North Carolina.

This part of the report identifies factors that are significantly related to severe injury crashes. First, the proportion of severe crashes for each factor (K+A/(K+A+B+C+O)) is determined.

Next, an estimate for the standard error for a binomial proportion tests the significance of each factor. This technique uses the following formula to account for differing sample sizes:

$$SE = \{[p*(1-p)]/n\}^{0.5}$$

SE is an estimate of the standard error of the proportion of crashes for a given factor that are severe (K+A), p is the proportion of crashes that are severe, and n is the total number of crashes associated with that factor. Therefore, an upper-bound for the standard error for each factor with a sample size of n can be found:

The greatest possible value is $SE = \{[0.5*(1-0.5)]/n\}^{0.5} = \{[0.5*0.5]/n\}^{0.5} = \{[0.25]/n\}^{0.5}$

For example, if the sample size is 100, an upper-bound estimate of the standard error for the percentage of crashes that are severe is {[0.25]/100}0.5 = 0.05. If the sample size is 5,000, an upper-bound estimate of the standard error for the percentage of crashes that are severe is {[0.25]/5,000}0.5 = 0.00707. A factor will be considered significant when the percentage of severe crashes associated with that factor is at least two standard errors greater than the percentage of all crashes in the database that are severe (see Example below). Assuming that the proportions of severe crashes are distributed normally, at least 95 percent of the difference between proportions will be due to factors other than random chance. Note that this method used to test for significance is conservative because it uses an upper-bound estimate for standard error.

Example

This example shows how the estimate for the standard error of a binomial proportion was used in Table D.1 to determine the statistical significance of crash factors. The proportion of severe crashes (K+A) on urban two-lane HSIS highways was 0.062 (6.2 percent, N=34,629). Both curved, hillcrest (N=428, K+A=10.1 percent) and curved, grade (N=4092, K+A=8.5 percent) had a higher proportion of severe crashes than the roadway system as a whole. To determine if the proportion of severe crashes for either road characteristic was significantly higher, the standard error upper-bounds reference table was used (Table D.2).

First, the difference between the curved, hillcrest and overall proportions was determined to be 0.101-0.062=0.039. Next, because there were 428 curved, hillcrest crashes, the N=400 row was used as a conservative estimate of the upper-bound of the standard error for the curved, hillcrest severe crash proportion. Finally, the significance was found in terms of standard errors. The proportion 0.062 was more than one standard error (0.0250) smaller, but not two standard errors (0.0500) smaller than 0.101. Therefore, curved, hillcrest did not have statistical significance at the "two standard error" (95 percent confidence) level.

The difference between the proportion of severe curved, grade and all urban two-lane HSIS crashes was 0.085-0.062=0.023. Using the reference table N=4000, the proportion 0.062 was determined to be more than two standard errors (0.0158), but less than three standard errors (0.0237) smaller than 0.085. Therefore, curved, grade was a statistically significant severe crash factor.

Therefore, some factors that have marginal significance will not be highlighted even though they may have a noticeable relationship with injury severity. In addition, this method does not control for the effect of combinations of factors on injury severity.

The results of significance testing on each variable are presented in Appendix D.

Data Description

Overall, severe (K+A) crashes make up 5.2 percent (24735/478450) of HSIS crashes. Examining the HSIS database by urban and rural classification shows that 6.2 percent (2151/34629) of urban two-lane, 5.9 percent (6731/174048) of rural two-lane, and only 3.9 percent (15853/269773) of crashes on other HSIS roads are severe (Figure 13). The proportions of severe crashes on urban two-lane, rural two-lane, and all other HSIS roads are each significantly different from the overall percentage of severe HSIS crashes at a five standard error level.

In contrast, only 3.4 percent (22451/652043) of non-HSIS crashes are severe. However, 2.9 percent (15944/544878) of non-HSIS urban and 6.1 percent (6507/107165) of non-HSIS rural crashes are severe (Figure 14). These proportions are each significantly different from the overall percentage of severe non-HSIS crashes at the five standard error level. Note that a smaller percentage of rural two-lane crashes are severe on HSIS highways, but rural routes have a greater percentage of severe crashes than urban routes in the non-HSIS database.

Though all non-HSIS roadways were expected to have more severe crash problems because they are not the primary highways and arterials in North Carolina, only the rural non-HSIS (non-state-owned) roads had a higher proportion of severe crashes than all HSIS roadways. Non-HSIS urban roads, which contain many subdivision streets and minor urban streets, had a smaller percentage of severe crashes than all HSIS roadways.

Next, the databases are queried according to specific characteristics to identify factors that are related to severe crashes. The variables used to determine these factors include:

Roadway factors

Road characteristics (straight level, hillcrest, grade, and bottom, and curve level, hillcrest, grade, and bottom)
Road feature (bridge, underpass, driveway, intersection, beginning/end of divided highway, etc.)
Road configuration (undivided one-way and two-way, and divided)
Road defects (loose material, low shoulders, etc.)
Road condition (dry, wet, muddy, snowy, icy, and other)
Road surface (concrete, smooth and coarse asphalt, gravel, etc.)
Traffic signal
Traffic control (stop sign, yield sign, flashing signal, etc.)

Figure 13. HSIS crashes on urban and rural two-lane and all other roads by severity

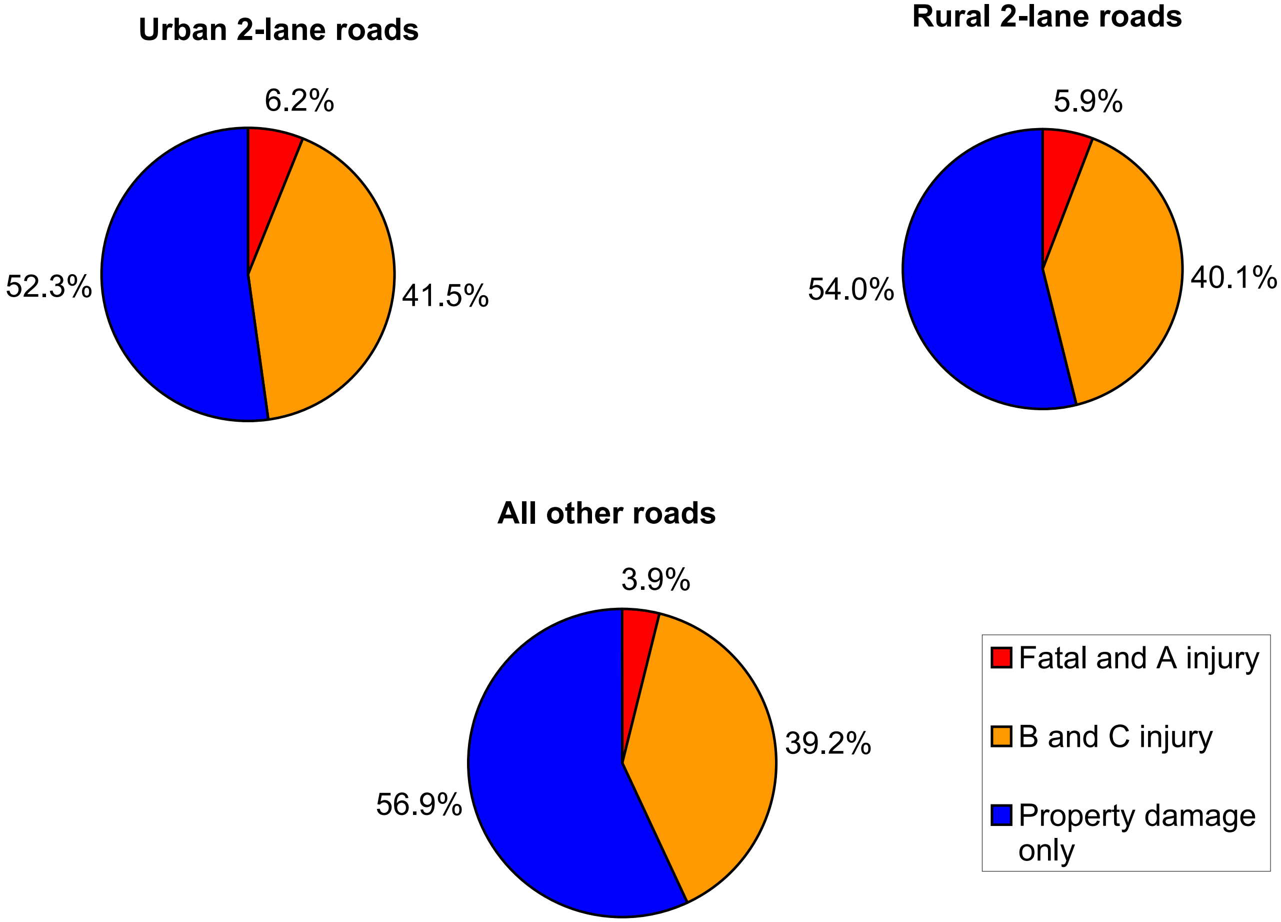
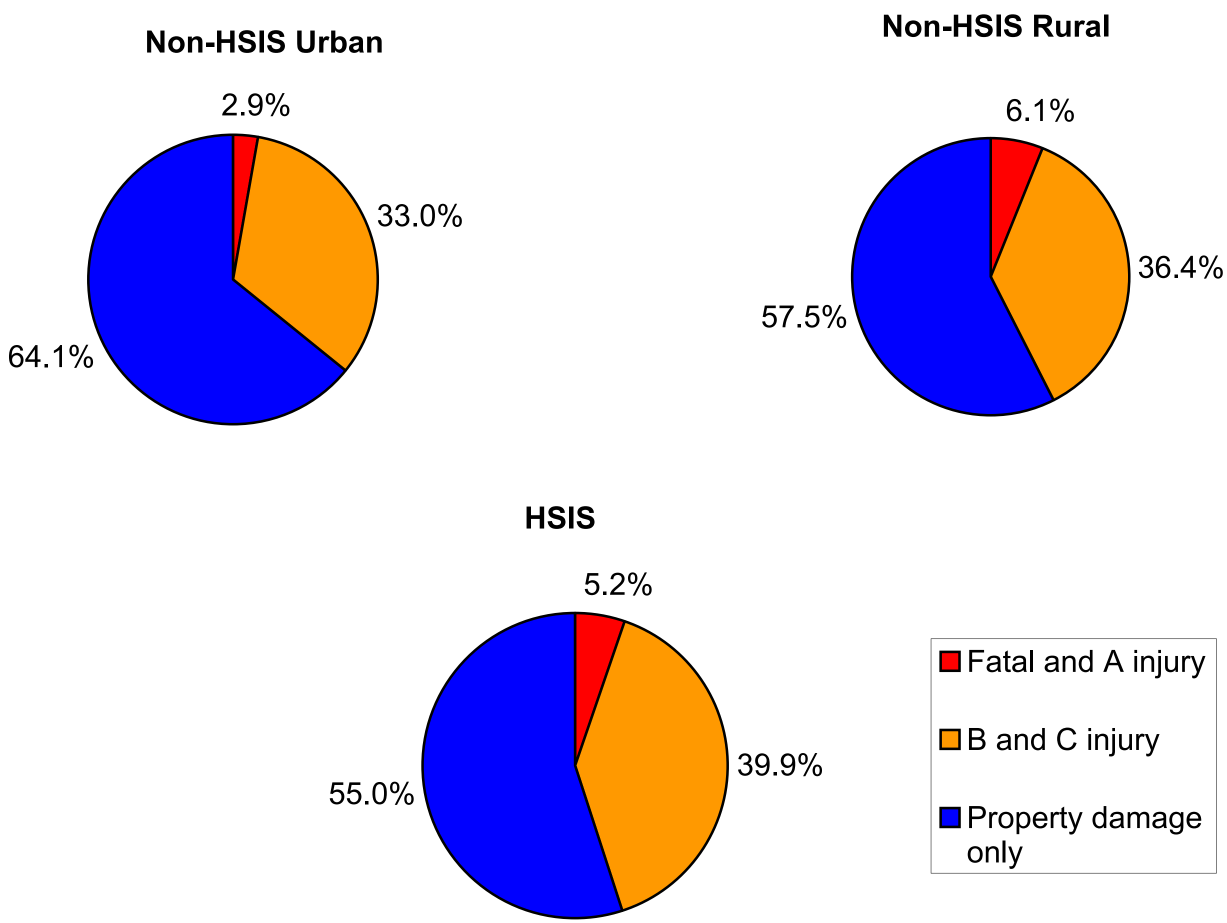


Figure 14. HSIS vs. non-HSIS urban and rural crashes by severity



Crash factors
Accident type (run-off-road rollover, head-on, angle/turn, rear end/sideswipe, etc.)
Means of involvement (run-off-road, hit fixed object, hit non-fixed object, car vs. car, car vs. truck or bus, 2+ vehicles involved, etc.)
Number of units involved in accident
Bicycle accident
Pedestrian accident

Vehicle factors
Vehicle type (car, small truck, large truck, bus, pedestrian, motorcycle, bicyclist, and other)

Driver factors
Alcohol involvement

Environmental factors
Light condition (daylight, dusk, dawn, dark with streetlight, dark without streetlight)
Day of week
Weather condition (clear, cloudy, rain, snow, fog, etc.)

Sample sizes are presented in Appendix E, and Table 1 shows the general structure of the severe crash factor analysis.

Table 1. Structure of detailed crash factor analysis

	Roadway System				
Crash Factor Category	**HSIS**			**Non-HSIS**	
	Urban 2-lane	*Rural 2-lane*	*Other*	*Urban*	*Rural*
Roadway Factors					
Crash Factors					
Vehicle Factors					
Driver Factors					
Environmental Factors					

C. ANALYSIS OF HSIS TWO-LANE URBAN, HSIS TWO-LANE RURAL, AND OTHER HSIS ROUTES

	Roadway System				
Crash Factor	**HSIS**			**Non-HSIS**	
Category	*Urban 2-lane*	*Rural 2-lane*	*Other*	*Urban*	*Rural*
Roadway Factors					
Crash Factors					
Vehicle Factors					
Driver Factors					
Environmental Factors					

Roadway Factors

Curved road segments had a significantly higher percentage of severe crashes than straight segments on urban two-lane highways, rural two-lane highways, and all other types of HSIS roadways (Figure 15). This difference was particularly noticeable for level segments of urban highways, where 5.0 percent of crashes on straight roads of this type (N=16,568) were severe, while nearly ten percent of crashes on curved roads of this type (N=4,316) were severe.

Bridges and underpasses were significant roadway features related to severe crashes on rural two-lane and other HSIS routes and were a noticeable factor on urban two-lane highways (Figure 16). Though they lacked statistical significance due to a small sample size, railroad crossings and the beginning or end of divided highways were associated with high percentages of severe crashes on urban two-lane highways. Railroad crossings were also a noticeable factor on non-two-lane highways. There were small sample sizes for railroad crossings on urban two-lane highways (N=90) and crashes at the beginning or end of divided highways on urban two-lane highways (N=27).

Multilane undivided roadways were a significant road configuration in the HSIS database as a whole, but the breakdown of the database into 2-lane urban and 2-lane rural highways and all other routes did not allow for a comparative analysis. Though this analysis did not identify any significant road configurations, it suggested that divided two-lane highways had lower crash severity than undivided two-lane highways but that divided highways had slightly higher crash severities for all other HSIS roads. For all other HSIS routes, 4.3 percent of crashes on divided highways were severe (N=91,016), but only 3.5 percent of crashes on undivided two-way roads were severe (N=75,454). This result was surprising because undivided roadways are normally associated with more severe injuries than divided roadways. However, this may simply be the result of higher vehicle speeds on the divided multi-lane roads, as compared to individual routes.

About 95 percent of HSIS crashes were on roadways with no defects. Though relatively few crashes were on roads with defects, nearly 10 percent of crashes on rural two-lane highways with **low shoulders** (N=1085) were severe compared to only 5.9 percent of all rural two-lane highway crashes (Figure 17). Low shoulders on rural two-lane highways was the only significant

Figure 15. Severe crashes on urban and rural two-lane HSIS roads by road character

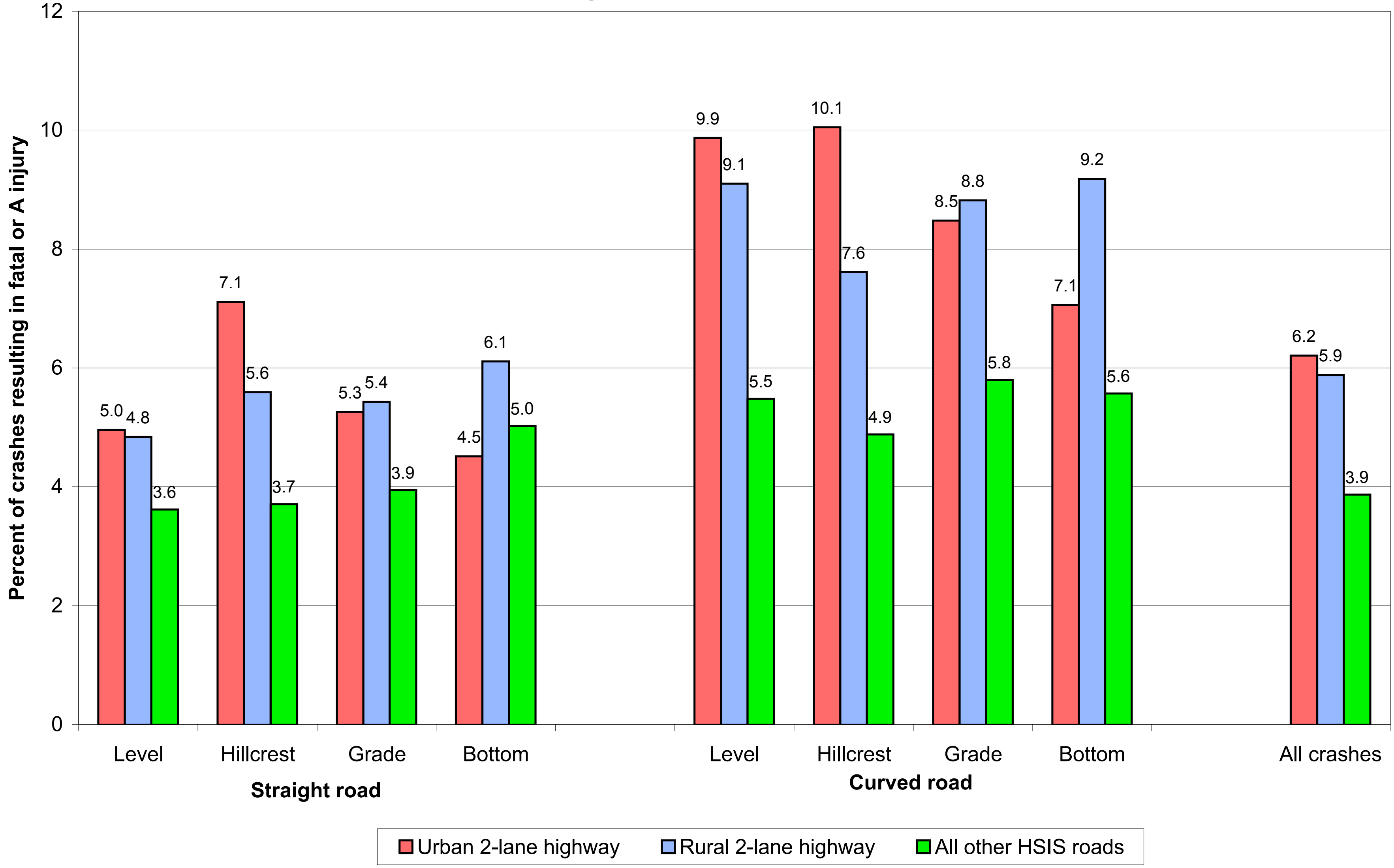


Figure 16. Severe crashes on urban and rural two-lane HSIS roads by road feature

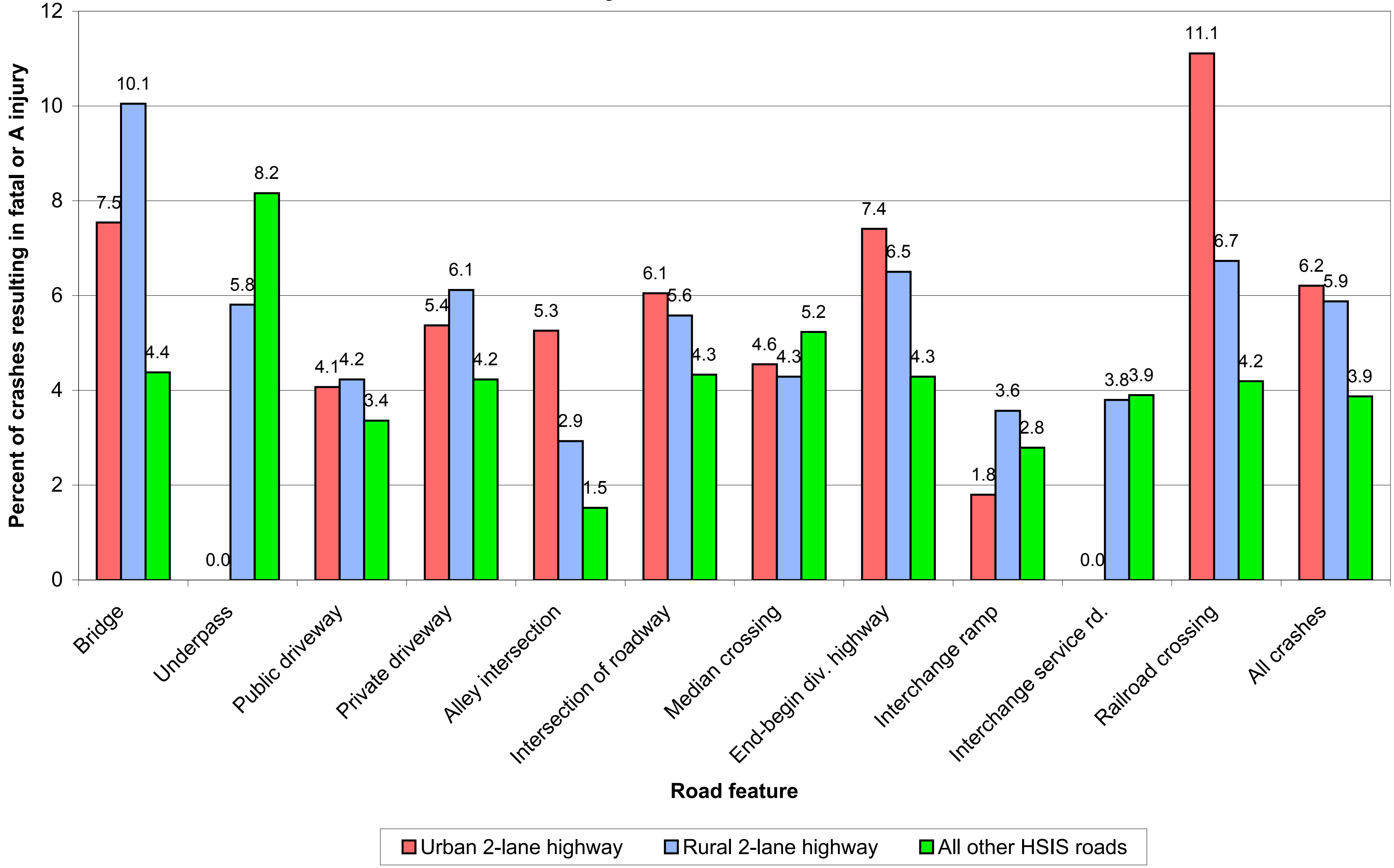
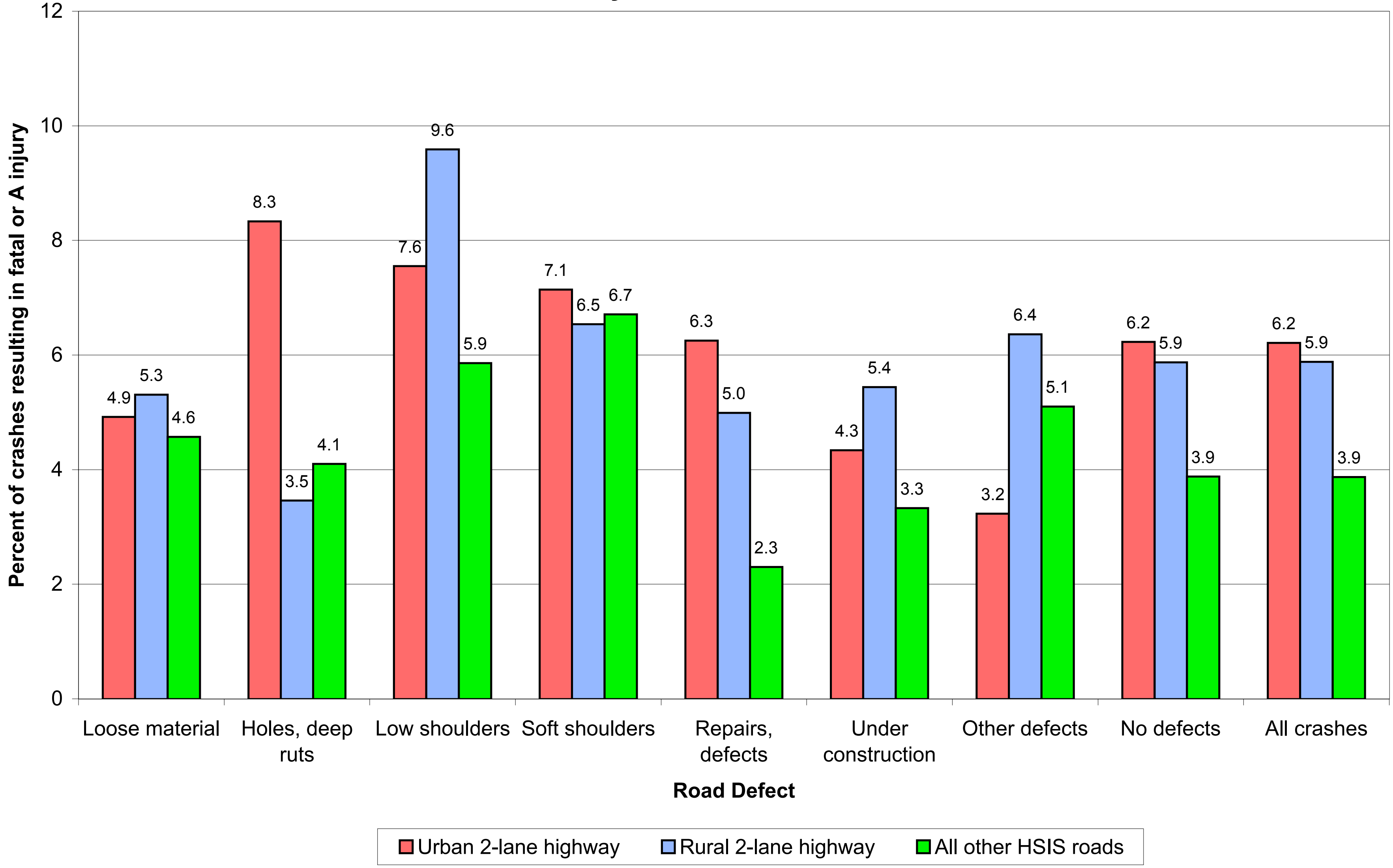


Figure 17. Severe crashes on urban and rural two-lane HSIS roads by road defect



roadway defect, but low and soft shoulders were associated with an above-average percentage of severe crashes on all three types of HSIS routes. One explanation for why locations with low shoulders are a severe crash factor is that they tend to be associated with run-off-road and head-on crashes.

Dry roads were associated with the greatest incidence of severe crashes on all three types of HSIS roadways, though this condition was a significant crash factor only on rural two-lane roadways. Interestingly, the incidence of severity was lower than average on snowy, icy, and wet roads for all three classifications. This finding was consistent with research by Khattak, Kantor, and Council (1998). Though more crashes may occur in these conditions, people often drive at lower speeds in snowy and icy conditions than on dry roads, which may result in a smaller percentage of severe crashes.

The analysis did not reveal any specific road surface to be a significant severe crash factor due to the small sample sizes of crashes on gravel, sand, and soil road surfaces. Though concrete road pavement was associated with a higher percentage of severe crashes on non-two-lane HSIS roads, this is logically the result of concrete being used on high-speed, multilane roadways, which have a higher percentage of severe crashes than lower-speed roads.

On multilane HSIS roadways, crashes occurring at locations with **traffic signals** were associated with a significantly higher proportion of severe crashes compared to HSIS roadways as a whole. Yet, injury severity in these locations may be explained better by other factors, such as being associated with intersections, which were also more likely to have severe crashes compared to all locations as a whole.

Crash Factors

Preliminary analysis of the HSIS database identified head-on, run-off-road, single-vehicle, and bicycle and pedestrian crashes to be associated with significantly higher percentages of severe injuries. Dividing the database into two-lane urban, two-lane rural, and all other HSIS routes gave similar results. The percentage of **head-on** crashes resulting in severe injury was about six times greater than the corresponding percentage for all crashes on all three types of routes (Figure 18). The greatest difference in the percentage of severe **pedestrian and bicycle** crashes and percentage of severe crashes on each roadway type overall was for all other HSIS routes and the smallest difference was for urban two-lane highways. Pedestrian and bicycle crashes are discussed in more detail below. **Run-off-road** crashes, especially those on rural two-lane highways, were also associated with a significantly high percentage of severe injuries.

Several means of involvement had significantly high percentages of severe injuries on HSIS routes. Data from all three types of roadways showed that **run-off-road** crashes and crashes with two or more vehicles had a higher incidence of severe injuries than other types of crashes (Figure 19). Yet, it should be noted that the HSIS database reports only the most severe injury in a crash. When more vehicles are involved, there is a greater likelihood that one of the passengers will have a severe injury. As mentioned above, run-off-road crashes tend to have more severe injuries, but they should also require extra attention due to their frequent occurrence. These crashes accounted for over 30 percent of urban two-lane highway and over 25 percent of rural two-lane highway crashes in the HSIS database.

Figure 18. Severe crashes on urban and rural two-lane HSIS roads by accident type

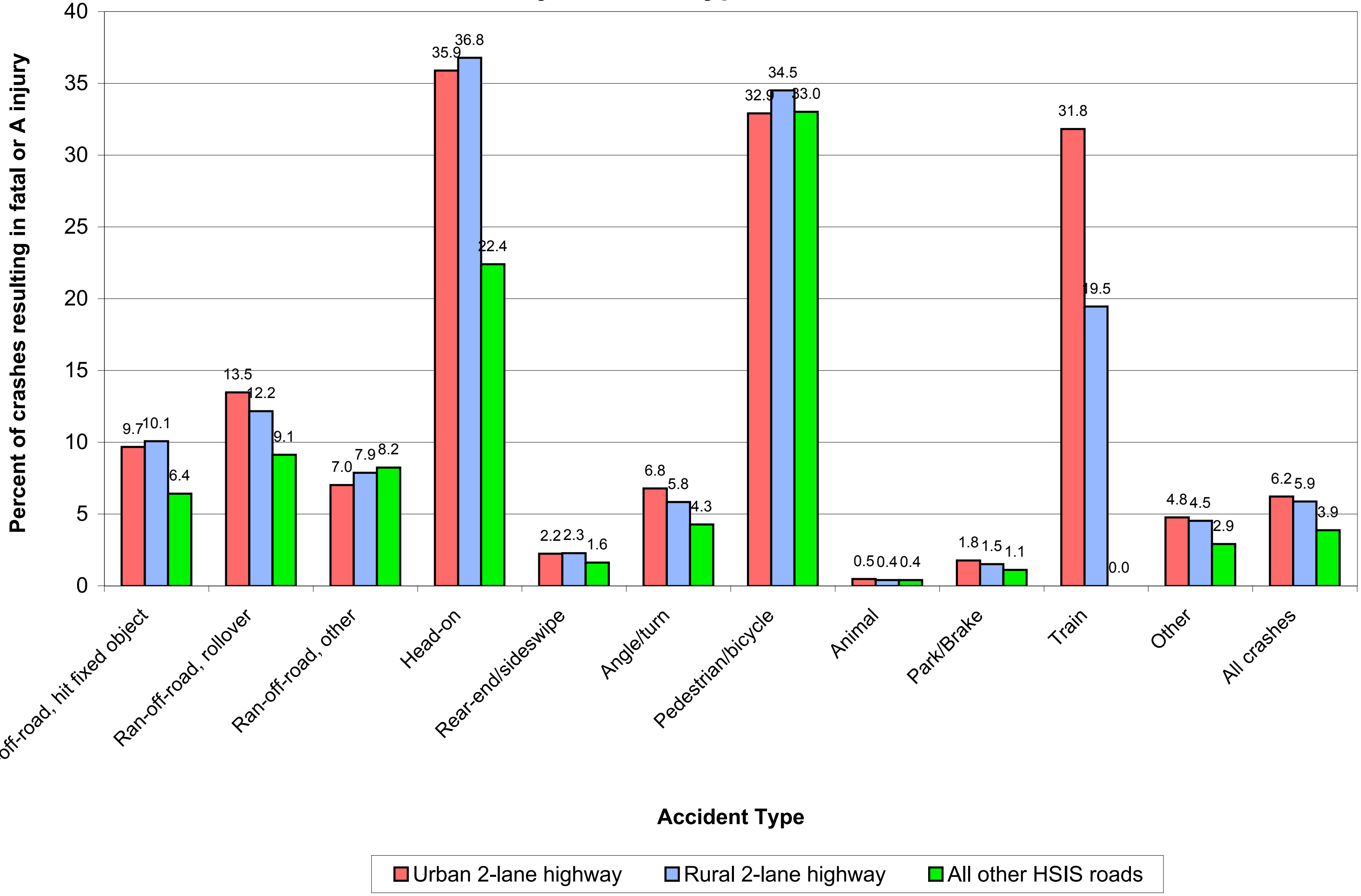
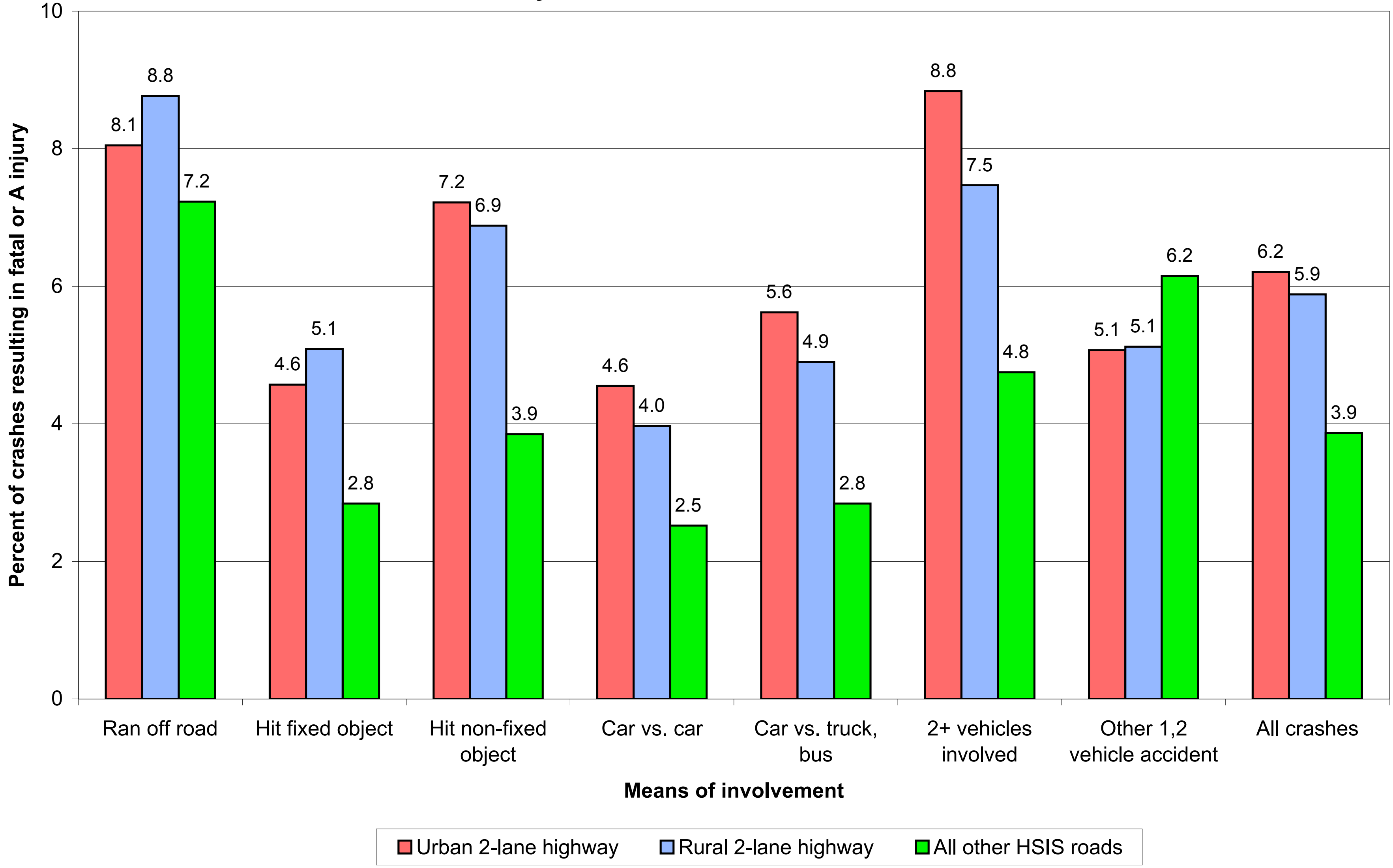


Figure 19. Severe crashes on urban and rural two-lane HSIS roads by means of involvement



Additional data were used to analyze the types of objects being hit by vehicles that ran off the road. This database subset showed that 9.7 percent of crashes on urban two-lane, 10.1 percent on rural two-lane, and 6.4 percent on other HSIS highways were severe. Among the most common objects struck on HSIS highways were **trees** (N=18,949), utility poles (N=7,507), fences (N=3,719), mailboxes (N=2,765), and parked vehicles (N=1,501). Though trees were the only object significantly related to severe crashes on all three types of routes (about 13 percent K+A on urban and rural two-lane routes and over eight percent K+A on other routes), **utility poles** were associated with a high proportion of fatal and serious injuries on urban two-lane (10.8 percent K+A) and non-two-lane HSIS roads (8.5 percent K+A).

Single-vehicle crashes were the most severe on rural two-lane and non-two-lane HSIS routes. About 40 percent of crashes on urban and rural two-lane HSIS routes and 18 percent on non-two lane HSIS routes were single-vehicle, so this type of crash is important to address with safety countermeasures. There were no significant findings related to number of vehicles involved on urban two-lane HSIS routes. Though crashes with three or more vehicles involved had the highest percentage of severe injuries on urban two-lane HSIS routes, this finding may be the result of the database reporting the most severe injury from each crash, which is more likely to be severe when there are more vehicles involved. Crashes on all three classifications of HSIS roadways were least likely to be severe when two vehicles were involved.

The percentage of crashes that are severe when **bicycles** were involved was between three and five times higher and the percentage of crashes that were severe when **pedestrians** were involved was between seven and twelve times higher than other crashes on all HSIS roadways (Figure 20). This difference was greatest for non-two-lane HSIS roads, meaning that these multilane highways were the most dangerous for pedestrians and bicycles compared other types of roads. Overall, about 45 percent of injuries in HSIS pedestrian crashes and about 20 percent of injuries in HSIS bicycle crashes were severe. It should be pointed out that HSIS urban two-lane highways had only a small number of bicycle crashes (N=156) and pedestrian crashes (N=186).

<u>Vehicle Factors</u>

Motorcycle, **pedestrian**, and **bicycle** crashes were all associated with a significantly high percentage of severe crashes on all types of HSIS routes (Figure 21). **Large trucks** were a significant severe crash factor on rural two-lane highways. In fact, all four vehicle types had a severe crash percentage that was at least 20 percent higher than the mean of 7.2 percent on rural two-lane routes.

Crashes involving school buses had a lower percentage of severe injuries than other crashes for all types of HSIS routes. The analysis was limited by a relatively small sample of school bus crashes in each classification, especially on two-lane urban highways (N=173).

<u>Driver Factors</u>

The percentage of crashes that were severe when drinking or drugs were involved was almost four times greater on urban and rural two-lane HSIS roadways and slightly more than four times

Figure 20. Severe crashes on urban and rural two-lane HSIS roads by bicycle and pedestrian involvement

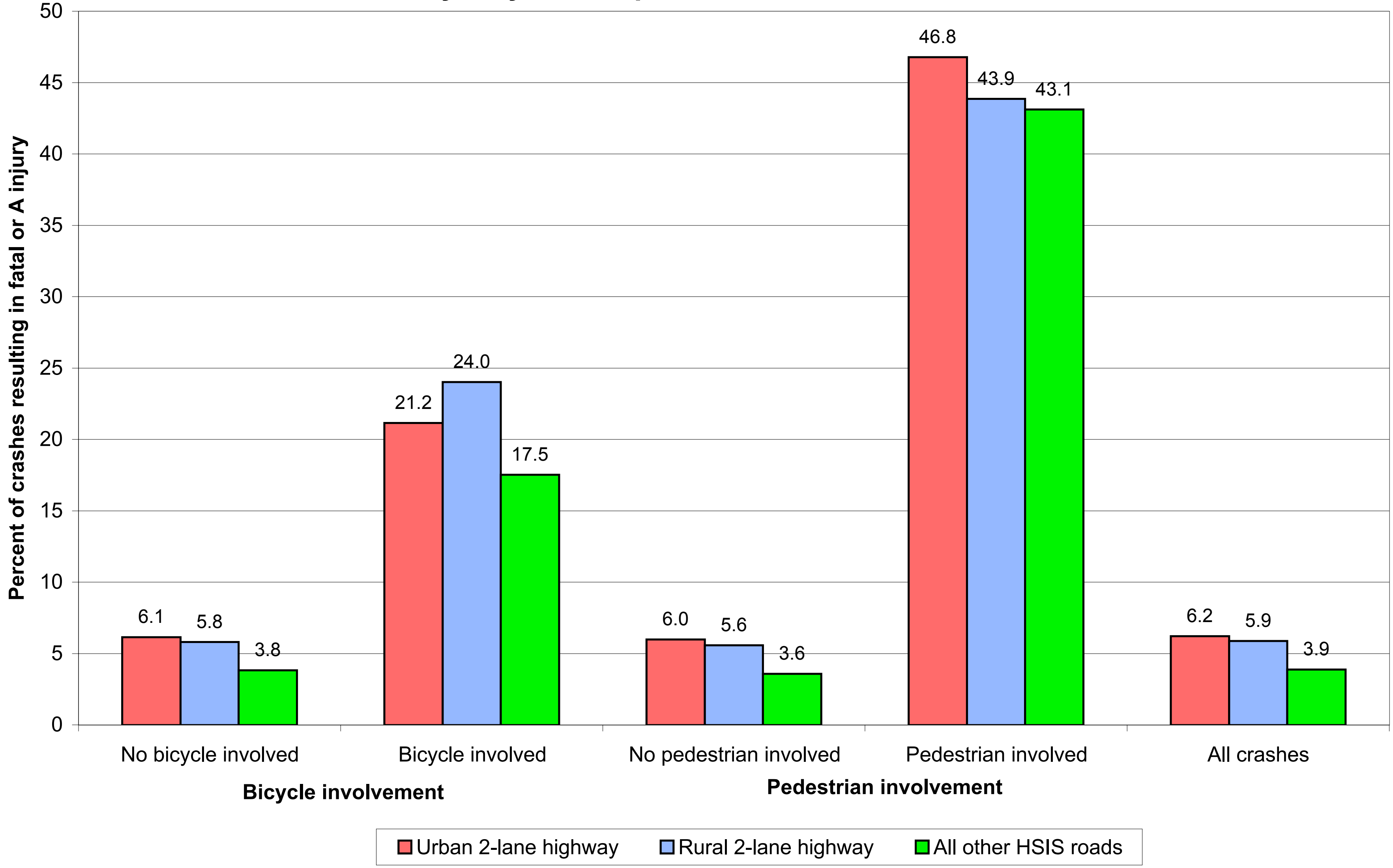
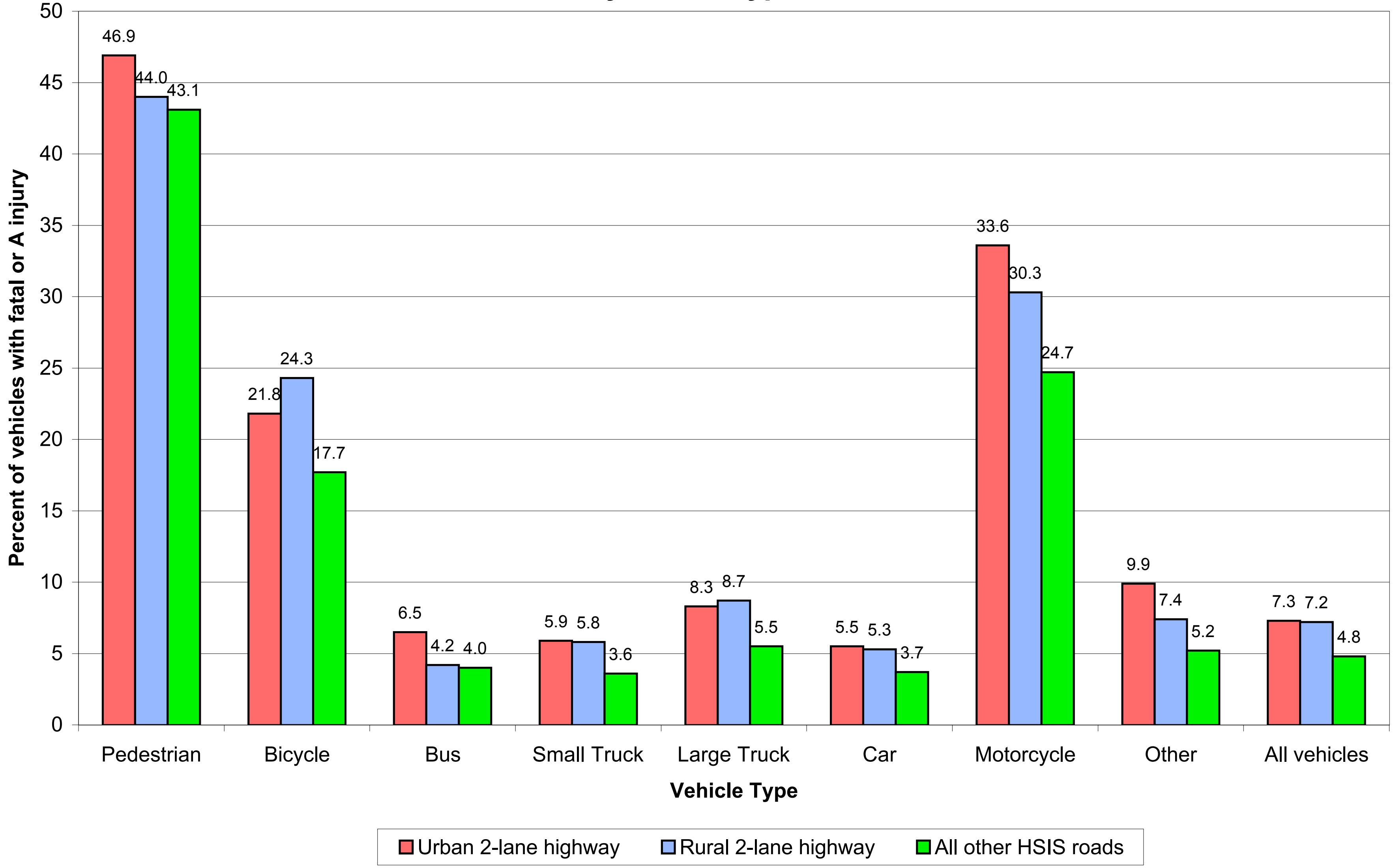


Figure 21. Severe crashes on urban and rural two-lane HSIS roads by vehicle type



greater for all other HSIS roadways (Figure 22). Though **alcohol involvement** is a significant severe crash factor on all types of routes, it should be noted that alcohol was involved in a greater percentage of crashes on urban (7.7 percent) and rural (6.8 percent) two-lane HSIS roads than on other HSIS roads (4.0 percent).

Environmental Factors

Darkness without streetlight was the most significant environmental crash factor on all types of highways in the HSIS database (Figure 23). More than 25 percent of crashes on urban and rural two-lane HSIS roadways occurred under this lighting condition.

Crashes occurring on **weekends** were more likely to be severe than weekdays on all types of HSIS routes (Figure 24). Yet, weekends were only a significant crash factor for rural two-lane and non-two-lane HSIS routes

The most noticeable weather condition related to severe injuries on rural two-lane and non-two-lane HSIS routes was fog, smog, smoke, or dust. However, no weather conditions were significantly-related to severe crashes on any type of HSIS route.

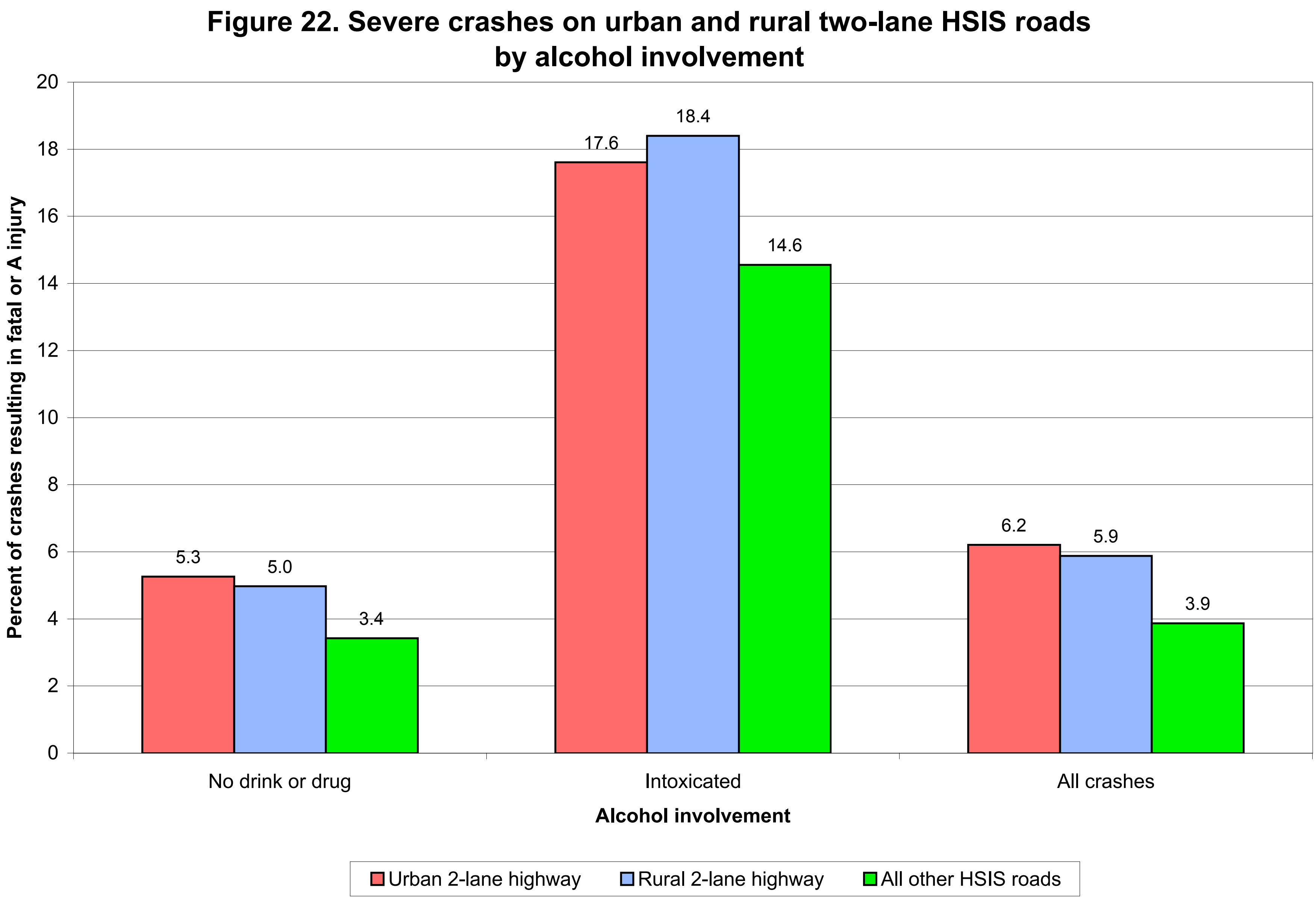


Figure 22. Severe crashes on urban and rural two-lane HSIS roads
by alcohol involvement
Percent of crashes resulting in fatal or A injury
20
18
16
14
12
10
8
6
4
2
0
5.3
5.0
3.4
17.6
18.4
14.6
6.2
5.9
3.9
No drink or drug
Intoxicated
All crashes
Alcohol involvement
Urban 2-lane highway
Rural 2-lane highway
All other HSIS roads

Figure 23. Severe crashes on urban and rural two-lane HSIS roads by lighting condition

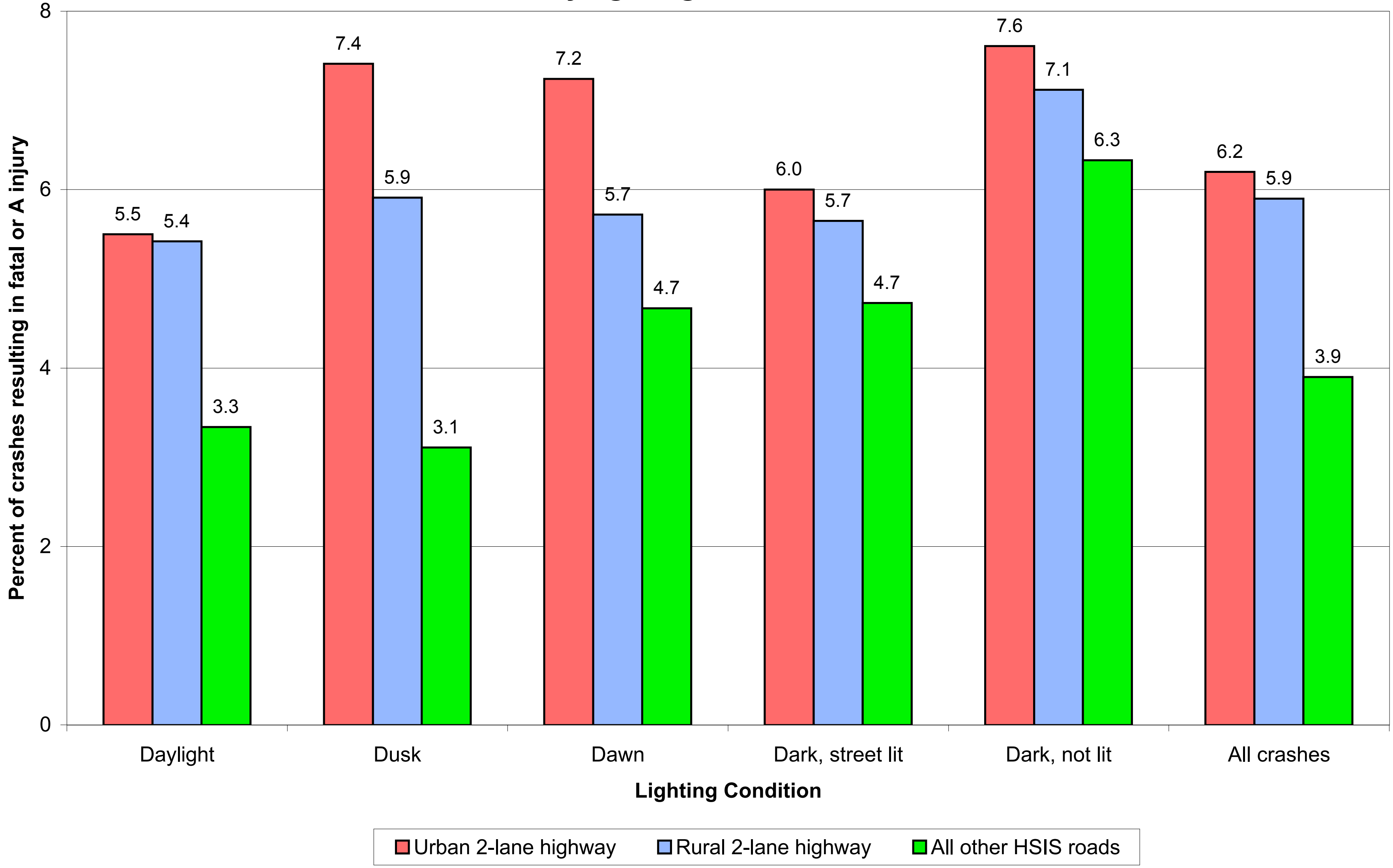
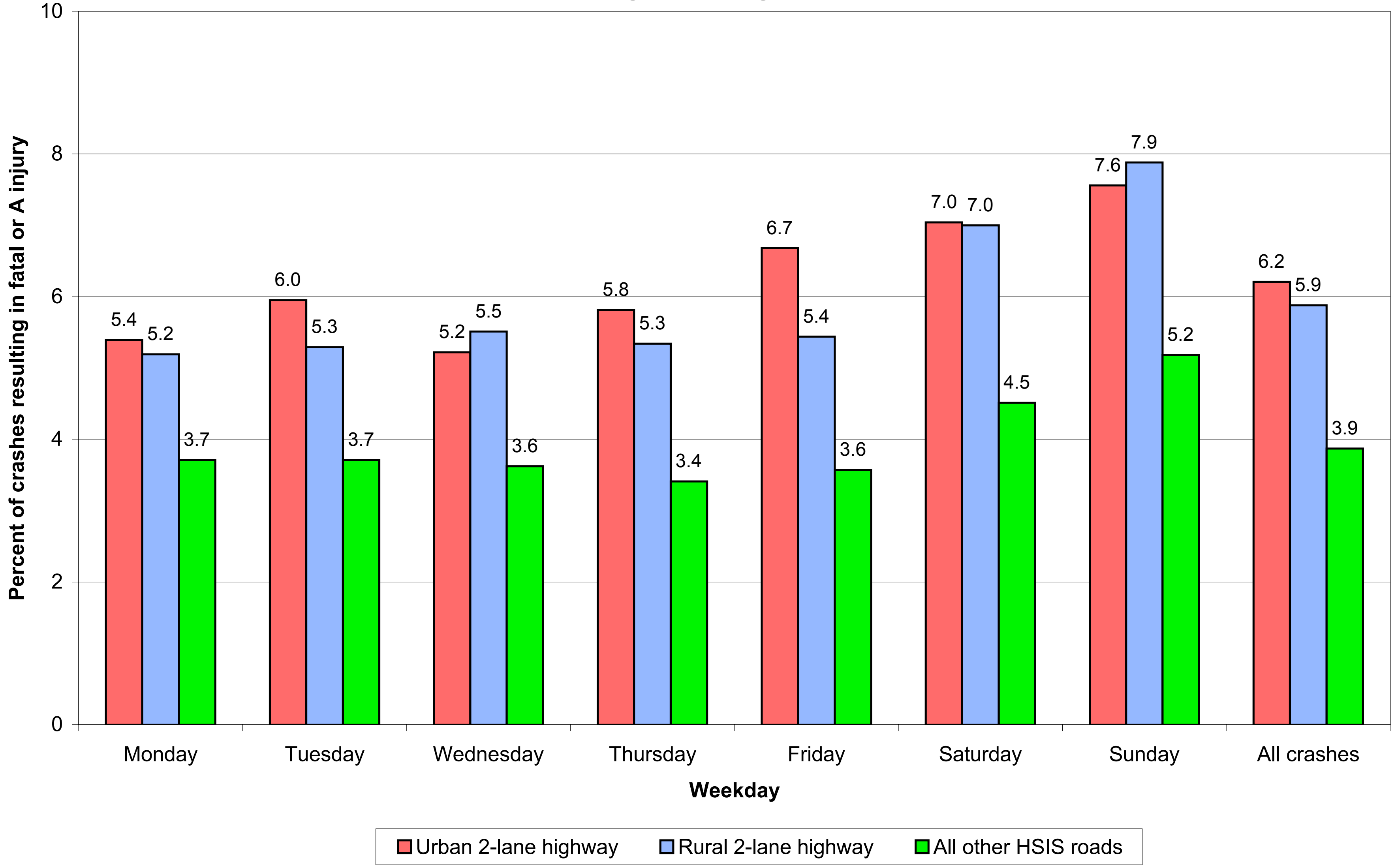


Figure 24. Severe crashes on urban and rural two-lane HSIS roads by weekday



D. ANALYSIS OF NON-HSIS URBAN AND RURAL ROUTES

	Roadway System				
Crash Factor	**HSIS**			**Non-HSIS**	
Category	*Urban 2-lane*	*Rural 2-lane*	*Other*	*Urban*	*Rural*
Roadway Factors					
Crash Factors					
Vehicle Factors					
Driver Factors					
Environmental Factors					

Roadway Factors

Curved roadways were associated with a significantly greater percentage of severe crashes than straight roadways on non-HSIS routes. This result complements what was found using the HSIS database. About 5.5 percent of crashes on level, curved urban non-HSIS roads (N=24,318) were severe, but only 2.6 percent of crashes on level, straight urban non-HSIS roads (N=372,419) were severe. Similarly, while almost nine percent of crashes on level, curved rural non-HSIS roads (N=19,298) were severe, only 4.7 percent of crashes on level, straight rural non-HSIS roads (N=49,321) were severe.

Bridges had the highest incidence of severe crashes on rural non-HSIS routes (Figure 25). This result complements the finding that bridges are a significant severe crash factor on rural two-lane HSIS highways. Intersections also had a large enough sample size to be a statistically significant severe crash factor on urban non-HSIS roads, though only a slightly-higher percentage of this type of crash was severe compared to urban non-HSIS routes overall (3.7 percent K+A versus 2.9 percent K+A).

The undivided two-way road configuration was associated with the highest percentage of severe crashes on HSIS routes, but none of undivided one-way, undivided two-way, or divided roadway on urban or rural non-HSIS routes were related to a significantly higher incidence of severe injuries.

Low shoulders were the most noticeable roadway defects on HSIS highways and were a significant severe crash factor on rural two-lane routes. These defects were also associated with a significantly high percentage of severe crashes on rural non-HSIS routes (Figure 26). While 6.1 percent of all rural non-HSIS crashes (N=107,070) were severe, 11.3 percent of crashes on roadways with **low shoulders** (N=514) were severe. About three percent of all urban non-HSIS crashes were severe, but 4.6 percent of crashes on roads with soft shoulders (N=769) and 4.0 percent on roads with low shoulders (N=1014) were severe.

Though snowy and icy roadway conditions may be expected to generate more severe crashes, the opposite held on non-HSIS rural and urban routes. These findings supported the results of the HSIS analysis.

Figure 25. Severe crashes on urban and rural non-HSIS roads by road feature

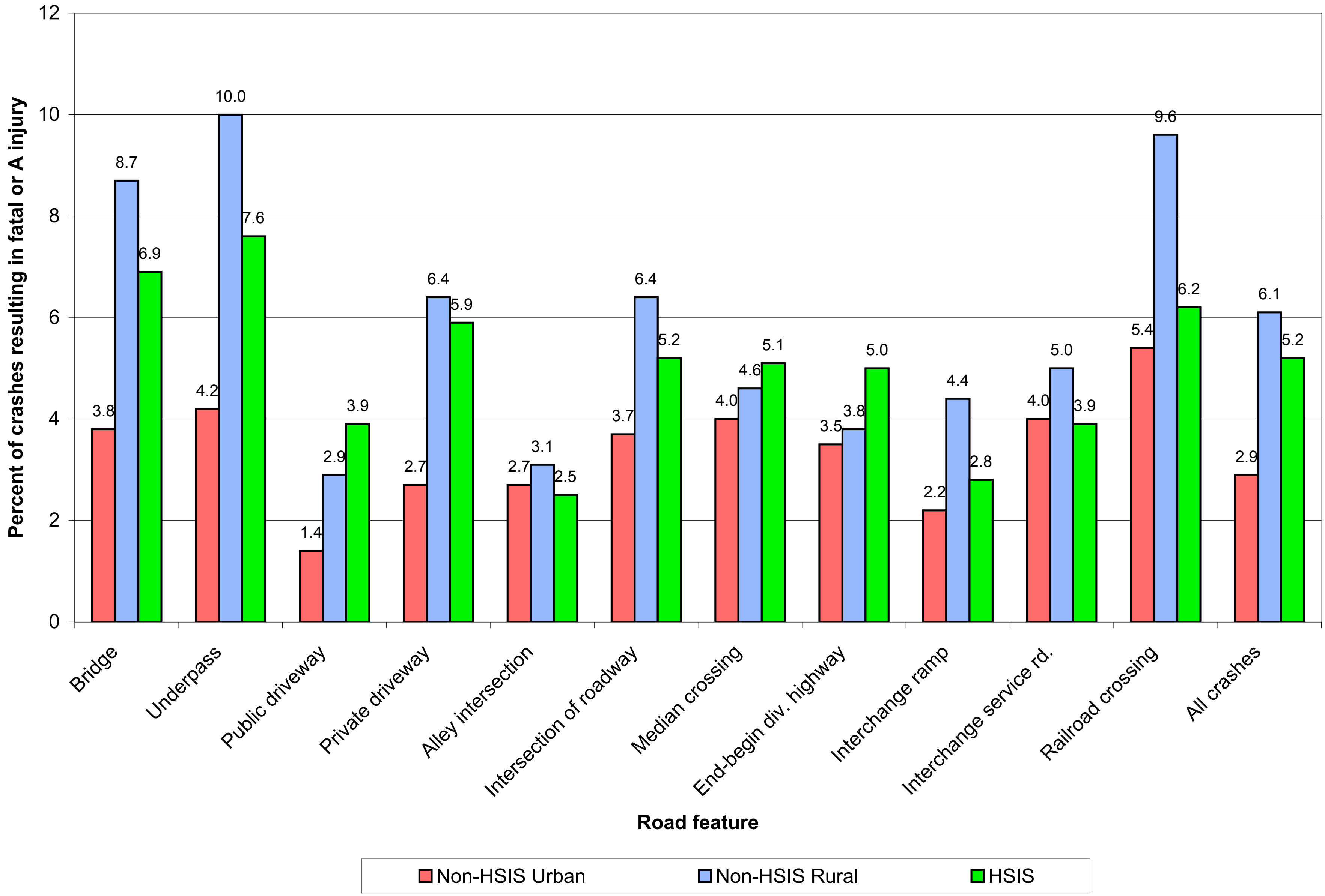
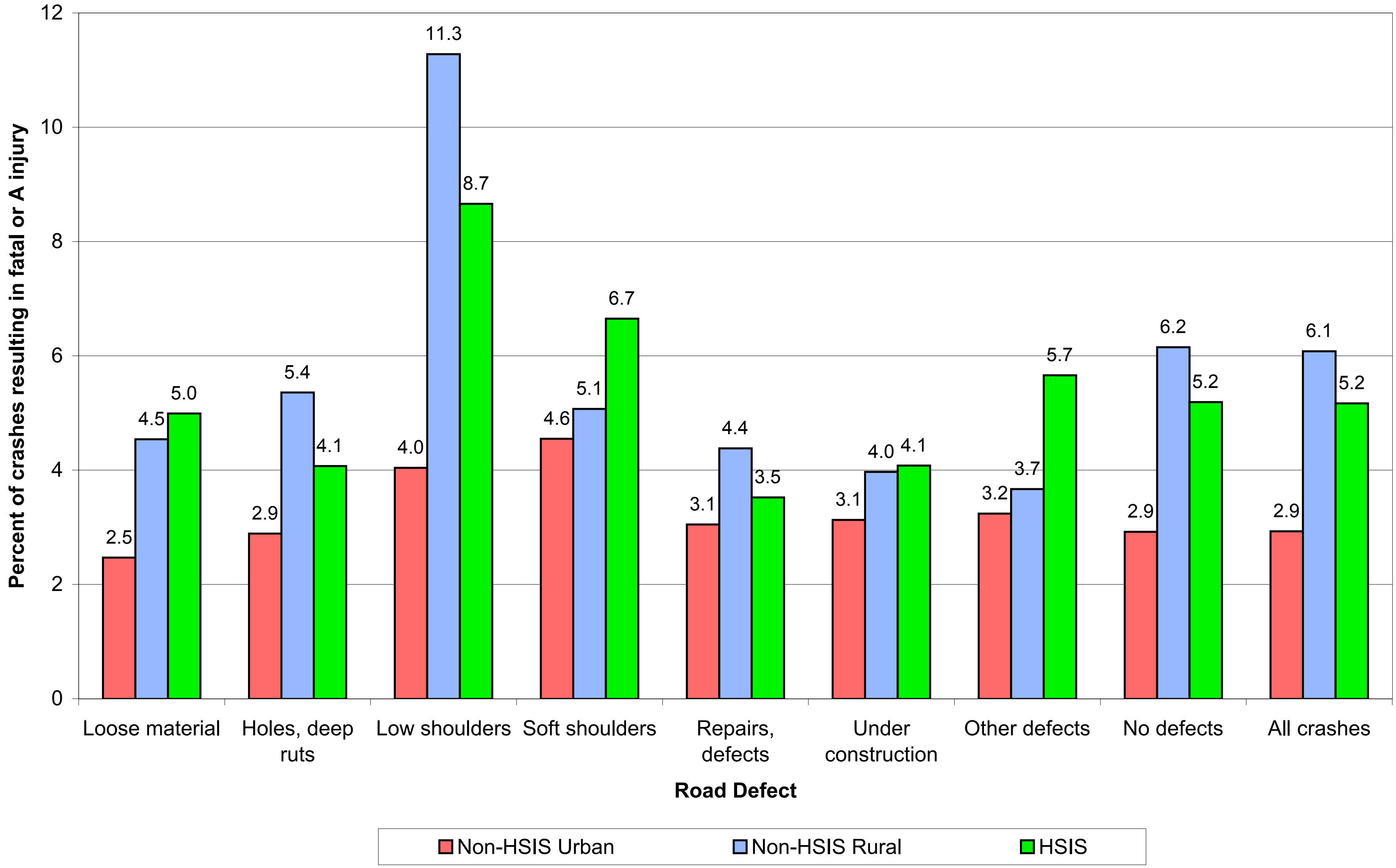


Figure 26. Severe crashes on urban and rural non-HSIS roads by road defect



Road surface was not a significant crash factor on HSIS routes or non-HSIS routes. The most notable finding was that both rural and urban non-HSIS routes with smooth and coarse asphalt surfaces were associated with a slightly higher percentage of severe crashes than routes with concrete and grooved concrete surfaces.

Though no traffic control features were significant severe crash factors, several were associated with a higher frequency of severe crashes on rural and urban non-HSIS routes. Flashing signals, railroad flashers, and railroad crossbucks were related to greater severity on both types of roadways, though there were small samples of crashes with these features. Stop signs were also associated with a higher incidence of severity on urban routes.

Crash Factors

Though **head-on**, **pedestrian and bicycle**, and **run-off-road** accident types, which were significant crash factors on all types of HSIS roadways, were also significant on urban and rural non-HSIS routes, the non-HSIS analysis provided several other notable findings. First, while accounting for under one percent of crashes on HSIS and non-HSIS urban roadways, head-on crashes made up 4.0 percent (N=1,805) of all non-HSIS rural crashes (Figure 27). Of these 1,805 crashes, 19.7 percent were severe. Another interesting finding was that while nearly 25 percent of HSIS crashes were run-off-road, less than six percent of non-HSIS rural and less than two percent of non-HSIS urban crashes were of this type.

Different means of involvement contributed to high incidences of severe crashes on HSIS, non-HSIS rural, and non-HSIS urban routes (Figure 28). Significant factors on all HSIS and non-HSIS routes were **run-off-road** crashes and crashes with two or more vehicles involved. In fact, the percentage of severe crashes with two or more vehicles involved on non-HSIS rural roadways (10.1 percent) was more than 50 percent higher than the percentage of all severe crashes on non-HSIS rural roads (6.1 percent). Similarly, while only 2.9 percent of all non-HSIS urban crashes were severe, almost seven percent of run-off-road crashes in this subset of the database were severe. Though **hit non-fixed object** crashes, which include pedestrian and bicycle crashes, were not significant on HSIS highways, they were significant on both urban and rural non-HSIS routes.

A subset of non-HSIS crashes was used to analyze which types of objects were being struck in run-off-road crashes. Unlike the results from the HSIS database, trees were not a statistically significant severe crash factor, though the non-HSIS analysis was limited by small sample sizes. The only object struck that came close to statistical significance was utility pole on urban routes. While only 4.8 percent of all urban non-HSIS run-off-road crashes were severe, 10.2 percent of utility pole crashes on urban non-HSIS roads were severe (N=362).

Though crashes with one vehicle involved had a higher incidence of severity on rural two-lane and non-two-lane HSIS highways, **single-vehicle** crashes were a significant severe crash factor only on urban non-HSIS routes. Like HSIS crashes, non-HSIS urban crashes were more likely to have severe injuries when three or more vehicles were involved and less likely to have severe injuries when two vehicles were involved.

Figure 27. Severe crashes on urban and rural non-HSIS roads by accident type

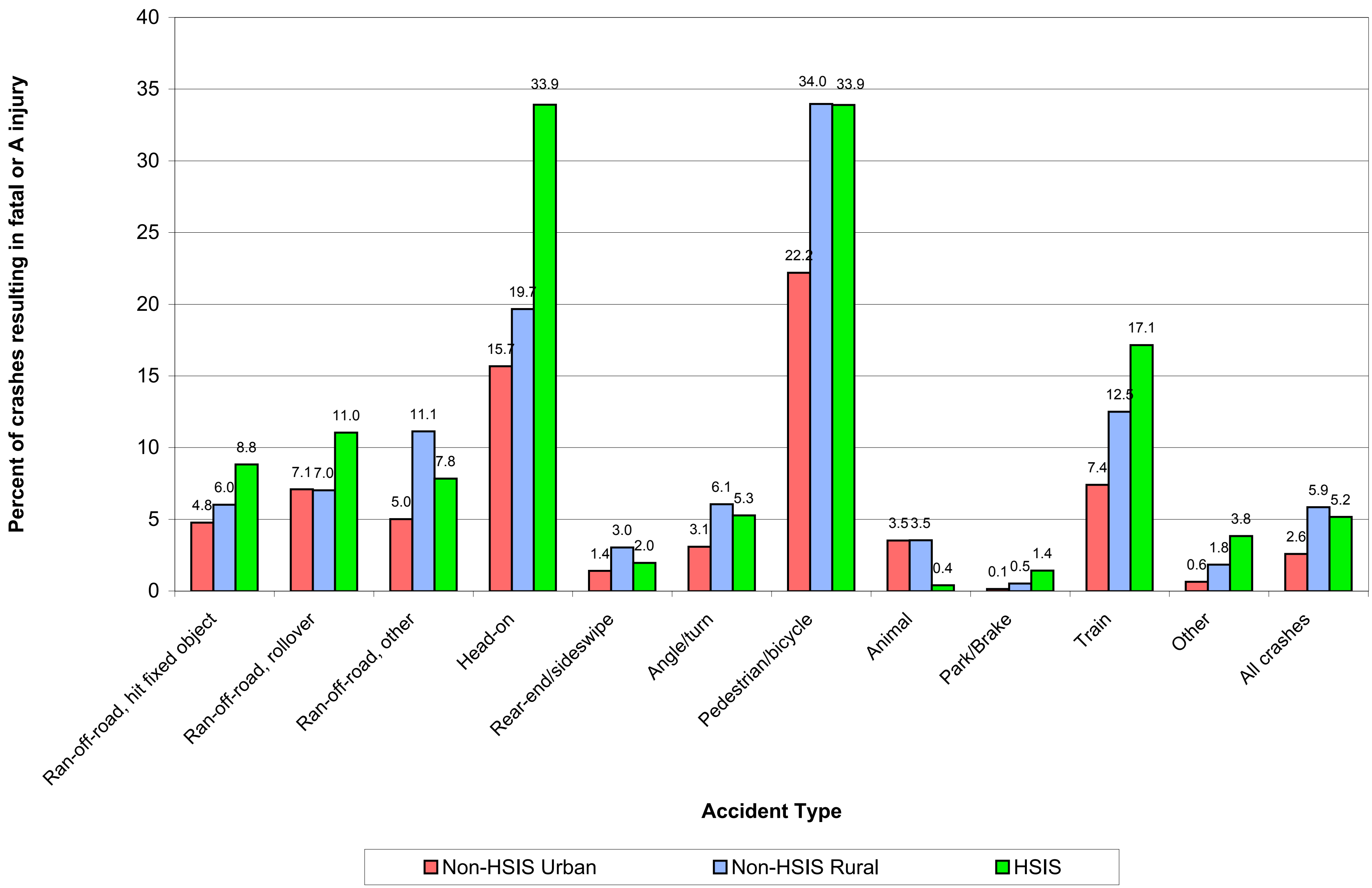
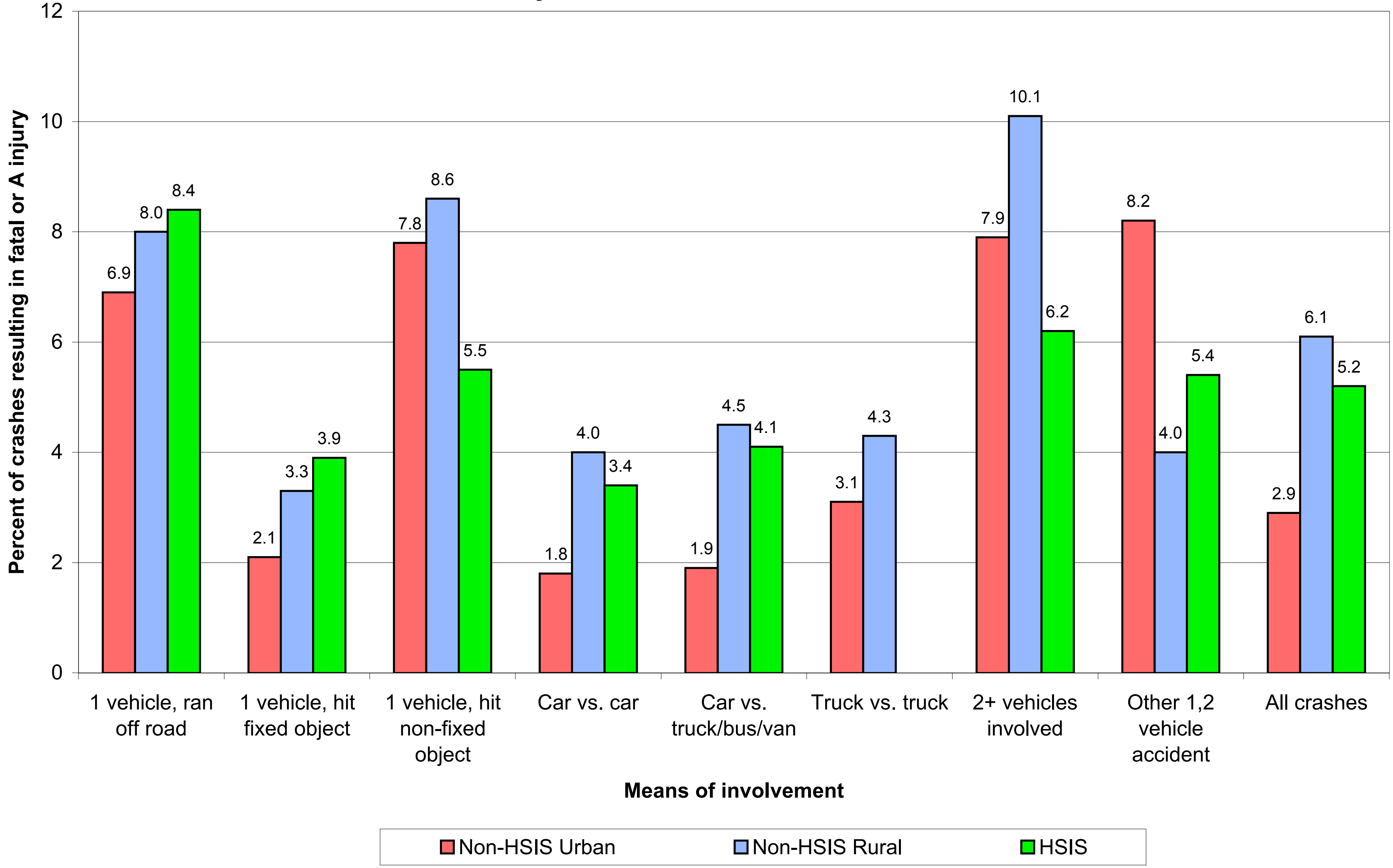


Figure 28. Severe crashes on urban and rural non-HSIS roads by means of involvement



As found for HSIS routes, crashes involving **bicycles and pedestrians** showed a significant association with injury severity on non-HSIS routes. The percentage of crashes that were severe when a bicycle was involved was more than four times greater on HSIS and rural non-HSIS routes and almost six times greater on urban non-HSIS routes (Figure 29). When a pedestrian was involved the percentage of crashes that were severe was more than six times greater on non-HSIS rural and about nine times greater on both HSIS and non-HSIS urban roadways. The difference in severity between crashes involving bicycles and pedestrians and other crashes was greater for urban non-HSIS crashes than rural non-HSIS crashes.

Vehicle Factors

Vehicles associated with greater percentages of severe crashes on non-HSIS urban and rural routes were **pedestrians**, **motorcycles**, and **bicycles** (Figure 30). These three vehicle types were also significant crash factors on HSIS roadways. Yet, though large trucks were associated with a high incidence of severe injuries on HSIS highways, they were not a significant crash factor on non-HSIS urban or rural routes. This may be because non-HSIS routes are less likely to be major shipping routes and typically have lower volumes of large trucks.

As found for HSIS routes, school bus crashes on both urban and rural non-HSIS routes had smaller percentages of severe injuries than other crashes.

Driver Factors

The most significant driver factor resulting in severe crashes on non-HSIS urban and rural routes was **intoxication**. The percentage of crashes that were severe when a driver had been drinking or using drugs was roughly four times higher than when no drinking or drugs were involved on non-HSIS urban, and non-HSIS rural routes. This result was similar to what was found for HSIS roadways. Therefore, strict enforcement of drinking and driving and alcohol awareness campaigns may be appropriate to help reduce severe crashes in North Carolina. The enforcement component may need to include educating the District Attorneys and judges to decrease legal maneuvering that relieve the perpetrators of many of the consequences of their actions.

Environmental Factors

Though lack of streetlight was not a significant severe crash factor for non-HSIS rural roadways, it was a major factor on non-HSIS urban routes. While 2.9 percent of all crashes in this subset were severe, 6.0 percent of crashes in **dark locations without streetlight** were severe. In addition, darkness with streetlights was a severe crash factor on urban non-HSIS routes. Note that some crashes during darkness may have had a higher incidence of severity because emergency response times to locations there was no streetlight may have been slower.

Weekends were related to a greater incidence of severe injuries on two-lane rural and non-two lane HSIS routes. Both urban and rural non-HSIS roadways experience a significantly higher percentage of severe crashes on **weekends**. Over seven percent of crashes on rural non-HSIS routes had severe injuries on weekends while severe injuries were found in less than six percent

Figure 29. Severe crashes on urban and rural non-HSIS roads by bicycle and pedestrian involvement

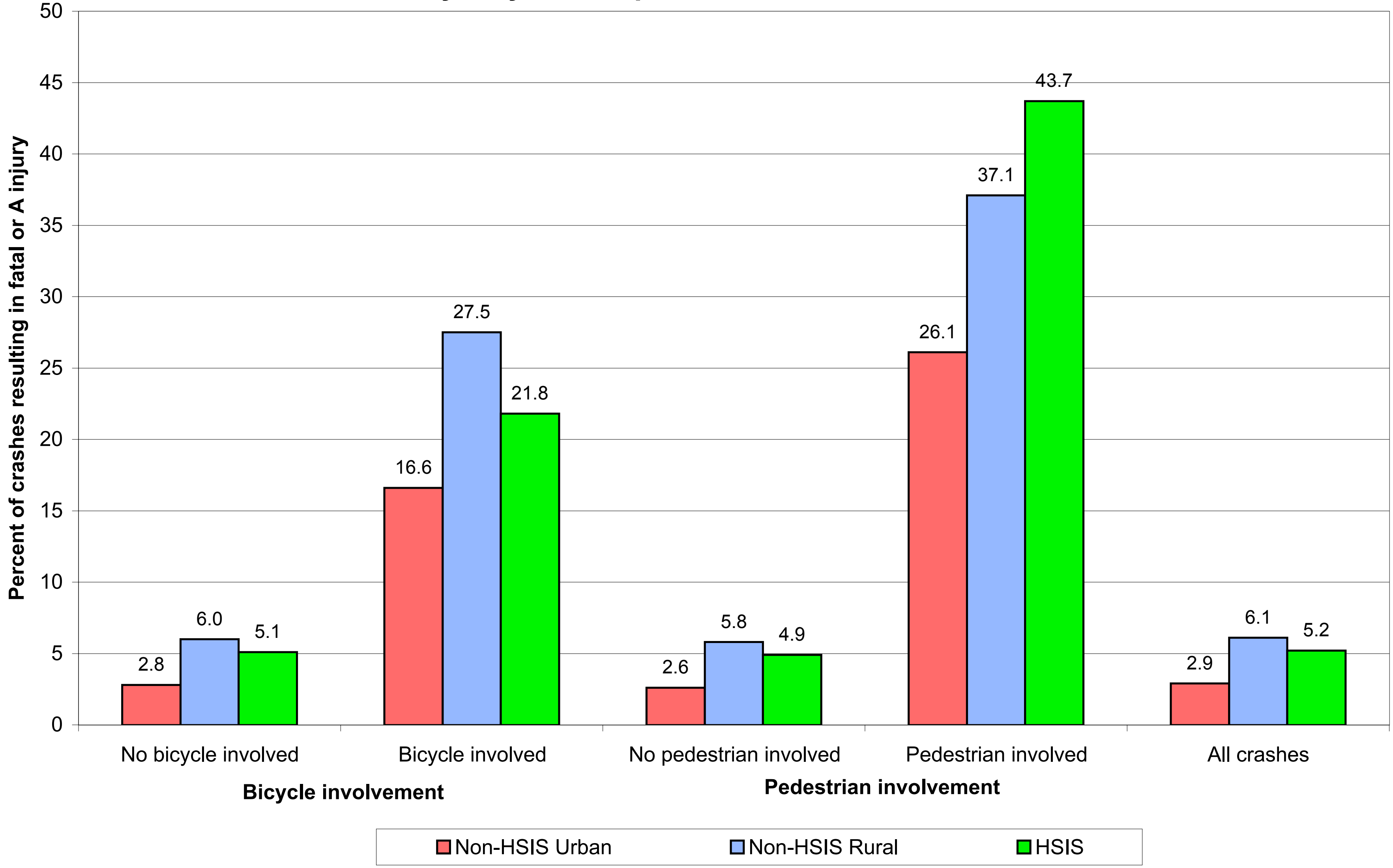
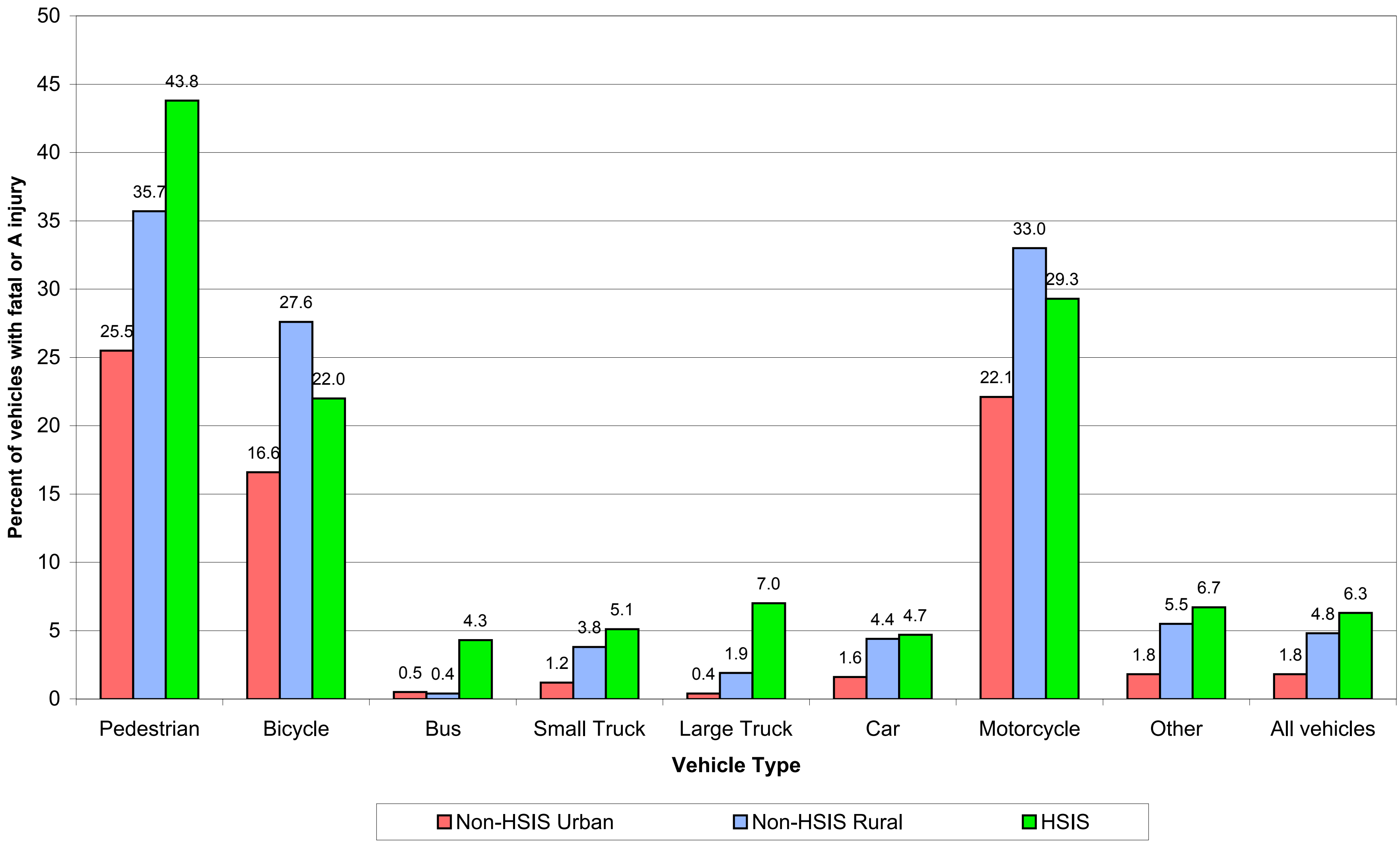


Figure 30. Severe crashes on urban and rural non-HSIS roads by vehicle type



of crashes on the same routes on weekdays. Urban non-HSIS roadways showed a similar pattern. About 3.4 percent of crashes on Saturday and 3.9 percent of crashes on Sunday were severe while less than three percent of weekday crashes on urban routes were severe.

Clear weather was associated with a significantly-higher percentage of severe crashes than for all crashes in the HSIS database. The non-HSIS analysis revealed no significant weather conditions.

E. Summary of Severe Crash Factors on HSIS and non-HSIS Routes

Analysis of the urban and rural two-lane highway subset of the HSIS database and data from non-HSIS rural and urban routes revealed the roadway, crash, vehicle, driver, and environmental factors that were related to significantly higher percentages of severe crashes (compared to the percentage of severe crashes on each roadway system as a whole) (Table 2). See Appendix D for the statistical tables used to identify each significant factor. Further details from the analysis are summarized on the following page.

Table 2. North Carolina sever crash factors

	Roadway System				
Severe Crash Factor*	**HSIS**			**Non-HSIS**	
	Overall	*Urban 2-lane*	*Rural 2-lane*	*Urban*	*Rural*
Roadway Factors					
Curve	X	X	X	X	X
Bridge/underpass	X		X		X
Multilane undivided	X				
Low shoulder			X		X
Crash Factors					
Head-on	X	X	X	X	X
Run-off-road	X	X	X	X	X
Single-vehicle	X		X	X	
Bicycle/pedestrian	X	X	X	X	X
Vehicle Factors					
Motorcycle	X	X	X	X	X
Large truck	X		X		
Driver Factors					
Alcohol	X	X	X	X	X
Environmental Factors					
Night, no streetlight	X	X	X	X	
Weekend	X		X	X	X

*A crash factor is significant when the proportion of severe (K+A) crashes with that given characteristic is at least 2 standard errors greater than the percentage of severe crashes on the roadway system as a whole (see Ex., p. 19).

1. Compared to the percentage of severe crashes on each roadway system as a whole, **curves** were associated with a significantly higher-than-average (above the 95 percent statistical confidence level) proportion of severe crashes for all types of roads. For all roadway systems, the percentage of crashes that were severe on curved roadways was *between 50 and 100 percent higher* than the percentage of crashes that were severe on straight roadways.

2. The most significant road defect was **low shoulders**, especially in rural locations. The incidence of severe crashes on roads with low shoulders was *over 50 percent higher* than for all crashes on both HSIS rural two-lane and non-HSIS rural routes.

3. The percentage of **head-on** crashes that were severe was *between three and six times greater* than the overall percentage of severe crashes on each type of HSIS and non-HSIS route. This difference was statistically significant.

4. **Run-off-road** was a significant means of involvement on all types of HSIS and non-HSIS roadways. For each type of roadway analyzed, the percentage of severe run-off-road crashes was *at least 30 percent higher* than the overall percentage of severe crashes on the roadway system. It is especially important to address these types of severe crashes because of their frequent occurrence.

5. The percentage of severe-injury run-off-road crashes involving **trees** was *40 percent higher* than the overall percentage of severe run-off-road crashes on HSIS highways. Though this was statistically significant, trees were not as significant severe crash factor on non-HSIS roads. This may indicate that the majority of the tree crashes are occurring on HSIS routes.

6. In comparison to other types of crashes on all routes, crashes involving **bicycles** are *between three and five times more likely* to have a severe injury and crashes involving **pedestrians** are *between six and twelve times more likely* to have a severe injury. These differences are statistically significant.

7. Crashes involving **motorcycles** were associated with significantly higher-than-average percentages of severe injuries, regardless of route. The percentage of motorcycle crashes that were severe compared to the percentage of all crashes that were severe ranged from about *five times greater* on HSIS highways to *over ten times greater* on non-HSIS urban routes.

8. **Alcohol** involvement was a significant severe crash factor on all HSIS and non-HSIS routes. The percentage of crashes that were severe when alcohol was involved was about *four times higher* than when alcohol was not involved.

9. **Darkness without streetlights** was related to a significantly higher occurrence of severe crashes on all routes analyzed except rural non-HSIS roadways. For urban non-HSIS roadways, the percentage of severe crashes occurring in darkness without streetlights is *two times higher* than the overall percentage of severe crashes on that system.

To summarize, the most significant factors associated with severe crashes throughout all roadway systems in North Carolina are:

- Curve
- Run-off-road (including tree and utility pole)
- Head-on
- Pedestrian
- Bicycle
- Motorcycle
- Alcohol
- Darkness

Part III describes appropriate countermeasures to target each of these factors and reduce the number of severe injury crashes in North Carolina.

PART III COUNTERMEASURES

A. INTRODUCTION

The purpose of this section of the report is to suggest countermeasures that can be used to reduce the incidence of severe injury crashes in North Carolina. These countermeasures are intended to address the eight factors that are most closely associated with severe crashes on all types of roadways, which were identified in Part I and Part II as:

1. Curve
2. Run-off-road
   -- Utility pole
   -- Tree
3. Head-on
4. Pedestrian
5. Bicycle
6. Motorcycle
7. Alcohol
8. Darkness

B. RECOMMENDED TREATMENTS

Countermeasures that can be used to address the most significant severe crash factors are listed and described according to crash type. The effects of these treatments have been tested through field research and reported in various studies. When possible, crash reduction statistics and limitations of each treatment will be cited. Note that the feasibility or cost-effectiveness of many of the countermeasures will depend largely on site-specific conditions, such as the availability and cost of right-of-way, alignment and access requirements, and environmental impacts.

Curve Crashes[8]

Because of the randomness of crash occurrence, engineers must assess existing conditions, operations, and accident records before choosing countermeasures for curve crashes. Though a location may have a sharp curve with a narrow roadway or a high number of recent crashes, implementing countermeasures may or may not be appropriate or effective. Yet, the decision to select countermeasures (if any) at each location can be improved by evaluating factors such as crash types, crash severity, vehicle speeds, frequency and spacing of access points, available sight distance, encroachment, and other geometric and operational characteristics. Gathering data on locations with possible curve crash problems can help lead to the selection of three types of countermeasures: 1) complete reconstruction (flatten curve, widen lanes, widen and/or surface shoulder, provide spiral transitions to curves) 2) physical rehabilitation and/or partial reconstruction (improve superelevation, remove roadside hazards, flatten sideslope), and 3) low-cost spot improvements (add/improve signing, marking, and delineation). Countermeasures from each of these categories are discussed below.

- **Flatten curve.** This strategy involves complete reconstruction of the roadway. Assuming the central angle of the curve is fixed, a curve can be flattened by increasing the overall curve length (increasing overall distance between the point of curve and point of tangent) so that the degree of curve is reduced, resulting in a less severe maneuver for drivers. Though curve flattening is costly, it has the greatest potential for reducing severe curve crashes. For example, flattening a 15 degree curve can be expected to reduce crashes between 24 and 78 percent, depending on the amount of flattening[8].

- **Widen lanes.** Wider roadway lanes give drivers more room for error when negotiating a curve. For example, widening 10-foot lanes to 12-foot lanes can be expected to reduce curve crashes by 12 percent, while widening the eight-foot lanes to 12 feet can result in a 21 percent reduction in curve crashes[8].

- **Widen and/or surface shoulder.** Shoulder improvements will decrease the likelihood of run-off-road crashes occurring at curves. Though widening paved shoulders will result in the greatest reduction in curve crashes, widening unpaved shoulders can also be beneficial. Widening each shoulder by between one foot and 10 feet is expected to reduce crashes by four to 33 percent for paved shoulders and three to 29 percent for unpaved shoulders[8]. Note that widening shoulders and lanes without increasing right-of-way may not be appropriate if the result is steeper sideslopes. Steep sideslopes (particularly steeper than 4:1) can lead to more rollover crashes and increased crash severity.

- **Provide a spiral transition.** A spiral curve has a gradually-decreasing radius and may be used to connect a tangent to a curve. This type of curve corresponds to a driver's normal turning of the steering wheel, providing drivers with a smoother transition into a curve. Everything else being equal, spiral transition curves at both ends of a curve can reduce curve related crashes by approximately five percent[8].

- **Upgrade deficient superelevation.** Increasing deficient superelevation to the AASHTO recommended values can reduce the number of vehicles that run off the outside of the curve. By upgrading deficient superelevation using the AASHTO Superelevation Criterion, curve crashes can be reduced by between five and ten percent[8].

- **Remove roadside hazards.** Removing trees, relocating utility poles, and providing traverseable drainage structures can increase the amount of relatively flat, unobstructed and smooth area adjacent to the roadway, allowing more space for drivers to recover a vehicle that has run off the road on a curve. Assuming no other improvements are made, increasing roadside recovery distance by five feet can be expected to reduce curve crashes by nine percent, and increasing recovery distance by fifteen feet is expected to reduce curve crashes by 23 percent[8].

- **Flatten sideslope.** Flattened sideslopes can reduce rollover crashes, which are associated with high injury severity. Depending on the amount of improvement, flattening sideslopes can be expected to reduce curve crashes by three to 15 percent[8].

- **Improve signing, marking, and delineation.** Installing large arrow signs, chevrons, delineators on guardrails, or painting warning arrows on the pavement ahead of an upcoming curve can provide drivers with a clearer picture of its sharpness, but these treatments can not necessarily be expected to solve a safety problem at a hazardous curve. Proper signing, marking, and delineation in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) is an essential complement to other treatments. Yet, even if it is not possible to reconstruct a poorly-designed curve, improvements to substandard signing, marking, and delineation alone are likely reduce crash severity.

Run-off-Road Crashes (General)[9]

- **Install shoulder or mid-lane rumble strips.** Rumble strips are crosswise grooves in the road shoulder that are about three inches deep, four inches apart, and cut in groups of four or five. Vehicle tires passing over the grooves create a rumbling sound and make the vehicle vibrate, causing inattentive, drowsy, or sleeping drivers to become aware that they have moved from the travel lane to the shoulder or roadside. Run-off-road crashes were reduced by 34 percent after adding shoulder rumble strips to the New York State Thruway. The FHWA estimates that rumble strips reduce the rate of run-off-road crashes between 20 and 50 percent[10]. Drawbacks of rumble strips include disrupting bicyclists using roadway shoulders, increasing noise, and making snow removal and other maintenance more difficult.

- **Improve delineation of curves.** This technique involves providing drivers with a clearer picture of the sharpness of an upcoming curve, causing them to reduce their speed before entering the curve. Strategies to enhance delineation of curves include installing large arrow signs, chevrons, delineators on guardrails, or painting warning arrows on the pavement ahead of the curve. Each of these treatments are low cost and available for implementation. A study by Taylor and Foody found that curve delineators reduced run-off-road crashes by 15 percent[11].

- **Provide new or improve existing pavement markings at appropriate locations.** Better pavement markings are intended to give drivers a more accurate picture of the true nature of the road and provide better guidance at locations where they may leave the roadway. Treatments such as high-contrast markings, wider lines, or raised pavement markers can achieve this goal. This strategy can be implemented at low cost and uses materials that are readily available. Yet, it is important to note that improving markings may cause drivers to increase speeds because they feel more comfortable with the roadway.

- **Improve roadway geometrics, especially for horizontal curves.** See section on curve crashes for list of possible countermeasures.

- **Provide skid-resistant pavement surfaces.**

- **Ensure consistency in design so that appropriate speeds are chosen.**

Utility Pole Crashes[12]

- **Remove poles and place utility wires underground.** Undergrounding utility lines is intended to increase the recovery area adjacent to the roadway. Yet, the effectiveness of this treatment will depend on removing other fixed objects that may be present or flattening steep sideslopes that may exist. Though removing poles and burying utility wires may be expensive and actually increase other run-off-road crashes, this strategy has been observed to reduce the percentage of severe run-off-road crashes in urban areas from about 50 percent to under 30 percent[13].

- **Relocate poles further from the roadway edge.** Utility poles located closer to the edge of the roadway are more likely to be hit, so moving the poles back should reduce the frequency of utility pole crashes[12]. Note that moving utility poles further from the roadway edge may increase other types of run-off-road crashes if other fixed-objects are not moved and sideslopes improved at the same time.

- **Reduce the number of poles.** Utility pole crashes are most strongly correlated with a high frequency of poles along roadways[12]. Therefore, using multiple poles at a single point (to carry both telephone and electric lines, for example), placing poles on only one side of the street instead of both, and increasing pole spacing can be used to reduce the number of poles and potential for utility pole crashes. One limitation of reducing the number of poles is that larger, more rigid poles may be required, which tend to be more costly and may result in greater crash severity when hit.

- **Install breakaway poles.** Because rapid vehicle deceleration is a major reason for severe injuries in utility pole crashes, breakaway poles are intended to break away upon impact and result in lower injury levels. The total reduction in severe utility pole crashes resulting from conversion to breakaway poles could be as high as 60 percent[13]. Note that while this countermeasure will reduce crash severity, crash frequency will not change.

- **Use other countermeasures.** Any treatment that reduces run-off-road crashes will have the additional benefit of reducing utility pole crashes. Therefore, indirect measures (that do not require moving or changing the existing utility poles) such as improving roadway alignment, improving roadway delineation, providing advance warning signs, overlaying skid-resistant pavement, widening travel lanes and shoulders, improving roadway lighting may also be effective.[12]

Tree Crashes[14]

- **Remove trees in hazardous locations.** The targets of this strategy are trees and stumps positioned in hazardous locations and having a high probability of being struck by motor vehicles. These include trees struck by motor vehicles in the past, located close to the roadway, located on the outside of horizontal curves, and trees which are located along poorly designed roads with narrow lanes and shoulders, sharp horizontal curves, and/or steep sideslopes where run-off-road crashes are likely to occur. It is important to identify sections of roadway with past experience with tree crashes so that improvements can be made first in the most hazardous locations. Trees should be removed so that a safe clear zone area results after the tree removal. For example, removing all trees on a steep sideslope may be impractical and would no longer be able to help prevent run-off-road vehicles from rolling over and falling to the bottom of the slope. In addition, though there has been a history of tree-related crashes, injuries, and deaths, it is common for citizens and environmental groups to strongly oppose the removal of trees within highway rights-of-way.

- **Provide guardrail.** This countermeasure involves installing guardrail beyond the edge of the roadway to reduce the risk of motorists running into trees. Guardrail will typically reduce the crash severity of run-off-road crashes, especially at sites with long, steep sideslopes where vehicles are likely to travel to the bottom of these embankments. Though it will reduce severe crashes, guardrail may increase crash frequency in some cases because a rigid object is placed closer to the roadway than trees or other objects.

- **Modify roadside clear zone.** Change to the sideslope or roadside clear zone can help reduce the likelihood and severity of tree crashes. For example, flatter sideslopes are known to reduce the probability of rollover and fixed-object collisions. In addition to flattening sideslope, other roadside improvements include grading sideslope to allow for easier vehicle recovery and clearing the roadside of objects. Like other countermeasures, this strategy requires adequate funding, but it can be used as a complement to the tree removal strategy.

Head-On Crashes[15]

- **Install centerline rumble strips on two-lane roads.** The design and purpose of centerline rumble strips is similar to that of shoulder and mid-lane rumble strips. Instead of preventing drivers from entering the shoulder and side of the road, centerline rumble strips alert drivers that they are crossing into the opposing traffic lane on a two-lane road. As for other types of rumble strips, snow removal, other maintenance, and increased noise are limitations of centerline rumble strips.

- **Reconstruct roadways with a "super-two" cross-section and alignment design.** This type of design uses wider lanes, wider shoulders, and a high-speed alignment with 100 percent passing sight distance. Yet, each of these improvements are made to a two-lane roadway instead of making a more costly conversion to a four-lane divided facility. Therefore, the "super-two" design is a lower-cost method of minimizing both run-off-road and head-on crashes. Though the technique is less expensive than building a divided roadway, the cost of reconstruction remains a constraint to this countermeasure.

- **Convert four-lane undivided arterials to two-lanes with a center left-turn lane.** This strategy reduces head-on crashes by giving left-turning drivers a more protected location to decide when to turn into a gap in the oncoming traffic. By moving left-turning drivers out of the through-lane, they will be able to find an adequate gap without worrying about being involved in a rear-end crash and other drivers will be able to pass the left-turning vehicle without changing lanes. Converting four-lane undivided roads to two with left-turn lane also creates a greater median clear zone between opposing directions of traffic. In addition, this type of conversion can increase the mobility and safety of pedestrians and bicyclists, especially when some of the available right-of-way is used for new bicycle lanes and sidewalks[16]. This type of conversion should not be used on high-traffic roadways where the congestion resulting from the lane reduction may cause drivers to use routes that are less safe than the original four-lane design.

- **Use positive separators for opposing lanes.** Instead of using a "super-two" design, opposing traffic is separated by a cable barrier placed in a four-foot paved median. This design has resulted in a large reduction in serous head-on crashes in Sweden[17]. Constraints to implementing this treatment include increased maintenance, difficulties with snow removal, and a high cost due to the amount of reconstruction needed.

- **Provide alternating passing zones or four-lane sections at key locations.** This countermeasure involves the construction of alternating passing zones or short four-lane sections at locations that have a large number of passing-related crashes. Because the major through-flows of traffic would be directed to the non-passing outside lanes, the number of head-on crashes would be reduced because of the wider space separating opposing traffic. Though the primary target of this treatment is head-on crashes resulting from passing maneuvers, the treatment would help prevent non-passing head-on crashes. The major drawback to this strategy is the high cost of reconstruction and possible right-of-way acquisition.

- **Restrict truck traffic at selected locations.** Because head-on crashes are more severe when a large truck is involved, decreasing the number of large trucks on high-speed, high volume routes without medians should reduce severe injuries. This countermeasure would target sections of two-lane rural routes that have a high rate of head-on crashes involving trucks. Yet, restrictions of this type are limited by political constraints. Therefore, successful implementation of this strategy would require identification of safer alternative truck routes, and the cooperation of law enforcement agencies and the trucking industry.

- **Install median barriers on narrow-width medians.** Median barriers prevent vehicles from crossing into oncoming traffic. Though they may not reduce the frequency of crashes, they will result in decreased injury severity.

Pedestrian Crashes

There are more than 50 specific pedestrian crash types that can be addressed by a wide variety of countermeasures. Yet, some treatments are inappropriate for certain crash types and highly effective for others. For example, installing a sidewalk will help to prevent walking-along-roadway crashes but may do little to reduce midblock dart/dash and multiple threat crashes, which involve crossing the street. Therefore, crash types must be understood before appropriate countermeasures can be implemented. The FHWA has simplified the process of typing pedestrian crashes by consolidating the specific crash types into 13 crash groups. These crash groups are summarized below and appropriate countermeasures for each group are given in Figure 31. For further information, see the FHWA *Pedestrian Facilities User Guide, Providing Safety and Mobility*[18].

Pedestrian Crash Groups:

1. **Midblock: Dart/Dash.** The pedestrian walked or ran into the roadway and was struck by a vehicle. The motorist's view of the pedestrian may have been blocked until an instant before the impact.
2. **Multiple Threat.** The pedestrian entered the traffic lane in front of stopped traffic and was struck by a vehicle traveling in the same direction as the stopped vehicle. The stopped vehicle may have blocked the sight distance between the pedestrian and the striking vehicle.
3. **Mailbox or other Midblock.** The pedestrian was struck while getting into or out of a stopped vehicle or while crossing the road to/from a mailbox, newspaper box, etc.
4. **Failure to Yield at Unsignalized Location.** The pedestrian stepped into the roadway and was struck by a vehicle at an unsignalized intersection or midblock location. The motorist failed to yield to the pedestrian and/or the pedestrian stepped directly into the path of the oncoming vehicle.
5. **Bus-Related.** The pedestrian was struck by a vehicle either: (1) by crossing in front of a commercial bus stopped at a bus stop, or (2) going to or from a school bus stop.
6. **Turning Vehicle at Intersection.** The pedestrian was attempting to cross at an intersection and was struck by a vehicle that was turning right or left.
7. **Through Vehicle at Intersection.** The pedestrian was struck at a signalized or unsignalized intersection by a vehicle that was traveling straight ahead.
8. **Walking Along Roadway.** The pedestrian was walking or running along the roadway and was struck from the front or from behind by a vehicle.
9. **Working/Playing in Road.** A vehicle struck a pedestrian who was (1) standing or walking near a disabled vehicle, (2) riding a play vehicle that was not a bicycle, (3) playing in the road, or (4) working in the road.
10. **Not in Road (Sidewalk, Driveway, Parking Lot, or Other).** The pedestrian was standing or walking near the roadway edge, on the sidewalk, in a driveway or alley, or in a parking lot when struck by a vehicle.
11. **Backing Vehicle.** The pedestrian was struck by a backing vehicle on a street, in a driveway, on a sidewalk, in a parking lot, or at another location.
12. **Crossing an Expressway.** The pedestrian was crossing a limited access expressway or expressway ramp when struck by a vehicle.
13. **Miscellaneous.** This category includes all other pedestrian crash types, such as: intentional crashes, driverless vehicle, a secondary crash after a vehicle-vehicle-collision, a pedestrian struck by falling cargo, emergency vehicle striking a pedestrian, a pedestrian standing or lying in the road, or other/unknown circumstances.

The countermeasures in Figure 31 are listed along with the types of pedestrian crashes that they may help to reduce.

Countermeasures	Midblock Dart/ Dash	Multiple Threat	Midblock Mailbox Etc.	Fail to Yield (Unsign.)	Bus Related	Turning Vehicle at Intersect	Thru Veh at Intersect	Walking Along Roadway	Working/ Playing in Road	Not in Road	Backing Vehicle	Crossing Express-way
1. Sidewalk/Walkway					●			●	●	●	●	
2. Street Furniture	●				●			●				
3. Curb Ramp				●			●	●				
4. Crosswalk Enhancements	●	●		●			●					
5. Transit Stop Treatments	●	●		●	●		●					
6. Roadway Lighting	●	●	●	●	●	●	●	●	●	●	●	●
7. Overpass/Underpass	●	●		●			●					●
8. Smaller Curb Radius						●	●					
9. Bike Lane/Shoulder	●	●		●	●		●	●	●	●		
10. Road/Lane Narrowing	●	●	●	●				●				
11. Fewer Lanes		●		●	●			●				
12. One Way Street						●						
13. Driveway Improvement										●	●	
14. Right Turn Slip Lane						●				●		
15. Raised Median	●	●	●	●			●					
16. Modern Roundabout						●	●					
17. Modified T-Intersection						●						
18. Median Barrier		●		●		●						●
19. Curb Extension	●	●		●	●	●	●			●	●	
20. Choker	●					●						
21. Pedestrian Island	●	●		●	●	●	●					
22. Chicane	●	●	●	●					●			
23. Mini-Circle				●					●			
24. Speed Humps	●		●	●					●			
25. Speed Table	●	●	●	●	x				●			

Figure 31. Pedestrian Crash Countermeasure Matrix

Countermeasures	Midblock Dart/ Dash	Multiple Threat	Midblock Mailbox Etc.	Fail to Yield (Unsign.)	Bus Related	Turning Vehicle at Intersect	Thru Veh at Intersect	Walking Along Roadway	Working / Playing in Road	Not in Road	Backing Vehicle	Crossing Express-way
26. Raised Intersection				●			●					
27. Raised Ped. Crossing	●	●		●							●	
28. Gateway	●			●					●			
29. Landscape Options				●		●						
30. Paving Treatments				●			●					
31. Driveway Link/Serptn.				●					●			
32. Woonerf	●								●			
33. Diverter	●								●			
34. Full Street Closure	●								●			
35. Partial Street Closure	●								●			
36. Pedestrian Street	●			●			●		●			
37. Traffic Signal	●	●		●	●	●	●					
38. Signal Enhancement	●					●	●					
39. Pedestrian Signal	●	●		●	●	●	●					
40. Ped. Signal Timing						●	●					
41. RTOR Restriction						●						
42. Advanced Stop Lines		●			●		●					
43. Sign Improvement	●	●	●	●	●	●	●	●	●			●
44. School Zone Imprvmnt	●	●		●	●	●	●	●		●		
45. Identify Neighborhood	●		●	●				●	●			
46. Speed Trailer	●		●	●			●	●	●			
47. ADA Improvement					●	●	●	●				
48. Parking Enhancement	●		●	●	●		●			●	●	
49. Ped/Driver Education	●	●	●	●	●	●	●	●	●	●	●	●
50. Police Enforcement	●	●	●	●	●	●	●	●	●	●		●

Figure 31, continued. Pedestrian crash countermeasure matrix.

Bicycle Crashes[19]

- **Widen outside roadway lanes or add bicycle lanes.** This strategy is used increase the amount of space for bicyclists on major urban streets with high traffic volumes and speeds. It can be achieved by widening or restriping the roadway. Wide outside roadway lanes should be between 14 and 15 feet (compared to normal 12 foot lanes) and bicycle lanes should be at least five feet wide. Like other improvements, wide outside lanes and bicycle lanes can also be included during roadway construction.

- **Use traffic calming techniques.** This countermeasure is most effective in residential areas where traffic volumes and speeds are high. Because children are most often involved in bicycle crashes on residential streets[19], they will receive the greatest benefit from slower automobile speeds resulting from traffic circles, speed humps, chicanes and other traffic calming techniques. Traffic calming measures should be implemented with the involvement of neighborhood residents.

- **Construct median crossing areas on arterial roadways.** Bicyclists often have difficulty crossing arterial roadways. By providing raised medians with thin curb cuts and connecting paths, bicyclists will have a refuge for crossing high traffic, high volume streets.

- **Provide funding for bicycle trail networks.** By providing new trails, connecting existing segments, and encouraging developers to include bicycle paths, there can be a greater separation of bicycle and vehicle traffic. This reduction in potential conflicts should result in a decrease in the overall number of bicycle crashes. In addition, trails are popular with the bicycling public. Yet, note that bicycle trails may cause safety problems at intersections.

- **Modify roadway bridges.** Many bridges have narrow outside lanes without shoulders, deteriorated deck surfaces, dangerous expansion joints, and high traffic volumes and speeds. These bridges can be modified to accommodate bicyclists by restriping lanes to add space for bicycles and repaving surfaces to increase bicycle stability. Though extremely costly, separate bridge facilities can be provided for bicyclists to relieve serious problems. New bridges should be constructed with the needs of bicyclists in mind.

- **Provide separate bridges or underpasses.** This treatment is very expensive, but it allows bicyclists to cross major roads at locations that can be accessed by the most bicyclists and does not require bicyclists to share the road with automobiles. The cost of bridges and underpasses can be reduced by taking advantage of the topography where they are installed.

- **Design signalized intersections to accommodate bicyclists.** Most traffic-actuated signalized intersections are not able to detect bicycles, signal timing may be too short for bicyclists to complete crossing an intersection, and/or visibility of signal heads may not be visible to bicyclists. Each of these factors may cause bicyclists to lose patience and cross against a red light, resulting in a higher number of bicycle crashes. Improvements that can be made include installing bicycle-sensitive loop detectors, adjusting signal timing, and testing signal heads for visibility. Providing bicycle-sensitive loop detectors may be relatively inexpensive if done during initial construction.

- **Improve rural road shoulders.** Bicyclists riding on rural roads with narrow or no shoulders must often share the roadway with high-speed, high-volume traffic and large trucks. Because severe bicycle crashes can result from this situation, smooth paved shoulders should be provided on all new construction and reconstruction. If it is not possible to install shoulders during construction, space should be provided for their addition at a later time. In addition, shoulders should be added and rumble strips should be restricted on popular bicycle routes.

Motorcycle Crashes

- **Enforce mandatory helmet laws.** A study by Rutledge and Stutts found that the risk of head injury in hospitalized motorcyclists was almost two times higher for unhelmeted riders compared to helmeted riders. Helmet laws help prevent head injury to motorcyclists[20].
- **Develop special licensing requirements and require motorcycle driver training.** Education may make motorcyclists develop safer riding habits so that they are involved in fewer and less severe crashes.
- **Improve roadway engineering.** Treatments such as improving road shoulders, removing trees and utility poles, upgrading deficient superelevation, and providing skid-resistant pavement surfaces will also improve the safety of motorcyclists.

Alcohol Crashes

- **Provide engineering treatments.** All engineering treatments listed in the sections above, especially those for curve, run-off-road, head-on, and nighttime crashes, will have the additional benefit of reducing the number of crashes involving alcohol. For example, installing rumble strips may decrease the time it takes a intoxicated driver to realize that they are in danger and to return to their lane. Straightening horizontal curves will reduce the amount of precision needed for turning so that an intoxicated driver can negotiate curves safely. Yet, engineering treatments should be supplemented with enforcement and/or education countermeasures to ensure that drivers do not think that improved roadways make it safe to drink and drive.

- **Increase enforcement of drunk driving laws.** Improving enforcement of drunk driving laws can help reduce the frequency of alcohol-related crashes. Enforcement can be improved by increasing drunk driving penalties and increasing the frequency of random sobriety checks.

- **Use education programs.** Educating drivers about the danger involved with driving while intoxicated may prevent some drunk driving crashes. Yet, this countermeasure may not be as effective as engineering and enforcement countermeasures.

Nighttime Crashes

- **Provide new and improve existing street lighting.** Improving nighttime lighting is especially effective at preventing crashes involving pedestrians, many of which are serious or fatal.

- **Provide other engineering treatments.** Many engineering treatments listed above can help reduce the number and severity of crashes occurring at night. For example, installing rumble strips, adding guardrail, modifying the clear zone, and installing median barriers will help reduce crashes where drowsy driving or alcohol are contributing factors.

CONCLUSIONS

This report summarizes the factors associated with serious and fatal injury crashes in North Carolina and suggests possible countermeasures to combat these contributing factors. To achieve the greatest severe crash reduction, a systematic approach for identifying combinations of severe crash factors should be followed. First, specific sites with a high number of severe crashes should be identified. Then, the significant contributing factors at those sites should be identified and treated with appropriate countermeasures.

Significant severe crash factors identified earlier in the report include curve, run-off-road, utility pole, tree, head-on, pedestrian, bicycle, darkness, and alcohol crashes. The countermeasures recommended in Part III can be used separately or in combination to reduce the number and severity of crashes that occur as a result of these factors. Ultimately, reductions in these types of crashes will result in fewer severe injuries and fatalities on North Carolina roadways.

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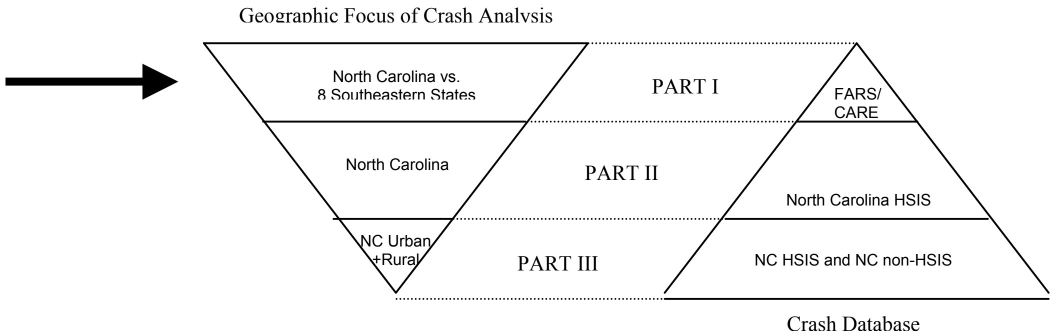
APPENDIX A COMPARISON OF NORTH CAROLINA WITH THE SOUTHEAST AS A WHOLE



This appendix presents a more detailed comparison of fatal crashes in North Carolina with fatal crashes in the eight Southeastern States that are part of FHWA Region IV, including North Carolina. To make this comparison, the Critical Analysis Reporting Environment (CARE) database was used. The CARE database contains 47,047 crashes in the Southeastern States as a whole (including North Carolina), occurring between 1993 and 1997. Of these, 6405 are in North Carolina. It should be kept in mind that a crash is fatal if one or more people in any of the vehicles involved die in the crash or within 30 days as a result of injuries suffered in the crash. Because North Carolina is contained in the eight Southeastern States, the results are conservative. According to the CARE web site (http://care.cs.ua.edu/care/sestudy.html), "the significance of the results of a comparison without North Carolina being included would be even *higher* than the significance indicated by the statistical test (alpha = 99 percent), since some of the difference is buffered out by its presence in the control."

This section presents comparisons of North Carolina versus the eight Southeastern States (including North Carolina) for the following variables: roadway function class, first harmful event, manner of collision, relation to junction, relation to roadway, traffic flow, number of travel lanes, speed limit, roadway alignment, roadway profile, roadway surface condition, traffic control device, light condition, atmospheric condition, body type, rollover, vehicle maneuver, most harmful event, violations charged, driver factors, restraint system, alcohol involvement, and injury severity. The categories that are over- or under-represented at the 99 percent level are listed for each variable. The categories are listed in descending order according to "MAX Gain"—see the "General Description of CARE Impact Outputs," starting below. The comparisons do not include variable categories that are neither over- nor under-represented at the 99 percent level.

A. GENERAL DESCRIPTION OF CARE IMPACT OUTPUTS
(Adapted from http://care.cs.ua.edu/care/sestudy/overview.html)

The summaries given here are the result of CARE Information Mining (IMPACT) performed on Fatal Accident Reporting System (FARS) data for the calendar years 1993-1997. These were performed to provide specific information for the SE Fatal Crash Study, and they are the result of a complete analysis of all variables in the respective databases that have been converted to CARE. Each variable has its codes sorted such that it is in worst-first order. Thus, those factors within the variable that has the highest potential for crash reduction are listed at the top within each variable. The "MAX Gain" column is the number of crashes that would be reduced if the over-represented factor could be reduced to its expected value, all other things being equal.

For example, fatal crashes on rural minor collector roadways were over-represented in North Carolina compared to the Southeast as a whole (Figure A.1, Table B.1). While 9.9 percent of fatal crashes were on rural minor collectors in North Carolina, only 5.6 percent of fatal crashes were on rural minor collectors in the Southeast, meaning that North Carolina was over-represented by 77 percent (overrepresentation factor=(9.9-5.6)/5.6=0.77). If the percent of fatal crashes on rural minor collectors was reduced to 5.6 percent, the number of fatalities in North Carolina would be reduced by 273. It is important to note that fatal crashes may be over-represented in North Carolina because it has more miles of rural minor collectors, because its rural minor collectors are more dangerous than those in other states, or a combination of both.

B. ANALYSIS

Crash-level analysis

Note that the tables referenced in this section are contained in Appendix B.

1. Roadway Function Class (Table B.1)

Four roadway function classes were over-represented (at a 99 percent significance level) in North Carolina relative to the eight Southeastern States (Figure A.1):

1 Rural local road (19.9 percent in NC vs. 13.8 percent in the SE, meaning that NC was over-represented by 44 percent. Therefore, the overrepresentation factor=(19.9-13.8)/13.8=0.44)
2. Rural minor collector (9.9 percent vs. 5.6 percent, 0.75)
3. Rural major collector (17.6 percent vs. 14.2 percent, 0.24)
4. Urban local road (11.4 percent vs. 8.1 percent, 0.40)

Five roadway function classes were under-represented in North Carolina (note that under-represented characteristics are assigned a negative value):

1. Rural principal arterial (14.2 percent in NC vs. 17.8 percent in the SE, underrepresentation factor=(5.8-4.7)/4.7=-0.25)
2. Urban principal arterial (4.2 percent vs. 9.0 percent, -1.14)
3. Urban major collector (6.2 percent vs. 7.5 percent, -0.21)
4. Rural minor arterial (8.3 percent vs. 10.6 percent, -0.28)
5. Urban minor arterial (5.8 percent vs. 8.9 percent, -0.53)

2. First Harmful Event (Table B.2)

The first harmful events that were over-represented in North Carolina (compared to other Southeastern States) were (Figure A.2):

Figure A.1. Roadway function class--overrepresented and underrepresented

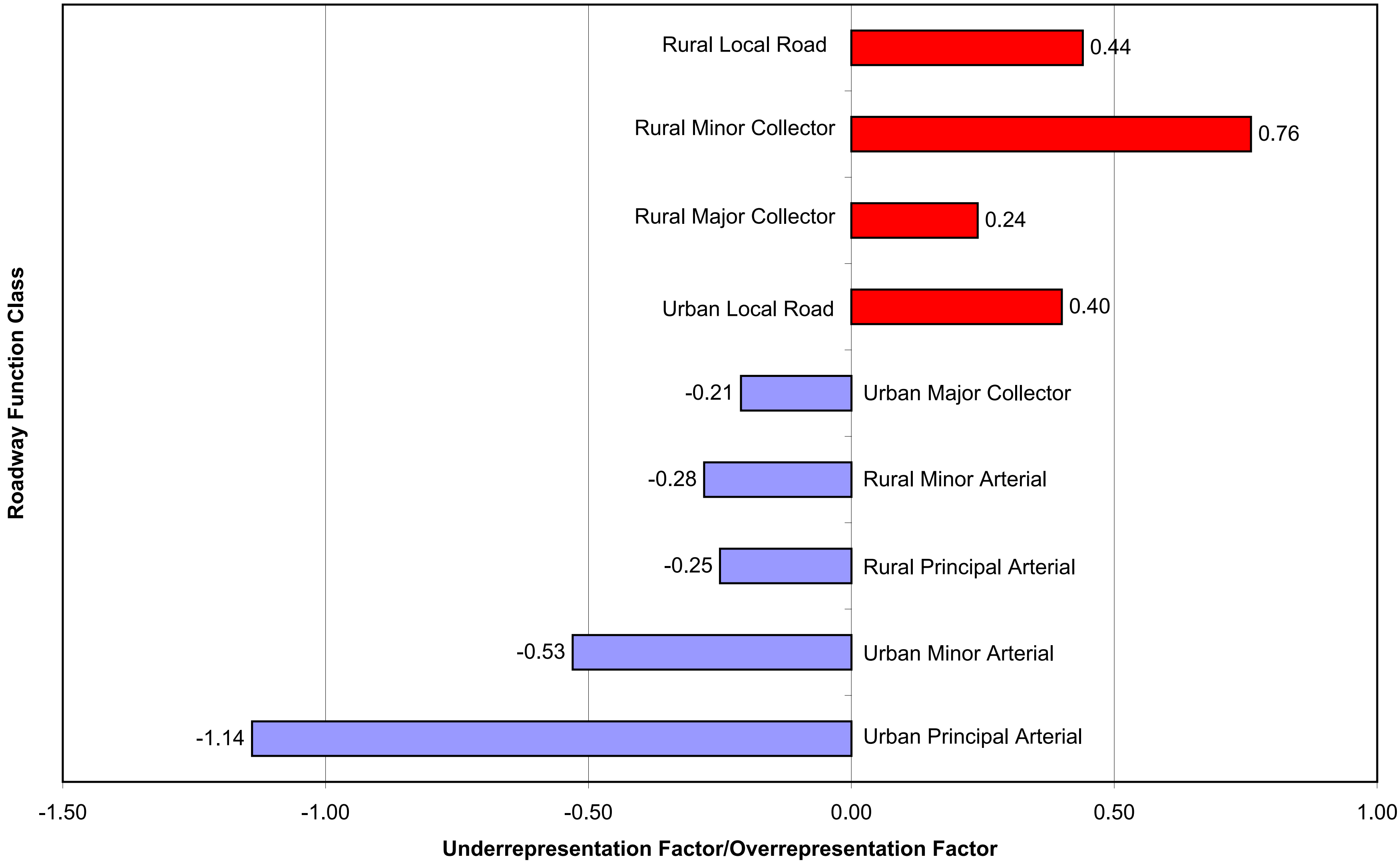
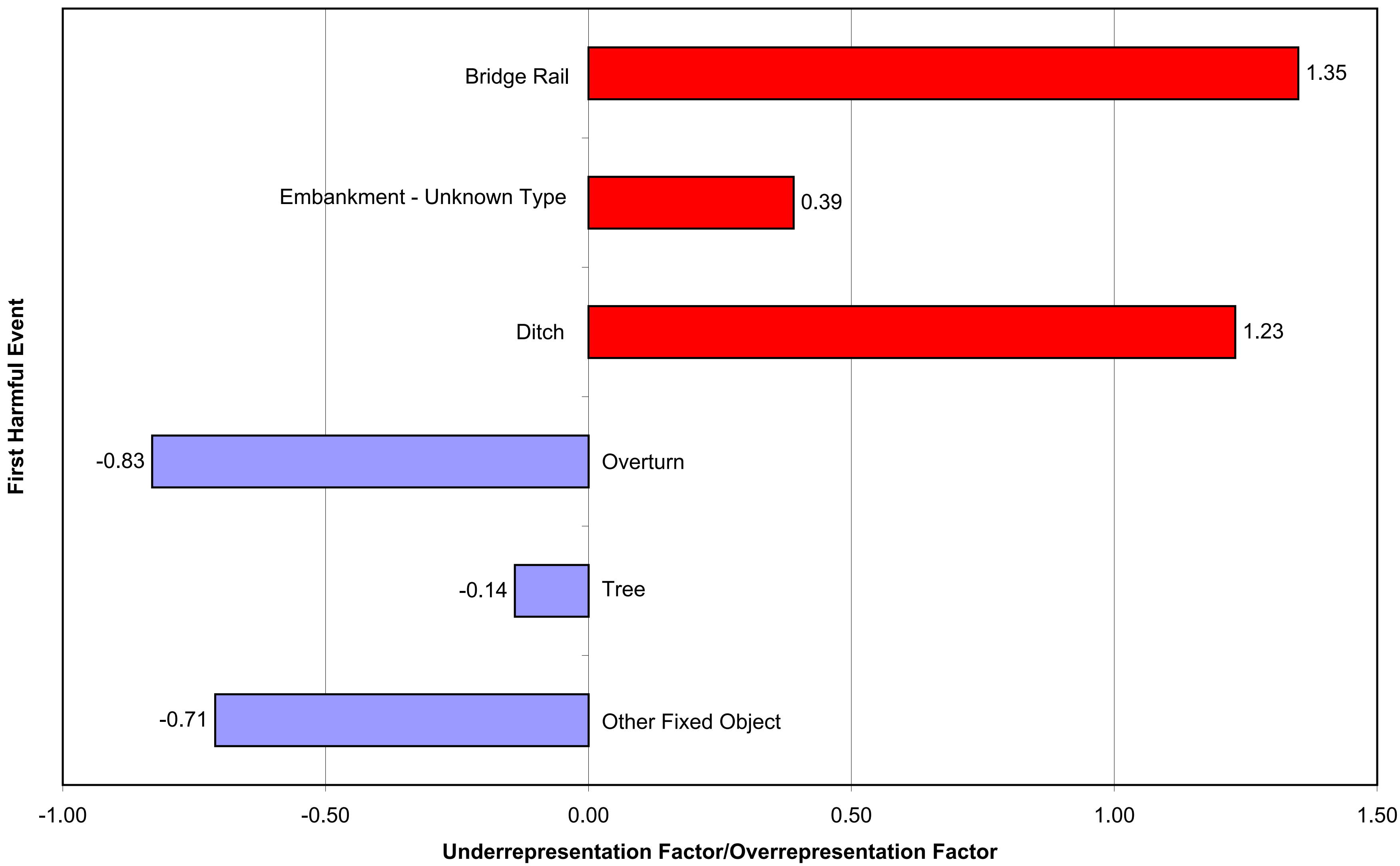


Figure A.2. First harmful event--overrepresented and underrepresented



1. Ditch (8.4 percent in NC vs. 3.8 percent in the SE, overrepresentation factor = 1.23)
2. Embankment—unknown (2.4 percent vs. 1.7 percent, 0.39)
3. Bridge rail (1.1 percent vs. 0.5 percent, 1.35)

These first harmful events were under-represented in North Carolina:

1. Other fixed object (0.7 percent vs. 1.2 percent, -0.71)
2. Tree (8.8 percent vs. 10.0 percent, -0.14)
3. Overturn (4.0 percent vs. 7.3 percent, -0.83)

Both the over- and under-represented events were associated with run-off-road crashes. Trees were under-represented as the first harmful event (8.8 percent) but over-represented as the most harmful event (13.6 percent; Table B.18). This suggests that vehicles may hit something else, such as a guardrail or embankment, before coming to rest against a tree.

3. Manner of Collision (Table B.3)

Fatal head-on crashes were over-represented in North Carolina. This may be partly due to the existence of more high-speed travel on two-lane rural roads in North Carolina compared to other Southeastern States.

4. Relation to Junction (Table B.4)

Non-intersection fatal crashes at driveways and alleys were over-represented in North Carolina. Non-intersection fatal crashes at ramps, intersections, and non-junctions were underrepresented.

5. Relation to Roadway (Table B.5)

Roadside, shoulder, and outside right-of-way were over-represented in North Carolina compared to all Southeastern States. These happen with run-off-road crashes, which were fairly common (about one-fourth of all crashes).

6. Trafficway Flow (Table B.6)

Fatal crashes were over-represented on roads that were not divided and on roads that had medians with barriers, including guardrail shielding bridge piers. Perhaps North Carolina has a higher proportion of two-lane, undivided roads, and/or head-on crashes (which often happen on two-lane roads and which are often severe), compared to the other Southeastern States. Or perhaps North Carolina's two-lane roads are more dangerous than two-lane roads in other Southeastern States. Roads that had medians but no barriers were underrepresented.

7. Number of Travel Lanes (Table B.7)

Two-lane roads were over-represented among fatal crashes in North Carolina. This reflects either a higher-than-average proportion of two-lane roads and/or head-on crashes (which often happen on two-lane roads and which are often severe). Three- and six-lane roads were underrepresented.

8. Speed Limit (Table B.8)

Speed limits of 51 - 55 MPH and 31 - 35 MPH were over-represented in North Carolina, whereas speed limits of 21 - 25, 61 - 65, and 46 - 50 MPH were underrepresented. The overrepresentation of 51 -55 MPH speed limits is likely the result of North Carolina having a higher proportion of travel occurring on roads with a 55 MPH speed limit, compared to the Southeastern States as a whole. It should be noted that speed limits on many rural freeways were increased between 1993 and 1997.

9. Roadway Alignment (Table B.9)

Fatal crashes on curves were over-represented in North Carolina, and straight roads were underrepresented.

10. Roadway Profile (Table B.10)

Sag, level, and hillcrest were over-represented. It is not clear why grade was underrepresented.

11. Roadway Surface Condition (Table B.11)

Compared to the Southeastern States, icy roads were over-represented in North Carolina, and dry roads were underrepresented. Ice may be more of a problem in North Carolina (especially in the populated Piedmont region) than in some of the other Southeastern States. Snow may be more common than ice in Kentucky, for example, and most of Florida is too warm for either ice or snow.

12. Traffic Control Device (Table B.12)

Fatal crashes were over-represented at locations with no controls and at locations with controls but no pedestrian signals. Many of the locations with no controls were two-lane rural roads. Many locations with controls but no pedestrian signals were rural intersections. Fatal crashes were under-represented where flash controls or controls with unknown pedestrian signal status were present.

13. Light Condition (Table B.13)

Dark, dawn, and dusk were over-represented, while dark but lighted was underrepresented. Dark but lighted conditions were more common on urban roads. If North Carolina has fewer urban roads than some of the other Southeastern States, then the proportion of fatal crashes on such roads will also be lower than the Southeast as a whole.

14. Atmospheric Condition (Table B.14)

Rain, sleet, and sleet and fog were all over-represented. Fog and normal conditions were both underrepresented.

Vehicle and driver level analysis

(from http://care.cs.ua.edu/care/sestudy/overview.html)
"Note: the vehicle and driver variables that follow apply to the unit considered to be the causal unit. FARS does not specify the causal unit. Thus, an algorithm is applied that weights all of the relevant factors related to the unit. The unit with the highest weight is considered to be the causal unit. For example, the presence of a high BAC would have a high weighting factor in determining causation. This enhancement of the data is valuable since we are most interested in characteristics of the unit that has the highest probability of being the causal unit as opposed to being the innocent victim unit. It is recognized that there are times when two units contribute equally, but in this case either vehicle will serve for statistical purposes. There is only one vehicle/driver considered per crash in the variables that are summarized below."

1. Body Type (Table B.15)

Compact pickups, unknown auto types, and SUT HI GVW (single-unit truck, high gross vehicle weight) were over-represented. Three-door and two-door hatchbacks, and standard pickups were underrepresented.

2. Rollover (Table B.16)

Rollover as a subsequent event was over-represented. Vehicles were likely to strike a guardrail or other fixed object before rolling over.

3. Vehicle Maneuver (Table B.17)

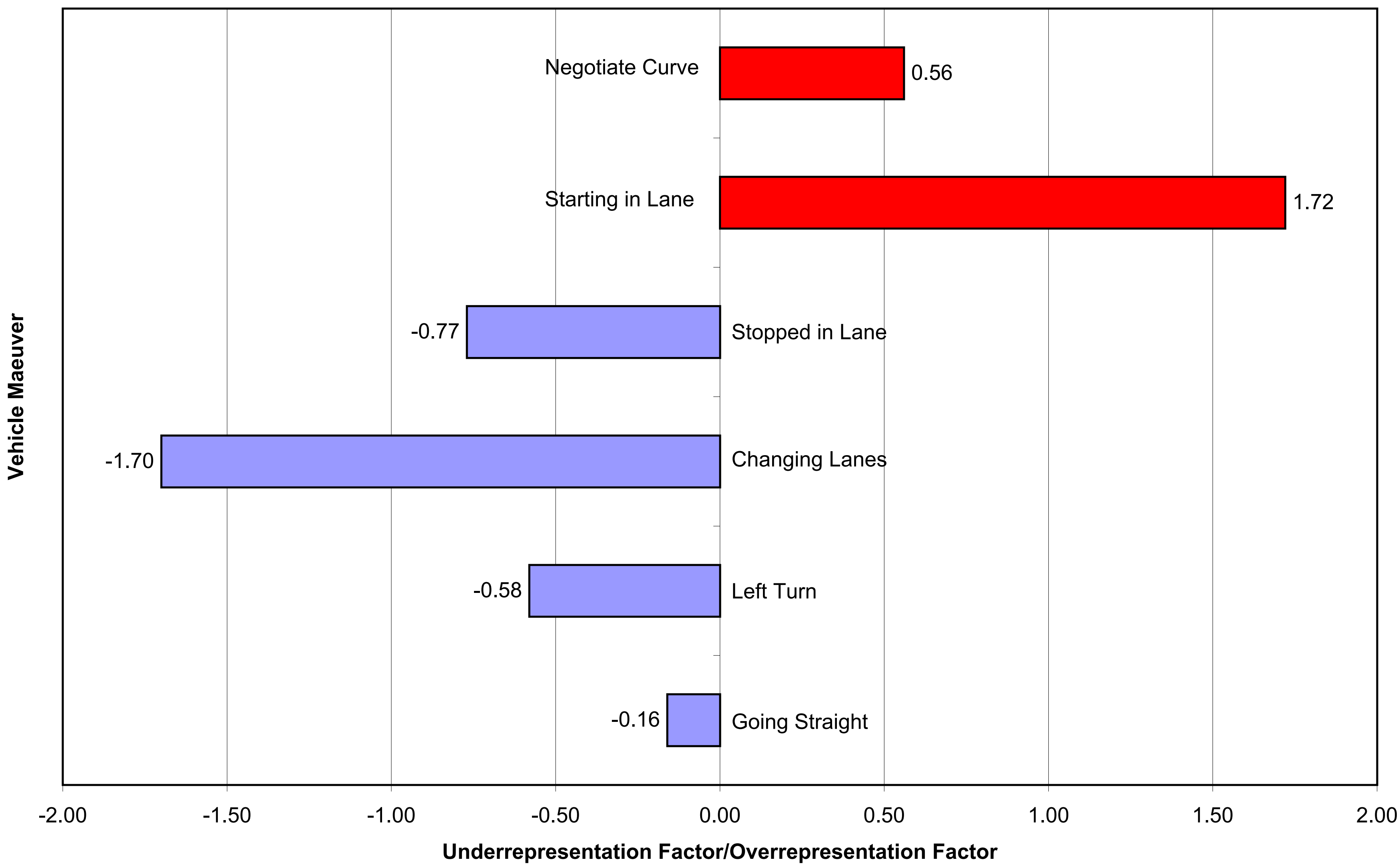
Three maneuvers – negotiating curve, starting in lane, and unknown – were over-represented (Figure A.3). In fact, negotiating curve was the maneuver used by nearly 30 percent of the at-fault drivers. This finding is consistent with the finding that curves were over-represented in fatal crashes (Table B.9). The under-represented maneuvers were stopped in lane, changing lanes, left turn, and going straight.

4. Most Harmful Event (Table B.18)

The most harmful events that were over-represented in North Carolina were:

1. Tree (13.6 percent in NC vs. 12.0 percent in the SE, overrepresentation factor = 0.13)
2. Vehicle in transport – other (1.6 percent vs. 1.0 percent, 0.60)
3. Immersion (1.1 percent vs. 0.7 percent, 0.45)
4. Ditch (1.4 percent vs. 1.1 percent, 0.32)
5. Building (0.6 percent vs. 0.3 percent, 0.90)
6. Bridge rail (0.5 percent vs. 0.3 percent, 0.72)

Figure A.3. Vehicle maneuver--overrepresented and underrepresented



The most harmful events that were under-represented in North Carolina were:

1. Culvert (0.6 percent in NC vs. 1.0 percent in the SE, underrrepresentation factor=-0.67)
2. Utility pole (2.0 percent vs. 3.0 percent, -0.50)
3. Overturn (14.1 percent vs. 15.2 percent, -0.08)

Several of the over-represented events were associated with run-off-road crashes, which comprised about one-fourth of all crashes, and which had higher percentages of K+A than all crashes (see Table B.3). On the other hand, the under-represented events were also associated with run-off-road crashes.

Trees were under-represented as the first harmful event (8.8 percent) but over-represented as the most harmful event (13.6 percent, Table B.18). This suggests that vehicles may hit something else, such as a guardrail or embankment, before coming to rest against a tree.

5. Violations Charged (Table B.19)

Among violations charged, those that were over-represented were:

1. Alcohol or drugs and speeding (8.8 percent in NC vs. 1.5 percent in the SE, overrepresentation factor = 4.72)
2. Other moving (8.1 percent vs. 4.9 percent, 0.64)
3. Speeding (4.0 percent vs. 1.0 percent, 3.07)
4. Alcohol or drugs (4.9 percent vs. 2.3 percent, 1.17)

These data seem to be inconsistent with alcohol involvement (Table B.24), which show that drivers with *no* alcohol involvement were over-represented. These data could suggest that North Carolina devotes more effort to enforcing alcohol and speeding laws than other parts of the Southeast.

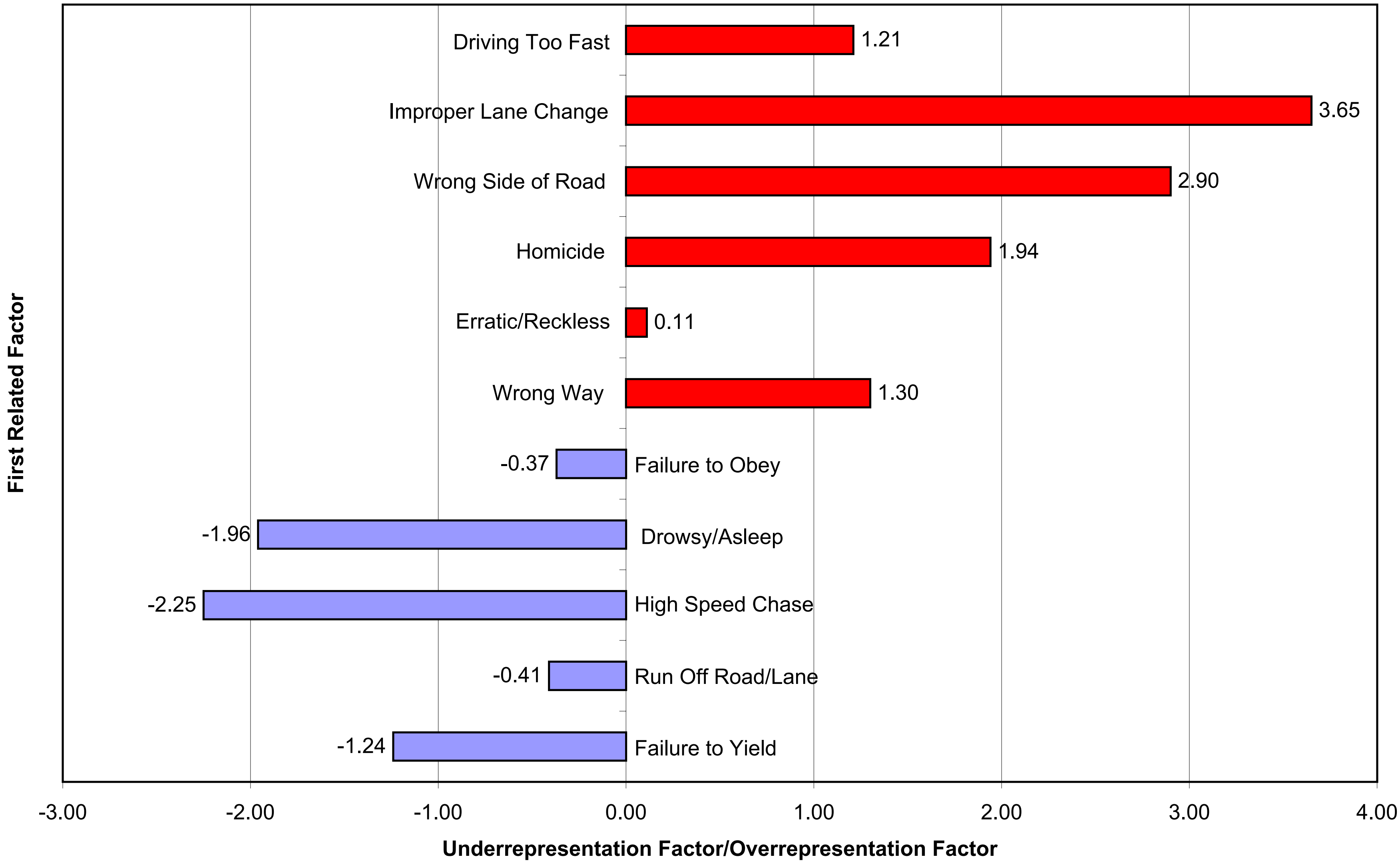
Under-represented violations were non-moving, unknown, and none.

6. First, Second, and Third Related Factors – Driver (Tables B.20, B.21, B.22)

These related factors were over-represented in North Carolina:

First (Figure A.4)
Driving too fast
Improper lane change
Wrong side of road
Homicide
Erratic/reckless
Wrong way

Figure A.4. First related factor - driver--overrepresented and underrepresented



Second
Wrong side of road
Erratic / reckless
Homicide
Failure to yield
High-speed chase
Stopping in road
Locked wheel
Operator inexperience
Unfamiliar with road

Third
Homicide
Erratic / reckless
Run off road / lane
Wrong side of road
Emotional
Improper lights
Prohibited passing
Unfamiliar with road
Wrong signal
Animal

Other related factors were under-represented in North Carolina:

First (Figure A.4)
Failure to obey
Drowsy, asleep
High-speed chase
Run off road / lane
Failure to yield

Second
None
Run off road / lane
Driving too fast

Third
Driving too fast

It is not known whether North Carolina's drivers are in fact more likely to drive too fast, change lanes improperly, etc., than their counterparts in other Southeastern States. Instead, it is likely that states differ in how consistently these factors are noted. For example, if "driving too fast" is often recorded as a related factor in North Carolina but not in other states, then "driving too fast" will appear to be over-represented, even if North Carolina's drivers are not more inclined to drive too fast.

7. Restraint System – Use (Table B.23)

The use of restraints was coded for the drivers of "at-fault" vehicles. It should be kept in mind that not every driver who "caused" the crash was killed. These categories of restraint system use were over-represented in North Carolina.

1. Lap and shoulder (51.5 percent in NC vs. 32.8 percent in the SE, overrepresentation factor=0.57)
2. Unknown (10.8 percent vs. 7.4 percent, 0.47)
3. Lap belt (3.2 percent vs. 2.0 percent, 0.55)
4. Motorcycle helmet (3.1 percent vs. 2.5 percent, 0.24)

Drivers who did not use restraints or for whom restraint use data were not available were underrepresented.

The overrepresentation of restraints probably reflects the fact that 80 percent or so of North Carolina's drivers buckle up, thanks to high-profile education and enforcement programs. In other words, a higher percentage of drivers in North Carolina were buckled up than in many other states. As a result, North Carolina accounted for a bigger share of buckled-up drivers in the Southeast than it did for total drivers in the Southeast. It is also believed that officers in North Carolina were more likely to record whether drivers were using restraints, than officers in other Southeastern States. Therefore, drivers who used restraints were over-represented.

8. Alcohol Involvement (Table B.24)

"Causal" vehicles in which alcohol was not involved or where alcohol involvement was not reported were over-represented. With a value of 17.0 percent, alcohol involvement was underrepresented, as was unknown alcohol involvement. This means that North Carolina has a lower proportion of alcohol-related crashes than the Southeastern States as a whole. This may be the result of North Carolina's aggressive enforcement of DWI laws, leading to fewer people driving soon after consuming alcohol. However, the data in Table B.24 seem to be inconsistent with violations charged (Table B.19), which show that alcohol/ drugs were over-represented.

9. Injury Severity (Table B.25)

This variable refers to injury severity for the driver of the vehicle that "caused" the crash, *i.e.*, the at-fault driver. The over-represented categories were possible, incapacitating, and unknown. No injury and fatal injury were underrepresented. In other words, the driver of the vehicle that caused the crash was less likely to be killed in North Carolina compared to the Southeastern States (47.9 vs. 49.9 percent). It should be kept in mind that a crash is fatal if one or more people in any of the vehicles involved die in the crash or within 30 days as a result of injuries suffered in the crash. Not every driver who "caused" the crash was killed.

APPENDIX B: CARE DATA TABLES

CARE IMPACT OUTPUT B NORTH CAROLINA
NORTH CAROLINA (SUBSET) VS. 8 SE STATES (OTHER)

The CARE IMPACT output given below compares the fatal crashes in North Carolina against those for the 8 SE States in general. This gives a conservative overview of how North Carolina differs from the rest of states in the SE region. The reason that it is conservative is that North Carolina is also contained in the 8 SE states. This means that the significance of the results of a comparison without North Carolina being included would be even *higher* than the significance indicated by the statistical test (alpha = 99%), since some of the difference is buffered out by its presence in the control.

TABLE B.1: ROADWAY FUNCTION CLASS

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
6	RUR LOCAL ROAD OR ST	1273	19.875	6514	13.846	1.435*	386.181
5	RUR MINOR COLLECTOR	634	9.899	2651	5.635	1.757*	273.092
4	RUR MAJOR COLLECTOR	1128	17.611	6696	14.233	1.237*	216.403
16	URB LOCAL ROAD OR ST	727	11.351	3808	8.094	1.402*	208.577
15	URB MINOR COLLECTOR	160	2.498	1107	2.353	1.062	9.293
20	UNKNOWN	8	0.125	508	1.080	0.116	-61.159
1	RUR PRIN ARTERIAL -	298	4.653	2710	5.760	0.808*	-70.941
11	URB PRIN ARTERIAL -	173	2.701	1861	3.956	0.683*	-80.357
14	URB MAJOR COLLECTOR	396	6.183	3508	7.456	0.829*	-81.581
3	RUR MINOR ARTERIAL	530	8.275	4967	10.558	0.784*	-146.210
2	RUR PRIN ARTERIAL -	611	9.539	5664	12.039	0.792*	-160.100
13	URB MINOR ARTERIAL	372	5.808	4185	8.895	0.653*	-197.748
12	URB PRIN ARTERIAL -	95	1.483	2393	5.086	0.292*	-230.784

TABLE B.2: FIRST HARMFUL EVENT

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
34	DITCH	537	8.384	1769	3.760	2.230*	296.168
12	VEH IN TRANSP	2717	42.420	19624	41.711	1.017	45.380
37	EMBANK-UNK	153	2.389	807	1.715	1.393*	43.135
23	BRIDGE RAIL	71	1.109	222	0.472	2.349*	40.777
8	PEDESTRIAN	867	13.536	6107	12.981	1.043	35.590
32	CULVERT	153	2.389	986	2.096	1.140	18.766
9	PEDALCYCLE	162	2.529	1104	2.347	1.078	11.701
19	BUILDING	18	0.281	88	0.187	1.502	6.020
31	OTHER POST/POLE	53	0.827	351	0.746	1.109	5.215
13	VEH IN TRANS OTH	94	1.468	665	1.413	1.038	3.467
21	BRIDGE PIER	34	0.531	233	0.495	1.072	2.279
14	PARKED MOTOR VEH	54	0.843	383	0.814	1.036	1.858
41	SHRUBBERY	5	0.078	24	0.051	1.530	1.733
30	UTILITY POLE	193	3.013	1407	2.991	1.008	1.450
20	IMPACT ATTENUATR	3	0.047	16	0.034	1.377	0.822
22	BRIDGE PARAPET	11	0.172	75	0.159	1.077	0.789
29	LIGHT SUPPORT	3	0.047	21	0.045	1.049	0.141
2	FIRE/EXPLOSION	1	0.016	7	0.015	1.049	0.047
15	OTHER NON-MOT	5	0.078	38	0.081	0.966	-0.173
28	OVERHEAD SIGN	1	0.016	11	0.023	0.668	-0.498
26	OTHER L-BARRIER	1	0.016	12	0.026	0.612	-0.634
40	FIRE HYDRANT	2	0.031	21	0.045	0.700	-0.859
11	ANIMAL	14	0.219	114	0.242	0.902	-1.520
16	OBJ THROWN/FALL	2	0.031	26	0.055	0.565	-1.540
7	OTHER NON-COLL	3	0.047	48	0.102	0.459	-3.535
17	BOULDER	1	0.016	35	0.074	0.210	-3.765
3	IMMERSION	6	0.094	74	0.157	0.596	-4.074
36	EMBANK-ROCK	6	0.094	87	0.185	0.507	-5.844
39	WALL	14	0.219	163	0.346	0.631	-8.191
25	CONCRETE BARRIER	11	0.172	141	0.300	0.573	-8.196
5	FELL FROM VEH	34	0.531	313	0.665	0.798	-8.612

33	CURB	41	0.640	366	0.778	0.823	-8.827
18	OTH NON-FIX OBJ	21	0.328	243	0.517	0.635	-12.082
10	RAIL TRAIN	40	0.625	395	0.840	0.744	-13.775
27	HWY SIGN POST	37	0.578	395	0.840	0.688	-16.775
24	GUARDRAIL	115	1.795	977	2.077	0.865	-18.009
38	FENCE	45	0.703	464	0.986	0.712	-18.169
43	OTHER FIXED OBJ	45	0.703	576	1.224	0.574*	-33.417
35	EMBANK-EARTH	8	0.125	458	0.973	0.128	-54.352
42	TREE	566	8.837	4713	10.018	0.882*	-75.630
1	OVERTURN	258	4.028	3437	7.305	0.551*	-209.915

TABLE B.3: MANNER OF COLLISION

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	HEAD-ON	1345	20.999	7127	15.149	1.386*	374.727
1	REAR-END	294	4.590	2232	4.744	0.968	-9.866
6	S-SWIPE:OPP DIR	21	0.328	269	0.572	0.573*	-15.622
5	S-SWIPE:SAME DIR	20	0.312	345	0.733	0.426*	-26.968
0	NOT COL W/ MVIT	3594	56.112	26740	56.837	0.987	-46.396
4	ANGLE	1131	17.658	10202	21.685	0.814*	-257.905

TABLE B.4: RELATION TO JUNCTION

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
4	NON-INT DR,ALLEY	625	9.758	1384	2.942	3.317*	436.582
3	NON-INT INT REL	133	2.077	917	1.949	1.065	8.159
7	NON-INT X-OVER	13	0.203	59	0.125	1.618	4.968
11	INT INTER REL	15	0.234	79	0.168	1.395	4.245
14	INT X-OVER	4	0.062	10	0.021	2.938	2.639
13	INT RAMP	16	0.250	105	0.223	1.119	1.705
12	INT DRIVEWAY	4	0.062	30	0.064	0.979	-0.084
9	NON-INT UNKNOWN	1	0.016	9	0.019	0.816	-0.225
15	INT OTHER	2	0.031	73	0.155	0.201	-7.938
6	NON-INT RAILXING	40	0.625	402	0.854	0.731	-14.728
5	NON-INT RAMP	21	0.328	278	0.591	0.555*	-16.847
2	NON-INT INTERSEC	1056	16.487	8668	18.424	0.895*	-124.065
1	NON-INT NON-JUNC	4475	69.867	34232	72.761	0.960*	-185.360

TABLE B.5: RELATION TO ROADWAY

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
4	ROADSIDE	1155	18.033	3537	7.518	2.399*	673.471
2	SHOULDER	769	12.006	2532	5.382	2.231*	424.292
5	OUTSIDE ROW	452	7.057	903	1.919	3.677*	329.065
1	ON ROADWAY	3933	61.405	28795	61.205	1.003	12.835
3	MEDIAN	95	1.483	691	1.469	1.010	0.927
7	PARKING LANE	1	0.016	15	0.032	0.490	-1.042

TABLE B.6: TRAFFICWAY FLOW

	Subset	Subset	Other	Other	OveRep	MAX

Code	Description	Freq	%	Freq	%	Factor	Gain
1	NOT DIVIDED	5484	85.621	33715	71.662	1.195*	894.025
3	MEDIAN W/BARRIER	440	6.870	1496	3.180	2.160*	236.334
4	ONE WAY TRAFFIC	15	0.234	89	0.189	1.238	2.883
9	UNKNOWN	1	0.016	130	0.276	0.057	-16.698
2	MEDIAN-NO BARRIER	465	7.260	11617	24.692	0.294*	-1116.544

TABLE B.7: NUMBER OF TRAVEL LANES

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	TWO LANES	5192	81.062	36172	76.885	1.054*	267.527
5	FIVE LANES	51	0.796	340	0.723	1.102	4.712
4	FOUR LANES	903	14.098	6641	14.116	0.999	-1.109
1	ONE LANE	2	0.031	206	0.438	0.071	-26.045
7	SEVEN OR MORE LANES	10	0.156	269	0.572	0.273	-26.622
3	THREE LANES	152	2.373	1778	3.779	0.628*	-90.058
6	SIX LANES	95	1.483	1473	3.131	0.474*	-105.535

TABLE B.8: SPEED LIMIT

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
11	51-55 MPH	3794	59.235	20840	44.296	1.337*	956.833
7	31-35 MPH	891	13.911	4979	10.583	1.314*	213.157
4	16-20 MPH	22	0.343	106	0.225	1.525	7.569
3	11-15 MPH	2	0.031	69	0.147	0.213	-7.394
12	56-60 MPH	5	0.078	103	0.219	0.357	-9.022
16	MISSING OR OUT OF RA	2	0.031	271	0.576	0.054	-34.894
5	21-25 MPH	63	0.984	926	1.968	0.500*	-63.066
14	66-70 MPH	25	0.390	653	1.388	0.281*	-63.900
9	41-45 MPH	1155	18.033	8974	19.075	0.945	-66.724
13	61-65 MPH	301	4.699	2864	6.088	0.772*	-88.906
10	46-50 MPH	122	1.905	1889	4.015	0.474*	-135.169
6	26-30 MPH	9	0.141	2416	5.135	0.027	-319.915
8	36-40 MPH	14	0.219	2863	6.085	0.036	-375.770
0	NO STATUTORY LIMIT	0	0.000	78	0.166	0.000	0.000

TABLE B.9: ROADWAY ALIGNMENT

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	CURVE	2173	33.927	12748	27.096	1.252*	437.482
1	STRAIGHT	4232	66.073	34225	72.746	0.908*	-427.407

TABLE B.10: ROADWAY PROFILE

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
4	SAG	195	3.044	263	0.559	5.446*	159.195
1	LEVEL	4134	64.543	29369	62.425	1.034*	135.691
3	HILLCREST	285	4.450	1801	3.828	1.162*	39.811
2	GRADE	1791	27.963	15124	32.147	0.870*	-267.988

TABLE B.11: ROADWAY SURFACE CONDITION

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
4	ICE	89	1.390	248	0.527	2.636*	55.237
2	WET	1034	16.144	7337	15.595	1.035	35.138
5	SAND DIRT OIL	1	0.016	3	0.006	2.448	0.592
3	SNOW OR SLUSH	16	0.250	115	0.244	1.022	0.344
8	OTHER	1	0.016	25	0.053	0.294	-2.404
9	UNKNOWN	3	0.047	115	0.244	0.192	-12.656
1	DRY	5261	82.139	39204	83.329	0.986*	-76.250

TABLE B.12: TRAFFIC CONTROL DEVICE

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
0	NO CONTROLS	5352	83.560	35189	74.795	1.117*	561.353
1	CNTL-NO PED SIG	130	2.030	157	0.334	6.082*	108.626
20	STOP SIGN	707	11.038	4817	10.239	1.078	51.211
69	RR:UNK ACTIVE DEVICE	15	0.234	21	0.045	5.247	12.141
21	YIELD SIGN	15	0.234	87	0.185	1.266	3.156
70	RR:CROSS BUCKS	14	0.219	89	0.189	1.155	1.883
38	SCH:OTHER RELATED SI	2	0.031	3	0.006	4.897	1.592
8	OTHER SIGNAL	3	0.047	14	0.030	1.574	1.094
30	SCH:SPEED LIMIT SIGN	2	0.031	7	0.015	2.099	1.047
79	RR:UNK PASSIVE DEVIC	1	0.016	7	0.015	1.049	0.047
98	OTHER	2	0.031	20	0.043	0.735	-0.723
50	OFFICER, CROSSING GU	6	0.094	54	0.115	0.816	-1.352
62	RR:TRAFFIC CONTROL S	1	0.016	20	0.043	0.367	-1.723
5	FLASH BEACON	7	0.109	70	0.149	0.735	-2.530
9	UNK SIGNAL	1	0.016	27	0.057	0.272	-2.676
99	UNKNOWN	3	0.047	69	0.147	0.319	-6.394
60	RR:GATES	2	0.031	69	0.147	0.213	-7.394
61	RR:FLASHING LIGHTS	7	0.109	117	0.249	0.439	-8.928
2	CNTL-W/PED SIG	1	0.016	84	0.179	0.087	-10.436
4	FLASH CNTRL	58	0.906	588	1.250	0.725*	-22.051
40	WARNING SIGN	10	0.156	949	2.017	0.077	-119.197
3	CNTL-UNK PED SIG	51	0.796	2189	4.653	0.171*	-247.011
28	OTHER REGULATORY SIG	15	0.234	2255	4.793	0.049	-291.997

TABLE B.13: LIGHT CONDITION

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	DARK	2358	36.815	15970	33.945	1.085*	183.837
4	DAWN	192	2.998	973	2.068	1.449*	59.535
5	DUSK	207	3.232	1160	2.466	1.311*	49.077
9	UNKNOWN	3	0.047	107	0.227	0.206	-11.567
1	DAYLIGHT	3077	48.041	23063	49.021	0.980	-62.807
3	DARK BUT LIGHTED	568	8.868	5774	12.273	0.723*	-218.075

TABLE B.14: ATMOSPHERIC CONDITION

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	RAIN	946	14.770	4875	10.362	1.425*	282.315
3	SLEET	66	1.030	130	0.276	3.729*	48.302
7	SLEET & FOG	23	0.359	25	0.053	6.758*	19.596
6	RAIN & FOG	14	0.219	50	0.106	2.057	7.193
4	SNOW	19	0.297	162	0.344	0.861	-3.055
9	UNKNOWN	3	0.047	155	0.329	0.142	-18.102
5	FOG	37	0.578	684	1.454	0.397*	-56.120
1	NORMAL	5297	82.701	40954	87.049	0.950*	-278.496

TABLE B.15: BODY TYPE

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
30	COMPACT PICKUP	743	11.600	4337	9.218	1.258*	152.559
9	UNK AUTO TYPE	223	3.482	1079	2.293	1.518*	76.104
2	2DR SEDAN/HT/COUPE	1462	22.826	10332	21.961	1.039	55.397
63	SUT HI GVW	115	1.795	491	1.044	1.720*	48.155
80	MOTORCYCLE	241	3.763	1513	3.216	1.170	35.019
66	TRUCK/TRACTOR	335	5.230	2241	4.763	1.098	29.909
20	MINIVAN	166	2.592	1088	2.313	1.121	17.879
1	CONVERTIBLE	34	0.531	173	0.368	1.444	10.448
6	STATION WAGON	145	2.264	1007	2.140	1.058	7.907
81	MOPED	13	0.203	40	0.085	2.387	7.554
15	LARGE UTILITY	39	0.609	270	0.574	1.061	2.242
92	FARM EQUIPMENT	9	0.141	59	0.125	1.120	0.968
11	AUTO PANEL	1	0.016	2	0.004	3.673	0.728
100	NO VEHICLE	1	0.016	2	0.004	3.673	0.728
60	STEP VAN	6	0.094	39	0.083	1.130	0.691
91	SNOWMOBILE	2	0.031	11	0.023	1.336	0.502
29	UNKNOWN VAN TYPE	7	0.109	48	0.102	1.071	0.465
93	CONSTR EQUIPMENT	2	0.031	12	0.026	1.224	0.366
23	VAN MOTORHOME	3	0.047	20	0.043	1.102	0.277
51	X-COUNTRY/INTERCITY	3	0.047	20	0.043	1.102	0.277
73	CAMPER OR MOTORHOME	3	0.047	20	0.043	1.102	0.277
22	STEP VAN	8	0.125	57	0.121	1.031	0.240
59	UNKNOWN BUS	2	0.031	15	0.032	0.979	-0.042
58	OTHER BUS	2	0.031	16	0.034	0.918	-0.178
83	RESERVED	2	0.031	16	0.034	0.918	-0.178
97	OTHER VEHICLE	6	0.094	47	0.100	0.938	-0.399
50	SCHOOL BUS	7	0.109	55	0.117	0.935	-0.488
48	UNK LT CONVENTIONAL	1	0.016	22	0.047	0.334	-1.995
52	TRANSIT BUS	1	0.016	22	0.047	0.334	-1.995
16	UTILITY STATION WAGO	12	0.187	104	0.221	0.848	-2.159
78	UNKNOWN MED/HVY	2	0.031	32	0.068	0.459	-2.356
61	SUT LOW GVW	10	0.156	93	0.198	0.790	-2.661
28	OTHER VAN TYPE	4	0.062	53	0.113	0.554	-3.215
64	SUT UNK GVW	1	0.016	46	0.098	0.160	-5.262
40	CAB CHASSIS BASED	4	0.062	70	0.149	0.420	-5.530
49	UNK LT VEHICLE	1	0.016	51	0.108	0.144	-5.943
10	AUTO PICKUP	1	0.016	53	0.113	0.139	-6.215
62	SUT MED GVW	13	0.203	143	0.304	0.668	-6.468
21	LARGE VAN	116	1.811	926	1.968	0.920	-10.066
39	UNKNOWN PICKUP	2	0.031	103	0.219	0.143	-12.022
5	5DR/4DR HATCHBACK	19	0.297	228	0.485	0.612	-12.040
90	ATV	3	0.047	122	0.259	0.181	-13.609
14	COMPACT UTILITY	236	3.685	1867	3.968	0.928	-18.174
99	UNKNOWN BODY TYPE	89	1.390	801	1.703	0.816	-20.049
32	PICKUP W/CAMPER	1	0.016	181	0.385	0.041	-23.641
4	4DR SEDAN/HT	1730	27.010	13095	27.834	0.970	-52.759
3	3DR/2DR HATCHBACK	102	1.593	1232	2.619	0.608*	-65.725
31	STANDARD PICKUP	477	7.447	4577	9.729	0.766*	-146.115

TABLE B.16: ROLLOVER

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
2	SUBSEQUENT EVENT	1278	19.953	6500	13.816	1.444*	393.087
3	NO VEHICLE	1	0.016	2	0.004	3.673	0.728
0	NO ROLLOVER	4871	76.050	37088	78.832	0.965*	-178.178
1	FIRST EVENT	255	3.981	3457	7.348	0.542*	-215.638

TABLE B.17: VEHICLE MANEUVER

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
17	NEGOTIATE CURVE	1881	29.368	8877	18.868	1.556*	672.481
3	STARTING IN LANE	179	2.795	483	1.027	2.722*	113.244
19	UNKNOWN	104	1.624	471	1.001	1.622*	39.878
10	RTOR:PERMITTED	16	0.250	29	0.062	4.053	12.052
2	SLOWING/STOPPING	40	0.625	246	0.523	1.194	6.509
15	BACKING UP	21	0.328	135	0.287	1.143	2.621
20	NO VEHICLE	1	0.016	2	0.004	3.673	0.728
7	PARKED	1	0.016	5	0.011	1.469	0.319
9	AVOID ANIMAL,ETC	89	1.390	695	1.477	0.941	-5.618
14	U-TURN	8	0.125	138	0.293	0.426	-10.787
5	PASSING	119	1.858	973	2.068	0.898	-13.465
12	RTOR:NOT KNOWN	9	0.141	226	0.480	0.293	-21.768
4	STOPPED IN LANE	41	0.640	532	1.131	0.566*	-31.427
16	CHANGING LANES	35	0.546	693	1.473	0.371*	-59.345
13	LEFT TURN	239	3.731	2766	5.879	0.635*	-137.564
1	GOING STRAIGHT	3622	56.550	30734	65.326	0.866*	-562.141

TABLE B.18: MOST HARMFUL EVENT

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
42	TREE	869	13.568	5650	12.009	1.130*	99.806
12	VEH IN TRANSP	2688	41.967	19289	40.999	1.024	61.987
13	VEH IN TRANS OTH	104	1.624	478	1.016	1.598*	38.925
8	PEDESTRIAN	879	13.724	6189	13.155	1.043	36.427
3	IMMERSION	69	1.077	350	0.744	1.448*	21.351
34	DITCH	89	1.390	497	1.056	1.315*	21.338
19	BUILDING	39	0.609	151	0.321	1.897*	18.443
23	BRIDGE RAIL	33	0.515	141	0.300	1.719*	13.804
9	PEDALCYCLE	161	2.514	1092	2.321	1.083	12.335
22	BRIDGE PARAPET	12	0.187	61	0.130	1.445	3.695
21	BRIDGE PIER	36	0.562	244	0.519	1.084	2.782
40	FIRE HYDRANT	2	0.031	6	0.013	2.448	1.183
41	SHRUBBERY	2	0.031	6	0.013	2.448	1.183
11	ANIMAL	8	0.125	53	0.113	1.109	0.785
4	GAS INHALATION	1	0.016	2	0.004	3.673	0.728
48	NO VEHICLE	1	0.016	2	0.004	3.673	0.728
15	OTHER NON-MOT	6	0.094	40	0.085	1.102	0.554
20	IMPACT ATTENUATR	1	0.016	6	0.013	1.224	0.183
26	OTHER L-BARRIER	1	0.016	6	0.013	1.224	0.183
28	OVERHEAD SIGN	1	0.016	10	0.021	0.735	-0.361
47	UNKNOWN	1	0.016	11	0.023	0.668	-0.498
37	EMBANK-UNK	39	0.609	297	0.631	0.965	-1.434
16	OBJ THROWN/FALL	1	0.016	18	0.038	0.408	-1.451
33	CURB	4	0.062	42	0.089	0.700	-1.718
7	OTHER NON-COLL	5	0.078	50	0.106	0.735	-1.807
14	PARKED MOTOR VEH	46	0.718	352	0.748	0.960	-1.921
27	HWY SIGN POST	7	0.109	71	0.151	0.724	-2.666
18	OTH NON-FIX OBJ	13	0.203	125	0.266	0.764	-4.018
31	OTHER POST/POLE	15	0.234	141	0.300	0.781	-4.196
36	EMBANK-ROCK	3	0.047	61	0.130	0.361	-5.305
25	CONCRETE BARRIER	6	0.094	89	0.189	0.495	-6.117
38	FENCE	21	0.328	203	0.431	0.760	-6.637
5	FELL FROM VEH	34	0.531	314	0.667	0.795	-8.748
39	WALL	9	0.141	155	0.329	0.427	-12.102
10	RAIL TRAIN	40	0.625	398	0.846	0.738	-14.184
24	GUARDRAIL	54	0.843	506	1.076	0.784	-14.887
43	OTHER FIXED OBJ	17	0.265	237	0.504	0.527	-15.265
32	CULVERT	41	0.640	465	0.988	0.648*	-22.305
35	EMBANK-EARTH	4	0.062	233	0.495	0.126	-27.721
2	FIRE/EXPLOSION	16	0.250	347	0.738	0.339	-31.241
30	UTILITY POLE	126	1.967	1422	3.023	0.651*	-67.592
1	OVERTURN	901	14.067	7168	15.236	0.923*	-74.855

TABLE B.19: VIOLATIONS CHARGED

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
3	ALC OR DRUGS-SPD	565	8.821	725	1.541	5.724*	466.298
6	OTHER MOVING	517	8.072	2312	4.914	1.643*	202.243

2	SPEEDING	259	4.044	468	0.995	4.065*	195.286
1	ALCOHOL OR DRUGS	315	4.918	1066	2.266	2.171*	169.874
10	NO DRIVER	1	0.016	2	0.004	3.673	0.728
8	UNKNOWN OR OTHER	1	0.016	44	0.094	0.167	-4.990
5	SUSPEND/REVOKED	12	0.187	178	0.378	0.495	-12.233
4	RECKLESS DRIVING	11	0.172	292	0.621	0.277	-28.753
7	NON-MOVING	27	0.422	458	0.973	0.433*	-35.352
9	UNKNOWN	94	1.468	1343	2.855	0.514*	-88.837
0	NONE	4603	71.866	40159	85.359	0.842*	-864.265

TABLE B.20: FIRST RELATED FACTOR - DR

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
44	DRIVING TOO FAST	1595	24.902	5295	11.255	2.213*	874.136
27	IMPR LANE CHANGE	507	7.916	801	1.703	4.649*	397.952
0	NONE	1480	23.107	8081	17.176	1.345*	379.849
51	WRONG SIDE OF RD	493	7.697	928	1.972	3.902*	366.662
91	HOMOCIDE	113	1.764	282	0.599	2.943*	74.608
36	ERRATIC/RECKLESS	587	9.165	3872	8.230	1.114*	59.864
50	WRONG WAY	20	0.312	64	0.136	2.295*	11.287
23	IMPROPER LIGHTS	15	0.234	61	0.130	1.806	6.695
24	W/O REQ EQUIP	12	0.187	41	0.087	2.150	6.418
90	HIT AND RUN	105	1.639	726	1.543	1.062	6.162
22	IMPROPER TOWING	9	0.141	29	0.062	2.280	5.052
8	PARAPLEGIC	4	0.062	8	0.017	3.673	2.911
19	INVALID LICENSE	4	0.062	10	0.021	2.938	2.639
17	RESERVED	3	0.047	8	0.017	2.755	1.911
16	RESERVED	2	0.031	3	0.006	4.897	1.592
14	FAILURE TAKE DRUGS	2	0.031	5	0.011	2.938	1.319
95	COMPUTER	2	0.031	5	0.011	2.938	1.319
7	WHEELCHAIR	2	0.031	8	0.017	1.836	0.911
15	RESERVED	2	0.031	9	0.019	1.632	0.775
18	TRAVELING PROHIBITED	2	0.031	9	0.019	1.632	0.775
94	FAX MACHINE	1	0.016	2	0.004	3.673	0.728
100	NO DRIVER	1	0.016	2	0.004	3.673	0.728
97	2-WAY RADIO	1	0.016	3	0.006	2.448	0.592
80	FLAT TIRE	10	0.156	70	0.149	1.049	0.470
13	MENTALLY CHALLENGED	1	0.016	4	0.009	1.836	0.455
20	VEH UNATTENDED	7	0.109	52	0.111	0.989	-0.079
12	DEAD FETUS	1	0.016	8	0.017	0.918	-0.089
43	WRONG SIGNAL	1	0.016	10	0.021	0.735	-0.361
3	EMOTIONAL	2	0.031	18	0.038	0.816	-0.451
45	UNDER MIN SPEED	3	0.047	27	0.057	0.816	-0.676
11	OTHER PHYSICAL	4	0.062	35	0.074	0.839	-0.765
52	OP INEXPERIENCE	1	0.016	15	0.032	0.490	-1.042
47	WRONG LANE TURN	2	0.031	24	0.051	0.612	-1.267
46	SPEED CHANGES	2	0.031	25	0.053	0.588	-1.404
77	CROSSWIND	1	0.016	18	0.038	0.408	-1.451
65	TREE,PLANTS	2	0.031	29	0.062	0.507	-1.948
71	OBSTRUCT ANGLES	1	0.016	26	0.055	0.283	-2.540
21	IMPROPER LOADING	4	0.062	63	0.134	0.466	-4.577
62	GLARE	1	0.016	74	0.157	0.099	-9.074

54	STOPPING IN RD	1	0.016	86	0.183	0.085	-10.708
87	WATER,SNOW,OIL	1	0.016	184	0.391	0.040	-24.050
48	OTHR IMPROP TURN	5	0.078	231	0.491	0.159	-26.448
2	ILL, BLACKOUT	2	0.031	222	0.472	0.066	-28.223
26	IMPROPER TAILING	1	0.016	218	0.463	0.034	-28.679
92	OTHER VIOLATION	4	0.062	311	0.661	0.094	-38.340
40	AROUND BARRIER	1	0.016	325	0.691	0.023	-43.246
34	PASS WRONG SIDE	2	0.031	396	0.842	0.037	-51.912
31	IMPR START/BACK	4	0.062	484	1.029	0.061	-61.892
39	FAILURE TO OBEY	173	2.701	1744	3.707	0.729*	-64.429
1	DROWSY, ASLEEP	34	0.531	740	1.573	0.337*	-66.744
99	UNKNOWN	61	0.952	966	2.053	0.464*	-70.512
37	HIGH SPEED CHASE	32	0.500	765	1.626	0.307*	-72.147
29	DRIVING SHOULDER	17	0.265	742	1.577	0.168	-84.016
35	PASS INSUFF DIST	6	0.094	782	1.662	0.056	-100.462
32	OPEN VEH CLOSURE	3	0.047	786	1.671	0.028	-104.006
30	IMP ENTRY/EXIT	11	0.172	875	1.860	0.092	-108.123
6	INATTENTIVE	4	0.062	1113	2.366	0.026	-147.524
33	PROHIBITED PASS	7	0.109	1307	2.778	0.039	-170.936
28	RUN OFF RD/LANE	767	11.975	7928	16.851	0.711*	-312.322
38	FAILURE TO YIELD	264	4.122	4340	9.225	0.447*	-326.850

TABLE B.21: SECOND RELATED FACTOR - DR

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
51	WRONG SIDE OF RD	554	8.649	729	1.550	5.582*	454.754
36	ERRATIC/RECKLESS	524	8.181	1176	2.500	3.273*	363.899
91	HOMOCIDE	394	6.151	921	1.958	3.142*	268.615
38	FAILURE TO YIELD	150	2.342	547	1.163	2.014*	75.531
37	HIGH SPEED CHASE	58	0.906	178	0.378	2.393*	33.767
54	STOPPING IN RD	40	0.625	161	0.342	1.825*	18.081
57	LOCKED WHEEL	34	0.531	126	0.268	1.982*	16.846
50	WRONG WAY	37	0.578	180	0.383	1.510	12.495
35	PASS INSUFF DIST	37	0.578	190	0.404	1.430	11.133
60	ON/OFF STOP VEH	36	0.562	184	0.391	1.437	10.950
52	OP INEXPERIENCE	25	0.390	104	0.221	1.766*	10.841
30	IMP ENTRY/EXIT	34	0.531	171	0.363	1.460	10.720
53	UNFAMILIAR W/RD	26	0.406	113	0.240	1.690*	10.616
88	RESERVED	14	0.219	34	0.072	3.025	9.371
33	PROHIBITED PASS	31	0.484	161	0.342	1.414	9.081
65	TREE,PLANTS	27	0.422	138	0.293	1.437	8.213
40	AROUND BARRIER	31	0.484	170	0.361	1.339	7.856
43	WRONG SIGNAL	18	0.281	86	0.183	1.537	6.292
59	ON/OFF MOV VEH	12	0.187	42	0.089	2.099	6.282
29	DRIVING SHOULDER	9	0.141	29	0.062	2.280	5.052
32	OPEN VEH CLOSURE	25	0.390	147	0.312	1.249	4.987
89	CARRYING HAZ CARGO	5	0.078	7	0.015	5.247	4.047
34	PASS WRONG SIDE	23	0.359	141	0.300	1.198	3.804
10	DEAF	21	0.328	130	0.276	1.187	3.302
45	UNDER MIN SPEED	15	0.234	88	0.187	1.252	3.020
71	OBSTRUCT ANGLES	16	0.250	96	0.204	1.224	2.931
78	TRUCK WIND	8	0.125	38	0.081	1.546	2.827
26	IMPROPER TAILING	19	0.297	124	0.264	1.125	2.119

94	FAX MACHINE	5	0.078	27	0.057	1.360	1.324
9	PREVIOUS INJURY	11	0.172	73	0.155	1.107	1.062
100	NO DRIVER	1	0.016	2	0.004	3.673	0.728
67	PARKED VEHICLE	9	0.141	61	0.130	1.084	0.695
85	PHANTOM VEHICLE	15	0.234	106	0.225	1.039	0.569
55	UNDERRIDE TRUCK	12	0.187	88	0.187	1.002	0.020
8	PARAPLEGIC	15	0.234	111	0.236	0.993	-0.112
69	INADEQ DEFROSTER	6	0.094	45	0.096	0.979	-0.126
5	OTHER DRUGS	22	0.343	163	0.346	0.991	-0.191
98	HEAD-UP DISPLAY	3	0.047	25	0.053	0.881	-0.404
97	2-WAY RADIO	4	0.062	35	0.074	0.839	-0.765
39	FAILURE TO OBEY	111	1.733	821	1.745	0.993	-0.771
56	LOW TIRE PRESSUR	15	0.234	118	0.251	0.934	-1.065
73	OTHER MIRROR	7	0.109	60	0.128	0.857	-1.168
15	RESERVED	9	0.141	77	0.164	0.859	-1.483
21	IMPROPER LOADING	31	0.484	239	0.508	0.953	-1.538
2	ILL, BLACKOUT	28	0.437	218	0.463	0.943	-1.679
19	INVALID LICENSE	1	0.016	22	0.047	0.334	-1.995
93	CELLULAR PHONE	6	0.094	60	0.128	0.735	-2.168
70	INADEQ LIGHTS	23	0.359	185	0.393	0.913	-2.186
14	FAILURE TAKE DRUGS	13	0.203	112	0.238	0.853	-2.248
24	W/O REQ EQUIP	8	0.125	78	0.166	0.753	-2.619
13	MENTALLY CHALLENGED	16	0.250	139	0.295	0.846	-2.924
23	IMPROPER LIGHTS	9	0.141	88	0.187	0.751	-2.980
80	FLAT TIRE	21	0.328	178	0.378	0.867	-3.233
83	ANIMAL	13	0.203	120	0.255	0.796	-3.337
1	DROWSY, ASLEEP	33	0.515	267	0.568	0.908	-3.350
25	UNLAWFUL NOISE	2	0.031	43	0.091	0.342	-3.854
82	RUT IN ROAD	10	0.156	102	0.217	0.720	-3.886
3	EMOTIONAL	18	0.281	162	0.344	0.816	-4.055
79	SLIPPERY SURFACE	5	0.078	67	0.142	0.548	-4.121
42	FAIL TO SIGNAL	8	0.125	91	0.193	0.646	-4.389
16	RESERVED	10	0.156	107	0.227	0.686	-4.567
46	SPEED CHANGES	12	0.187	122	0.259	0.722	-4.609
68	SPLASH,SPRAY	5	0.078	71	0.151	0.517	-4.666
17	RESERVED	9	0.141	102	0.217	0.648	-4.886
77	CROSSWIND	8	0.125	95	0.202	0.619	-4.933
75	IMPR WINDSHIELD	7	0.109	91	0.193	0.565	-5.389
22	IMPROPER TOWING	7	0.109	92	0.196	0.559	-5.525
12	DEAD FETUS	11	0.172	123	0.261	0.657	-5.745
41	FAIL TO OBS WARN	6	0.094	89	0.189	0.495	-6.117
47	WRONG LANE TURN	7	0.109	99	0.210	0.519	-6.478
64	BLDG,BILLBOARD	7	0.109	99	0.210	0.519	-6.478
86	PEDESTRIAN	2	0.031	63	0.134	0.233	-6.577
96	NAVIGATION SYS	1	0.016	56	0.119	0.131	-6.624
81	DEBRIS IN ROAD	9	0.141	118	0.251	0.560	-7.065
95	COMPUTER	2	0.031	70	0.149	0.210	-7.530
84	VEHICLE IN ROAD	6	0.094	101	0.215	0.436	-7.750
18	TRAVELING PROHIBITED	2	0.031	72	0.153	0.204	-7.802
31	IMPR START/BACK	13	0.203	153	0.325	0.624	-7.829
7	WHEELCHAIR	8	0.125	117	0.249	0.502	-7.928
63	CURVE,HILL,ETC	7	0.109	112	0.238	0.459	-8.248
11	OTHER PHYSICAL	23	0.359	232	0.493	0.728	-8.585

4	DRUGS-MEDICATION	11	0.172	144	0.306	0.561	-8.604
72	REAR MIRRORS	2	0.031	78	0.166	0.188	-8.619
76	OTHER OBSTRUCT	2	0.031	78	0.166	0.188	-8.619
20	VEH UNATTENDED	29	0.453	281	0.597	0.758	-9.255
66	MOVING VEHICLE	6	0.094	118	0.251	0.373	-10.065
62	GLARE	5	0.078	121	0.257	0.304	-11.473
74	HEAD RESTRAINTS	5	0.078	125	0.266	0.294	-12.018
27	IMPR LANE CHANGE	5	0.078	127	0.270	0.289	-12.290
61	WEATHER	21	0.328	245	0.521	0.630	-12.354
48	OTHR IMPROP TURN	5	0.078	173	0.368	0.212	-18.552
58	OVER CORRECTING	18	0.281	360	0.765	0.367	-31.011
87	WATER,SNOW,OIL	4	0.062	261	0.555	0.113	-31.533
90	HIT AND RUN	6	0.094	287	0.610	0.154	-33.072
6	INATTENTIVE	3	0.047	310	0.659	0.071	-39.204
99	UNKNOWN	61	0.952	982	2.087	0.456*	-72.690
92	OTHER VIOLATION	7	0.109	586	1.246	0.088	-72.778
0	NONE	2894	45.183	22397	47.606	0.949*	-155.138
28	RUN OFF RD/LANE	334	5.215	4137	8.793	0.593*	-229.213
44	DRIVING TOO FAST	112	1.749	3846	8.175	0.214*	-411.596

TABLE B.22: THIRD RELATED FACTOR - DR

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
91	HOMOCIDE	178	2.779	488	1.037	2.679*	111.563
36	ERRATIC/RECKLESS	148	2.311	275	0.585	3.953*	110.561
28	RUN OFF RD/LANE	118	1.842	430	0.914	2.016*	59.460
51	WRONG SIDE OF RD	64	0.999	89	0.189	5.282*	51.883
0	NONE	4553	71.085	33120	70.398	1.010	44.028
3	EMOTIONAL	54	0.843	167	0.355	2.375*	31.265
23	IMPROPER LIGHTS	43	0.671	132	0.281	2.393*	25.029
33	PROHIBITED PASS	44	0.687	175	0.372	1.847*	20.175
53	UNFAMILIAR W/RD	36	0.562	128	0.272	2.066*	18.574
43	WRONG SIGNAL	33	0.515	148	0.315	1.638*	12.851
83	ANIMAL	27	0.422	112	0.238	1.771*	11.752
50	WRONG WAY	79	1.233	494	1.050	1.175	11.747
73	OTHER MIRROR	30	0.468	139	0.295	1.585	11.076
93	CELLULAR PHONE	30	0.468	141	0.300	1.563	10.804
63	CURVE,HILL,ETC	32	0.500	156	0.332	1.507	10.762
13	MENTALLY CHALLENGED	34	0.531	174	0.370	1.435	10.312
4	DRUGS-MEDICATION	30	0.468	147	0.312	1.499	9.987
40	AROUND BARRIER	69	1.077	435	0.925	1.165	9.779
60	ON/OFF STOP VEH	60	0.937	371	0.789	1.188	9.492
84	VEHICLE IN ROAD	24	0.375	116	0.247	1.520	8.208
24	W/O REQ EQUIP	23	0.359	115	0.244	1.469	7.344
25	UNLAWFUL NOISE	10	0.156	22	0.047	3.339	7.005
64	BLDG,BILLBOARD	19	0.297	98	0.208	1.424	5.658
75	IMPR WINDSHIELD	7	0.109	26	0.055	1.978	3.460
65	TREE,PLANTS	6	0.094	23	0.049	1.916	2.869
95	COMPUTER	5	0.078	17	0.036	2.160	2.686
29	DRIVING SHOULDER	7	0.109	32	0.068	1.607	2.644
59	ON/OFF MOV VEH	8	0.125	40	0.085	1.469	2.554
69	INADEQ DEFROSTER	8	0.125	40	0.085	1.469	2.554
34	PASS WRONG SIDE	18	0.281	114	0.242	1.160	2.480
5	OTHER DRUGS	5	0.078	19	0.040	1.933	2.413
79	SLIPPERY SURFACE	7	0.109	40	0.085	1.285	1.554
85	PHANTOM VEHICLE	4	0.062	18	0.038	1.632	1.549
45	UNDER MIN SPEED	3	0.047	11	0.023	2.003	1.502
27	IMPR LANE CHANGE	4	0.062	19	0.040	1.546	1.413
35	PASS INSUFF DIST	6	0.094	35	0.074	1.259	1.235
89	CARRYING HAZ CARGO	4	0.062	23	0.049	1.277	0.869
100	NO DRIVER	1	0.016	2	0.004	3.673	0.728
38	FAILURE TO YIELD	8	0.125	54	0.115	1.088	0.648
20	VEH UNATTENDED	57	0.890	416	0.884	1.006	0.366
21	IMPROPER LOADING	1	0.016	6	0.013	1.224	0.183
15	RESERVED	3	0.047	23	0.049	0.958	-0.131
55	UNDERRIDE TRUCK	2	0.031	16	0.034	0.918	-0.178
54	STOPPING IN RD	15	0.234	112	0.238	0.984	-0.248
56	LOW TIRE PRESSUR	1	0.016	10	0.021	0.735	-0.361
68	SPLASH,SPRAY	1	0.016	10	0.021	0.735	-0.361
9	PREVIOUS INJURY	3	0.047	28	0.060	0.787	-0.812
30	IMP ENTRY/EXIT	58	0.906	432	0.918	0.986	-0.813
74	HEAD RESTRAINTS	13	0.203	103	0.219	0.927	-1.022

19	INVALID LICENSE	5	0.078	47	0.100	0.781	-1.399
39	FAILURE TO OBEY	16	0.250	130	0.276	0.904	-1.698
70	INADEQ LIGHTS	53	0.827	402	0.854	0.968	-1.728
49	PHYS REST COMPLY	4	0.062	43	0.091	0.683	-1.854
94	FAX MACHINE	8	0.125	75	0.159	0.784	-2.211
14	FAILURE TAKE DRUGS	15	0.234	135	0.287	0.816	-3.379
1	DROWSY, ASLEEP	3	0.047	55	0.117	0.401	-4.488
37	HIGH SPEED CHASE	5	0.078	73	0.155	0.503	-4.938
80	FLAT TIRE	41	0.640	346	0.735	0.870	-6.105
90	HIT AND RUN	44	0.687	393	0.835	0.822	-9.503
72	REAR MIRRORS	9	0.141	194	0.412	0.341	-17.411

22	IMPROPER TOWING	7	0.109	182	0.387	0.283	-17.778
82	RUT IN ROAD	4	0.062	162	0.344	0.181	-18.055
10	DEAF	56	0.874	563	1.197	0.731	-20.647
52	OP INEXPERIENCE	5	0.078	189	0.402	0.194	-20.731
32	OPEN VEH CLOSURE	6	0.094	213	0.453	0.207	-22.998
62	GLARE	3	0.047	192	0.408	0.115	-23.139
42	FAIL TO SIGNAL	6	0.094	215	0.457	0.205	-23.270
2	ILL, BLACKOUT	9	0.141	255	0.542	0.259	-25.716
12	DEAD FETUS	7	0.109	273	0.580	0.188	-30.166
44	DRIVING TOO FAST	32	0.500	565	1.201	0.416*	-44.919
99	UNKNOWN	64	0.999	952	2.024	0.494*	-65.606
92	OTHER VIOLATION	10	0.156	1504	3.197	0.049	-194.755

TABLE B.23: RESTRAINT SYSTEM-USE

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
3	LAP AND SHOULDER	3299	51.507	15436	32.810	1.570*	1197.536
16	UNKNOWN	693	10.820	3463	7.361	1.470*	221.546
2	LAP BELT	203	3.169	961	2.043	1.552*	72.169
5	M-CYCLE HELMET	200	3.123	1187	2.523	1.238*	38.401
13	SAFETY BELT USED IMP	1	0.016	3	0.006	2.448	0.592
15	RES USED--TYPE UNK	1	0.016	6	0.013	1.224	0.183
17	NO DRIVER/PERSON REC	18	0.281	195	0.414	0.678	-8.547
0	NONE USED OR N/A	1990	31.069	22266	47.327	0.656*	-1041.303

TABLE B.24: ALCOHOL INVOLVEMENT

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
0	NO (ALCOHOL NOT INVO	4176	65.199	24709	52.520	1.241*	812.106
8	NOT REPORTED	481	7.510	2990	6.355	1.182*	73.940
10	NO DRIVER/PERSON REC	18	0.281	195	0.414	0.678	-8.547
1	YES (ALCOHOL INVOLVE	1090	17.018	8602	18.284	0.931*	-81.080
9	UNKNOWN	640	9.992	10551	22.427	0.446*	-796.418

TABLE B.25: INJURY SEVERITY

Code	Description	Subset Freq	Subset %	Other Freq	Other %	OveRep Factor	MAX Gain
1	POSSIBLE	454	7.088	2547	5.414	1.309*	107.250
3	INCAPACITATING	845	13.193	5706	12.128	1.088*	68.183
9	UNKNOWN	80	1.249	377	0.801	1.559*	28.675
2	NON INCAPACITY	598	9.336	4258	9.051	1.032	18.314
10	NO DRIVER/PERSON REC	18	0.281	195	0.414	0.678	-8.547
0	NO	1341	20.937	10466	22.246	0.941*	-83.846
4	FATAL INJURY	3069	47.916	23491	49.931	0.960*	-129.075

APPENDIX C: PRELIMINARY HSIS ANALYSIS HYPOTHESES AND DATA

Table C.1. Selected hypotheses regarding risk of crashes on roadway segments

Variable	**Severity measures** 1. Severe crash rate (# of K + A crashes per million vehicle miles). 2. Relative severity of crashes (% of K + A crashes/total crashes).
Number of lanes	Due to design, vehicle, driver and collision factors, two lane roads are more likely to have severe crashes.
Road speed	Higher posted speeds often imply higher collision speeds and greater transfer of energy to occupants, resulting in more sever injuries
Roadway shoulders	Presence of shoulders provide recovery area, reducing the risk of severe collisions
Access control	Greater access control is expected to reduce conflict and some severe crash types. On the other hand the higher associated speeds may increase severity.
Geography/Terrain	Due to more curves, grades and roadside hazards, mountainous counties may have more severe crashes. However, driver behavior may compensate for added danger mountainous counties.
Primitive road surface	Primitive road surface is expected to increase injury severity. On the other hand, driver compensation (lowering speed) may decrease severity.
Rural vs urban	Rural crashes are expected to be more severe (less traffic and higher actual speed).
Median	Crashes on divided roads are expected to be less severe because of the physical separation between lanes.

Table C.2. Selected hypotheses regarding crashes (the hypotheses assume that a crash has occurred and that "all else being equal").

Variable	**Severity measure** 1 Most severe injury in crash measured on KABCO scale. 2 Total injuries in a crash on KABCO scale.
Driver/occupant factors	Alcohol involvement is expected to increase injury severity.
Vehicle factors	Larger vehicles involved in crashes provide more protection to occupants and therefore lesser injury Pedestrians, bicyclists and motorcyclists are more exposed and therefore more likely to be injured
Roadway/Environmental factors	Bad weather, lower visibility, presence of curves, grades and roadside hazards, and higher speeds increase crash severity. Crashes on two-lane roads are more likely to be severe.
Crash factors	Single vehicle run-off-road, head-on, large truck involved, bicycle, motorcycle involved and pedestrian involved crashes are expected to be more severe than other crashes.
Time trends	Due to improvement in vehicle technology and roadway design, crash severity will decrease over time.

Table C.3. Crashes by roadway type.

			ALL CRASHES FOR EACH ROADWAY TYPE			SEVERE CRASHES FOR EACH ROADWAY TYPE			CRASH SEVERITY BY ROADWAY TYPE
ROADWAY TYPE	**CRITERIA**	**# OF SEGMENTS IN SAMPLE**	**KABCO CRASHES # of crashes**	**% of total KABCO crashes**	**# KABCO 1,000,000 vehicle miles**	**K+A CRASHES # of crashes**	**% of total K+A crashes**	**# K+A 1,000,000 vehicle miles**	**% K+A OF # OF KABCO CRASHES**
Rural 2 lane highway	outside urbanized area no full access control 2 lanes or less	27425	269,773	56.4	2.09	15,853	64.15	0.12	5.876
Rural multilane undivided (non-freeway)	outside urbanized area no full access control 3 lanes or more undivided	2784	67,312	14.1	2.61	2,323	9.40	0.09	3.451
Rural multilane divided (non-freeway)	outside urbanized area no full access control 3 lanes or more median	2039	50,135	10.5	1.55	1,936	7.83	0.06	3.862
Urban 2 lane highway	inside urbanized area no full access control 2 lanes or less	2964	34,629	7.2	2.09	2,151	8.70	0.13	6.212
others	Roads with primitive, unimproved, graded and drained, soil or gravel surface type	2032	28,616	6.0	0.80	1,193	4.83	0.04	4.169
Rural freeway	outside urbanized area full access control more than 3 lanes	687	21,251	4.4	0.61	942	3.81	0.03	4.433
Urban freeway	inside urbanized area full access control more than 3 lanes	100	3,429	0.7	0.45	163	0.66	0.02	4.754
Urban multilane divided (non-freeway)	inside urbanized area no full access control 3 lanes or more median	78	2,279	0.5	0.99	120	0.49	0.05	5.266
Urban multilane undivided (non-freeway)	inside urbanized area no full access control 3 lanes or more undivided	61	736	0.2	1.01	33	0.13	0.05	4.484
TOTAL		38,170	478,160	100		24,714	100		100

Table C.4. Road segment data: crashes for each county ranked by severity.

County	# of segments	# of KABCO Crashes	# KABCO for county/ # of KABCO all counties	# of KABCO Crashes per million vehicle miles	# of K+A Crashes	# of K+A for county/ # of K+A all counties	# of K+A Crashes per million vehicle miles	Crash severity (# of K+A crashes/ # of KABCO crashes)
Graham	69	445	0.0009	2.160	54	0.0022	0.262	0.121
Clay	108	610	0.0013	2.033	70	0.0028	0.233	0.115
Swain	92	310	0.0006	0.618	33	0.0013	0.066	0.106
Stokes	233	2121	0.0044	1.632	221	0.0089	0.170	0.104
Camden	47	451	0.0009	1.039	46	0.0019	0.106	0.102
Columbus	391	3853	0.0081	1.852	358	0.0145	0.172	0.093
Haywood	353	3537	0.0074	1.145	330	0.0133	0.107	0.093
Dare	128	1236	0.0026	0.578	114	0.0046	0.053	0.092
Alexander	843	2377	0.0050	2.850	217	0.0088	0.260	0.091
Pamlico	98	723	0.0015	1.677	65	0.0026	0.151	0.090
Richmond	427	3297	0.0069	2.023	292	0.0118	0.179	0.089
Madison	191	1187	0.0025	1.861	104	0.0042	0.163	0.088
Cherokee	232	1259	0.0026	1.533	108	0.0044	0.132	0.086
Macon	195	1439	0.0030	1.345	124	0.0050	0.116	0.086
Davie	171	2032	0.0042	1.195	175	0.0071	0.103	0.086
Chowan	107	805	0.0017	1.859	65	0.0026	0.150	0.081
Surry	597	5774	0.0121	1.669	466	0.0188	0.135	0.081
Gates	89	885	0.0018	1.867	71	0.0029	0.150	0.080
Pender	220	2722	0.0057	1.361	213	0.0086	0.107	0.078
Jones	84	1142	0.0024	1.489	87	0.0035	0.113	0.076
Chatham	331	3988	0.0083	2.045	298	0.0120	0.153	0.075
Lenior	314	4480	0.0094	1.923	337	0.0136	0.145	0.075
Perquimans	100	654	0.0014	1.580	49	0.0020	0.118	0.075
Polk	148	1048	0.0022	1.323	79	0.0032	0.100	0.075
Warren	150	1131	0.0024	1.586	84	0.0034	0.118	0.074
Transylvania	187	1425	0.0030	1.411	103	0.0042	0.102	0.072
Yadkin	253	2604	0.0054	1.447	185	0.0075	0.103	0.071
Beaufort	361	4003	0.0084	2.441	282	0.0114	0.172	0.070
Bertie	428	1891	0.0040	1.735	130	0.0053	0.119	0.069
Washington	141	943	0.0020	1.556	65	0.0026	0.107	0.069
Hyde	90	428	0.0009	1.783	29	0.0012	0.121	0.068
Stanly	325	2872	0.0060	1.587	192	0.0078	0.106	0.067
Currituck	74	1592	0.0033	1.409	106	0.0043	0.094	0.067
Rockingham	571	6507	0.0136	1.919	427	0.0173	0.126	0.066
Alleghany	194	942	0.0020	3.119	61	0.0025	0.202	0.065
Randolph	768	8473	0.0177	1.896	548	0.0222	0.123	0.065
Yancey	352	1010	0.0021	1.797	66	0.0027	0.117	0.065
Alamance	818	7833	0.0164	1.725	511	0.0207	0.113	0.065
Sampson	419	4179	0.0087	1.692	273	0.0110	0.111	0.065

Table C.4, continued. Road segment data: crashes for each county ranked by severity.

County	# of segments	# of KABCO Crashes	# KABCO for county/ # of KABCO all counties	# of KABCO Crashes per million vehicle miles	# of K+A Crashes	# of K+A for county/ # of K+A all counties	# of K+A Crashes per million vehicle miles	Crash severity (# of K+A crashes/ # of KABCO crashes)
Montgomery	323	1635	0.0034	1.434	107	0.0043	0.094	0.065
Craven	322	4291	0.0090	1.421	273	0.0110	0.090	0.064
Northampton	227	1734	0.0036	1.294	111	0.0045	0.083	0.064
Person	203	2401	0.0050	2.377	152	0.0061	0.150	0.063
Rowan	614	7529	0.0157	1.780	474	0.0192	0.112	0.063
Burke	496	5877	0.0123	1.593	368	0.0149	0.100	0.063
Hoke	165	1830	0.0038	2.143	115	0.0046	0.135	0.063
Anson	279	1951	0.0041	2.049	121	0.0049	0.127	0.062
Greene	146	1519	0.0032	2.133	93	0.0038	0.131	0.061
Lincoln	220	3441	0.0072	1.978	209	0.0084	0.120	0.061
Martin	208	2032	0.0042	1.881	123	0.0050	0.114	0.061
Hertford	188	1492	0.0031	1.860	91	0.0037	0.113	0.061
Halifax	480	4439	0.0093	1.574	269	0.0109	0.095	0.061
Wilkes	434	4586	0.0096	1.960	277	0.0112	0.118	0.060
Avery	222	1325	0.0028	1.813	80	0.0032	0.109	0.060
Jackson	205	1830	0.0038	1.245	109	0.0044	0.074	0.060
Mitchell	106	766	0.0016	1.695	45	0.0018	0.100	0.059
Bladen	259	2750	0.0057	1.846	159	0.0064	0.107	0.058
Rutherford	431	3848	0.0080	1.773	223	0.0090	0.103	0.058
Duplin	370	4654	0.0097	2.155	264	0.0107	0.122	0.057
Caldwell	448	5117	0.0107	2.225	289	0.0117	0.126	0.056
Union	475	7111	0.0149	2.003	400	0.0162	0.113	0.056
Vance	253	3232	0.0068	1.971	182	0.0074	0.111	0.056
Carteret	332	3766	0.0079	1.427	212	0.0086	0.080	0.056
Robeson	709	8399	0.0176	1.412	473	0.0191	0.079	0.056
Iredell	527	7100	0.0148	1.187	397	0.0161	0.066	0.056
Nash	531	5418	0.0113	1.160	304	0.0123	0.065	0.056
Harnett	391	6227	0.0130	2.147	345	0.0139	0.119	0.055
Edgecombe	538	4082	0.0085	2.051	223	0.0090	0.112	0.055
Scotland	404	2505	0.0052	1.898	139	0.0056	0.105	0.055
McDowell	240	3586	0.0075	1.587	199	0.0080	0.088	0.055
Moore	550	3903	0.0082	1.561	216	0.0087	0.086	0.055
Davidson	715	8286	0.0173	1.509	457	0.0185	0.083	0.055
Lee	295	4243	0.0089	2.122	225	0.0091	0.113	0.053
Cleveland	694	6812	0.0142	2.009	353	0.0143	0.104	0.052
Wayne	564	6078	0.0127	1.917	315	0.0127	0.099	0.052
Buncombe	785	11364	0.0238	1.476	586	0.0237	0.076	0.052
Orange	462	6599	0.0138	1.598	330	0.0133	0.080	0.050

Table C.4, continued. Road segment data: crashes for each county ranked by severity.

County	# of segments	# of KABCO Crashes	# KABCO for county/ # of KABCO all counties	# of KABCO Crashes per million vehicle miles	# of K+A Crashes	# of K+A for county/ # of K+A all counties	# of K+A Crashes per million vehicle miles	Crash severity (# of K+A crashes/ # of KABCO crashes)
Wilson	421	4904	0.0102	1.504	245	0.0099	0.075	0.050
Johnston	597	8109	0.0169	1.474	407	0.0165	0.074	0.050
Pasquotank	187	2207	0.0046	2.287	108	0.0044	0.112	0.049
Brunswick	269	4148	0.0087	1.401	205	0.0083	0.069	0.049
Franklin	190	3226	0.0067	2.210	156	0.0063	0.107	0.048
Henderson	384	4827	0.0101	1.801	231	0.0093	0.086	0.048
Ashe	215	1681	0.0035	2.172	78	0.0032	0.101	0.046
Durham	673	15097	0.0316	1.654	696	0.0281	0.076	0.046
Catawba	775	11056	0.0231	2.110	482	0.0195	0.092	0.044
Forsyth	917	12029	0.0251	1.094	518	0.0209	0.047	0.043
Pitt	466	8383	0.0175	2.260	347	0.0140	0.094	0.041
Onslow	329	8022	0.0168	2.204	324	0.0131	0.089	0.040
Gaston	849	10500	0.0219	1.659	420	0.0170	0.066	0.040
Tyrrell	62	407	0.0009	2.098	15	0.0006	0.077	0.037
Caswell	147	2031	0.0042	2.638	73	0.0030	0.095	0.036
Granville	305	3293	0.0069	1.470	117	0.0047	0.052	0.036
Cumberland	769	17999	0.0376	1.967	625	0.0253	0.068	0.035
Guilford	1308	22754	0.0476	1.591	796	0.0322	0.056	0.035
Wake	1601	28371	0.0593	1.405	998	0.0403	0.049	0.035
Watauga	254	3060	0.0064	2.170	103	0.0042	0.073	0.034
Cabarrus	549	8100	0.0169	1.971	278	0.0112	0.068	0.034
Mecklenberg	1057	31940	0.0668	1.805	915	0.0370	0.052	0.029
New Hanover	364	10339	0.0216	2.678	252	0.0102	0.065	0.024
TOTAL	**38198**	**478,449**	**1.0000**		**24735**	**1.0000**		**0.052**

TABLE C.5 --TWENTY COUNTIES WITH HIGHEST INJURY SEVERITY (%K+A) ON RURAL TWO-LANE ROADS

COUNTY	*PERCENT OF CRASHES THAT ARE K+A*	*K+A MILLION VEHICLE MILES*	*KABCO MILLION VEHICLE MILES*
Graham	12.36	0.26	2.12
Clay	11.74	0.23	1.99
Swain	10.60	0.09	0.89
Stokes	10.52	0.20	1.94
Columbus	10.36	0.20	1.97
Haywood	10.09	0.23	2.28
Dare	9.98	0.06	0.58
Camden	9.92	0.13	1.29
Richmond	9.27	0.23	2.51
Pamlico	8.88	0.15	1.67
Alexander	8.87	0.25	2.81
Cherokee	8.71	0.19	2.19
Pender	8.70	0.17	1.93
Lenoir	8.62	0.19	2.18
Madison	8.58	0.18	2.12
Macon	8.53	0.14	1.60
Surry	8.52	0.21	2.46
Davie	8.52	0.15	1.78
Transylvania	8.23	0.11	1.32
Gates	8.07	0.15	1.86

TABLE C.6 -- TWENTY COUNTIES WITH HIGHEST INJURY SEVERITY (%K+A) ON URBAN TWO-LANE ROADS

COUNTY	*PERCENT OF CRASHES THAT ARE K+A*	*KABCO MILLION VEHICLE MILES*	*K+A MILLION VEHICLE MILES*
Davie	15.07	1.20	0.18
Rowan	10.58	2.10	0.22
Alexander	10.19	3.86	0.39
Burke	9.83	3.84	0.38
Caldwell	8.74	2.06	0.18
Randolph	8.44	1.45	0.12
Nash	7.98	1.59	0.13
Alamance	7.57	3.16	0.24
Wayne	7.48	2.21	0.17
Edgecombe	7.24	3.09	0.22
Gaston	7.24	2.03	0.15
Chatham	7.17	2.63	0.19
Union	7.06	2.66	0.19
Buncombe	6.80	2.57	0.17
Guilford	6.55	2.56	0.17
Mecklenburg	6.54	0.96	0.06
Forsyth	6.44	1.74	0.11
Davidson	6.44	2.09	0.13
Durham	6.02	1.90	0.11
Wake	5.75	2.51	0.14

APPENDIX D: CRASH FACTOR SIGNIFICANCE TABLES

Table D.1. Crash Factor Significance Levels

(See Example 2.1 for further explanation)

Sample Size=Number of crashes having given characteristic (N)

Proportion=Number of severe crashes divided by the total number of crashes for each characteristic ((K+A)/(K+A+B+C+O))

Significance=Maximum number of standard errors for the proportion of severe crashes that fall within the difference between the proportion of severe crashes for a given characteristic and the proportion of severe crashes for the roadway system as a whole

*A crash factor is significant when the percentage of severe crashes associated with that given characteristic are at least 2 standard errors greater than the percentage of severe crashes on the roadway system as a whole

	Sample Size	Proportion
HSIS URBAN 2-LANE	34629	0.062
HSIS RURAL 2-LANE	174048	0.059
HSIS OTHER	269773	0.039
NON-HSIS URBAN	544878	0.029
NON-HSIS RURAL	107165	0.061
HSIS	478450	0.052

HSIS Analysis	Urban 2-lane highway			Rural 2-lane highway			All other HSIS roads		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.062			0.059			0.039	
ROAD CHARACTERISTIC									
Straight, level	16568	0.050	0	153779	0.048	0	118766	0.036	0
Straight, hillcrest	1462	0.071	0	9895	0.056	0	6661	0.037	0
Straight, grade	6653	0.053	0	42039	0.054	0	30769	0.039	0
Striaght, bottom	731	0.045	0	4191	0.061	0	2292	0.050	0
Curved, level	4316	0.099	4	30933	0.091	5	6408	0.055	2
Curved, hillcrest	428	0.101	1	2614	0.076	1	1168	0.049	0
Curved, grade	4092	0.085	2	23937	0.088	5	7014	0.058	2
Curved, bottom	340	0.071	0	1895	0.092	2	539	0.056	0
		0.062			0.059			0.039	
ROAD FEATURE									
Bridge	504	0.075	0	3573	0.101	4	4658	0.044	0
Underpass	18	0.000	0	241	0.058	0	993	0.082	2
Public driveway	1547	0.041	0	12672	0.042	0	6876	0.034	0
Private driveway	2531	0.054	0	16186	0.061	0	1371	0.042	0
Alley intersection	19	0.053	0	273	0.029	0	197	0.015	0
Intersection of roadway	10320	0.061	0	79308	0.056	0	49331	0.043	1
Median crossing	22	0.046	0	303	0.043	0	1587	0.052	1
Begin/End divided hwy.	27	0.074	0	277	0.065	0	629	0.043	0
Interchange ramp	111	0.018	0	785	0.036	0	7932	0.028	0
Interchange service road	3	0.000	0	79	0.038	0	282	0.039	0
Railroad crossing	90	0.111	0	713	0.067	0	382	0.042	0

Table D.2. Significance level reference table

K standard error upper bounds for proportions as a function of sample size N

N	K 1	2	3	4	5
100	0.0500	0.1000	0.1500	0.2000	0.2500
150	0.0408	0.0816	0.1225	0.1633	0.2041
200	0.0354	0.0707	0.1061	0.1414	0.1768
250	0.0316	0.0632	0.0949	0.1265	0.1581
300	0.0289	0.0577	0.0866	0.1155	0.1443
400	0.0250	0.0500	0.0750	0.1000	0.1250
500	0.0224	0.0447	0.0671	0.0894	0.1118
750	0.0183	0.0365	0.0548	0.0730	0.0913
1000	0.0158	0.0316	0.0474	0.0632	0.0791
1250	0.0141	0.0283	0.0424	0.0566	0.0707
1500	0.0129	0.0258	0.0387	0.0516	0.0645
2000	0.0112	0.0224	0.0335	0.0447	0.0559
3000	0.0091	0.0183	0.0274	0.0365	0.0456
4000	0.0079	0.0158	0.0237	0.0316	0.0395
5000	0.0071	0.0141	0.0212	0.0283	0.0354
7500	0.0058	0.0115	0.0173	0.0231	0.0289
10000	0.0050	0.0100	0.0150	0.0200	0.0250
20000	0.0035	0.0071	0.0106	0.0141	0.0177
30000	0.0029	0.0058	0.0087	0.0115	0.0144
50000	0.0022	0.0045	0.0067	0.0089	0.0112
100000	0.0016	0.0032	0.0047	0.0063	0.0079
200000	0.0011	0.0022	0.0034	0.0045	0.0056
300000	0.0009	0.0018	0.0027	0.0037	0.0046

APPENDIX E: HSIS AND NON-HSIS SAMPLE SIZE TABLES

HSIS Analysis	Urban 2-lane highway			Rural 2-lane highway			All other HSIS roads		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.062			0.059			0.039	
ROAD CONFIGURATION									
Undivided, one-way	109	0.064	0	3645	0.030	0	7038	0.025	0
Undivided, two-way	33617	0.063	0	249955	0.060	0	75454	0.035	0
Divided	876	0.039	0	15713	0.059	0	91016	0.043	0
ROAD DEFECT									
Loose material	264	0.049	0	2185	0.053	0	1620	0.046	0
Holes, deep ruts	48	0.083	0	347	0.035	0	293	0.041	0
Low shoulders	212	0.076	0	1085	0.096	2	273	0.059	0
Soft shoulders	196	0.071	0	1086	0.065	0	313	0.067	1
Repairs, defects	64	0.063	0	641	0.050	0	915	0.023	0
Under construction	346	0.043	0	3180	0.054	0	5920	0.033	0
Other defects	62	0.032	0	472	0.064	0	314	0.051	0
No defects	33420	0.062	0	260428	0.059	0	163893	0.039	0
ROAD SURFACE CONDITION									
Dry	25393	0.067	1	202842	0.062	3	128271	0.041	1
Wet	7498	0.054	0	56169	0.049	0	38914	0.032	0
Muddy	23	0.087	0	230	0.034	0	146	0.069	0
Snowy	316	0.044	0	2501	0.032	0	1376	0.027	0
Icy	1348	0.038	0	7377	0.040	0	4744	0.032	0
Other	17	0.177	0	169	0.083	0	120	0.058	0
ROAD SURFACE									
Concrete	219	0.078	0	1364	0.035	0	17130	0.048	1
Grooved concrete	167	0.072	0	1415	0.060	0	2795	0.045	0
Smooth asphalt	26134	0.064	0	201408	0.059	0	114213	0.038	0
Coarse asphalt	7864	0.055	0	63429	0.058	0	37395	0.036	0
Gravel	64	0.063	0	451	0.049	0	761	0.041	0
Sand	5	0.000	0	91	0.000	0	105	0.029	0
Soil	123	0.033	0	1032	0.050	0	982	0.043	0
Other	27	0.037	0	165	0.073	0	182	0.028	0

HSIS Analysis	Urban 2-lane highway			Rural 2-lane highway			All other HSIS roads		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.062			0.059			0.039	
TRAFFIC CONTROL									
No traffic signal	34262	0.062	0	264476	0.059	0	165525	0.038	0
Traffic signal	367	0.087	0	5297	0.059	0	8523	0.062	3
ACCIDENT TYPE									
ROR, hit fixed object	5289	0.097	4	30087	0.101	5	17633	0.064	5
ROR, rollover	141	0.135	1	1102	0.122	4	821	0.091	2
ROR, other	6567	0.070	1	46840	0.079	5	9720	0.082	5
Head-on	457	0.359	5	3061	0.368	5	844	0.224	5
Rear-end/sideswipe	8136	0.022	0	70013	0.023	0	74501	0.016	0
Angle/turn	9178	0.068	1	77682	0.058	0	56783	0.043	1
Pedestrian/bicycle	386	0.329	5	3665	0.345	5	2132	0.330	5
Animal	3342	0.005	0	26666	0.004	0	4532	0.004	0
Park/brake	396	0.018	0	4236	0.015	0	1627	0.011	0
Train	22	0.318	0	149	0.095	0	39	0.000	0
Other	715	0.048	0	6272	0.045	0	5416	0.029	0
MEANS OF INVOLVEMENT									
Ran-off-road	11039	0.081	3	71722	0.088	5	23397	0.072	5
Hit fixed object	175	0.046	0	1671	0.051	0	2109	0.028	0
Hit non-fixed object	540	0.072	0	4232	0.069	1	3867	0.039	0
Car vs. car	8263	0.046	0	74384	0.040	0	65188	0.025	0
Car vs. truck, bus	7010	0.056	0	56212	0.049	0	44983	0.028	0
2+ vehicles involved	1572	0.088	2	13836	0.075	3	15243	0.048	1
Other 1,2 vehicle acciden	6030	0.051	0	47716	0.051	0	19261	0.062	4
RAN-OFF-ROAD, OBJECT STRUCK*		*0.097*			*0.101*			*0.064*	
Parked vehicle	123	0.041	0	890	0.045	0	488	0.103	1
Tree	2497	0.126	2	13224	0.135	5	3228	0.084	2
Utility pole	812	0.108	0	5161	0.099	0	1534	0.085	1
Traffic island	21	0.143	0	323	0.065	0	818	0.070	0
Mailbox	470	0.055	0	2163	0.051	0	132	0.068	0
Fence/fence post	549	0.040	0	2739	0.045	0	431	0.033	0
Other	817	0.065	0	5587	0.079	0	11002	0.055	0

HSIS Analysis	Urban 2-lane highway			Rural 2-lane highway			All other HSIS roads		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.062			0.059			0.039	
NUMBER OF VEHICLES									
1	14759	0.064	0	101966	0.065	3	31328	0.055	5
2	18298	0.058	0	153971	0.053	0	127477	0.034	0
3	1572	0.088	2	13836	0.075	3	15243	0.048	1
BICYCLE AND PEDESTRIAN									
No bicycle involved	34473	0.061	0	268578	0.058	0	173432	0.038	0
Bicycle involved	156	0.212	3	1195	0.240	5	616	0.175	5
No pedestrian involved	34443	0.060	0	267714	0.056	0	172784	0.036	0
Pedestrian involved	186	0.468	5	2059	0.439	5	1264	0.431	5
VEHICLE TYPE*		*0.073*			*0.072*			*0.048*	
Pedestrian	354	0.469	5	4003	0.440	5	2418	0.431	5
Bicycle	293	0.218	4	2185	0.243	5	1131	0.177	5
Bus	291	0.065	0	1927	0.042	0	1107	0.040	0
Small truck	26408	0.059	0	194185	0.058	0	108586	0.036	0
Large truck	1526	0.083	1	16459	0.087	3	21262	0.055	1
Car	8024	0.055	0	59588	0.053	0	42778	0.037	0
Motorcycle	1181	0.336	5	7320	0.303	5	2774	0.247	5
Other	262	0.099	1	3026	0.074	0	1839	0.052	1
ALCOHOL INVOLVEMENT									
No drink or drug	31965	0.053	0	251470	0.050	0	167033	0.034	0
Intoxicated	2664	0.176	5	18303	0.184	5	7015	0.146	5
LIGHTING CONDITION									
Daylight	22055	0.055	0	177272	0.054	0	125903	0.033	0
Dusk	864	0.074	0	6616	0.059	0	4687	0.031	0
Dawn	746	0.072	0	5545	0.057	0	2718	0.047	0
Dark, street lit	667	0.060	0	12428	0.057	0	19208	0.047	1
Dark, not lit	10269	0.076	2	67476	0.071	5	21115	0.063	5

HSIS Analysis	Urban 2-lane highway			Rural 2-lane highway			All other HSIS roads		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.062			0.059			0.039	
WEEKDAY									
Monday	4915	0.054	0	38459	0.052	0	25574	0.037	0
Tuesday	4786	0.060	0	36977	0.053	0	24335	0.037	0
Wednesday	4927	0.052	0	37718	0.055	0	25299	0.036	0
Thursday	5133	0.058	0	39173	0.053	0	25819	0.034	0
Friday	5823	0.067	0	48082	0.054	0	34049	0.036	0
Saturday	5142	0.070	1	39523	0.070	3	23016	0.045	1
Sunday	3903	0.076	1	29841	0.079	5	15956	0.052	2
WEATHER									
Clear	22083	0.066	1	174899	0.062	1	109844	0.041	1
Cloudy	5687	0.061	0	43397	0.060	0	27336	0.038	0
Raining	5577	0.051	0	41946	0.048	0	31877	0.032	0
Snowing	420	0.043	0	3301	0.033	0	2117	0.033	0
Fog, smog, smoke, dust	598	0.062	0	4361	0.062	0	1175	0.054	0
Sleet, hail	229	0.022	0	1329	0.041	0	1213	0.027	0

Non-HSIS Analysis	Urban			Rural			HSIS		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.029			0.061			0.052	
ROAD CHARACTERISTIC									
Straight, level	372419	0.026	0	49321	0.047	0	289113	0.043	0
Straight, hillcrest	23965	0.031	0	2881	0.053	0	18018	0.050	0
Straight, grade	89547	0.029	0	14615	0.056	0	79461	0.048	0
Striaght, bottom	7531	0.041	2	1679	0.061	0	7214	0.056	0
Curved, level	24318	0.055	5	19298	0.086	5	41657	0.086	5
Curved, hillcrest	5361	0.051	3	1588	0.087	2	4210	0.071	2
Curved, grade	18175	0.055	5	16258	0.074	2	35043	0.082	5
Curved, bottom	1797	0.064	2	1342	0.092	2	2774	0.082	2
ROAD FEATURE									
Bridge	3799	0.038	0	2349	0.087	2	8735	0.069	2
Underpass	1120	0.042	0	160	0.100	0	1252	0.076	1
Public driveway	58857	0.014	0	4316	0.029	0	21095	0.039	0
Private driveway	16268	0.027	0	6329	0.064	0	20088	0.059	1
Alley intersection	1122	0.027	0	65	0.031	0	489	0.025	0
Intersection of roadway	168636	0.037	5	14621	0.064	0	138959	0.052	0
Median crossing	2407	0.040	0	218	0.046	0	1912	0.051	0
Begin/End divided hwy.	856	0.035	0	133	0.038	0	933	0.050	0
Interchange ramp	5198	0.022	0	1125	0.044	0	8828	0.028	0
Interchange service road	371	0.040	0	60	0.050	0	364	0.039	0
Railroad crossing	1730	0.054	1	354	0.096	1	1185	0.062	0
ROAD CONFIGURATION									
Undivided, one-way	30973	0.019	0	1818	0.040	0	10792	0.027	0
Undivided, two-way	399897	0.030	1	91832	0.062	0	359026	0.055	3
Divided	105684	0.031	1	12981	0.054	0	107605	0.043	0
ROAD DEFECT									
Loose material	6488	0.025	0	2290	0.045	0	4069	0.050	0
Holes, deep ruts	1559	0.029	0	466	0.054	0	688	0.041	0
Low shoulders	1014	0.040	0	514	0.113	2	1570	0.087	1
Soft shoulders	769	0.046	0	789	0.051	0	1595	0.067	1
Repairs, defects	1639	0.031	0	274	0.044	0	1620	0.035	0
Under construction	7695	0.031	0	1838	0.040	0	9446	0.041	0
Other defects	863	0.032	0	354	0.037	0	848	0.057	0
No defects	523680	0.029	0	100545	0.062	0	457741	0.052	0

Non-HSIS Analysis	Urban			Rural			HSIS		
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.029			0.061			0.052	
ROAD SURFACE CONDITION									
Dry	428071	0.030	1	80107	0.065	1	356506	0.055	3
Wet	102563	0.026	0	20831	0.052	0	102581	0.043	0
Muddy	675	0.021	0	392	0.043	0	399	0.048	0
Snowy	2785	0.020	0	1177	0.024	0	4193	0.032	0
Icy	8053	0.021	0	4414	0.032	0	13469	0.037	0
Other	643	0.036	0	105	0.067	0	306	0.078	0
ROAD SURFACE									
Concrete	13900	0.022	0	2429	0.058	0	18713	0.048	0
Grooved concrete	4426	0.026	0	817	0.045	0	4377	0.051	0
Smooth asphalt	372699	0.030	1	63120	0.062	0	341755	0.053	1
Coarse asphalt	142684	0.030	0	30880	0.065	1	108688	0.050	0
Gravel	4502	0.019	0	6926	0.040	0	1276	0.045	0
Sand	658	0.023	0	1198	0.048	0	201	0.015	0
Soil	3470	0.026	0	1531	0.047	0	2137	0.046	0
Other	874	0.030	0	182	0.033	0	374	0.048	0
TRAFFIC CONTROL									
No traffic signal	443663	0.030	1	104866	0.061	0	464263	0.051	0
Traffic signal	98455	0.028	0	2143	0.039	0	14187	0.061	1
ACCIDENT TYPE									
ROR, hit fixed object	3526	0.048	2	980	0.060	0	53009	0.088	5
ROR, rollover	367	0.071	1	57	0.070	0	2064	0.110	5
ROR, other	2817	0.050	1	1599	0.111	3	63127	0.078	5
Head-on	3744	0.157	5	1805	0.197	5	4362	0.339	5
Rear-end/sideswipe	153889	0.014	0	16169	0.030	0	152650	0.020	0
Angle/turn	200093	0.031	1	16206	0.061	0	143643	0.053	0
Pedestrian/bicycle	12677	0.222	5	1463	0.340	5	6183	0.339	5
Animal	312	0.035	0	85	0.035	0	34540	0.004	0
Park/brake	61452	0.001	0	4102	0.005	0	6259	0.014	0
Train	54	0.074	0	8	0.126	0	210	0.171	3
Other	42427	0.006	0	2609	0.018	0	12403	0.038	0

Non-HSIS Analysis		**Urban**			**Rural**			**HSIS**	
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.029			0.061			0.052	
MEANS OF INVOLVEMENT									
Ran-off-road	42073	0.069	5	44869	0.080	5	106158	0.084	5
Hit fixed object	12651	0.021	0	1404	0.033	0	3955	0.039	0
Hit non-fixed object	4043	0.078	5	2198	0.086	2	8639	0.055	0
Car vs. car	237809	0.018	0	16719	0.040	0	147835	0.034	0
Car vs. truck, bus	136716	0.019	0	15623	0.045	0	108205	0.041	0
Truck vs. truck	16746	0.031	0	3735	0.043	0			
2+ vehicles involved	43199	0.079	5	4408	0.101	5	30651	0.062	3
Other 1,2 vehicle acciden	44632	0.082	5	17351	0.040	0	73007	0.054	0
RAN-OFF-ROAD, OBJECT STRUCK*		*0.048*			*0.060*			*0.088*	
Parked vehicle	1938	0.035	0	503	0.048	0	1501	0.063	0
Tree	221	0.077	0	99	0.141	0	18949	0.125	5
Utility pole	362	0.102	1	50	0.040	0	7507	0.097	1
Traffic island	202	0.045	0	15	0.000	0	1162	0.070	0
Mailbox	115	0.087	0	46	0.065	0	2765	0.052	0
Fence/fence post	129	0.047	0	45	0.044	0	3719	0.043	0
Other	559	0.056	0	222	0.063	0	17406	0.063	0
NUMBER OF VEHICLES									
1	63521	0.055	5	62082	0.063	0			
2	437281	0.023	0	40537	0.045	0			
3 or more	44076	0.050	5	4546	0.062	0			
BICYCLE AND PEDESTRIAN									
No bicycle involved	540820	0.028	0	106714	0.060	0	476483	0.051	0
Bicycle involved	4058	0.166	5	451	0.275	5	1967	0.218	5
No pedestrian involved	537025	0.026	0	106243	0.058	0	474941	0.049	0
Pedestrian involved	7853	0.261	5	922	0.371	5	3509	0.437	5

Non-HSIS Analysis		**Urban**			**Rural**			**HSIS**	
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance
OVERALL		0.029			0.061			0.052	
VEHICLE TYPE*		*0.018*			*0.048*			*0.063*	
Pedestrian	7986	0.255	5	892	0.357	5	6775	0.438	5
Bicycle	4049	0.166	5	450	0.276	5	3609	0.220	5
Bus	3968	0.005	0	682	0.004	0	3225	0.043	0
Small truck	196692	0.012	0	40021	0.038	0	329179	0.051	0
Large truck	14275	0.004	0	3628	0.019	0	39247	0.070	2
Car	712514	0.016	0	97765	0.044	0	110390	0.047	0
Motorcycle	4856	0.221	5	1662	0.330	5	11275	0.293	5
Other	3852	0.018	0	821	0.055	0	5127	0.067	0
ALCOHOL INVOLVEMENT									
No drink or drug	522613	0.026	0	97740	0.049	0	450468	0.044	0
Intoxicated	22265	0.112	5	9425	0.186	5	27982	0.174	5
LIGHTING CONDITION									
Daylight	407278	0.026	0	60906	0.059	0	325230	0.046	0
Dusk	15466	0.029	0	2700	0.074	1	12167	0.049	0
Dawn	5828	0.034	1	2486	0.047	0	9009	0.055	0
Dark, street lit	89020	0.036	3	2971	0.035	0	32303	0.051	0
Dark, not lit	25226	0.060	5	37976	0.065	1	98860	0.070	5
WEEKDAY									
Monday	81729	0.027	0	14666	0.056	0	68948	0.047	0
Tuesday	79410	0.027	0	14064	0.056	0	66098	0.048	0
Wednesday	80515	0.027	0	14467	0.053	0	67944	0.048	0
Thursday	82650	0.028	0	14859	0.056	0	70125	0.047	0
Friday	102166	0.028	0	17829	0.059	0	87954	0.048	0
Saturday	71073	0.034	3	17021	0.073	2	67681	0.062	4
Sunday	47335	0.039	3	14259	0.071	2	49700	0.070	5

Non-HSIS Analysis	Urban			Rural			HSIS			
	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	Sample Size	Proportion	Significance	
OVERALL		0.029			0.061			0.052		
WEATHER										
Clear	366692	0.030	1	70395	0.064	1	306826	0.055	4	
Cloudy	90963	0.028	0	17492	0.060	0	76420	0.052	0	
Raining	77106	0.026	0	14944	0.050	0	79400	0.041	0	
Snowing	3762	0.024	0	1466	0.027	0	5838	0.034	0	
Fog, smog, smoke, dust	2380	0.041	1	2076	0.058	0	6134	0.061	1	
Sleet, hail	1769	0.022	0	653	0.031	0	2771	0.004	0	

*Data set used for variable is different from roadway system crash files used for other variables. Percent of crashes that are K+A for the data set is given in parentheses.