2007-07-13

A Safety Analysis of Fatigue and Drowsy Driving in the State of Utah

Hunter T. Young
Brigham Young University - Provo

BYU ScholarsArchive Citation

Young, Hunter T., "A Safety Analysis of Fatigue and Drowsy Driving in the State of Utah" (2007). *All Theses and Dissertations*. 1161.
https://scholarsarchive.byu.edu/etd/1161

A SAFETY ANALYSIS OF FATIGUE AND DROWSY DRIVING IN THE STATE OF UTAH

by

Hunter T. Young

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Civil and Environmental Engineering
Brigham Young University
August 2007

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Hunter T. Young

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Grant Schultz, Chair
Date	Mitsuru Saito
Date	Dennis Eggett

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Hunter T. Young in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date

Grant G. Schultz
Chair, Graduate Committee

Accepted for the Department

E. James Nelson
Graduate Coordinator

Accepted for the College

Alan R. Parkinson
Dean, Ira A. Fulton
College of Engineering and Technology

ABSTRACT

A SAFETY ANALYSIS OF FATIGUE AND DROWSY DRIVING IN THE STATE OF UTAH

Hunter T. Young

Department of Civil and Environmental Engineering

Master of Science

Fatigue and drowsy driving in the state of Utah has been a causal factor in thousands of crashes over the years and poses a serious threat to public safety. Consequently, the purpose of this research was to evaluate the impact of drowsy driving in the state, to identify locations where fatigue and drowsy driving may be contributing factors to current crashes, and to identify methods to help mitigate these crashes.

A 3-year drowsy driving crash rate spanning the years 2002 – 2004 was used to determine which segments of Utah highway are most prone to drowsy driving crashes. Drowsy driving corridors were located on Interstates 15, 70, 80, and 84 as well as United States Routes 89 and 91. Furthermore, State Route 36 also had two drowsy driving corridors. In order to recommend appropriate drowsy driving countermeasures for the drowsy driving corridors, a review of the existing countermeasures was conducted. The existing countermeasures included cable median barrier, rumble strips, rest areas, and drowsy driving freeway signage. The freeway signage is used to alert drivers of the adverse effects of drowsy driving and was the basis for a before-after study as well as a public survey of drowsy driving along Interstate 80 west of Salt Lake City.

The before-after study of the drowsy driving freeway signage concluded that the freeway signage has played a part in reducing the number of crashes by as much as 63 percent in the eastbound direction and by as much as 22 percent in the westbound direction. As indicated, a public survey was conducted at two rest areas to supplement the findings of the before-after analysis. Using the 405 completed surveys, 14 Chi-Square tests were conducted with five of the test yielding statistically significant results.

Finally, recommendations were made for the 41 drowsy driving corridors resulting from the 3-year crash rate analysis. Drowsy driving countermeasures recommended include: additional shoulder and centerline rumble strips, cable median barrier, guardrail replacement, and drowsy driving highway signage. Drowsy driving countermeasures not yet implemented but which should be considered by the Utah Department of Transportation are transverse rumble strips, wider longitudinal pavement markings, in-lane pavement markings indicating “AVOID FATIGUE DRIVING,” minimizing edge drop off, flattening slopes in clear zones, and adding a modified rest area.

ACKNOWLEDGMENTS

The author would like to acknowledge the role of Dr. Grant G. Schultz in the completion of this thesis. His contributions, time, and feedback have proven very valuable and are greatly appreciated. Additionally, a special thanks to Douglas Anderson, UDOT Research and Development for his assistance with this work. The author wishes to thank everyone else at UDOT who had a part with this research. To Dr. Saito and Dr. Eggett, thank you for serving on the committee. The author also appreciates the time offered by the Center for Statistical Consultation and Collaborative Research in providing valuable help and background related to the statistical analyses conducted in this research.

Finally, the author would like to thank his loving wife, Rosa, for providing the support and encouragement needed to complete this thesis. She has been an inspiration throughout the course of this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The purpose of this thesis is to present the results of research conducted to assess fatigue and drowsy driving on Interstate freeways and state highways in the state of Utah. The study was part of a research project initiated in September 2006 by the Utah Department of Transportation (UDOT) and conducted by researchers at Brigham Young University (BYU). To understand the nature of drowsy driving in the state of Utah, this chapter is divided into four sections including a problem statement section, a background section, an objectives section, and a thesis organization section.

1.1 Problem Statement

A number of research projects have been performed to assess the fundamental causes of fatigue and drowsy driving. Typical results yield that approximately 1,500 fatalities each year can be attributed to falling asleep at the wheel or driving while severely fatigued in the United States (U.S.) (Knipling and Wang 1994). In Western Australia, driver fatigue is considered a factor in one in five fatal crashes (Main Roads 2007a). Other research indicates that almost 20 percent of all serious car crash injuries are associated with driver sleepiness, independent of alcohol effects (Connor et al. 2002). Due to the seriousness of fatigue and drowsy driving in the state of Utah, it was imperative that a study be conducted to evaluate the impact of fatigue and drowsy driving in the state.

To complete the assessment of fatigue and drowsy driving in the state of Utah, the UDOT crash database, a tool that has been proven extremely useful through previously conducted research studies, was utilized. The crash database permits researchers the ability to create filters, which can then be used to examine crash data. The filters allow users to retrieve crash data characteristics, identify high crash locations, and establish crash trends. This information can then be incorporated into a study to evaluate the character traits of the roadways in which these conditions occur, leading to the development of hypotheses on the possible reasons for such conditions. This information is very useful in establishing relationships between geometric and/or traffic conditions and overall safety levels.

1.2 Background

In recent years the United States Department of Transportation (USDOT) has placed a greater emphasis on reducing fatigue and drowsy driving. According to research conducted by the United States National Highway Traffic Safety Administration (NHTSA), drowsiness or fatigue has been indicated as a primary factor in 3.6 percent of fatal crashes (Knipling and Wang 1994). In the state of Utah, preliminary research shows that at least 10 percent of all fatal crashes are caused by either fatigue or drowsy driving according to current crash report statistics. Furthermore, research indicates that 2.9 percent of all crashes in Utah are directly related to drowsy drivers.

In contrast to alcohol related crashes, no blood, breathalyzer, or other objective test can be performed at the scene of a crash to determine if the cause of a crash was fatigue or drowsy driving. With no specific test to determine the level of drowsiness at the scene of a crash, police officers have difficulty identifying driver fatigue as a contributing cause to a crash; hence fatigue-related crashes are likely under-reported and may be contributing to significantly more crashes than statistics indicate.

While most people are aware of the dangers of drinking and driving, many fail to recognize that driving while extremely fatigued can be just as dangerous and deadly. Research indicates that fatigue appears to be second only to alcohol as the most common cause of serious injury in vehicle crashes (Mitler 1989). Similar to drivers who are under the influence of alcohol, drowsy drivers have a slower reaction time, decreased awareness of their environment, and lack of judgment in their actions. In 2004, the American Automobile Association (AAA) Foundation surveyed U.S. and Canadian police officers.

Of those surveyed, 88 percent had stopped a driver who they believed was under the influence of alcohol, but turned out to be drowsy (AAA 2004).

UDOT has recognized the seriousness of fatigue and drowsy driving and has taken a number of countermeasures to reduce fatigue-related crashes. One of the primary measures was the creation and installation of fatigue warning signs at several locations on Interstate 80 (I-80) between Wendover and Salt Lake City in mid 2004 as well as a more recent installation on eastbound Interstate 70 (I-70) approximately 50 miles west of Green River. The 2005 crash data on I-80 has tended toward a reduction in crash numbers related to drowsy driving, presumably as a result of the installation of the fatigue warning signs. In addition to the creation and installation of the fatigue warning signs, a task force comprised of the Utah Highway Patrol (UHP), UDOT, Utah Highway Safety Office, and a private consulting firm was formed in 2005 to promote awareness of drowsy driving through various media avenues. One of the primary accomplishments of the task was a media and education campaign that was carried out through radio public service announcements, television commercials, internet sources, and through displays at public events to help educate the public on the safety aspects of drowsy driving.

1.3 Objective

Due to the seriousness of fatigue and drowsy driving in the state of Utah, the need exists to evaluate the impact of fatigue and drowsy driving in the state, to identify locations where fatigue and drowsy driving may be contributing factors to current crashes, to identify methods to help mitigate these crashes, and to determine the effectiveness of the drowsy driving freeway signage on I-80. The purpose of this research, therefore, is to develop a strategy to mitigate fatigue-related crashes statewide and determine the role that the drowsy driving freeway signage plays in reducing drowsy driving crashes. The first step in this process is to identify high crash locations where fatigue and drowsy driving may be the significant causal factors. The next step in the process is to evaluate the effectiveness of current mitigation measures utilized by UDOT specifically the Interstate drowsy driving warning signs. The third step is to propose and evaluate possible engineering solutions to mitigate the concerns at the identified locations. These solutions may include additional highway signage, rumble strips, rest stops, and others. Finally recommendations will be provided for mitigation measures at the identified locations.

The results of this project will provide direction and guidance to UDOT on the identification and prioritization of corridors in which driver fatigue is a potential causal factor for crashes. Fatigue and drowsy driving is one of the primary focus areas of the “ZERO Fatalities” initiative currently underway in the state. UDOT will benefit from this research by implementing engineering mitigation measures at high crash locations identified to reduce crashes caused by fatigue and drowsy driving. The documented results will also be useful in aiding UDOT in understanding how to best apply the signage and education efforts for fatigue and drowsy driving in the future.

1.4 Thesis Organization

This thesis is organized into the following eight chapters: 1) Introduction; 2) Literature Review; 3) Analysis Procedure; 4) Results; 5) Existing Countermeasures; 6) Public Survey: Drowsy Driving; 7) Evaluation of Candidate Sites; and 8) Conclusions. A reference section and an Appendix follow the indicated chapters.

Chapter 2 is a literature review that outlines and defines the root causes of fatigue and drowsy driving and quantifies how rampant this problem is among drivers across the country. The countermeasures currently in use to combat drowsy driving are discussed followed by the background of the UDOT crash database.

Chapter 3 documents the steps followed during the analyses using the UDOT crash database. The procedure followed in using the crash database is outlined in sufficient detail so that correct data may be extracted for similar future analyses. Background on two before-after crash rate analyses on I-80 is also provided.

Chapter 4 presents the results of the analyses including tables and figures to aid in the presentation of the results. The chapter contains crash data for the highway corridors prone to have drowsy driving crashes based upon corridors found to have crash rates in excess of a critical crash rate. Drowsy driving statistics pertinent to each highway are identified. Examples of these statistics include the time of day and day of the week of drowsy driving crashes. Also identified are the vehicle type, severity, and result of drowsy driving crashes.

Chapter 5 summarizes the current countermeasures implemented by UDOT to reduce the number of drowsy driving crashes. These countermeasures include drowsy driving freeway signage, rumble strips, and cable median barrier. Also, the results of two before-after crash rate analyses are presented.

Chapter 6 outlines the results of a drowsy driving public survey conducted at two rest areas on I-80 west of Salt Lake City. The results of 14 Chi-Square analyses are provided in which correlations among gender and age were determined.

Chapter 7 identifies the recommended drowsy driving countermeasures for the critical corridors determined in Chapter 4.

Chapter 8 provides conclusions of the research. The chapter also recommends future research possibilities related to the effectiveness of yet to be installed countermeasures.

The Appendix includes the results of two corridor analyses spanning three, five, and 13 years as well as statistical analysis data from before-after studies discussed in Chapter 5. Also included in the Appendix are the results of the Chi-square tests performed using the public survey results.

2 LITERATURE REVIEW

A comprehensive literature review has been performed on aspects related to the causes and mitigation techniques of fatigue and drowsy driving. This process consisted of assembling applicable information that could contribute to this study. The literature review covers several different topics. First, the common causes of drowsy driving are outlined including high-risk drowsy driving groups. High-risk groups identified include drivers with sleep disorders, young adults, and shiftworkers. Second, general characteristics of drowsy driving crashes are summarized using case studies. Characteristics discussed include time of day, age of driver, severity, speed, location, number of vehicles, and result of drowsy driving crashes. Third, a review of countermeasures and their effectiveness as implemented in other states and countries is performed. Countermeasures discussed to reduce drowsy driving crashes include rumble strips, cable median barrier, rest areas, physical stimuli, educational programs, and in-car countermeasures. Fourth, the background on crash database tools as useful resources for fatigue and drowsy driving analysis is given.

2.1 Common Causes of Drowsy Driving

Drowsy or fatigue driving is a concept generally understood by the public and yet difficult to narrowly define. Fatigue is defined as a “disinclination to continue performing the task at hand” (Brown 1994, pp. 298). Furthermore, fatigue refers to the reluctance to continue a task as a result of physical or mental exertion or a prolonged period of performing the same task. Sleepiness, also referred to as drowsiness, is defined as the urge to fall asleep (Beirness et al. 2005). Although the two terms have distinct meanings, they are used interchangeably throughout the literature since the difference is somewhat negligible.

Drivers may succumb to sleep for many reasons, but as noted in *Principles and Practice of Sleep Medicine*, “Heavy meals, warm rooms, boring lectures, and the monotony of long-distance automobile driving unmask the presence of physiological sleepiness, but do not cause it” (Roehrs et al. 2000, pp. 44). Drivers with sleep disorders, who use alcohol or medication, who are young, and who work odd shift hours fall into the high-risk category for sleep-related crashes. Related to young people, law enforcement officers and young military personnel are also part of the high-risk population (Stutts et al. 2005).

The following subsections discuss drivers who are at a high-risk for drowsy driving crashes due human factors or lifestyle. Other factors which contribute to sleep-related crashes are also outlined including the time on task at hand and circadian rhythm.

2.1.1 Sleep and Sleep Disorders

The National Sleep Foundation (NSF) indicates that adults should sleep seven to nine hours every night (NSF 2007). In a poll conducted by the NSF it was reported that 16 percent of American adults sleep six or fewer hours per night on weekdays, while 71 percent sleep less than the recommended eight hours (NSF 2005). For many people, sleeping seven to nine hours does not occur due to the need to allow more time for work, family obligations, or social events. One of the most common reasons behind drowsy driving crashes is sleeping less than five hours (Connor et al. 2002). Stutts et al. (2003) indicates that those who sleep between six and seven hours are 2.6 times more likely to be involved in a drowsy driving crash than someone who sleeps eight hours while those who sleep less than four hours are almost 20 times more likely to be in a fatigue-related crash. With such a small percentage of the population able to sleep as much as recommended, it is evident why thousands are involved each year in automobile crashes stemming from fatigue or drowsy driving.

Besides the 71 percent who sleep less than eight hours each night, millions of Americans suffer from sleep disorders. The National Heart, Lung, and Blood Institute

(NHLBI) estimated in 2003 that 50 to 70 million Americans suffer from a chronic disorder of sleep and wakefulness (NHLBI 2003). This may be in the form of chronic insomnia, restless legs syndrome, and sleep apnea (Colten and Altevogt 2006). Two of the most prominent sleep disorders are sleep apnea and narcolepsy. Sleep apnea is a condition in which a person stops breathing during sleep as the throat muscles relax and collapse thus blocking the intake of air. Persons with this disorder must constantly arouse to resume breathing (Stutts et al.1999). The marker of sleep apnea is snoring, which occurs when the airway is narrow. This is one side of the spectrum while not breathing at all is the other end (Sagberg et al. 2004). Although sleep apnea appears in all age groups of both men and women, men are 2.0 to 3.7 times as likely as women to have a sleep disorder such as sleep apnea. Sleep apnea occurs in about 4 percent of middle-aged males and 2 percent of middle-aged females (Young et al. 1993). Untreated sleep apnea patients are three to four times more likely to have automobile crashes (NSF 2006; Teran-Santos et al. 1999). In one survey, driving was reported as a sleep-inducing situation by 50 percent of sleep apnea patients (Roehrs et al. 2000).

Although less common than sleep apnea, narcolepsy is equally serious and just as potentially dangerous for automobile drivers. Narcolepsy is a neurological disorder in which the brain fails to regulate sleep-wake cycles correctly thus causing a person to fall asleep without warning. Narcolepsy affects both sexes equally at any age, but symptoms typically surface first in young adulthood (Mignot 2005). The prevalence of narcolepsy has been documented in multiple population-based studies and occurs in 0.02 to 0.05 percent of the population of Western Europe and North America (Mignot 1998).

2.1.2 Alcohol and Medication

In the United States, alcohol-induced impairment is the single greatest contributing factor in fatal car crashes (CSA 1986). Although this may be true regarding all types of crashes, one study indicated that only 2 percent of drivers who nod off at the wheel reported having had consumed alcohol while 12 percent reported taking medications prior to their trip (Royal 2003). This same report indicated that drivers in the age bracket of 30 to 45 are least likely to report alcohol or medication as a factor in their drowsy driving episodes.

In a New York survey, 35 percent of those involved in a drowsy driving crash reported having consumed alcohol while another 10 percent admitting to taking medication (McCartt et al. 1996). Studies indicate that using certain medications increases the risk of drowsy driving crashes, particularly using prescribed benzodiazepine anxiolytics and sedating antihistamines (Ray et al. 1992; Gengo and Manning 1990). Other drugs that cause sedation include opioid analgesics, tricyclic antidepressants, antipsychotics, certain antihypertensives, and muscle relaxants (Lyznicki et al. 1998).

Alcohol can independently induce sleepiness, but research has shown that sleepiness and alcohol interact, with sleep restriction exacerbating the sedating effects of alcohol. Thus, one's psychomotor skills are adversely affected to a greater extent than that of sleepiness or alcohol alone (Roehrs et al. 1994).

2.1.3 Young Drivers

Many reasons exist as to why young adults tend to have poor sleeping habits. Carskadon (1990) in her research discussed multiple reasons why younger people, and specifically adolescents, do not sleep enough. Younger people are at risk for excessive sleepiness due to maturational changes which increase the need for sleep, changes in sleep patterns thus reducing nighttime sleep, and lifestyle factors. Lifestyle factors encompass demands from school and work, extracurricular activities, or socializing late into the night. Over a quarter of high school and college students were found to be sleep deprived according to Wolfson and Carskadon (1998). Carskadon (1990) also identified that young males working more than 20 hours per week while being involved in extracurricular activities were most likely to report falling asleep at the wheel.

Multiple studies in which drowsy driving crash data by gender and age group were analyzed determined that young people, and specifically males, were most likely to be involved in a drowsy driving crash (McConnell et al. 2003; Pack et al. 1995; Horne and Reyner 1995; Knipling and Wang 1994). In these four specific research studies, the label of "young" was defined differently, but the range spans from 16 to 29 years of age.

Pack et al. (1995) indicated that the peak age was 20 years old while the median age of the driver in all of the drowsy driving crashes studied was 23.5 years old. For the years 1989-1993, Knipling and Wang (1994) determined that 59 percent of drivers involved in drowsy driving crashes were under 30 years of age while Horne and Reyners' (1995) study revealed that 45 percent of the 606 drivers they studied were under 30 years of age.

2.1.4 Shiftworkers

Shiftwork is on the rise and more prevalent in the rapid growing service sector of the economy according to Presser (1989). Research by Presser (1995) also indicated that one in five to one in six employed Americans do not work regular daytime schedules. Shiftworkers, and especially rotating shift workers, often have problems receiving sufficient sleep to perform necessary duties. They also tend to suffer from poor quality of sleep (Stutts et al.1999).

One specific group of people working irregular hours is truck drivers. The schedules of long-distance truck drivers may place them at higher risk for drowsy driving (Williamson et al. 1996). This higher risk is attributed not only to high levels of driving exposure due to long, irregular work hours, but also due to truck drivers who frequently traverse long, monotonous, high-speed corridors. Furthermore, these drivers have limited opportunities to obtain restorative sleep, thus minimizing their sleep debt (McCartt et al. 2000). Truck drivers typically obtain less sleep than is required for alertness on the job (Mitler et al. 1997). The irregular work hours of truck drivers includes rotating shifts and night shifts, which has been linked to sleepiness-related driving (McCartt et al. 1996).

2.1.5 Time on Task at Hand

Drowsy driving is typically associated with drivers who have been behind the wheel for an extremely long period of time. The general public may experience long driving hours during vacations as drivers attempt to cover long distances over short periods of time—24 to 48 hours (Smiley 2002). Although drowsy driving does occur when driving for many hours, one study indicated that 47 percent of drivers who recently experienced a drowsy driving episode had only been on the road for an hour or less. In the same study, of those who had been on the road for five or more hours only 22 percent indicated having a drowsy driving issue (Royal 2003). A study of six years of drowsy driving crashes in Tennessee found that in almost 61 percent of the fatal/serious sleep-related crashes, the drivers were less than 25 miles from home, although the research could not verify how long the drivers had been driving (McConnell et al. 2003).

A meta-analysis conducted by Folkard (1997) showed that during the first two hours of driving there seems to be an early increase of risk of being in a drowsy driving crash. This was followed by a decrease for the next two hours before increasing again. Maycock (1996) noticed a greater risk of being involved in a fatigue-related crash when driving a longer time without taking a break, specifically when driving three hours or longer.

2.1.6 Circadian Rhythm

The sleep-wake cycle is governed by two factors, namely the homeostatic and circadian factors. Homeostasis relates to the neurobiological need to sleep, therefore, the longer one remains awake the greater the desire to sleep and more difficult it is to resist (Dinges 1995). The circadian pacemaker is an internal clock located in the hypothalamus which regulates physiological and behavioral functions on a 24-hour basis. Most people who have a regular routine of nightly sleep experience two periods of maximum sleepiness, at night during the hours of 1 a.m. to 6 a.m. and again in the midafternoon generally between the hours of 2 p.m. and 4 p.m. (Lyznicki et al. 1998). The circadian rhythm is synchronized by various time-keepers such as the rising and setting of the sun, knowledge of clock time, and work time (Kroemer and Grandjean 1997).

As indicated previously, shiftworkers work irregular hours and thus are more likely to be involved in a drowsy driving crash. This higher risk is likely associated with the circadian rhythm. Shiftworkers can readjust their circadian rhythm so that physiological activity is higher during the work period and lower during sleep, but the reversal is not usually complete even after several weeks (Kroemer and Grandjean 1997).

One study of commercial motor vehicle drivers concluded that the strongest and most consistent factor influencing driver fatigue and alertness is time of day due to the circadian rhythm (Wylie 1996).

2.1.7 High-Risk Drowsy Driving Summary

The previous sections identified groups of people at high-risk of being involved in drowsy driving crashes. The sleepiness which precedes drowsy driving leads to crashes because it impairs the human body's ability to perform safe driving (Dinges and Kribbs 1991). Impairments which have been identified by Dinges (1995) through laboratory and in-vehicle studies include slower reaction time and slower processing of information. Increasing reaction time intuitively decreases a driver's ability to avoid a collision. Also, pointed out by Dinges (1995) is that performance declines due to the diminished ability to process information and retain information in one's short-term memory.

2.2 Drowsy Driving Characteristics

One impediment to better understanding drowsy driving is the number of crashes caused by drowsiness which never are reported under this category. It is believed that drowsiness as a primary factor in crashes where the driver fell asleep is under-reported because in many cases no evidence suggests the driver fell asleep behind the wheel (McCartt et al. 2000). In contrast to alcohol-related crashes, no blood, breath, or other objective test for sleepiness currently exists that is administered to a driver at the scene of a crash. As indicated previously, drowsiness is defined differently for every person, and as such, no criteria are available for establishing how sleepy a driver is or at what point a driver is unable to safely maneuver a vehicle (NHTSA 1998). Despite the under-reporting of drowsy driving crashes, a relatively clear understanding of the statistics, characteristics, and trends of drowsy driving crashes can be identified as outlined in the following sections.

2.2.1 Time of Day and Age of Drivers in Drowsy Driving Crashes

Pack et al. (1995) identified trends in drowsy driving crashes by time of day. The crash data studied indicated that drowsy driving crashes predominately occurred after midnight with a secondary peak in the late afternoon. The timing of these crashes is consistent with the circadian rhythm as mentioned previously (NHTSA 1998). Knipling and Wang (1994) also cited that drowsy driving crashes peak in the early morning hours. Of the drowsy driving crashes studied from 1989 to 1993, 55 percent occurred between midnight and 8:00 a.m. with another 18 percent taking place between 1:00 p.m. and 5:00 p.m. (Knipling and Wang 1994). Other studies also identify the role that time of day plays in drowsy driving crashes (Horne and Reyner 1995; McCartt et al. 1996).

The temporal variation in drowsy driving crashes has been shown to be a function of age. From 16 to 45 years of age, drowsy driving crashes occur most commonly during the night; for drivers between 45 to 65 years of age, the peak hour is at 7 a.m.; lastly, for drivers over 65, the afternoon from 1 p.m. to 3 p.m. is the mostly likely time to have a drowsy driving crash (Pack et al. 1995; Åkerstedt and Kecklund 2001).

Multiple studies in which drowsy driving crash data by gender and age group were analyzed determined that young people, and specifically males, were most likely to be involved in a drowsy driving crash (Pack et al. 1995; Horne and Reyner 1995; Knipling and Wang 1994). McConnell et al. (2003) specifically indicated that the greatest number of sleep-related crashes in his study occurred during the late-night weekend hours, with the greatest number of 15 to 24 year old drivers falling asleep and crashing on Saturday followed closely by Sunday.

2.2.2 Severity of Drowsy Driving Crashes

The mortality rates associated with drowsy driving crashes are high, which may be in part due to the higher speeds involved in such crashes (Horne and Reyner 1995). Furthermore, drowsy drivers typically have a slower reaction time and reduced ability to process information, which when coupled with high speeds may result in more severe crashes (Dinges 1995). In a Tennessee study spanning the years 1994 to 1999, 38,797 fatal and/or injury crashes took place, 1,269 (3.3 percent) of which were attributed to drowsy drivers. Specifically, 1.9 percent of drowsy driving crashes were fatal while another 9.4 percent were incapacitating injuries. For comparison purposes, only 0.6 percent of all other crashes in the study resulted in fatalities, and 3.1 percent in incapacitating injuries (McConnell et al. 2003). Similar studies have concluded that a higher proportion of the most serious crashes are sleepiness related (Maycock 1996; Pack et al. 1995).

2.2.3 Speed, Location, Number of Vehicles, and Result of Drowsy Driving Crashes

Speed seems to play a role in the seriousness of drowsy driving crashes. Although speed does not cause drowsy driving, research indicates that a large percentage of sleep-related crashes occur where speeds are in excess of 50 mph (Pack et al. 1995; Stutts et al. 2005). Other research indicates that such crashes occur on roadways with 55 to 65 mph speed limits, and in non-urban areas (Knipling and Wang 1994). This is also confirmed by the NHTSA whose research shows that most drowsy driving crashes take place on higher speed roads in nonurban areas (NHTSA 1998).

Referring to a Tennessee study, 75 percent of sleep-related fatal and/or injury crashes occurred on rural roads. The same research indicated that of all rural road drowsy driving crashes studied, 55 percent took place on two-lane roads while another 22 percent happened on four-lane divided highways (McConnell et al. 2003). Another study of four years of crash data concluded that 75 percent of drowsy driving crashes occurred on two-lane roadways (Stutts et al. 2005). Maycock (1996) found that a larger absolute number of drowsy driving crashes occur in built-up areas, which is possibly due to the greater exposure of drivers in cities.

An analysis of North Carolina police crash reports showed that most non-alcohol, drowsy driving crashes were single-vehicle roadway departures (Pack et al. 1995). Validating the findings of Pack et al., McConnell et al. (2003) found that 77 percent of the fatal and/or injury sleep-related crashes studied involved single-vehicles.

Among a New York State telephone survey, almost 48 percent of drivers involved in a drowsy driving crash cited having driven off the roadway. Furthermore, almost 25 percent reported going off the road even though they did not crash (McCartt et al. 1996). Besides leaving the roadway altogether, research in Norway concluded that drifting out of one's lane occurs frequently (Sagberg 1999). In addition to run-off-road crashes, sleepy drivers also are likely to be overrepresented in rear-end and head-on collisions (Knipling and Wang 1994).

2.3 Drowsy Driving Countermeasures

As has been identified in this chapter, drowsy driving is a widespread concern which results in many fatalities each year. To combat the effects of drowsy driving and prevent tragic crashes, many types of countermeasures have been implemented by various agencies across the U.S. and other countries to reduce the number of drowsy driving crashes. This section discusses several drowsy driving countermeasures and their effectiveness. Countermeasures discussed in the following subsections include rumble strips, cable median barrier, wide longitudinal edge lines, rest areas, physical stimuli, educational programs, and in-vehicle countermeasures.

2.3.1 Rumble Strips

One of the most important objectives of good roadway design is to maintain vehicles in their designated lanes. If a vehicle accidentally drifts out of a lane and crosses the edgeline, effective highway design should facilitate the recovery of the vehicle and aid the driver in safely reentering the roadway. Sorrowfully, in many cases, vehicles leave their lane of travel, cross over onto the shoulder, and end up as a run-off-road crash as has been identified previously (Neuman et al. 2003). To prevent run-off-road crashes, many states have installed rumble strips. Rumble strips function by providing audible and physical vibrations inside a vehicle when it runs over them. The physical jarring of a car passing over rumble strips is a technique used to alert and warn drivers of changes in roadway alignment when they have partially or completely left the travel lane (Harwood 1993). Wood (1994) indicated that run-off-road crashes can be reduced by as much as 70 percent using rumble strips. To have such success many types of rumble strips have been designed. These include shoulder rumble strips, centerline rumble strips, transverse rumble strips, and midlane rumble strips.

2.3.1.1 Shoulder Rumble Strips

Shoulder rumble strips are used to alert drivers that they have left the traveled way and that a steering correction is necessary to return to the middle of the travel lane (Harwood 1993). Two types of shoulder rumble strips which are used are continuous and discontinuous rumble strips. Figure 2-1 illustrates continuous shoulder rumble strips while Figure 2-2 shows discontinuous rumble strips.

Shoulder rumble strips have gained increased popularity over the past 15 years. In 1993, it was estimated that 18 to 21 states had shoulder rumble strips on rural highways (Harwood 1993). A more recent evaluation of shoulder rumble strips by the Federal Highway Administration (FHWA) indicated that approximately 85 percent of states now use this type of countermeasure to reduce run-off-road crashes (FHWA 1997).

(Photo by Hunter Young 2007)

Figure 2-1. Continuous shoulder rumble strips.

(Photo by Brian Christensen 2006)

Figure 2-2. Discontinuous rumble strips.

In recent years, multiple studies of rumble strips have been conducted to determine their effectiveness in preventing crashes. Research has shown that shoulder rumble strips reduce single-vehicle run-off-road crashes from 20 percent to as much as 70 percent (Griffith 1999; FHWA 1997). A Montana study not only attributed a 14 percent reduction in Interstate run-off-road crash rates to shoulder rumble strips, but also a 24 percent reduction in severity rates (Marvin and Clark 2003). Table 2-1 provides a summary of the effectiveness of shoulder rumble strips in reducing single-vehicle run-off-road crashes.

Table 2-1. Summary of Effectiveness of Shoulder Rumble Strips (FHWA 1997)

State	Year	Highway Type	Percent Crash Reduction
Pennsylvania	1994	Thruway – Rural	70
New Jersey	1995	Turnpike – Rural	34
New York	1994	Thruway – Rural	72
Massachusetts	1997	Turnpike – Rural	42
Washington	1991	Six Locations	18
California	1985	Interstate – Rural	49
Kansas	1991	Turnpike – Rural	34
FHWA	1985	Interstate – Rural (Five States)	20

2.3.1.2 Centerline Rumble Strips

The primary purpose of centerline rumble strips is to warn drivers whose vehicles are crossing the centerline of two-lane, two-way roadways to prevent crashes with opposing traffic (Russell and Rys 2005; Saito and Richards 2005). An illustration of centerline rumble strips provided by the Minnesota Department of Transportation (Mn/DOT) is shown in Figure 2-3. In 2004 it was reported that 20 U.S. states and several Canadian provinces were using centerline rumble strips (Noyce and Elango 2004).

(Source: Mn/DOT 2006)

Figure 2-3. Centerline rumble strips.

Various studies of the effectiveness of centerline rumble strips have been conducted across the U.S. One of the most compelling case studies took place on U.S. Route 301 in Delaware. U.S. Route 301 had a high fatality rate from head-on collisions, but after installing centerline rumble strips the fatality rate dropped to zero. Furthermore, a 90 percent decrease in head-on collisions resulted (FHWA 2002). Another centerline rumble strip study of three highways in Massachusetts found that the installation of centerline rumble strips showed no significant change in crash frequencies; however, no fatal crashes were observed at two of the three test sites after installation of the rumble strips (Noyce and Elango 2004). A before-after crash analysis of 17 miles of centerline rumble strips conducted by the Colorado Department of Transportation determined that head-on collisions were reduced by 34 percent with a 37 percent reduction in cross-over sideswipe crashes (Outcalt 2001).

2.3.1.3 Transverse Rumble Strips

Transverse rumble strips consist of a pattern of raised or grooved bars spaced relatively close to one another and are oriented perpendicular to the flow of traffic (Harwood 1993). In Harwood's (1993) report, 23 states are mentioned as having transverse rumble strips and using them for a range of applications. The most frequently identified reasons for this type of rumble strip pattern were to alert drivers of an unanticipated intersection and warn drivers in work zones (Harwood 1993). Another reason to use transverse rumble strips may be to enhance delineation of sharp curves in roadway alignment (Neuman et al. 2003). A before-and-after study conducted in Texas determined that the speeds of vehicles after passing over transverse rumble strips prior to a horizontal curve decreased between 1 mph to slightly more than 5 mph (Miles et al. 2005). Figure 2-4 shows an example of the transverse rumble strips used in the Texas study identified.

(Source: Miles et al. 2005)

Figure 2-4. Transverse rumble strips.

2.3.1.4 Midlane Rumble Strips

Midlane rumble strips are rumble strips located in the center of the travel lane verses the edge of the shoulder and are installed parallel with the flow of traffic. This type of rumble strip is an experimental treatment which could be used on roadways with no shoulders or narrow paved shoulders where insufficient shoulder width does not accommodate shoulder rumble strips (Neuman et al. 2003). As with all types of rumble strips, pros and cons do exists with midlane rumble strips. Some safety engineers believe that adding rumble strips to the middle of a lane will be another distraction for drivers. This type of rumble strip should be pilot tested before widespread use (Neuman et al. 2003).

2.3.1.5 Rumble Strips Summary

In conclusion, rumble strips do yield positive results as indicated by the various studies examined, but they also do have some adverse effects. In various surveys, states identified noise problems as well as pavement deterioration as main problems with rumble strips. Bicycle riders, motorcycle riders, and emergency vehicle operators have also been noted as parties with concerns about the use of rumble strips (Noyce and Elango 2004; Harwood 1993). One specific concern of centerline rumble strips is the effect they have on passing operations on two-lane, two-way highways. A study conducted in College Station, Texas concluded that centerline line rumble strips have little effect on passing operations when they are installed in passing zones on rural two-lane, two-way traffic (Pratt et al. 2006).

2.3.2 Cable Median Barrier

Cable median barrier has been found on the nation's highways since about the 1930s. Today cable barriers use three or four cables supported by weak steel posts and have been used significantly by multiple states (McClanahan et al. 2004). Cable barriers are placed in the median between opposing directions of travel to reduce the probability of a crossover crash. When the cable is struck, the posts yield and the cable deflects up to

12 feet, effectively catching and decelerating the vehicle and keeping it in the median (Chandler 2007).

The South Carolina Department of Transportation completed the installation of 315 miles of cable median barrier on Interstates with medians less than 60 feet wide to address the growing concern of crossover median crashes. From 1999 to 2000, more than 70 people lost their lives in 57 separate Interstate median crashes in the state. During the three years following installation, the cable median barrier system was hit 3,000 times. Only 15 vehicles, which represented less than 1 percent of those that hit the median barrier, penetrated the cable system resulting in eight fatalities or 2.7 fatalities per year (Zeitz 2003). Figure 2-5 illustrates the cable median barrier implemented in South Carolina in 2003.

(Source: TFHRC 2007)

Figure 2-5. Cable median barrier in South Carolina.

In the 1990s, the Washington State Department of Transportation (WSDOT) was interested in installing cable median barrier in medians wider than 30 feet. WSDOT chose the cable barrier in part because it could be installed for about one-third the cost of concrete barrier and two-thirds the cost of W-beam guardrail. Following installation of the barrier, WSDOT conducted a before-after crash analysis of the cable median barrier installed along 24 miles of Interstate 5 in three locations. The number of annual fatal crossover crashes was 1.6 crashes before installation of the cable and dropped to 0 fatal crashes after having the cable installed. WSDOT reported that the number of annual crossover crashes was 16 crashes before installation of the cable, which decreased to 3.8 crossover crash following cable median installation, a 76 percent reduction (McClanahan et al. 2004).

The state of Missouri has recently undertaken an initiative to have 500 total miles of cable median barrier installed statewide by the end of 2008. The Missouri Department of Transportation (Missouri DOT) decided to install cable barrier on all Interstates with medians less than 60 feet wide. The installation of cable median barrier according to Missouri DOT costs \$60,000 to \$100,000 per mile depending on the amount of grading work to be done. One specific case study was conducted on I-70, the most heavily traveled highway in the state. In 2002, 24 motorists were killed in cross-median crashes on I-70 leading the state to install 179 miles of cable median barrier. In 2006, only two cross-median fatalities were reported on I-70, a 92 percent decrease (Chandler 2007).

2.3.3 Wide Longitudinal Edge Line Pavement Markings

Over the past two decades a greater understanding of drivers' visibility needs have become more prevalent. As such, some state transportation agencies have implemented the use of longitudinal pavement markings that are wider than the standard 4-inch minimum line width for centerline, edge line, or lane line applications. As of summer 2001, 29 of the 50 state DOTs were using some type of wider pavement marking to improve marking visibility (Gates and Hawkins 2002). Edge lines of 6-inch width are common on freeways and some lower class roads. Using a wide edge line of 8 in. to 12 in. on curvilinear sections, while not common, has been used to emphasize curves and provide a stronger visual guide for motorists (McGee and Hanscom 2006). McGee and Hanscom (2006) specify that a wide edge line on roadways with a pavement width less than 20 feet not be used as motorists could move too far left into opposing traffic. Figure

2-6 illustrates a wide 8-in. longitudinal pavement marking used to delineate a curvilinear roadway alignment.

(Source: McGee and Hanscom 2006)

Figure 2-6. Rural highway with 8-inch edge line.

Wide edge lines do have benefits and drawbacks. Gates and Hawkins (2002) identified the benefits of wider pavement markings to include: improved long-range detection under nighttime driving conditions, improved stimulation of peripheral vision, improved lane positioning, and improved driver comfort. The only drawback determined was the increased cost due to increased amounts of material. The benefits though appear to outweigh the drawbacks as indicated in a case study from New York. A study by the New York DOT in 1988 found that sections of curving two-lane rural roads with new 8-in. edge lines resulted in higher crash rate reductions than similar sections which had new 4-in. wide edge lines. The study cited that a 10 percent decrease in total crashes occurred where wider edge lines were used versus a 5 percent increase in total crashes where 4-in. wide edge lines were used (Neuman et al. 2003).

2.3.4 Rest Areas on Interstates

According to the California Department of Transportation (Caltrans) Web site, “Rest areas provide opportunities for motorists to safely stop, stretch, take a nap, use the restroom, get water, check maps, place telephone calls, switch drivers, check vehicles and loads, and exercise pets. Rest areas reduce drowsy and distracted driving and provide a safe and convenient alternative to unsafe parking along the roadside” (Caltrans 2007). Stutts et al. (2005) indicated that since most drowsy driving crashes occur on two-lane rural roadways “states should provide a continuum of options for safe stopping, ranging from smaller rest areas with most of the usual amenities to simple roadside parks with minimal or no amenities” (pp. V-11).

2.3.5 Physical Stimuli

Many types of countermeasures used to fight sleepiness are aimed at physical stimuli in the body. Techniques used to combat fatigue while behind the wheel include listening to music, drinking caffeinated beverages, rolling down the window, turning on the air conditioning, smoking, slapping oneself, and pulling off the highway to nap, eat, or stretch (Nguyen et al. 1998). Several of these countermeasures are discussed in the following paragraphs.

In a study by Stutts et al. (1999), 467 drivers that had been involved in sleep/fatigue-related crashes were asked what types of countermeasure strategies drowsy drivers use to maintain alertness while driving. In reporting the results, drivers deemed to have fallen asleep at the wheel were separated from those crashes reported due to fatigue. The most frequently cited strategy for these two groups was opening the window or adjusting the air conditioner to let in fresh air and reduce the temperature inside the vehicle cabin (Stutts et al. 1999). The overwhelming majority of sleep crash drivers (69 percent) and many of the fatigue crash drivers (57 percent) cited with the above strategy to maintain alertness. The second most cited countermeasure was listening to the radio, a tape, or a CD, which was cited by nearly 45 percent of drivers in both the sleep and fatigue crashes (Stutts et al. 1999). Interestingly, only 12 percent of sleep/fatigue crash drivers identified stopping to take a nap as a way they reduce drowsiness behind the wheel.

Although nearly half of drivers from the Stutts et al. (1999) study indicated listening to music as a method to reduce drowsiness, Reyner and Horne (1998) concluded that cold air and listening to the radio/tape player are of marginal and transient benefit. They even report that such countermeasures are effective for only about 15 minutes, long enough to allow a driver to stop at a suitable place and rest (Horne and Reyner 1999).

Sleeping seems to be the obvious remedy to drowsy driving. Naitoh (1992) indicated that the duration of each sleep episode must be longer than 4-10 minutes to be recuperative while at the same time unaccustomed naps beyond 20 minutes lead to unwanted sleep inertia or grogginess. Fifteen minutes seems to be the optimum length of time for a nap (Gillberg et al. 1994; Naitoh 1992). Horne and Reyner (1996) studied the consequences of giving test subjects a shorter than 15 minute nap, 150 mg of caffeine, and a coffee placebo. Their results concluded that naps and caffeine, which is a pharmacological stimulant, significantly reduced driving impairment. Other research also supports the claim that caffeine helps maintain alertness (Cummings et al. 2001). To this end, drivers in Western Australia can receive a cup of coffee free of charge at any one of over 100 "roadhouses." An example of the roadway signs implemented to remind drivers of free coffee is shown in Figure 2-7.

(Source: MainRoads 2007b)

Figure 2-7. Highway signage in Western Australia indicating free coffee for drivers.

2.3.6 Educational Programs

Public education of drowsy and fatigue driving has been implemented by various agencies in recent years. The NHTSA (1998) in their report outlined three priorities for their educational campaign. First, educate young males ages 16 to 24 about drowsy driving and how to reduce lifestyle-related risks. Second, promote shoulder rumble strips as an effective countermeasure for drowsy driving. Third, educate shift workers about the risks of drowsy driving.

One method in which young drivers both male and female are educated about drowsy driving is through driver training courses and more specifically through graduated drivers license programs. Research indicates that some graduated drivers license programs have reduced total fatalities among young drivers by as much as 19 percent (Morrisey et al. 2006). Other courses of action to educate the general public about drowsy driving include television commercials and Web sites. This approach has been implemented in Utah as part of the Zero Fatalities: A Goal We Can All Live With campaign (UDOT 2006a). McConnell et al. (2003) believe that educational interventions have the most promise for mitigating drowsy driving since there are no legal sanctions against drowsy driving.

2.3.7 In-car Countermeasures

In recent years various in-vehicle systems have been created to measure sleepiness or some behavior associated with sleepiness in commercial and noncommercial driving. The technological tools include brain wave monitors, eye-closure monitors, devices that detect steering variance, and tracking devices that detect lane drift (Dinges 1995). Eye-closure monitors have received attention in research studies for many years. Stern et al. (1994) and Sagberg et al. (2004) identified eye-closure rates to be a good index of sleepiness, but Horne and Reyner (1999) disagree finding that eye-closure rates are unreliable since blinking in the driver is affected by a host of variables including the outside road lighting, oncoming headlights, and the air temperature and state of the ventilation system in the vehicle.

Brown (1997) remarked in research on technological countermeasures that even if wide-spread implementation of such countermeasures were to succeed, educational and exhortational countermeasures will continue to be needed. One reason Brown identified the continual need for educating the public is that drivers are typically aware that they are becoming drowsy, but that this awareness is not a reliable guide to their true alertness. A problem then exists since fatigue countermeasures rely solely on drivers self-monitoring their status. Although in-car countermeasures may ultimately yield some benefit, Sagberg et al. (2004) reported that “a possible negative effect of in-car warning systems may be that driver’s use them to stay awake and drive for longer periods rather than stopping and have a nap” (pp. 38).

2.4 Background of the UDOT Crash Database Tool

The research conducted in this report is the first such investigation of drowsy driving in the state of Utah. To determine from recent history where drowsy driving crashes have occurred, crash data was evaluated. Crash records were extracted from UDOT’s crash database that can be used to analyze crash statistics for all Interstate freeways, U.S. Routes, and Utah State Routes (S.R.).

One objective of the crash database is to allow for rapid retrieval and analysis of crash data. The system is designed to improve the investigation of the data in six ways (Anderson et al. 2005):

1. Custom tables and reports are created with only selected parameters, leaving off unneeded data. This simplifies the analysis by focusing on what is important to each individual user.
2. Placing the data on a “smart map” allows the decision-maker to visually identify hot spots or deficient areas. The analysis can be further refined by extracting selected information from the map as needed.
3. Simple statistical processes can be applied to the data by location using “Fixed Segment,” “Floating Segment,” or “Cluster” analysis.
4. Providing information from multiple databases in one Web site allows users to conduct “loose” integration of the data. Information extracted through a series

of queries from different data sources can be saved into a single spreadsheet for analysis. For example wet weather crashes, skid index, and AADT could be acquired for a site from three different databases.

5. Decision-makers will have more time to analyze the data since it takes less time to gather and compile the information. This will enhance the identification of problem areas, program delivery, and improved designs.
6. The system is designed to quickly download data for performance measurement. The effectiveness of improvements can be monitored over time in an efficient manner.

Crash analysis is a useful tool in the evaluation of the safety conditions of a highway. Crash reports include large quantities of information which supplement the type of crash recorded. This supplemental data encompasses the severity, cause, and location of where crashes occur. An in depth study of this information can lead to the implementation of effective engineering solutions and thus improve roadway safety. Crash analysis can also evaluate the impacts of safety improvements already in place by conducting before and after crash statistics. Various research projects have been conducted with the aid of the UDOT crash database, which include assessing the safety impacts of access management techniques (Schultz and Lewis 2006) and creating a prioritization process for access management implementation in Utah (Schultz and Braley 2007).

2.5 Literature Review Summary

In this chapter, a literature review was organized consisting of pertinent information regarding fatigue and drowsy driving. Common causes of drowsy driving were outlined as well as general statistics related to drowsy driving using case studies. A review of countermeasures and their effectiveness as implemented in other states and countries was discussed. Lastly, the background on crash database tools as useful resources for fatigue and drowsy driving analysis was given. In the following chapter, the analysis procedure used to determine drowsy driving corridors is outlined along with statistics of drowsy driving on Utah highways.

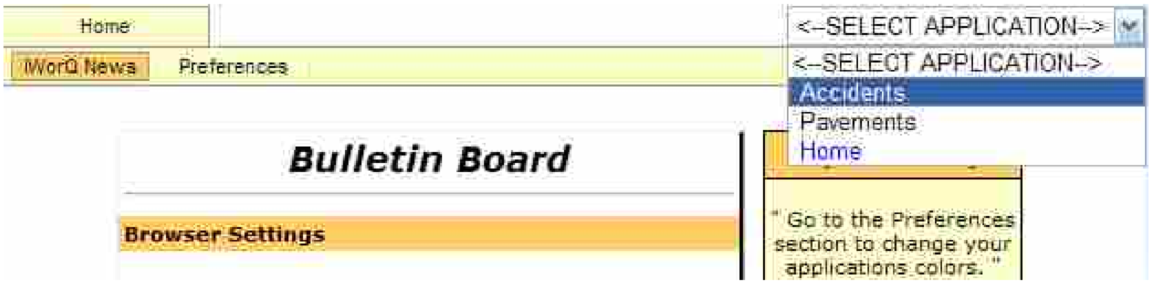
3 ANALYSIS PROCEDURE

To establish which corridors of Utah highway are most prone to drowsy driving crashes, a set procedure was created to utilize two corridor analyses. The manner in which data was retrieved from the UDOT crash database is set forth followed by the two corridor analyses. The first analysis is based upon crash rates while the second is based upon the number of crashes within a predetermined segment. The analyses were divided into rural and urban portions since the characteristics between these types of areas is drastic. How the rural-urban boundaries were determined is also outlined followed by the time periods in which the analyses were conducted. Background for two before-after crash rate analyses conducted on I-80 is also provided. The first before-after analysis discussed relates to the effectiveness of drowsy driving freeway signs while the second analysis discussed relates to the effectiveness of a rest area on drowsy driving crashes. In the following section, the process for extracting drowsy driving crash data is set forth.

3.1 Data Retrieval from UDOT Crash Database

The key tool in retrieving the necessary data for all drowsy and fatigue-related analyses was UDOT's crash database. The crash database consists of records and statistics from police reports for crashes occurring on Interstate freeways, U.S. Routes, and Utah S.R. highways. The database also has geographic information system (GIS) capabilities that allow users to generate a map identifying the location of crashes according to specified parameters. The crash database includes crash data and statistics dating back to 1992. Although the most recent crash data available from the UDOT crash database is for the year 2005, the drowsy driving critical corridors were determined using crash data through the end of 2004 as this was the most recent data available at the time the analyses were conducted. Crash data for the year 2005 was included in the before-after crash rate analyses, which were conducted after the 2005 data was added to the UDOT crash database.

Upon arriving at UDOT's crash database Web site, the "Accidents" option is chosen from the "Select Application" drop-down menu located at the top right corner of the screen as illustrated in Figure 3-1 (Anderson et al. 2005). At the top of the screen are located five tabs, which are used to navigate through various sections of the crash database. The first step to extracting the necessary data for analysis is to create a filter, where a filter is a set group of analysis parameters established by the user. The database then compares all of the data in its inventory according to the chosen filter and retrieves only the data with matching results.



" Go to the Preferences section to change your applications colors. "

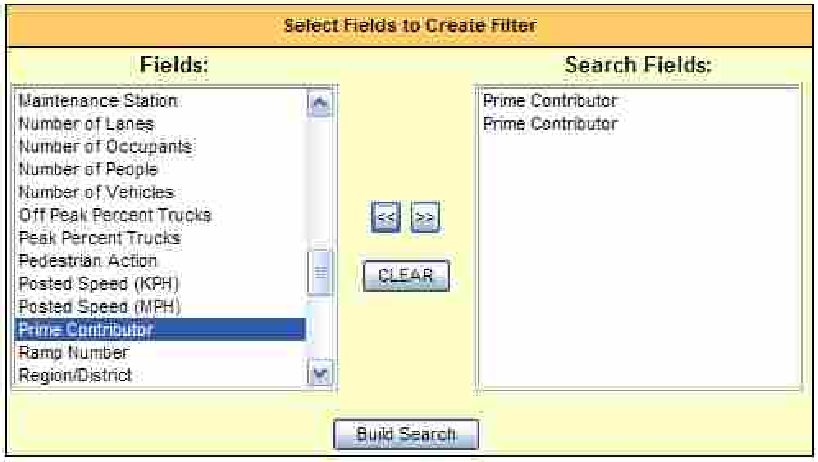
Figure 3-1. UDOT crash database homepage.

After selecting the "Filters" tab, two options located below the "Search" tab are available, namely "Filter Management" and "Create a Filter." The "Create a Filter" option is selected as illustrated in Figure 3-2.

Under the "Fields" section are 66 available parameters which may be used to construct a filter. Filters use Boolean operators to sift through the crash database inventory extracting applicable results. To create the "OR" Boolean operator, the user must choose the same parameter from the "Fields" menu multiple times until the desired variable appears under the "Search Fields" section the appropriate number of selected times as demonstrated in Figure 3-3. If the "AND" Boolean operator is desired as part of the filter, the user must select each desired parameter only once.

Filter: 2002-ROR R-Asleep-Fatal

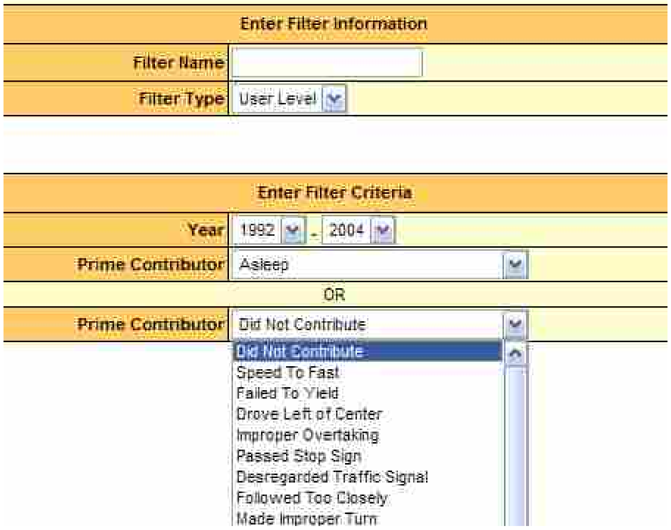
Figure 3-2. Example of "filters" tab in UDOT crash database.



Search Fields:
Prime Contributor
Prime Contributor

Figure 3-3. Example of a filter with "OR" Boolean operator capabilities.

Once the desired parameters have been added to the "Search Fields" section, the user selects the "Build Search" button where a filter name may be entered. Other specific information under the "Enter Filter Criteria" must be supplied such as the required years of analysis as well as which specific fields to be used as already chosen from Figure 3-3. Continuing the previous example of the "OR" Boolean function with two "Prime Contributor" selections, one variable from each range of choices is selected as illustrated in Figure 3-4 followed by the "Save" button.



Enter Filter Information

Filter Name

Filter Type: User Level

Enter Filter Criteria

Year: 1992 - 2004

Prime Contributor: Asleep

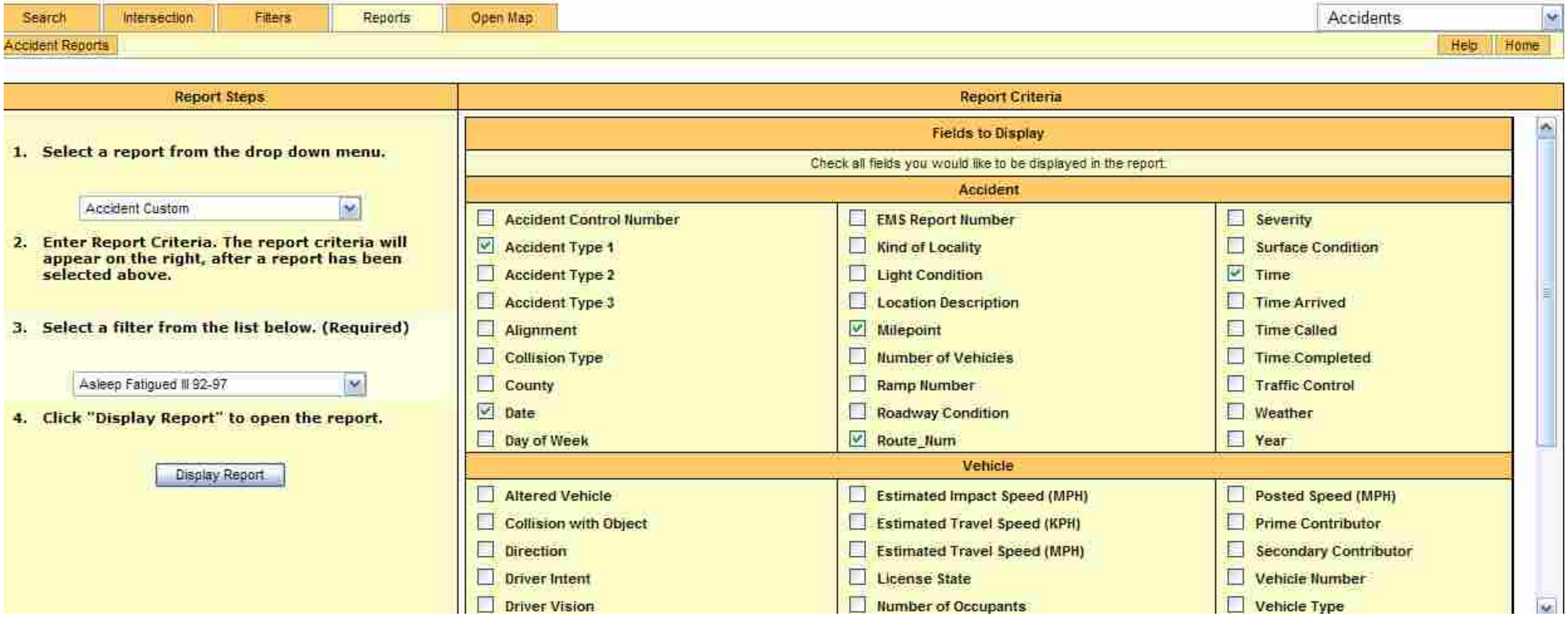
OR

Prime Contributor: Did Not Contribute

Figure 3-4. Example of entering filter criteria.

After a filter is created, the data sought may be retrieved in a report format. Two types of reports may be produced using the crash database, namely an “accident” report and a “vehicle” report. When creating an “accident” report, the UDOT crash database generates one line of results for every crash meeting the filter criteria. Contrastingly, when producing a “vehicle” report, one line of results for each person involved in a crash is generated in the database.

Referring to Figure 3-2, the “Reports” tab is selected after which the four steps under the “Report Steps” section are followed to create the report as demonstrated in Figure 3-5. From the drop-down menu in step one, “Accident Custom” is selected, from which the results are chosen. Likewise, from the drop-down menu in step three, the desired filter followed by the “Display Report” button is selected. With the desired results selected, a report can be generated very quickly. An “accident” report for the parameters outlined in Figure 3-5 is illustrated in Figure 3-6. The results of any report may be easily transferred from the crash database to a spreadsheet program. The data to be transferred to a spreadsheet is simply copied and pasted where desired. With the results in a spreadsheet, the data may be analyzed to determine trends, create graphs, or calculate other pertinent statistics.



1. Select a report from the drop down menu.

Accident Custom

2. Enter Report Criteria. The report criteria will appear on the right, after a report has been selected above.

3. Select a filter from the list below. (Required)

Asleep Fatigued Ill 92-97

4. Click "Display Report" to open the report.

Fields to Display

Check all fields you would like to be displayed in the report.

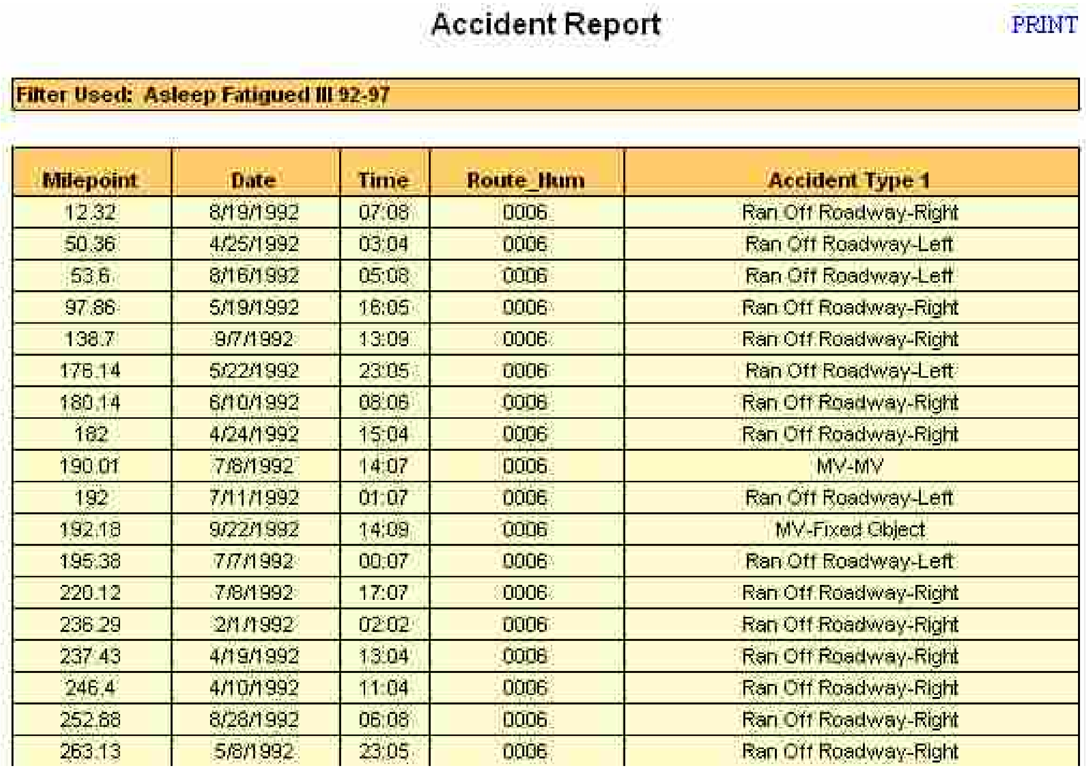
Accident

☐ Accident Control Number
☑ Accident Type 1
☐ Accident Type 2
☐ Accident Type 3
☐ Alignment
☐ Collision Type
☐ County
☑ Date
☐ Day of Week
☐ EMS Report Number
☐ Kind of Locality
☐ Light Condition
☐ Location Description
☑ Milepoint
☐ Number of Vehicles
☐ Ramp Number
☐ Roadway Condition
☑ Route_Num
☐ Severity
☐ Surface Condition
☑ Time
☐ Time Arrived
☐ Time Called
☐ Time Completed
☐ Traffic Control
☐ Weather
☐ Year

Vehicle

☐ Altered Vehicle
☐ Collision with Object
☐ Direction
☐ Driver Intent
☐ Driver Vision
☐ Estimated Impact Speed (MPH)
☐ Estimated Travel Speed (KPH)
☐ Estimated Travel Speed (MPH)
☐ License State
☐ Number of Occupants
☐ Posted Speed (MPH)
☐ Prime Contributor
☐ Secondary Contributor
☐ Vehicle Number
☐ Vehicle Type

Figure 3-5. Example of preparing an “accident” report with a filter using the crash database tool.



Filter Used: Asleep Fatigued Ill 92-97

Milepoint	Date	Time	Route_Num	Accident Type 1
12.32	8/19/1992	07:08	0006	Ran Off Roadway-Right
50.36	4/25/1992	03:04	0006	Ran Off Roadway-Left
53.6	8/16/1992	05:08	0006	Ran Off Roadway-Left
97.86	5/19/1992	16:05	0006	Ran Off Roadway-Right
138.7	9/7/1992	13:09	0006	Ran Off Roadway-Right
176.14	5/22/1992	23:05	0006	Ran Off Roadway-Left
180.14	6/10/1992	08:06	0006	Ran Off Roadway-Right
182	4/24/1992	15:04	0006	Ran Off Roadway-Right
190.01	7/8/1992	14:07	0006	MV-MV
192	7/11/1992	01:07	0006	Ran Off Roadway-Left
192.18	9/22/1992	14:09	0006	MV-Fixed Object
195.38	7/7/1992	00:07	0006	Ran Off Roadway-Left
220.12	7/8/1992	17:07	0006	Ran Off Roadway-Right
236.29	2/1/1992	02:02	0006	Ran Off Roadway-Right
237.43	4/19/1992	13:04	0006	Ran Off Roadway-Right
246.4	4/10/1992	11:04	0006	Ran Off Roadway-Right
252.88	8/28/1992	06:08	0006	Ran Off Roadway-Right
263.13	5/8/1992	23:05	0006	Ran Off Roadway-Right

Figure 3-6. Example of an "accident" report using the crash database tool.

3.2 Corridor Analyses

It has been determined through preliminary research that a relatively low number of crashes on a rural road may yield an extremely high crash rate depending upon the volume of traffic; therefore, it was recommended for practical purposes that the number of drowsy driving crashes within a predetermined segment be calculated as a starting point for this research followed by more detailed crash rate analyses. The count of drowsy driving crashes in 5-mile increments was then used to quickly determine which highways in Utah justified further investigation regarding high-crash drowsy driving corridors. Based upon the number of drowsy driving crashes on each facility statewide, the vast majority of highways were eliminated from further study and not included in the two corridor analyses discussed in the following sections.

Two unique methods were implemented to determine which corridors of Utah highway are most prone to have drowsy driving or fatigue-related crashes. The first method counted the number of crashes occurring in 5-mile increments while the second procedure incorporated annual average daily traffic (AADT) combined with the number of crashes to calculate a crash rate. In both cases, the data analyzed was limited to each crash having been caused by a driver who was asleep, fatigued, or ill as outlined in the police report. Additionally, the roadway surface conditions were restricted to dry or wet surface conditions. Muddy, snowy, icy, and oily surface conditions were excluded from the data based upon the recommendation of the UDOT technical advisory committee (TAC). The two corridor analyses mentioned were then conducted on the state system.

3.2.1 Corridor Analysis by Number of Crashes

In preparation for analyzing crash data, two filters were created to span the 13-year study period. As mentioned previously, data was limited to crashes having been caused by a driver who was asleep, fatigued, or ill on dry or wet pavement as outlined in police reports. The crash database reports were entered into a spreadsheet to facilitate the examination of the data. The parameters included in the two reports were route number, milepost (M.P.), time of day, direction of travel, and date.

The critical corridors were determined using a macro in a spreadsheet. The macro incorporated two independent parameters: 1) the interval length measured in miles and 2) the minimum number of crashes to be counted before displaying any results. All Interstate freeways, U.S. Routes, and S.R. highways were examined using an interval length of 5 miles. The minimum-number-of-crashes parameter was set to zero crashes to identify all crashes within each predetermined segment of roadway.

The macro developed only simulates what is known as a “floating segment analysis,” but is not actually executed in the same manner as “floating segment analysis.” A true “floating segment analysis” permits a user to inspect an entire corridor of highway using a moving interval of specified length. After the first interval of the facility is examined, the moving or “floating” segment advances according to a “floating incremental length” as defined by the user. However, for the purposes of this research the macro did not use a "floating incremental length," but rather it counted the number of drowsy driving crashes in the first 5-mile segment before advancing to the next M.P. representing a different crash wherein a new 5-mile segment was inspected. This process was continued until the end of the highway under consideration was reached.

Once the number of crashes for all segments of highways included in the study was calculated, a mean and standard deviation of the number of crashes were calculated for all of the segments included in the analysis. A unique critical number-of-crashes value was then calculated from which corridors most prone to drowsy driving crashes were easily discernable. The number of crashes for all segments was calculated by direction of travel as this can be an important part in understanding where crashes take place. Again, a mean, standard deviation, and critical number-of-crashes value were calculated. This methodology, in which critical corridors were determined by direction of travel, was incorporated when determining the final critical corridors

3.2.2 Corridor Analysis by Crash Rate

Population-base rates or exposure-based rates can be calculated for various highway crash statistics. Examples include fatalities, crashes, or involvements per 1,000 miles of highway. Rates are standardized to aid in comparing crash rates from different facilities. The standard used in this research was the number of drowsy driving crashes per 1 million vehicle-miles traveled (VMT). Drowsy driving crash rates were calculated for 5-mile segments according to Equation 3-1 (Hummer 2000). The segment length of 5 miles was used in the analyses for two reasons. First, smaller stretches of highway such as 1 or 2 miles were deemed too narrow considering that one of the research objectives was to determine broad areas where drowsy driving was a causal factor in many crashes. Second, 5-mile corridors were used to ensure that high-crash areas were captured in the analyses due to inaccurate reporting of the locations of drowsy driving crashes by law enforcement personnel.

$$RSEG = \frac{1{,}000{,}000 \times A}{365 \times T \times V \times L} \tag{3-1}$$

where: $RSEG$ = crash rate for the segment (crashes per million VMT),

A = number of reported crashes for the time period,

T = number of years being analyzed,

V = weighted AADT for analysis segment, and

L = length of the segment in miles.

For the Interstate freeways, U.S. Routes, and S.R. highways analyzed, AADT volumes were available at regular intervals along the corridors, and as such were used when calculating the crash rates for these facilities. Due to the dynamic nature of AADT, the volumes for the specified years under analysis were used when calculating multiple-year crash rates. Furthermore, since AADT changes according to geographic location and may change within a segment under consideration, a weighted AADT volume must be calculated before computing a crash rate. Equation 3-2 (Schultz and Lewis 2006) demonstrates how weighted AADT volumes were calculated for segments which contain varying AADT volumes. More specific information on the AADT volumes utilized in this analysis is provided in the section that follows.

$$AADT_{wt} = \frac{(AADT_1 \times L_1) + (AADT_2 \times L_2) + \ldots + (AADT_n \times L_n)}{L_1 + L_2 + \ldots + L_n} \tag{3-2}$$

where: $\mathrm{AADT}_{\mathrm{wt}}$ = weighted AADT for analysis segment,

$AADT_n$ = AADT of each individual section within the analysis segment,

L_n = length of individual section within the analysis segment, and

n = total number of AADT sections in analysis segment.

3.2.2.1 Annual Average Daily Traffic Data

AADT data are available on UDOT’s Web site for the years 1986-2005. From UDOT’s home page, the “Inside UDOT” tab is selected followed by the “Systems Planning and Programming” link. From there, the “Traffic Statistics” link is selected from the list of "Subtopics." Lastly, the "Automatic Traffic Monitoring Station History" link is selected followed by the "AADT History – 2005-1986" link. Once the document is downloaded, a specific highway may be located by scrolling down through the file. Furthermore, the AADT values may be copied and inserted into a spreadsheet for easy analysis. A modified excerpt from "AADT History – 2005-1986" from UDOT's Web site is provided in Table 3-1.

Table 3-1. Example AADT Volumes for 2003-2005 of I-80 (Adapted from UDOT 2005)

Starting M.P.	Ending M.P.	Description	2005	2004	2003
0	1.48	Nevada State Line	6,230	6,110	5,995
1.48	2.55	Wendover Interchange	7,520	7,835	7,690
2.55	3.99	East Incl. Wendover	7,520	7,835	7,690
3.99	41.28	Bonneville Speedway Interchange	7,775	7,626	7,460
41.28	48.94	Knolls Interchange	7,900	7,600	7,458
48.94	56.2	Clive Interchange	8,005	7,850	7,705
56.2	61.84	Aragonite Interchange	8,485	8,323	8,200
61.84	69.53	Lakeside Interchange	8,415	8,255	8,100
69.53	76.42	Delle Interchange	8,450	8,285	8,130
76.42	83.38	Rowley Interchange	9,360	9,090	9,145
83.38	88.42	Stansbury Interchange/Grantsville	10,940	10,624	10,695

With drowsy driving crash rates calculated for 5-mile segments according to Equation 3-1, a method was sought to determine which corridors of highway are most prone to drowsy driving crashes. Critical crash rates for each facility under inspection were calculated to aid in this determination. In addition to examining each highway without regards to direction of travel, critical crash rates were calculated for each direction of travel. This was done to determine if one direction of travel had more crashes within a given area than the opposing direction of travel. It was assumed that the directional distribution of each weighted AADT was 50 percent in each direction. In determining the final critical corridors, the analyses in which the direction of travel was separated were used as these analyses were more accurate and representative of fatigue and drowsy driving situations.

3.2.2.2 Critical Crash Rates

The purpose of a critical crash rate unique to each facility was to determine those segments of highway with crash rates exceeding the critical crash rate. With crash rates computed for all 5-mile segments as outlined in Equation 3-1, a mean and standard deviation of the rates were calculated for all of the segments included in the analysis period. Distinctive critical crash rates were then calculated using a confidence level of 95 percent in one tail (Z = 1.645) in accordance with Equation 3-3 (Hummer 2000). The overlying assumption for determining critical corridors is that approximately 5 percent of each corridor has critical segments on the upper end of the distribution (greater than the mean). The location of corridors with a crash rate in excess of the calculated critical crash rate was quickly identified once the critical crash rate was determined.

$$C = \bar{x} + (Z \times \sigma_s) \qquad (3\text{-}3)$$

where: C = critical crash rate for portion of facility under consideration,
$\bar{x}$ = mean crash rate for portion of facility under consideration,
Z = constant corresponding to a level of confidence (Z = 1.645 for this analysis), and
σ_s = sample standard deviation for portion of facility under consideration.

3.3 Rural-Urban Corridors

Three of the most heavily traveled facilities in Utah traverse both rural and urban areas. Due to the stark contrast in driving conditions and traffic volumes between these two types of areas, Interstate 15 (I-15) and I-80 as well as U.S. 89 were divided into sections where rural areas were analyzed separately from those deemed to be urbanized areas. Two methods were used to identify the rural-urban boundaries, namely UDOT's Roadview program (UDOT 2007a) and "AADT History – 2005-1986" (UDOT 2005).

First, Roadview Explorer 2.0 was utilized (UDOT 2007a). This program consists of video footage of every Interstate, U.S. Route, and S.R. highway in Utah. The user can view a highway by selecting a route number, direction of travel, and M.P. as illustrated in Figure 3-7. Figure 3-8 illustrates northbound I-15 at M.P. 0.

Route_nr: 0015
Direction: +
milepost: 0.00
Frame:
☑ Close on Apply

(Source: UDOT 2007a)

Figure 3-7. Roadview Explorer search dialog box.

Route_nr: 0015
Direction: +
District: 5
Countyname: WASHINGTON
Heading: N
Logdate: 05/23/2005
Session_name: 5_0015_N
Frame: 1
Milepost: 0.000
Latitude: 36.99985
Longitude: -113.622492
Altitude: 813
Increment:
☑ GPS On

(Source: UDOT 2007a)

Figure 3-8. Example of Roadview Explorer on I-15 at M.P. 0.

The rural-urban boundaries were located in Roadview Explorer by visually identifying the location where the speed limit changed from a rural speed limit of 75 mph to an urban speed limit of 65 mph. Second, the "AADT History – 2005-1986" (UDOT 2005) as mentioned in Section 3.2.2.1 was used. This history file not only contains AADT volumes, but also a description of each segment as illustrated previously in Table 3-1. These descriptions specify the location of the rural-urban boundaries used in the analyses. Based on the two methodologies outlined, the beginning and ending urban mileposts for I-15, I-80, and U.S. 89 are shown in Table 3-2. All other sections of highway not located within the boundaries identified in Table 3-2 are rural, including the whole of I-70.

Table 3-2. Rural-Urban Boundaries

Highway	Beginning Urban M.P.	Ending Urban M.P.
I-15	255	345
I-80	110	130
U.S. 89	325	470

3.4 Multiple-Year Analyses

The two analyses described in Sections 3.2.1 and 3.2.2, namely the *Corridor Analysis by Number of Crashes* and *Corridor Analysis by Crash Rate*, were used to determine critical drowsy driving corridors for time periods spanning three, five, and 13 years in length. This methodology was completed to determine if critical drowsy driving corridors located in the 13-year analysis also resulted from the 3- and 5-year analyses, or if critical drowsy driving corridors from the 13-year study were possibly eliminated in the shorter timeframe studies due to influential factors such as maintenance activities, land use changes, traffic volumes, roadway improvements, etc.

Cheng and Washington (2005) indicate that longer crash history periods are usually associated with increasingly less stable safety performance functions over time. Furthermore, three years of crash history is optimal as this timeframe is sufficient to minimize random fluctuation in the number of crashes and yet short enough to exclude the effects of population growth or other demographic changes. In addition to the 3-year crash analysis, which is the basis for the results of this research, the following subsections include a brief summary of the 5- and 13-year analyses for comparison purposes.

3.4.1 3-Year Analysis

A 3-year crash analysis for the years 2002-2004 was conducted. The crash rate for all sections of highway was calculated using Equation 3-1. The number of crashes and weighted AADT were modified to generate a multiple-year crash rate. Table 3-3 illustrates the 3-year crash rate for each 5-mile segment of eastbound I-80 as an example. Similar tables for the 3-year analysis of other facilities are included in Appendix A. From the calculated crash rates in Table 3-3, the mean, standard deviation, and critical crash rates were calculated using Equation 3-3. The crash rates identified in bold print in Table 3-3 are the crash rates in excess of the critical crash rate; no urban segments were deemed critical in this example.

3.4.2 5-Year Analysis

A 5-year analysis consisting of the years 2000-2004 inclusive was conducted to compare with the initial results of the 3- and 13-year analyses. The crash rate for each section of highway was calculated using Equation 3-1 with one modification—the number of drowsy driving crashes and weighted AADT were adapted to reflect a multiple-year crash rate. Table 3-4 displays the results of eastbound I-80 for the 5-year analysis as an example. Similar tables for the 5-year analysis of other facilities are included in Appendix A. From the crash rates in Table 3-4, the mean, standard deviation, and critical crash rates were calculated using Equation 3-3. Again, the crash rates identified in bold print in Table 3-4 are the crash rates in excess of the critical crash rate. No critical segments were identified in the urbanized area of Salt Lake City.

Table 3-3. Eastbound I-80 3-Year Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled	
	Milepost	**2002 - 2004**
Rural Area	0-5	0.000
	5.01-10	0.000
	10.01-15	0.143
	15.01-20	0.096
	20.01-25	0.048
	25.01-30	0.000
	30.01-35	0.239
	35.01-40	**0.383**
	40.01-45	0.288
	45.01-50	**0.335**
	50.01-55	0.233
	55.01-60	0.270
	60.01-65	**0.356**
	65.01-70	0.089
	70.01-75	0.266
	75.01-80	0.122
	80.01-85	0.037
	85.01-90	0.128
	90.01-95	0.028
	95.01-100	0.097
	100.01-105	0.102
	105.01-110	0.084
Urban Area	110.01-115	0.070
	115.01-120	0.000
	120.01-125	0.007
	125.01-130	0.021
Rural Area	130.01-135	0.042
	135.01-140	0.034
	140.01-145	0.045
	145.01-150	0.087
	150.01-155	0.125
	155.01-160	0.055
	160.01-165	0.057
	165.01-170	0.055
	170.01-175	0.027
	175.01-180	0.053
	180.01-185	0.134
	185.01-190	0.057
	190.01-197	0.283

Table 3-4. Eastbound I-80 5-Year Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled	
	Milepost	**2000 - 2004**
Rural Area	0-5	0.000
	5.01-10	0.000
	10.01-15	0.086
	15.01-20	0.086
	20.01-25	0.029
	25.01-30	0.000
	30.01-35	0.172
	35.01-40	0.258
	40.01-45	0.228
	45.01-50	**0.339**
	50.01-55	**0.278**
	55.01-60	0.243
	60.01-65	0.239
	65.01-70	0.079
	70.01-75	**0.290**
	75.01-80	0.197
	80.01-85	0.115
	85.01-90	0.119
	90.01-95	0.035
	95.01-100	0.119
	100.01-105	0.097
	105.01-110	0.081
Urban Area	110.01-115	0.058
	115.01-120	0.000
	120.01-125	0.008
	125.01-130	0.026
Rural Area	130.01-135	0.031
	135.01-140	0.032
	140.01-145	0.051
	145.01-150	0.054
	150.01-155	0.077
	155.01-160	0.069
	160.01-165	0.053
	165.01-170	0.034
	170.01-175	0.016
	175.01-180	0.033
	180.01-185	0.097
	185.01-190	0.102
	190.01-197	0.250

3.4.3 13-Year Analysis

The 13-year analysis was conducted differently from the 3- and 5-year analyses. A multiple-year crash rate spanning the 13-year dataset was not calculated for each 5-mile segment whereas with the 3- and 5-year data a multiple-year crash rate was determined according to the corresponding number of years. A mean, standard deviation, and critical crash rate were calculated for rural areas as well as urban areas where applicable. With a crash rate calculated for each 5-mile segment, the number of years a segment was critical was determined. If a segment had at least three of 13 years deemed critical then it was included in the results for this analysis.

The overlying assumption for determining critical corridors is that approximately 5 percent of each highway has critical segments, or 0.05. Therefore, the three year minimum was determined by testing each segment to ascertain if the proportion of critical years over the 13-year time period was greater than 0.05. To determine whether or not a segment should be included in the results of this analysis, a *p*-value for each segment was calculated based upon three values. First, an "*x*" value representing the proportion of critical years out of the 13-year study period was calculated. Second, the standard deviation of "*x*" was computed using Equation 3-4 (Ramsey and Schafer 2002). Lastly, a Z-statistic was calculated using Equation 3-5 (Ramsey and Schafer 2002) and used in conjunction with a cumulative standard normal distribution table to determine *p*-values (Ramsey and Schafer 2002). Table 3-5 outlines how the *p*-value for each of critical year was calculated.

$$S_i = \sqrt{\frac{x_i(1-x_i)}{n}} \tag{3-4}$$

where: S_i = standard deviation where i is the number of critical years,

x_i = proportion of years out of n-year study period, and

n = total number of years in sample size.

$$Z_i = \frac{x_i - 0.05}{S_i} \qquad (3\text{-}5)$$

where: Z_i = standard normal score

x_i = proportion of years out of *n*-year study period, and

S_i = standard deviation where *i* is the number of critical years.

Table 3-5. *P*-value Calculations for the 13-Year Analysis

Number of Years	x_i	S_i	Z_i	*p*-value
1	0.077	0.074	0.364	0.358
2	0.154	0.100	1.038	0.150
3	0.231	0.117	1.547	0.061
4	0.308	0.128	2.013	0.022
5	0.385	0.135	2.480	0.007
6	0.462	0.138	2.976	0.001
7	0.538	0.138	3.533	0.000
8	0.615	0.135	4.190	0.000
9	0.692	0.128	5.018	0.000
10	0.769	0.117	6.155	0.000
11	0.846	0.100	7.956	0.000
12	0.923	0.074	11.813	0.000

As indicated in Table 3-5, the *p*-value for four or more critical years is less than 0.05, which is the usual standard for representing significance at the 95th percentile. Initially, four years was the minimum threshold, but after considering the number of variables which affect drowsy driving crashes and their reporting, variables such as changes in roadway alignment and inaccurate reporting of the exact M.P. of crash locations, it was determined through initial discussion and consultation with the TAC that the difference in using three years versus four years as a minimum threshold was not practically important. Thus, all 5-mile segments which had three or more years deemed critical were included in the initial results. Table 3-6 indicates the crash rates for eastbound I-80 for this analysis while other facilities are located in Appendix A. The crash rates identified in bold print are the crash rates in excess of the critical crash rate.

Table 3-6. Eastbound I-80 13-Year Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural Area	0-5	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.00	0.00	0.00	0.00	0.00	0.00
	10.01-15	0.17	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.28	0.00	0.14
	15.01-20	0.17	0.34	0.16	0.15	0.00	0.00	0.00	0.14	0.00	0.14	0.28	0.00	0.00
	20.01-25	0.17	0.00	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.14
	25.01-30	0.34	**0.50**	0.16	0.00	0.32	0.00	0.29	**0.42**	0.00	0.00	0.00	0.00	0.00
	30.01-35	0.34	0.00	**0.64**	0.15	0.00	0.29	**0.43**	0.14	0.00	0.14	0.28	0.29	0.14
	35.01-40	**0.85**	**0.67**	0.00	0.00	0.32	0.00	0.14	0.00	0.00	0.14	**0.84**	0.15	0.14
	40.01-45	0.17	0.33	0.16	0.30	0.31	**0.87**	0.00	0.14	0.28	0.00	**0.56**	0.15	0.14
	45.01-50	0.33	**0.66**	0.00	**0.45**	0.16	**0.58**	0.00	**0.41**	0.27	**0.42**	**0.42**	0.29	0.29
	50.01-55	0.17	0.00	0.31	**0.45**	0.31	0.14	0.28	0.27	0.14	**0.55**	0.00	**0.71**	0.00
	55.01-60	0.00	**0.49**	0.30	**0.72**	**0.45**	0.14	**0.69**	0.27	0.27	0.14	0.14	**0.68**	0.00
	60.01-65	0.00	0.00	0.30	0.28	0.15	0.14	0.14	0.13	0.13	0.00	**0.53**	**0.40**	0.13
	65.01-70	0.16	0.00	0.15	0.00	0.30	**0.41**	0.13	0.13	0.00	0.13	0.13	0.00	0.13
	70.01-75	0.16	0.31	0.00	0.00	0.15	**0.55**	0.13	0.39	0.26	**0.39**	0.13	0.27	**0.40**
	75.01-80	**0.44**	**0.44**	0.14	0.13	**0.55**	0.26	0.39	**0.62**	0.25	0.38	0.00	0.00	0.37
	80.01-85	0.14	0.00	0.27	0.00	0.26	0.25	0.37	0.24	**0.48**	0.00	0.11	0.00	0.00
	85.01-90	0.13	**0.40**	**0.40**	0.12	0.13	0.12	0.00	0.00	0.11	0.10	0.09	0.19	0.10
	90.01-95	0.12	0.12	0.13	0.00	0.25	0.00	0.00	0.00	0.00	0.09	0.00	0.09	0.00
	95.01-100	0.34	0.17	0.26	0.25	0.00	0.22	0.21	0.21	0.26	0.06	0.11	0.17	0.00
	100.01-105	0.27	0.13	0.00	0.12	0.06	0.00	0.05	0.05	0.09	0.09	0.08	0.13	0.09
	105.01-110	0.15	0.07	0.00	0.07	0.06	0.06	0.11	0.06	0.16	0.00	0.05	0.10	0.11
Urban Area	110.01-115	**0.12**	**0.16**	0.00	0.05	**0.14**	0.05	**0.13**	0.08	0.04	0.04	0.10	0.03	0.07
	115.01-120	0.03	0.00	0.00	0.02	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	120.01-125	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0.00
	125.01-130	0.00	**0.13**	0.09	0.00	0.00	0.00	0.03	0.06	0.00	0.07	0.04	0.00	0.02
Rural Area	130.01-135	0.07	0.03	0.00	0.03	0.00	0.00	0.00	0.06	0.00	0.03	0.05	0.03	0.05
	135.01-140	0.00	0.07	0.06	0.03	0.00	0.08	0.03	0.03	0.06	0.00	0.08	0.03	0.00
	140.01-145	0.04	0.04	0.04	0.07	0.00	0.00	0.06	0.00	0.06	0.06	0.05	0.03	0.05
	145.01-150	0.08	0.16	0.14	0.00	0.00	0.06	0.06	0.06	0.00	0.00	0.05	0.11	0.10
	150.01-155	0.11	0.00	0.29	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.08	0.15
	155.01-160	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.10	0.09	0.08	0.08	0.00
	160.01-165	0.00	0.00	0.23	0.00	0.00	0.10	0.00	0.00	0.00	0.09	0.00	0.09	0.09
	165.01-170	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00
	170.01-175	0.00	0.00	0.00	0.10	0.10	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.08
	175.01-180	0.00	0.00	0.00	0.00	0.10	0.00	0.09	0.00	0.00	0.00	0.16	0.00	0.00
	180.01-185	0.12	0.22	0.00	0.10	0.00	0.00	0.00	0.08	0.08	0.00	0.23	0.08	0.08
	185.01-190	0.12	0.33	0.11	0.10	0.20	0.19	0.28	0.09	0.17	0.17	0.00	0.09	0.09
	190.01-197	0.00	0.16	0.08	0.38	0.38	0.21	0.21	0.26	0.19	0.12	0.23	0.20	0.20

3.5 Interstate 80 Drowsy Driving Signage—A Before-After Study

On July 21, 2004, UDOT completed the installation of drowsy driving freeway signage in the west desert of I-80 in both the westbound and eastbound directions. The purpose of these signs is to warn drivers of the adverse affects of driving while extremely fatigued. To determine the effectiveness in reducing the drowsy driving crash rate west of Salt Lake City, a before-after analysis of crash data was conducted.

The "after" time period used in the before-after analysis began August 21, 2004 and terminated December 31, 2005. The one month grace period directly following the completion of installation of the signs was necessary to ensure that long term results of the statistical analysis would not be distorted by short term reaction to the new signs. The ending date of the analysis was the final day of 2005 since no crash data for 2006 was available via the UDOT crash database at the time of the analysis. With the "after" time period confirmed, the "before" timeframe of the analysis was established encompassing the same duration of time beginning August 21, 2002 and ending December 31, 2003.

Following the procedures outlined in Section 3.1, two filters were created to extract the necessary data from the UDOT crash database. The filters were generated based upon four parameters, namely the prime contributor, date, surface conditions, and route number. As in Section 3.2, the prime contributors implemented in this filter were asleep, fatigued, and ill while the date parameter comprised of time intervals from August 21st to December 31st according to the years retrieved. The surface conditions were set to wet or dry with the route number set to I-80.

Once the filters were created, two reports were produced. The selected parameters included in each report were milepoint, date, time, and direction. The report data were then transferred into a spreadsheet, sorted by direction of traveled, and analyzed. Since the drowsy driving signs were installed at different locations according to the direction of travel, the report data were sorted in this manner to facilitate the comparing of drowsy driver sign location with crash locations. The crash data were grouped into bins 5 miles in length and then plotted to visualize the trends produced.

Once the plots were created, the locations of the drowsy driving signs were added to the two figures for comparison purposes.

3.6 Interstate 80 Milepost 54 Rest Area—A Before-After Study

Rest areas typically provide amenities such as restrooms, picnic tables, water fountains, telephone services, and parking for both trucks and recreational vehicles. They offer travelers a place to relax, take photos of scenery, and if necessary, sleep. The Grassy Mountain rest area was constructed at M.P. 54. in 2000. To determine whether this specific rest area has played a role in reducing the drowsy driving crash rate west of Salt Lake City, the researchers conducted a before-after analysis of drowsy driving crash data.

Following the procedures outlined in Section 3.1, the researchers created two filters used to extract the necessary data encompassing the time periods studied. The filters were generated based upon four parameters, namely the prime contributor, date, surface conditions, and route number. The prime contributors used were asleep, fatigued, and ill. The "before" time period incorporated the years 1997-1999 while the "after" timeframe included the years 2001-2003.

3.7 Analysis Procedure Summary

In order to determine which corridors of highway are most prone to drowsy driving crashes, a set procedure for two analyses was outlined in this chapter. The analyses are the *Corridor Analysis by Crash Rate* and the *Corridor Analysis by Number of Crashes*. Each analysis was performed twice—once without regards to direction of travel and once with direction of travel included. Using UDOT's crash database, many types of data were retrieved for use in two before-after crash rate analyses. The results of the corridor analyses are discussed in Chapter 4 while the results of the before-and-after crash rate analyses are presented in Chapter 5. To supplement the before-after studies, Chapter 6 summarizes the findings from Chi-Square analyses.

4 RESULTS

The stretches of roadway most prone to drowsy or fatigue-related crashes are naturally those along the Interstate freeways due to the excessive volume, high speed, and high exposure rate of vehicles using these facilities. The results of the 3-year crash rate analysis yielded various corridors across the state where a crash rate for a section of highway exceeded the critical crash rate. Critical corridors were located on Interstates 15, 70, 80, and 84. In similar fashion to Interstate freeways, many U.S. and S.R. highways have excessive volume, high speed, and high exposure rate of vehicles. U.S. Routes 89 and 91 as well as S.R. 36 contained segments in which the critical crash rate for each highway was exceeded.

The set procedure for analyzing corridors described in Chapter 3 is followed in this chapter for the analysis of drowsy driving crashes. In this chapter results for each critical corridor prone to have drowsy driving crashes are outlined by direction of travel. These results identify the M.P. location of critical corridors in accordance with the method outlined in Section 3.2.2. In addition to discussing the critical corridor results, drowsy driving trends and statistics are provided for each Interstate freeway, U.S. Route, and S.R. highway containing critical corridors. Statistics include: drowsy driving crash consequences, roadway alignment impact, time of day and day of week of drowsy driving crashes, vehicle type and object struck in drowsy driving crashes, and a comparison of the severity of drowsy driving crashes versus all crashes. Lastly, an estimate of how under-reported drowsy driving crashes are in the state of Utah is provided.

4.1 Interstate 15

I-15 is the major north-south facility providing accessibility to many of the most densely populated areas in the state of Utah. Beginning at the Arizona-Utah border to the south and terminating at the Idaho-Utah border to the north, I-15 consists of 400 miles of roadway and is one of the most heavily traveled routes in the state. The 3-year crash rate analysis for the years 2002-2004 indicated that I-15 has nine critical corridors ranging in length from 5 miles to 10 miles. The M.P. and direction of travel for these corridors are summarized in Table 4-1. To better understand the spatial relationship among the segments in Table 4-1, the critical sections have been highlighted in black on a Utah state map as illustrated in Figure 4-1. The sections are labeled according to direction and M.P.

Seven of the nine critical corridors are located in rural areas of which two corridors have both northbound and southbound directions that coincide. The first of these areas is located north of Parowan beginning at M.P. 90 and extending to M.P. 95 near the junction of S.R. 20. The second coinciding critical corridor begins at M.P. 190 north of Scipio and terminates at M.P. 195.

Table 4-1. I-15 Drowsy Driving Corridors

Area and Direction of Travel	**Rural Area**		**Urban Area**	
	Northbound (NB)	**Southbound (SB)**	**Northbound (NB)**	**Southbound (SB)**
Critical Crash Rate per Million VMT	0.286	0.202	0.069	0.055
M.P.	0 - 5	--	--	--
	--	80 - 85	--	--
	90 - 95	90 - 95	--	--
	--	170 - 175	--	--
	190 - 200	185 - 195	--	--
	--	--	--	255 - 260
	--	--	340 - 345	--

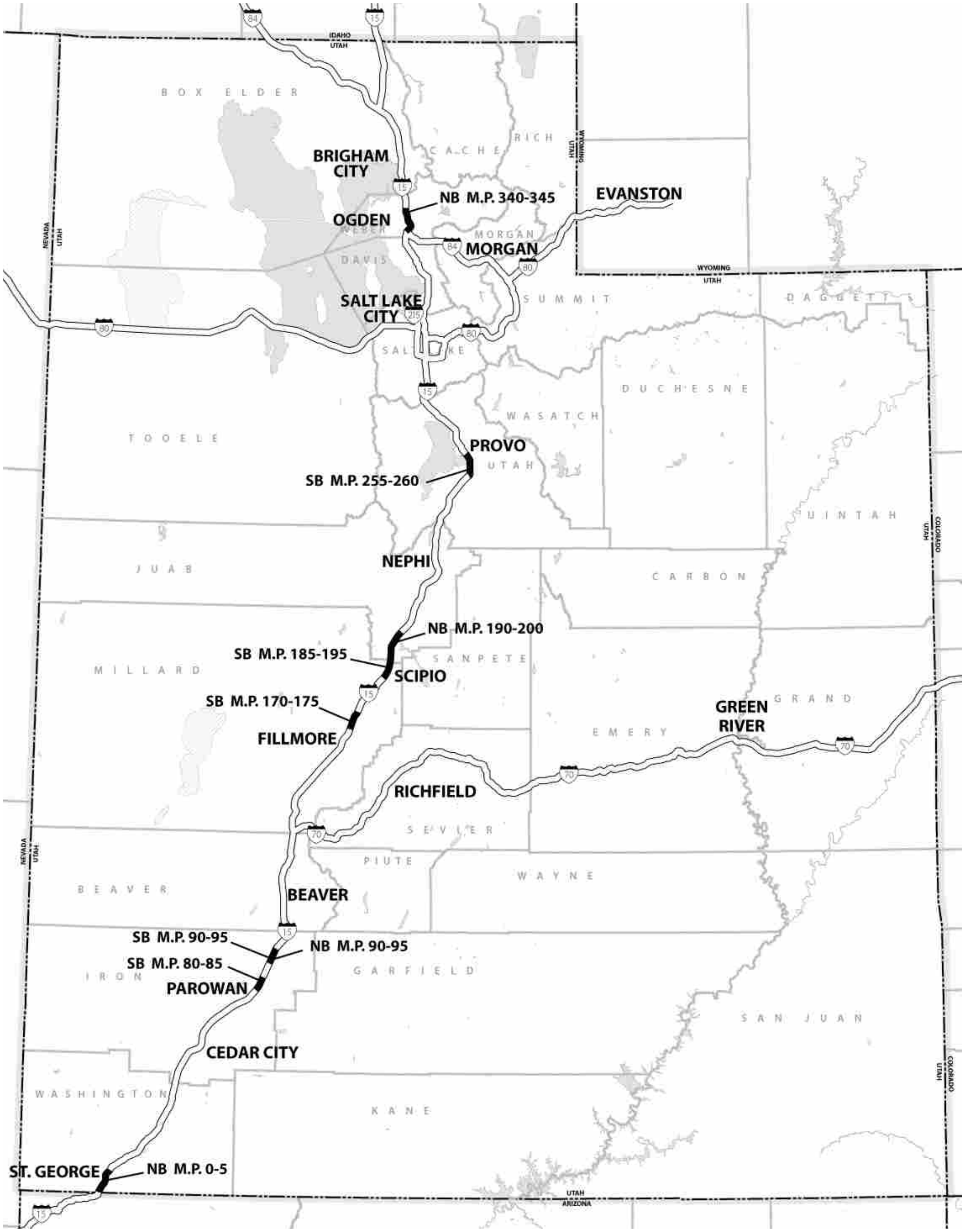


Figure 4-1. I-15 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to the fatigue and drowsy driving crashes. One mile intervals were scanned using a “floating segment” one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. An interval length of one mile may seem large when seeking out specific roadway curves but was necessary due to possible inaccurate reporting of M.P. The corridor from M.P. 0-5 has a curve in the alignment between M.P. 4 and M.P. 5 at which 10 drowsy driving crashes occurred during the years 1992-2004. This particular curve had the greatest number of reported crashes due to a curve in roadway alignment within the drowsy driving corridors. Other curves in the critical corridors which yielded similar results are located near M.P. 94 and 257 (seven crashes in each corridor), M.P. 185 and 197 (eight crashes in each corridor), and M.P. 174 and 342 (nine crashes in each corridor). For comparison purposes, the maximum number drowsy driving crashes at one curve was 17 and occurred twice, once at M.P. 270 and again at M.P. 282.

The two urban area critical corridors are the most northern and southern 5-mile segments of the 90-mile urban corridor traversing Utah, Salt Lake, and Davis counties. It is theorized that these two segments may be critical for the following reason. A relatively large AADT is found in the Springville/Provo area (M.P. 255-260) and the Ogden area (M.P. 340-345) when compared to the rural area AADT’s of I-15, but when compared to the AADT volumes near Salt Lake City, which exceed 100,000 vehicles per day, the two critical corridors do not handle nearly as much daily traffic. This leads to higher crash rates due to lower AADT volumes when other variables are held constant in Equation 3-1.

As mentioned previously, seven of the nine critical corridors are located in rural areas. These corridors are isolated areas between urban cities. The only exception is the northbound corridor consisting of M.P. 0-5, a portion of which passes through the Bloomington area of St. George.

Various statistics pertinent to drowsy driving crashes on I-15 were calculated to serve two purposes. First, to provide the necessary background and understanding of drowsy driving crashes in Utah such that appropriate mitigation techniques may be implemented to reduce drowsy driving crashes and second, to verify, and add to, the drowsy driving statistics reported in the literature. All statistics reported are for the years 1992-2004.

Of the 3,883 drowsy driving crashes on I-15 for the years previously identified, 3,194 (82.3 percent) were reported as single-vehicle crashes while only 689 crashes (17.7 percent) involved two or more vehicles. This coincides well with the literature in which one study indicated that 80 percent of drowsy driving crashes were single-vehicle crashes (Knipling et al. 1994). Of the 3,883 drowsy driving crashes on I-15, 147 fatal crashes (3.8 percent) resulted in 178 fatalities. During the specified years for all types of crashes 977 fatalities occurred, which interprets to 18.2 percent of all fatalities on this facility being related to drowsy driving.

4.1.1 Run-Off-Roadway Crashes and Roadway Alignment

The majority of fatigued drivers ran off the roadway. This is outlined in Table 4-2 by the 75.3 percent of drivers who "Ran Off Roadway-Thru Median," "Ran Off Roadway-Right," and "Ran Off Roadway-Left." During the course of the research, it was determined there may be no apparent difference between "Ran Off Roadway-Thru Median" and "Ran Off Roadway-Left." This difference is based upon how the reporting officer identifies the crash in his or her crash report. Also identified in Table 4-2 is the number of motor-vehicle/motor-vehicle (MV-MV) crashes, which represent almost 14 percent of the drowsy driving crashes.

The roadway alignment can play an important factor in the location of where drowsy driving crashes occur. Table 4-3 breaks down how drowsy driving crashes relate to roadway alignment. As identified in Table 4-3, 2,240 of the 3,883 drowsy driving crashes (57.7 percent) occurred on stretches which were "Straight and Level" while 23.1 percent of the crashes occurred in locations where a curve was present.

Table 4-2. I-15 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Right	1,270	32.8
Ran Off Roadway-Left	1,004	25.9
Ran Off Roadway-Thru Median	650	16.7
MV-MV	541	13.9
MV-Fixed Object	322	8.3
Other Non-Collision	48	1.2
Overturned	30	0.8
MV-Other Object	12	0.3
MV-Animal (Wild)	5	0.1
MV-Bicycle	1	0.0
Total	3,883	100.0

Table 4-3. Drowsy Driving Correlation to Roadway Alignment on I-15.

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	2,240	57.7
Grade Straight	692	17.8
Curve Level	512	13.2
Curve Grade	359	9.2
Hillcrest Straight	45	1.2
Curve Hillcrest	22	0.6
Dip Straight	8	0.2
Dip Curve	5	0.1
Total	3,883	100.0

4.1.2 Time of Day and Day of Week

Drowsy driving crashes occur at all hours of the day, but generally have two peaks—one in the morning and one in the afternoon, both of which are shown in Figure 4-2. The morning peak reached a climax of 319 crashes (8.2 percent of drowsy driving crashes) during the 7 a.m. hour while the afternoon peak was calculated as 69 percent of the morning peak, or 219 crashes (5.6 percent of drowsy driving crashes). The latter peak occurred during the 4 p.m. hour. The hour in which the least number of drowsy driving crashes occurred was the 9 p.m. hour in which only 43 crashes (1.1 percent) occurred. The variation in time of day of the drowsy driving crashes on I-15 coincides extremely well with the data presented in the literature. The timing of these crashes is consistent with the circadian rhythm where typically the morning peak represents the period in which the most drowsy driving crashes occur (NHTSA 1998). Also included in Figure 4-2 is the percentage of total background traffic in Salt Lake City by hour as recorded by UDOT. Although the total percentage of traffic is relatively low in the early morning hours, the percentage of drowsy driving crashes is relatively high by comparison. The trend in total background traffic is relatively consistent with the overall trend in drowsy driving crashes following the 8 a.m. hour. After 5 p.m. in the afternoon, both the drowsy driving crash trend as well as the total background traffic trend decrease until approximately the 9 p.m. hour.

The results indicate that drowsy driving crashes occurred more on weekends than during the week. Figure 4-3 identifies this trend in the data by separating the number of crashes according to the day of the week. Of all drowsy driving crashes, 712 (18.3 percent) occurred on Saturday followed by Sunday with 650 crashes (16.7 percent). On I-15 the day in which the least number of drowsy driving crashes occurred was Wednesday with 480 crashes (12.4 percent). Also identified in Figure 4-3 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. and the percentage of total background traffic by day as recorded by UDOT. These are included to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours as well as comparing drowsy driving crashes to overall daily traffic. Specifically, 35.1 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. For drowsy driving crashes that occurred between the hours of 12 a.m. and 7 a.m., 276 (7.1 percent) took place during the middle of the night or early morning hours on Saturday.

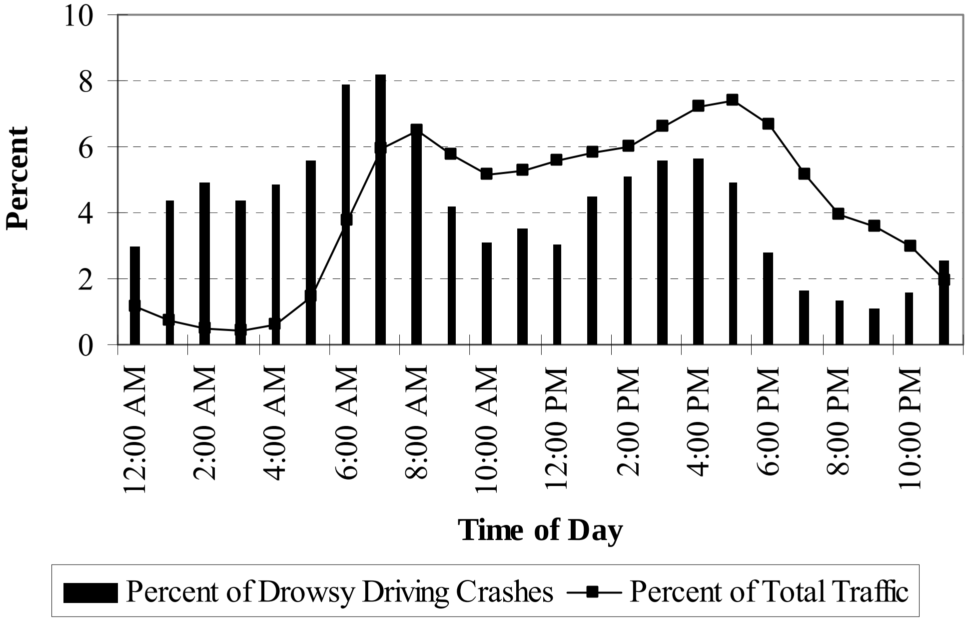


Figure 4-2. Histogram of drowsy driving crashes on I-15.

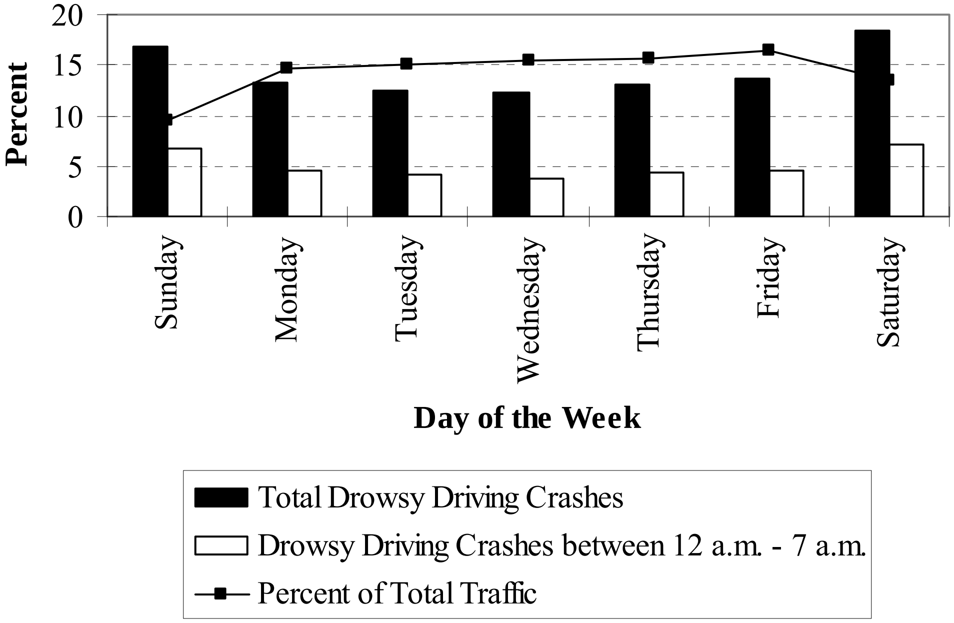


Figure 4-3. Drowsy driving crashes by day of the week on I-15.

4.1.3 Vehicle Type, Object Struck, and Severity

Although truck drivers do travel long distances frequently, they only accounted for slightly more than 4 percent of all vehicles involved in drowsy driving crashes. The most common vehicle type involved in this style of crash on I-15 was the passenger car as denoted in Table 4-4. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 4,001 crashes, 118 more than the total number of crashes. In some cases, the police report indicated that two drivers were responsible for the crash.

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-5. The most frequently hit object on I-15 was a delineator post, which was struck by 19.2 percent of drowsy drivers. In 1 percent of the crashes, the reporting officer cited "Other" for the object struck. The specific objects struck that were recorded as "Other" were not included in the UDOT crash database. No object was struck in 36.3 percent of the crashes.

Table 4-4. Vehicle Types of Drowsy Drivers on I-15

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	3,403	85.1
Truck/Tractor and Trailer	179	4.5
Passenger Car/Pickup with Trailer	65	1.6
Single Unit Enclosed Box (Min. 2 Axles and 6 Tires)	20	0.5
Motorcycle	6	0.1
Dump Truck	4	0.1
Buses—Commercial and School	3	0.1
No Vehicle Type Recorded	321	8.0
Total	4,001	100.0

Table 4-5. Objects Struck by Drowsy Drivers on I-15

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Delineator Post	767	19.2
Fence	374	9.3
Dirt Embankment/Ditch/Berm (Mountainside)	350	8.7
Rigid Barrier (Concrete)	299	7.5
Guardrail	229	5.7
Sign Post	154	3.8
Tree/Shrubbery	100	2.5
Bridge Culvert or Other Highway Structure	66	1.6
Guardrail End Section	53	1.3
Crash Attenuator	51	1.3
Other	39	1.1
Utility Pole	27	0.7
Traffic Channelization Device	19	0.5
Building/Other Structure (Wall)	6	0.1
Wild Animal	5	0.1
Snow Embankment	4	0.1
Curb or Safety Island	3	0.1
Mailbox or Fire Hydrant	3	0.1
No Object Struck	1,452	36.3
Total	4,001	100.0

The UDOT crash database includes license plate data, specifically the state in which a vehicle is registered, dating back to the year 1996. To determine if the distribution of drowsy driving crashes on I-15 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis encompassed 2,850 crashes. Utah residents represented 66.6 percent of drivers responsible for the fatigue-related crashes in this study while 33.3 percent were recorded as out-of-state drivers. Vehicle license plates were not recorded in 0.1 percent of the crashes.

One interesting question to be answered through the research was whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. Table 4-6 is divided into two parts in order to answer this question. The first part indicates a percentage for each severity type among solely persons involved in drowsy driving crashes while the second part gives a percentage for each severity level generated from all persons involved in all crashes on I-15 from 1992-2004. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall with fewer persons able to escape such crashes with "No Injury."

Table 4-6. Severity of Drowsy Driving Crashes Versus All Crashes on I-15

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	3.8	0.9
Broken Bones or Bleeding Wound	20.9	6.4
Bruises and Abrasions	16.1	8.0
Possible Injury	14.9	20.5
No Injury	44.3	64.2
Total	100.0	100.0

4.1.4 Directional Distribution

I-15 traverses an array of topography from a hot desert in the south to rugged mountainous regions in the north parts of Utah. For this reason the trends in directional distribution of drowsy driving crashes were determined. Of the 3,883 drowsy driving crashes, 54.4 percent occurred in the northbound direction while the remaining 45.6 percent were in the southbound direction. Figure 4-4 illustrates the directional distribution from M.P. 0 to M.P. 200 while Figure 4-5 shows the same trends from M.P. 200 to M.P. 401. From M.P. 90 to M.P. 110, 152 northbound crashes took place while 71 occurred in the southbound direction; therefore, twice as many northbound crashes occurred as southbound crashes. From Figure 4-5, it can be seen that the 5-mile section of highway with the most drowsy driving crashes from 1992-2004 was between M.P. 280 to M.P. 285 near the city of Lehi.

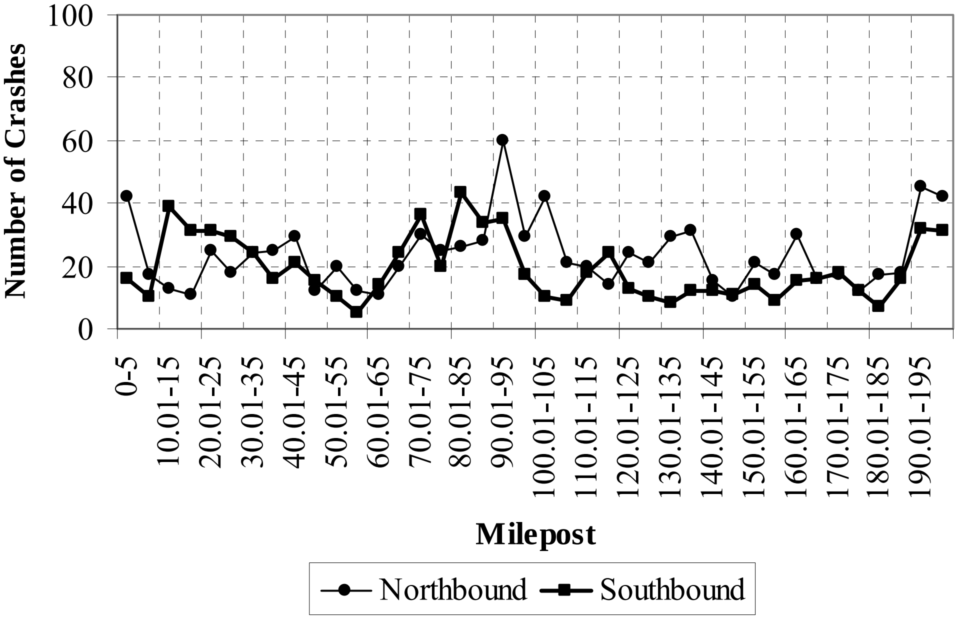


Figure 4-4. Directional distribution of drowsy driving crashes on I-15 from M.P. 0 to M.P. 200.

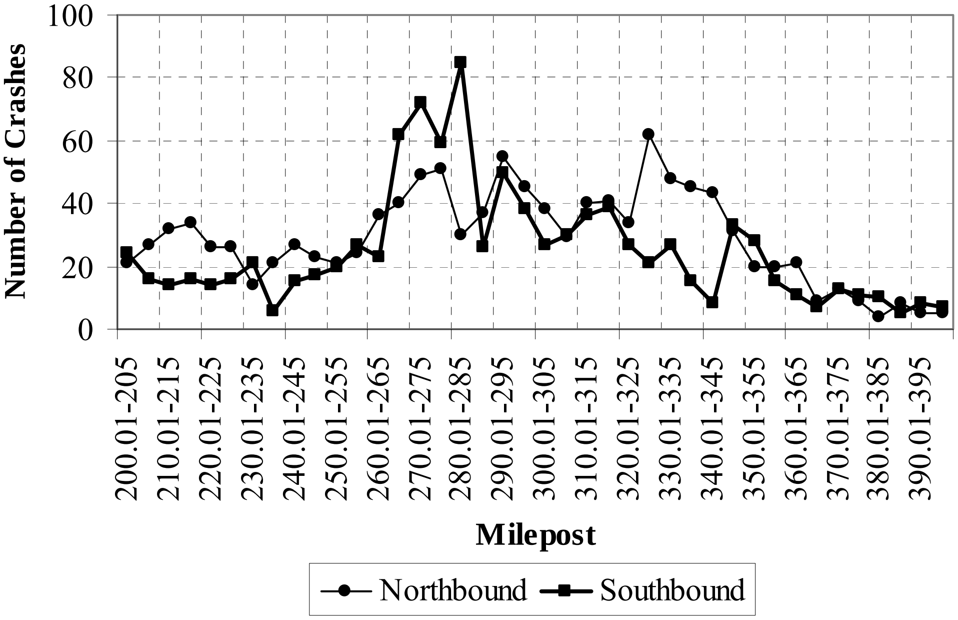


Figure 4-5. Directional distribution of drowsy driving crashes on I-15 from M.P. 200 to M.P. 401.

4.2 Interstate 70

I-70 is one of two east-west facilities providing accessibility to many of the rural areas of Utah. Beginning 20 miles north of Beaver, Utah and terminating at the Colorado-Utah border approximately 25 miles west of Grand Junction, Colorado, I-70 consists of 232 miles of highway. The 3-year crash rate analysis for the years 2002-2004 indicated that I-70 has seven critical corridors ranging in length from 5 miles to 10 miles. Table 4-7 identifies the M.P. and direction of travel for these corridors while Figure 4-6 graphically illustrates the corridors by their direction and M.P. on a Utah state map. As indicated previously, I-70 does not traverse an urbanized area. None of the three eastbound critical corridors coincide with westbound corridors although a change in direction does occur at M.P. 135 as well as at M.P. 160 near the city of Green River.

Table 4-7. I-70 Drowsy Driving Corridors

Area and Direction of Travel	Rural Area	
	Eastbound (EB)	**Westbound (WB)**
Critical Crash Rate per Million VMT	0.482	0.360
M.P.	--	20 - 25
	--	95 - 100
	--	125 - 135
	135 - 140	--
	155 - 160	--
	--	160 - 165
	225 - 232	--

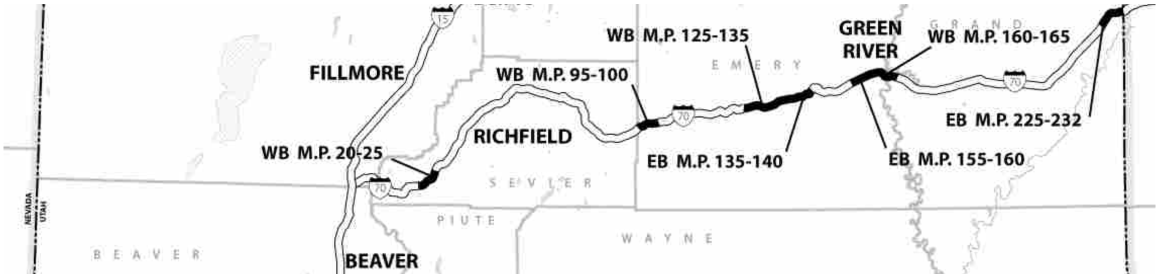


Figure 4-6. I-70 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to fatigue and drowsy driving crashes. One mile intervals were scanned using a "floating segment" one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. Only two curves out of the seven corridors had at least seven drowsy driving crashes. The corridor from M.P. 20-25 has one curve in the alignment near M.P. 20 at which seven drowsy driving crashes occurred during the years 1992-2004. This value was only superseded between M.P. 228 and M.P. 229 where 10 crashes occurred. This particular curve had the greatest number of reported crashes due to a curve in roadway alignment within the drowsy driving corridors on I-70. For comparison purposes, the maximum number drowsy driving crashes at one curve was 10, which occurred at the location previously described as well as between M.P. 32 and M.P. 33.

Various drowsy driving statistics were calculated for I-70 spanning the years 1992-2004. During this time period, 864 drowsy driving crashes (96.1 percent) were reported as single-vehicle crashes while only 35 crashes (3.9 percent) involved two or more vehicles. Of the 899 drowsy driving crashes, 75 crashes (8.3 percent) were identified as fatal resulting in 80 fatalities. Considering only 179 fatalities occurred on I-70 for all types of crashes, drowsy driving fatalities represented 44.7 percent of all fatalities on this facility.

4.2.1 Run-Off-Roadway Crashes and Roadway Alignment

The majority of fatigued drivers on I-70 were involved in run-off-road crashes. This is outlined in Table 4-8 by the 86.9 percent of drivers who "Ran Off Roadway-Thru Median", "Ran Off Roadway-Right", and "Ran Off Roadway-Left." Independent of run-off-road crashes, 65 (7.5 percent) and 29 (3.2 percent) hit a fixed object and another vehicle, respectively. Roadway alignment plays an important role in the location of drowsy driving crashes. Table 4-9 breaks down how drowsy driving crashes related to roadway alignment for the years 1992-2004. Of the 899 drowsy driving crashes, 418 (46.5 percent) occurred on stretches which were "Straight and Level" while 34.7 percent of the crashes occurred in locations where a curve was present. Overall, 65.0 percent of the crashes were on a straight portion of highway alignment.

Table 4-8. I-70 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Left	350	38.9
Ran Off Roadway-Right	331	36.9
Ran Off Roadway-Thru Median	100	11.1
MV-Fixed Object	65	7.2
MV-MV	29	3.2
Overturned	16	1.8
Other Non-Collision	5	0.6
MV-Animal (Wild)	2	0.2
MV-Other Object	1	0.1
Total	899	100.0

Table 4-9. Drowsy Driving Correlation to Roadway Alignment on I-70.

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	418	46.5
Curve Grade	196	21.8
Grade Straight	156	17.4
Curve Level	103	11.5
Curve Hillcrest	12	1.3
Hillcrest Straight	10	1.1
Dip Straight	3	0.3
Dip Curve	1	0.1
Total	899	100.0

4.2.2 Time of Day and Day of Week

Two peaks are generally characteristic of drowsy driving crashes—one in the morning and one in the afternoon. The morning peak, which climaxed at 109 crashes, is easily discernable in Figure 4-7 whereas the afternoon peak is practically nonexistent.

The afternoon peak occurred during both the 12 p.m. hour and 3 p.m. hour. Five percent of all drowsy driving crashes occurred in each of these two hours. The hour in which the least overall percentage of drowsy driving crashes occurred was the 10 p.m. hour, which had only 0.9 percent of all drowsy driving crashes on I-70. Also included in Figure 4-7 is the percentage of total background traffic by hour, which can be used to compare with the percentage of drowsy driving crashes. Although the total percentage of traffic is relatively low in the early morning hours, the percentage of drowsy driving crashes is relatively high by comparison. In the afternoon hours, a large difference between the total percentage of drowsy driving crashes and the total background traffic can be seen. Overall, the drowsy driving crash and traffic trends identified in Figure 4-7 are typical of major facilities such as I-70. The traffic data in Figure 4-7 was not collected on I-70, but rather adapted from the *Traffic Monitoring Guide* (FHWA 2001) as typical hourly data on a rural highway.

Although drowsy driving crashes typically occur more on weekends than during the week, the drowsy driving crashes on I-70 remained relatively constant throughout the week as indicated in Figure 4-8. Of all drowsy driving crashes, 149 (16.6 percent) occurred on Saturday followed by Monday with 133 crashes (14.8 percent). On I-70 the days in which the least number of drowsy driving crashes occurred were Tuesday and Thursday with 121 crashes (13.5 percent). Also identified in Figure 4-8 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. This is included in the figure to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours. Specifically, 29.8 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. For drowsy driving crashes that occurred between the hours of 12 a.m. and 7 a.m., 48 (5.3 percent) took place during the middle of the night or early morning hours on Saturday. Similar to Figure 4-7, Figure 4-8 also contains the percentage of total background traffic by day for comparison purposes with the percentage of drowsy driving crashes.

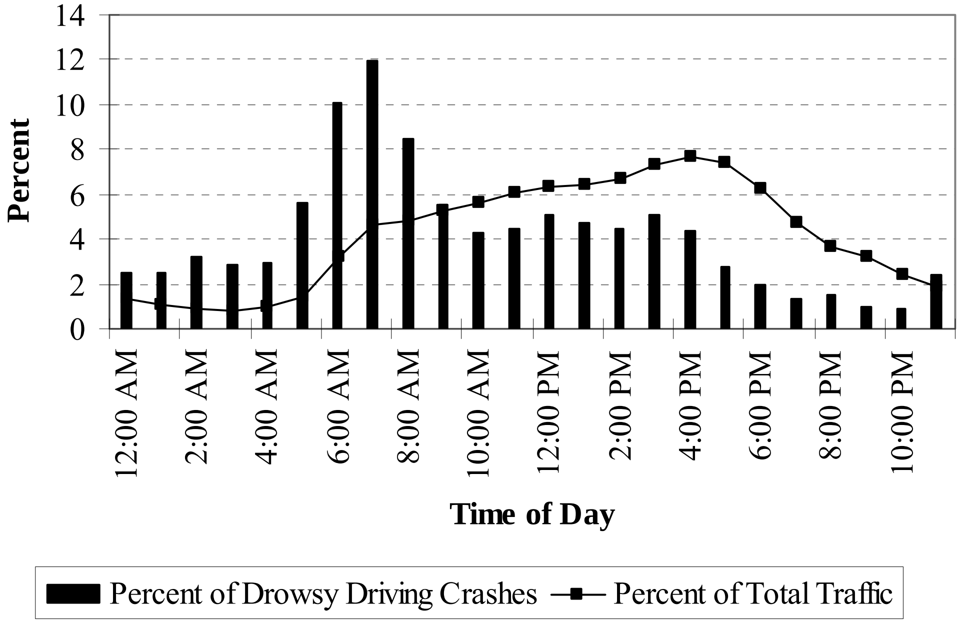


Figure 4-7. Histogram of drowsy driving crashes on I-70.

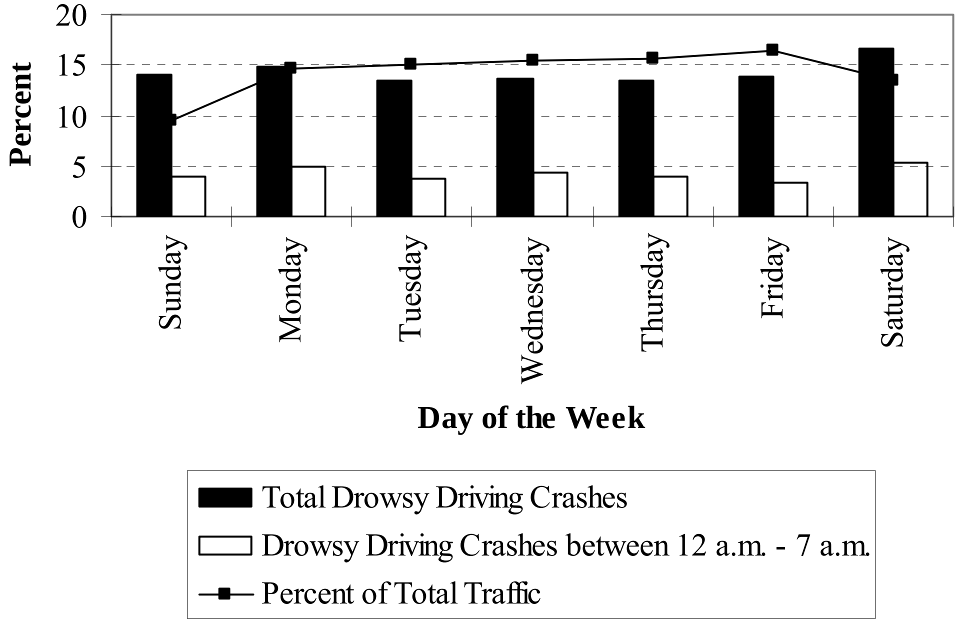


Figure 4-8. Drowsy driving crashes by day of the week on I-70.

4.2.3 Vehicle Type, Object Struck, and Severity

Semi-trucks represented approximately 6 percent of all vehicles involved in drowsy driving crashes on I-70. The most common vehicle type involved in this style of crash was the passenger car as outlined in Table 4-10, which was involved in nearly 82 percent of all drowsy driving crashes on I-70. No vehicle type was reported in 10 percent of the drowsy driving crashes on this facility. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 918 crashes, 19 more than the total number of crashes. In some cases, the police report indicated that two drivers were responsible for the crash.

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-11. The first and second most frequently hit objects were delineator post and dirt embankment, which were struck by 28.2 and 17.2 percent of drowsy drivers, respectively. Guardrails and fences were each hit in more than 6 percent of the crashes while the remaining 10 percent of vehicles struck other objects.

Table 4-10. Vehicle Types of Drowsy Drivers on I-70

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	751	81.8
Truck/Tractor and Trailer	53	5.8
Passenger Car/Pickup with Trailer	11	1.2
Single Unit Enclosed Box (Min. 2 Axles and 6 Tires)	7	0.8
Motorcycle	4	0.4
No Vehicle Type Recorded	92	10.0
Total	918	100.0

Table 4-11. Objects Struck by Drowsy Drivers on I-70

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Delineator Post	259	28.2
Dirt Embankment/Ditch/Berm (Mountainside)	158	17.2
Guardrail	62	6.8
Fence	58	6.3
Bridge Culvert or Other Highway Structure	20	2.2
Sign Post	19	2.1
Rigid Barrier (Concrete)	18	2.0
Guardrail End Section	13	1.4
Crash Attenuator	5	0.5
Other	3	0.3
Tree/Shrubbery	3	0.3
Utility Pole	3	0.3
Building/Other Structure (Wall)	2	0.2
Wild Animal	2	0.2
Curb or Safety Island	1	0.1
Traffic Channelization Device	1	0.1
No Object Struck	291	31.8
Total	918	100.0

To determine if the distribution of drowsy driving crashes on I-70 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis incorporated 687 crashes. Utah residents represented only 16.4 percent of drivers responsible for the fatigue-related crashes in this study while 83.4 percent were recorded as out-of-state drivers. Vehicle license plates were not recorded in 0.1 percent of the crashes.

The data in Table 4-12 are provided to determine whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. The first part of the table indicates a percentage for each severity type among solely persons involved in drowsy driving crashes while the second part gives a percentage for each severity level generated from all persons involved in all crashes on I-70 from 1992-2004. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall with fewer persons able to escape such crashes with "No Injury." The top two severity levels, "Fatal" and "Broken Bones or Bleeding Wounds," accounted for 34.9 percent of all persons involved in drowsy driving crashes, nearly twice that recorded for the same severity levels for all persons in all crashes on I-70.

Table 4-12. Severity of Drowsy Driving Crashes Versus All Crashes on I-70

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	8.4	3.1
Broken Bones or Bleeding Wound	26.5	15.3
Bruises and Abrasions	16.3	11.2
Possible Injury	12.4	9.9
No Injury	36.4	60.5
Total	100.0	100.0

4.2.4 Directional Distribution

The trends in directional distribution of drowsy driving crashes were determined for I-70. Of the 899 drowsy driving crashes, 60.4 percent occurred heading eastbound while the remaining 39.6 percent were in the westbound direction. Figure 4-9 illustrates the directional distribution from M.P. 0 to M.P. 232. For various sections of this facility the drowsy driving trends are consistent, but in two locations the trends vary greatly. In the 40-mile corridor from M.P. 125 to M.P. 165 west of Green River, 130 eastbound crashes took place over the 13 years from 1992-2004 while 61 crashes occurred in the westbound direction, thus more than twice as many drowsy driving crashes occurred heading eastbound. Similar results between M.P. 200 and M.P. 232 are shown in Figure 4-9 as 2.5 times as many crashes occurred in the eastbound direction as the westbound direction of travel.

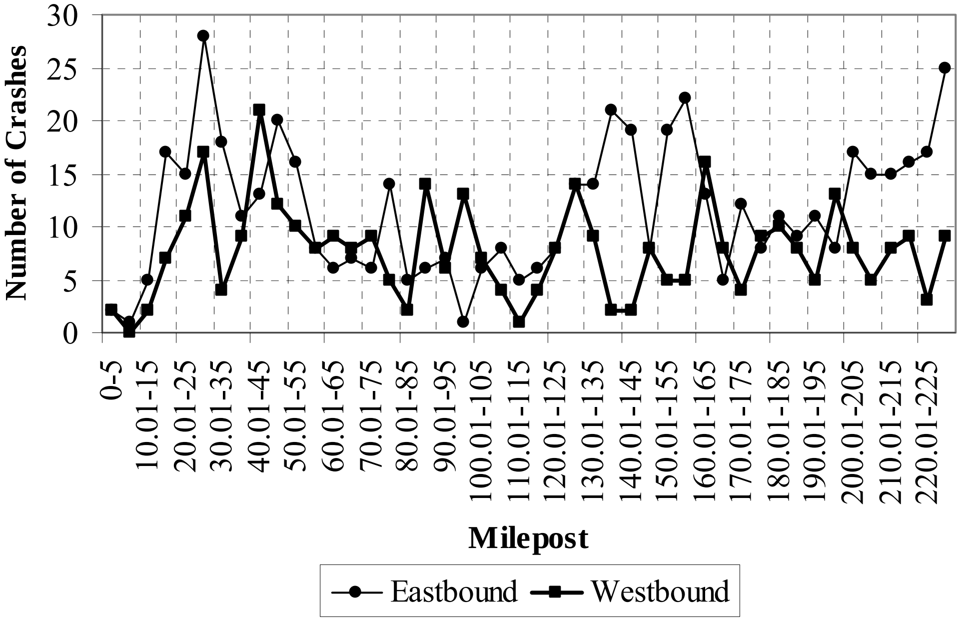


Figure 4-9. Directional distribution of drowsy driving crashes on I-70.

4.3 Interstate 80

I-80 traverses the state of Utah beginning at the Nevada-Utah border with the city of Wendover and terminating 196 miles to the east at the Wyoming-Utah border just a few miles west of Evanston, Wyoming. A short section of I-80, approximately 3 miles in length, coincides with I-15 near downtown Salt Lake City. All drowsy driving crashes which occurred on this short segment of highway were recorded with the I-15 data. The 3-year crash rate analysis for the years 2002-2004 indicated that I-80 has seven critical corridors all of which are 5 miles in length. Table 4-13 identifies the M.P. and direction of travel for these corridors while Figure 4-10 graphically illustrates the corridors on a Utah state map. All seven critical corridors are located in the desert west of Salt Lake City. None of the three eastbound critical corridors coincide with westbound corridors although at M.P. 35 a change in direction of critical corridors does occur.

Table 4-13. I-80 Drowsy Driving Corridors

Area and Direction of Travel	Rural Area		Urban Area	
	Eastbound (EB)	Westbound (WB)	Eastbound (EB)	Westbound (WB)
Critical Crash Rate per Million VMT	0.307	0.175	0.077	0.047
M.P.	--	5 - 10	--	--
	--	20 - 25	--	--
	--	30 - 35	--	--
	35 - 40	--	--	--
	45 - 50	--	--	--
	60 - 65	--	--	--
	--	70 - 75	--	--

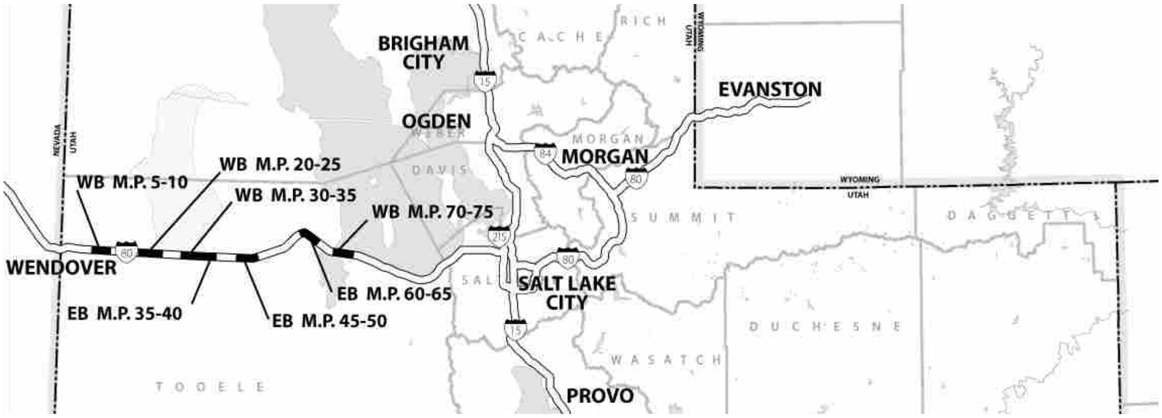


Figure 4-10. I-80 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to fatigue and drowsy driving crashes. One mile intervals were scanned using a "floating segment" one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. Only one curve out of the seven corridors had at least eight drowsy driving crashes. The curve is near M.P. 60 and had eight crashes during the years 1992-2004. For comparison purposes, the maximum number drowsy driving crashes at one curve was 10, which occurred just east of M.P. 132.

The first four critical corridors beginning at M.P. 5 and terminating at M.P. 40 encompass the Bonneville Salt Flats. This section of I-80 is extremely flat, straight, and somewhat monotonous. Very few services where drivers can rest, such as gas stations and restaurants, are located in the first 95 miles between Wendover on the Nevada-Utah border and the junction of S.R. 36 with I-80 north of Tooele. Although the monotony of driving through the Bonneville Salt Flats is only one of a few possible reasons as to why many drivers fall asleep behind the wheel, it does seem to be the most reasonable explanation for drowsy driving in the area.

Various drowsy driving statistics were calculated for I-80 spanning the years 1992-2004. During this time period, 818 drowsy driving crashes (88.7 percent) were reported as single-vehicle crashes while only 104 crashes (11.3 percent) involved two or more vehicles. Of the 922 drowsy driving crashes, 57 crashes (6.2 percent) were identified as fatal resulting in 62 fatalities. I-80 had 335 fatalities occur in all types of crashes; therefore, drowsy driving fatalities represented 18.5 percent of all fatalities on this facility.

4.3.1 Run-Off-Roadway Crashes and Roadway Alignment

The majority of fatigued drivers on I-80 were involved in run-off-roadway crashes. This is evident in Table 4-14 by the 79.7 percent of drivers who "Ran Off Roadway-Thru Median", "Ran Off Roadway-Right", and "Ran Off Roadway-Left." In 17.2 percent of the drowsy driving crashes, the driver either struck a fixed object or collided with another vehicle. In approximately 2 percent of the crashes, the vehicle overturned. Roadway alignment plays an important role in the location of drowsy driving crashes. Table 4-15 identifies how drowsy driving crashes related to roadway alignment for the years 1992-2004. Of the 922 drowsy driving crashes, 582 (63.1 percent) occurred on stretches which were "Straight and Level" while 24.9 percent of the crashes occurred in locations where a curve was present.

Table 4-14. I-80 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Left	309	33.5
Ran Off Roadway-Right	309	33.5
Ran Off Roadway-Thru Median	117	12.7
MV-Fixed Object	79	8.6
MV-MV	79	8.6
Overturned	18	1.9
Other Non-Collision	8	0.9
MV-Other Object	2	0.2
MV-Bicycle	1	0.1
Total	922	100.0

Table 4-15. Drowsy Driving Correlation to Roadway Alignment on I-80.

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	582	63.2
Curve Level	118	12.8
Curve Grade	105	11.4
Grade Straight	99	10.7
Hillcrest Straight	10	1.1
Curve Hillcrest	5	0.5
Dip Curve	2	0.2
Dip Straight	1	0.1
Total	922	100.0

4.3.2 Time of Day and Day of Week

Two peaks are generally characteristic of drowsy driving crashes—one in the morning and one in the afternoon. The morning peak, which climaxed at 88 crashes and occurred during the 6 a.m. hour, is easily discernable in Figure 4-11. The afternoon peak, although not as easy to discern as the morning peak, was 46 crashes during the 2 p.m. hour. The timing of the peaks is once again consistent with the circadian rhythm (Horne and Reyner 1995). The hour in which the least overall percentage of drowsy driving crashes occurred was the 8 p.m. hour, which had only 1.0 percent of all drowsy driving crashes on I-80. Also included in Figure 4-11 is the percentage of total background traffic by hour as recorded by UDOT, which can be used to compare with the percentage of drowsy driving crashes. The traffic data was collected on I-80 west of downtown Salt Lake City and illustrates well the difference between the percentage of traffic during both the early morning hours and the late afternoon hours with the percentage of drowsy driving in those time periods. Although the total percentage of traffic is relatively low in the early morning hours, the percentage of drowsy driving crashes is relatively high by comparison. In the afternoon and evening hours, a large difference between the total percentage of drowsy driving crashes and the total background traffic can be identified during the 4 p.m. and 8 p.m. hours, respectively. Overall, the drowsy driving crash and traffic trends identified in Figure 4-11 are typical of major facilities such as I-80.

Drowsy driving crashes typically occur more on weekends than during the week. Figure 4-12 indicates that for the years studied more drowsy driving crashes took place on I-80 on Saturdays and Sundays than occurred during the week. Of all drowsy driving crashes, 182 (19.7 percent) occurred on Saturday followed by Sunday with 169 crashes (18.3 percent). On I-80 the day in which the least number of drowsy driving crashes occurred was Wednesday with 101 crashes (11.0 percent). Also identified in Figure 4-12 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. This is included in the figure to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours. Specifically, 38.1 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. Of all drowsy driving crashes, 74 (8.0 percent) took place during the middle of the night or early morning hours on Saturday. Similar to Figure 4-11, Figure 4-12 also contains the percentage of total background traffic as recorded by UDOT by day for comparison purposes with the percentage of drowsy driving crashes.

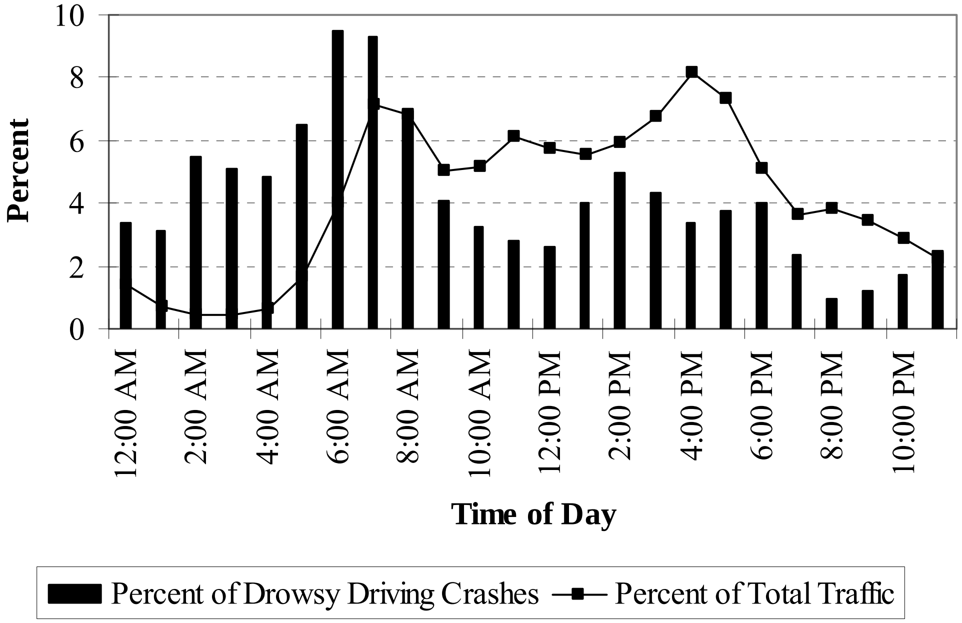


Figure 4-11. Histogram of drowsy driving crashes on I-80.

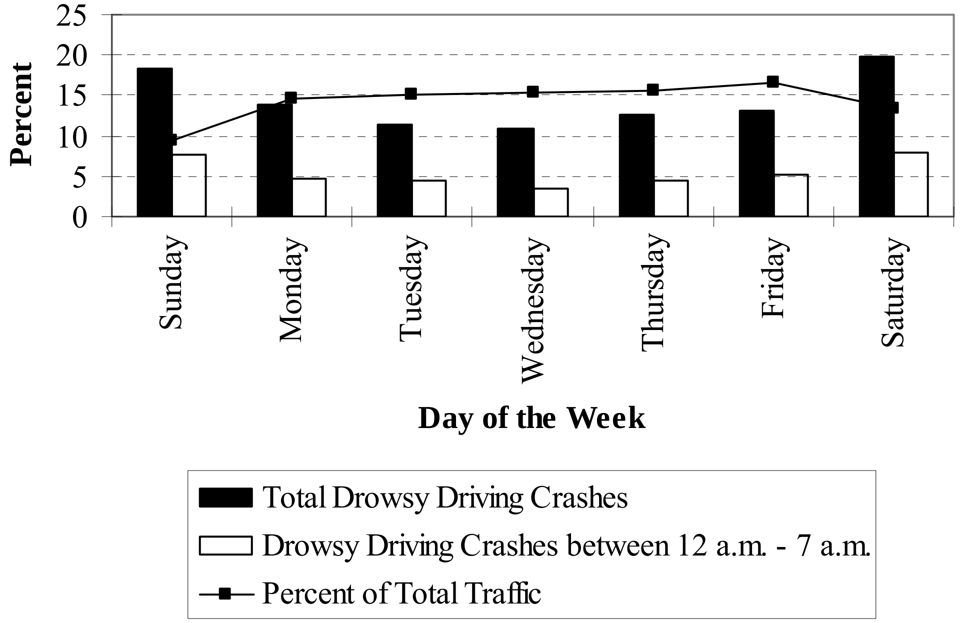


Figure 4-12. Drowsy driving crashes by day of the week on I-80.

4.3.3 Vehicle Type, Object Struck, and Severity

Semi-trucks represented approximately 6 percent of all vehicles involved in drowsy driving crashes on I-80. The most common vehicle type involved in this style of crash was the passenger car, which was involved in more than 84 percent of the drowsy driving crashes as outlined in Table 4-16. In 69 drowsy driving crashes (7.3 percent), no vehicle type was recorded The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 943 crashes, 21 more than the total number of crashes. In some cases, the police report indicated that two drivers were responsible for the crash.

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-17. The first and second most frequently hit objects were delineator post and dirt embankment, which were struck by 24.8 and 9.5 percent of drowsy drivers, respectively. Other frequently hit objects included concrete barriers, fences, and guardrails. No object was struck in more than 40 percent of the crashes.

Table 4-16. Vehicle Types of Drowsy Drivers on I-80

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	795	84.3
Truck/Tractor and Trailer	60	6.4
Passenger Car/Pickup with Trailer	10	1.1
Single Unit Enclosed Box (Min. 2 Axles and 6 Tires)	6	0.6
Buses—Commercial and School	1	0.1
Concrete Mixer	1	0.1
Motorcycle	1	0.1
No Vehicle Type Recorded	69	7.3
Total	943	100.0

Table 4-17. Objects Struck by Drowsy Drivers on I-80

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Delineator Post	234	24.8
Dirt Embankment/Ditch/Berm (Mountainside)	90	9.5
Rigid Barrier (Concrete)	58	6.2
Fence	51	5.4
Guardrail	37	3.9
Sign Post	33	3.5
Other	14	1.7
Bridge Culvert or Other Highway Structure	7	0.7
Tree/Shrubbery	7	0.7
Crash Attenuator	6	0.6
Guardrail End Section	6	0.6
Utility Pole	5	0.5
Traffic Channelization Device	3	0.3
Building/Other Structure (Wall)	2	0.2
Curb or Safety Island	1	0.1
No Object Struck	389	41.3
Total	943	100.0

To determine if the distribution of drowsy driving crashes on I-80 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis incorporated 668 crashes. Utah residents represented only 64.8 percent of drivers responsible for the fatigue-related crashes in this study while 35.2 percent were recorded as out-of-state drivers.

The data in Table 4-18 can be used to determine whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall. The top two severity levels, “Fatal” and “Broken Bones or Bleeding Wounds,” accounted for 26.8 percent of all persons involved in drowsy driving crashes, nearly three times that recorded for the same severity levels for all persons in all crashes on I-80.

Table 4-18. Severity of Drowsy Driving Crashes Versus All Crashes on I-80

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	6.0	1.6
Broken Bones or Bleeding Wound	20.8	8.4
Bruises and Abrasions	19.7	9.2
Possible Injury	13.5	15.8
No Injury	40.0	65.0
Total	100.0	100.0

4.3.4 Directional Distribution

I-80 is unique among the Interstate freeways in Utah due to the geographical areas which it traverses. To determine the trends in directional distribution for drowsy driving crashes, Figure 4-13 is provided. Drowsy driving crashes have been an increasing concern in the desert west of Salt Lake City over the past few years. Figure 4-13 illustrates that more drowsy driving crashes occurred in the westbound direction of travel from M.P. 0 to M.P. 30 than eastbound. From M.P. 30 to the urban boundary of Salt Lake City at M.P. 110, a large increase in drowsy driving crashes occurred. Of the 922 drowsy driving crashes, 63.6 percent were heading eastbound while the remaining 36.4 percent were driving westbound. The possible reasons for these trends are discussed in Chapter 5. The directional distribution of drowsy driving crashes was approximately the same in the area of Salt Lake City, but quickly separated near M.P. 130. Near the Utah-Wyoming border, a large increase in drowsy driving crashes occurred in the last seven miles of highway for eastbound drivers between M.P. 190 and M.P. 197. In this section, 38 drowsy driving crashes occurred heading eastbound while only eight crashes occurred in the westbound direction over the 13 years of data analyzed.

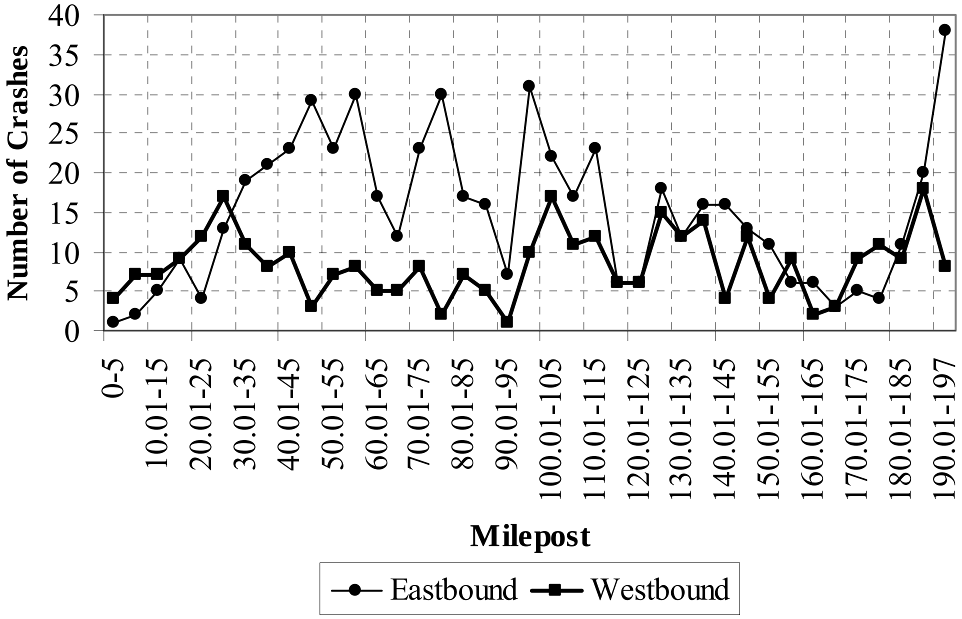


Figure 4-13. Directional distribution of drowsy driving crashes on I-80.

4.4 Interstate 84

Interstate 84 (I-84) begins at the Idaho-Utah border 40 miles north of the City of Tremonton and terminates 120 miles to the east at the junction of I-80 approximately 30 miles from the Wyoming-Utah border. Although I-84 is 120 miles in length, a 40 mile stretch from Tremonton to Ogden coincides with I-15. Therefore, all drowsy driving crashes which occurred on the I-15/I-84 corridor were recorded as part of the I-15 data. The 3-year crash rate analysis for the years 2002-2004 indicated that I-84 has two critical corridors. Table 4-19 identifies the M.P. and direction of travel for these corridors while Figure 4-14 graphically illustrates the corridors on a Utah state map. The two critical corridors coincide with each other from M.P. 110 to M.P. 115. No curves in the roadway alignment were identified in this critical corridor.

M.P. 110-115 is located near the small city of Henefer east of Morgan. I-84 in this particular area is rural and winds through some small canyons before entering a flatland just before M.P. 115. The speed limit in this area is 70 mph.

Table 4-19. I-84 Drowsy Driving Corridors

Area and Direction of Travel	Rural Area	
	Eastbound (EB)	Westbound (WB)
Critical Crash Rate per Million VMT	0.231	0.135
M.P.	110 - 115	110 - 115

Figure 4-14. I-84 drowsy driving corridors.

Various drowsy driving statistics were calculated for I-84 across the years 1992-2004. During this time period, 143 drowsy driving crashes (89.4 percent) were reported as single-vehicle crashes, while 17 crashes (10.6 percent) involved two or more vehicles. Of the 160 drowsy driving crashes, 6 crashes (3.8 percent) were identified as fatal resulting in 10 fatalities. Considering 59 fatalities occurred on I-84 for all types of crashes, drowsy driving fatalities represented 16.9 percent of all fatalities on this facility.

4.4.1 Run-Off-Roadway Crashes and Roadway Alignment

The majority of fatigued drivers on I-84 were involved in run-off-road crashes. This is evident in Table 4-20 by the 77.5 percent of drivers who “Ran Off Roadway-Thru Median”, “Ran Off Roadway-Right”, and “Ran Off Roadway-Left.” Besides run-off-road crashes, 7.5 percent of crashes resulted in one motor-vehicle colliding with another motor-vehicle.

Roadway alignment as indicated previously plays an important role in the location of drowsy driving crashes. Table 4-21 identifies how drowsy driving crashes related to roadway alignment for the years 1992-2004 on I-84. Of the 160 drowsy driving crashes, 70 (43.8 percent) occurred on stretches which were “Straight and Level” while 40.6 percent of the crashes occurred in locations where a curve was present.

Table 4-20. I-84 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Right	55	34.3
Ran Off Roadway-Left	43	26.9
Ran Off Roadway-Thru Median	26	16.3
MV-Fixed Object	15	9.4
MV-MV	12	7.5
Overturned	5	3.1
MV-Other Object	3	1.9
MV-Pedestrian	1	0.6
Total	160	100.0

Table 4-21. Drowsy Driving Correlation to Roadway Alignment on I-84.

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	70	43.7
Curve Level	37	23.1
Curve Grade	24	15.0
Grade Straight	22	13.8
Curve Hillcrest	3	1.9
Hillcrest Straight	3	1.9
Dip Curve	1	0.6
Total	160	100.0

4.4.2 Time of Day and Day of Week

Generally, two peaks are characteristic of drowsy driving crashes—one in the morning and one in the afternoon. The drowsy driving crashes on I-84 did not follow the typical trend. The afternoon peak, which climaxed at 15 crashes and occurred during the 3 p.m. hour, is easily discernable in Figure 4-15. The morning time period did not have a specific peak hour as drowsy driving crashes were spread out. Also included in Figure 4-15 is the percentage of total background traffic by hour, which can be used to compare with the percentage of drowsy driving crashes. Although the total percentage of traffic is relatively low in the early morning hours, the percentage of drowsy driving crashes is relatively high by comparison. The traffic data in Figure 4-15 was not collected on I-84, but rather adapted from the *Traffic Monitoring Guide* (FHWA 2001) as typical hourly data on a rural highway.

Drowsy driving crashes typically occur more on weekends than during the week. Figure 4-16 indicates that for the years studied the most drowsy driving crashes took place on I-84 on Saturdays. Of all drowsy driving crashes, 34 (21.3 percent) occurred on Saturday followed by Sunday with 21 crashes (14.4 percent). On I-84 the day in which the least number of drowsy driving crashes occurred was Monday with 16 crashes (10.0 percent). Also identified in Figure 4-16 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. This is included in the figure to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours. Specifically, 34.4 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. Of all drowsy driving crashes, 11 (6.9 percent) took place during the middle of the night or early morning hours on Saturday. Similar to Figure 4-15, Figure 4-16 also contains the percentage of total background traffic by day for comparison purposes with the percentage of drowsy driving crashes.

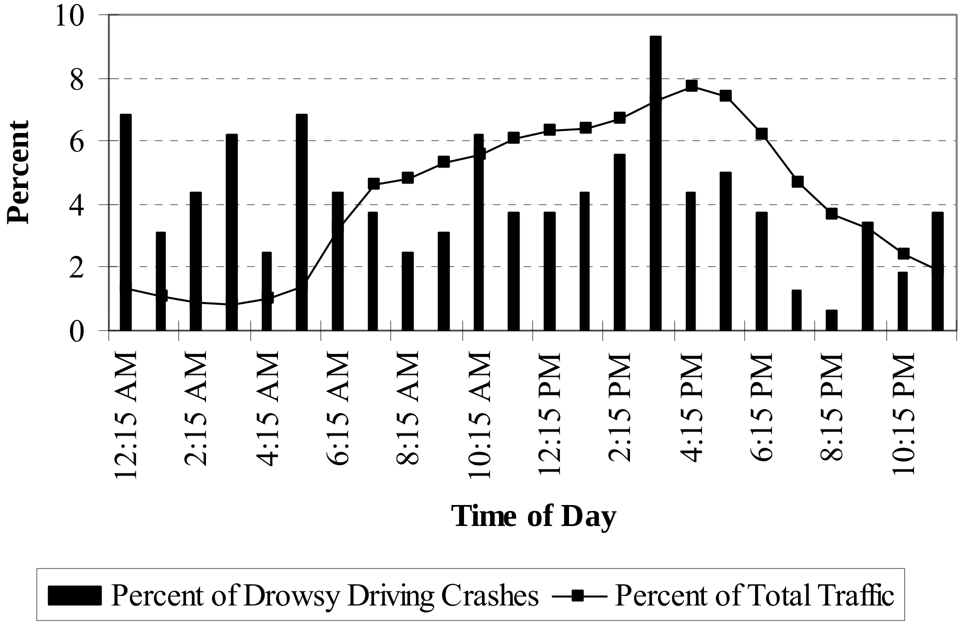


Figure 4-15. Histogram of drowsy driving crashes on I-84.

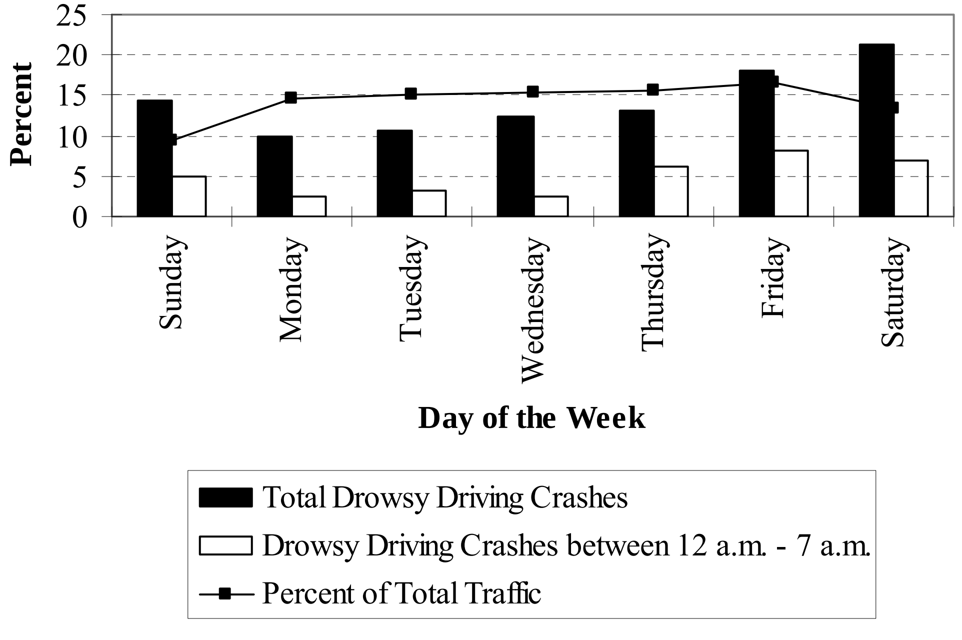


Figure 4-16. Drowsy driving crashes by day of the week on I-84.

4.4.3 Vehicle Type, Object Struck, and Severity

Semi-trailer trucks on I-84 accounted for 12.3 percent of all vehicles involved in drowsy driving crashes, which is twice as much as calculated on I-15 (4.5 percent), I-70 (5.8 percent), or I-80 (6.4 percent). The most common vehicle type involved in this style of crash was the passenger car as denoted in Table 4-22, which was involved in slightly more than 77 percent of the reported crashes. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 163 crashes, 3 more than the total number of crashes as in some instances the police report indicated that two drivers were responsible for the crash.

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-23. The most frequently hit objects were a delineator post, which was struck by 27.6 percent of drowsy drivers, and a mountainside. The mountainside or dirt embankment was struck in 9.2 percent of the crashes while in 1.8 percent of the crashes, the reporting officer cited "Other" for the object struck. The specific objects struck that were recorded as "Other" were not included in the UDOT crash database. No object was struck in 22.7 percent of the crashes.

Table 4-22. Vehicle Types of Drowsy Drivers on I-84

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	126	77.3
Truck/Tractor and Trailer	20	12.3
Passenger Car/Pickup with Trailer	3	1.8
No Vehicle Type Recorded	14	8.6
Total	163	100.0

Table 4-23. Objects Struck by Drowsy Drivers on I-84

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Delineator Post	45	27.6
Dirt Embankment/Ditch/Berm (Mountainside)	15	9.2
Fence	14	8.7
Rigid Barrier (Concrete)	12	7.4
Guardrail	10	6.1
Sign Post	9	5.5
Tree/Shrubbery	7	4.3
Bridge Culvert or Other Highway Structure	3	1.8
Crash Attenuator	3	1.8
Other	3	1.8
Traffic Channelization Device	2	1.2
Guardrail End Section	1	0.6
Snow Embankment	1	0.6
Utility Pole	1	0.6
No Object Struck	37	22.8
Total	163	100.0

To determine if the distribution of drowsy driving crashes on I-84 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis encompassed 131 crashes. Utah residents represented 60.3 percent of drivers responsible for the fatigue-related crashes in this study while 39.7 percent were recorded as out-of-state drivers.

The data in Table 4-24 are provided to determine whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. The first part of this table indicates a percentage for each severity type among persons involved in drowsy driving crashes while the second part gives a percentage for each severity level from all persons involved in all crashes on I-84. As noted, drowsy driving crashes yielded a greater percentage of fatalities and fewer persons able to escape such crashes with “No Injury.”

Table 4-24. Severity of Drowsy Driving Crashes Versus All Crashes on I-84

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	5.6	1.6
Broken Bones or Bleeding Wound	26.8	9.0
Bruises and Abrasions	15.1	8.5
Possible Injury	13.4	13.1
No Injury	39.1	67.8
Total	100.0	100.0

4.4.4 Directional Distribution

The trends in directional distribution of crashes were determined for I-84 and are illustrated in Figure 4-17. Of the 160 drowsy driving crashes, 51.3 percent and 48.7 percent occurred in the eastbound and westbound directions, respectively. The number of crashes climaxed near Tremonton, but decreased after I-84 merged with I-15.

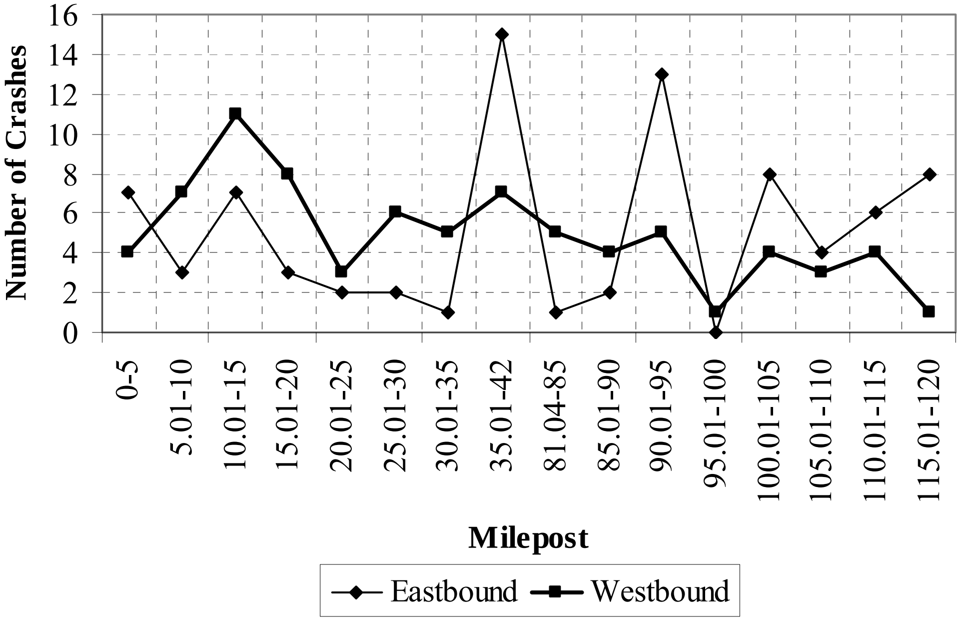


Figure 4-17. Directional distribution of drowsy driving crashes on I-84.

4.5 United States Route 89

U.S. 89 begins at the Arizona-Utah border a few miles north of Page, Arizona and terminates at M.P. 503 north of Garden City, Utah at the Idaho-Utah border. Although U.S. 89 is 503 miles in length it does shares multiple segments of roadway with other facilities in the state. The first portion of U.S. 89 to coincide with another highway occurs near Sevier (M.P. 191) at the junction of I-70. The two routes share 33 miles of I-70. U.S. 89 also shares a 10 mile stretch of highway with U.S. 6 between Thistle (M.P. 312) and the mouth of Spanish Fork Canyon (M.P. 322). In both the first and second scenarios where the roadway was shared, all drowsy driving crashes were reported with the I-70 and U.S. 6 data, respectively. Other locations where U.S. 89 coincides with other highways include U.S. 89 and I-15 at two locations (M.P. 353-362 and M.P. 389-396) and U.S. 89 and U.S. 91 southwest of Logan from M.P. 433 to M.P. 459. The 3-year crash rate analysis indicated that U.S. 89 has 12 critical corridors. Table 4-25 identifies these corridors while Figure 4-18 illustrates the corridors on a map. The coinciding corridors are between M.P. 140 and M.P. 145 and M.P. 325 and M.P. 330.

Table 4-25. U.S. 89 Drowsy Driving Corridors

Area and Direction of Travel	**Rural Area**		**Urban Area**	
	Northbound (NB)	**Southbound (SB)**	**Northbound (NB)**	**Southbound (SB)**
Critical Crash Rate per Million VMT	0.328	0.436	0.079	0.083
M.P.	5 - 10	--	--	--
	55 - 60	--	--	--
	--	90 - 95	--	--
	105 - 110	--	--	--
	--	115 - 125	--	--
	140 - 145	140 - 145	--	--
	--	180 - 185	--	--
	--	--	325 - 330	325 - 330
	--	--	--	345 - 353
	--	--	370 - 375	--

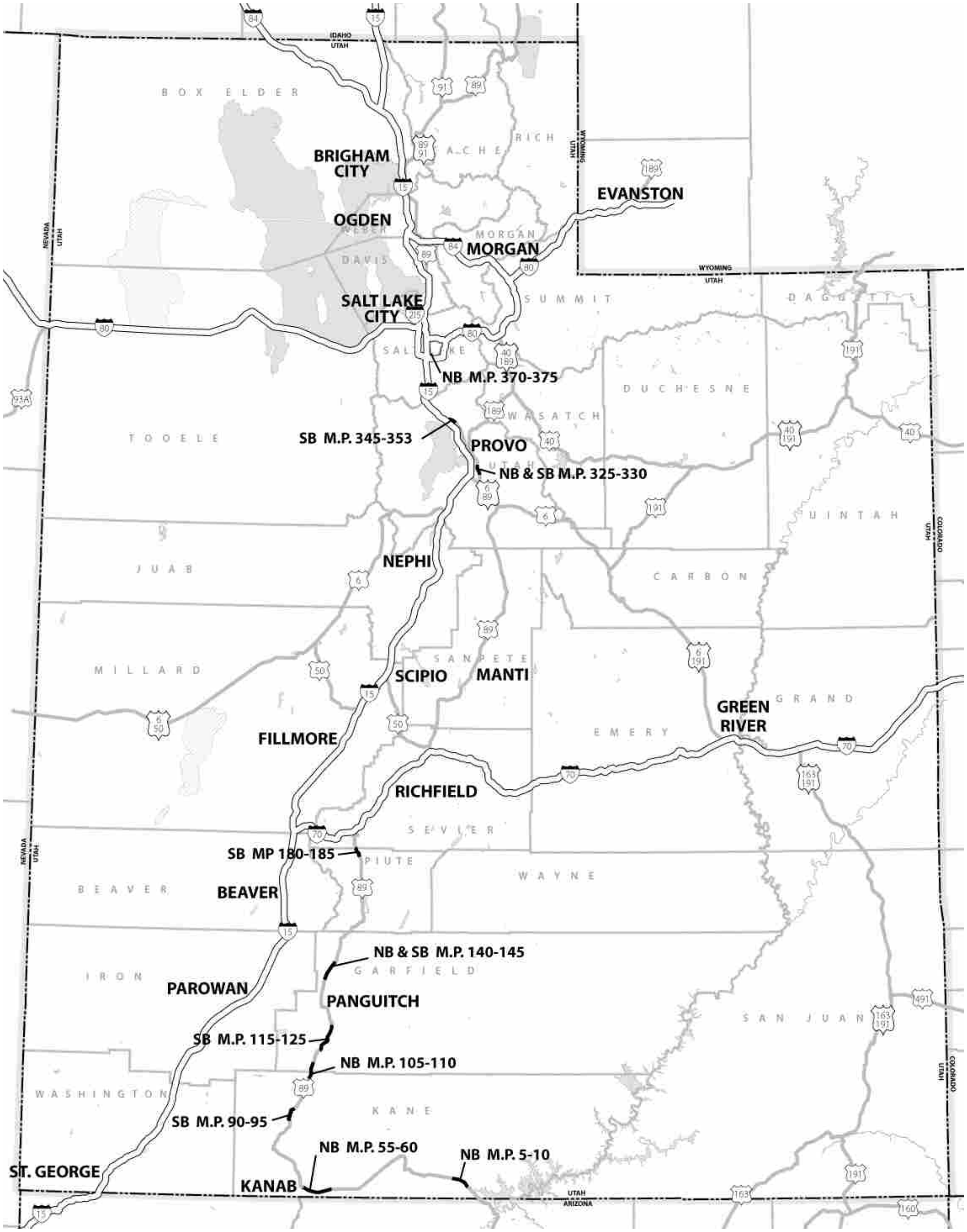


Figure 4-18. U.S. 89 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to fatigue and drowsy driving crashes. One mile intervals were scanned using a "floating segment" one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. None of the critical corridors yielded a relatively large number of crashes on any given curve. The maximum number of crashes on a curve for all of U.S. 89 was only four crashes.

Various drowsy driving statistics were calculated for U.S. 89 for the years 1992-2004. During this time period, 628 drowsy driving crashes (71.6 percent) were reported as single-vehicle crashes while 249 crashes (28.4 percent) involved two or more vehicles. Of the 877 drowsy driving crashes, 18 crashes (2.1 percent) were identified as fatal resulting in 22 fatalities. U.S. 89 had 404 fatalities in all types of crashes; therefore, drowsy driving fatalities represented 5.4 percent of all fatalities on this facility. By comparison this is approximately one-third of the drowsy driving mortality rates on Interstates 15, 80, and 84.

4.5.1 Run-Off-Roadway Crashes and Roadway Alignment

It is evident in Table 4-26 that the majority of fatigued drivers were involved in run-off-road crashes since 64.7 percent of drivers ran off the road on U.S. 89. Outside of run-off-road crashes, 23.7 percent of crashes involved two motor-vehicles, which is likely due to a lack of a barrier separating the direction of traffic. This is also reflected in the extremely low "Ran Off Roadway-Thru Median" percentage. In 9 percent of the crashes, the driver struck a fixed object along side of the highway.

Roadway alignment as indicated previously plays an important role in the location of drowsy driving crashes. Table 4-27 identifies how drowsy driving crashes related to roadway alignment for the years 1992-2004. Of the 877 drowsy driving crashes, 567 (64.7 percent) occurred on stretches which were "Straight and Level" while 17.9 percent of the crashes occurred in locations where a curve was present. Another 133 crashes (15.2) percent took place on a straight grade.

Table 4-26. U.S. 89 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Right	351	40.1
MV-MV	208	23.8
Ran Off Roadway-Left	207	23.6
MV-Fixed Object	79	9.0
Overturned	10	1.1
Ran Off Roadway-Thru Median	9	1.0
Other Non-Collision	8	0.9
MV-Other Object	3	0.3
MV-Animal (Domestic)	2	0.2
Total	877	100.0

Table 4-27. Drowsy Driving Correlation to Roadway Alignment on U.S. 89

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	567	64.7
Grade Straight	133	15.2
Curve Grade	84	9.6
Curve Level	68	7.8
Hillcrest Straight	17	1.9
Curve Hillcrest	5	0.5
Dip Straight	3	0.3
Total	877	100.0

4.5.2 Time of Day and Day of Week

The two peaks that are generally characteristic of drowsy driving crashes occur in the morning and in the afternoon. The morning peak, which climaxed at 54 crashes and occurred during both the 6 a.m. and 7 a.m. hours, is easily discernable in Figure 4-19. The afternoon peak was 64 crashes and occurred twice, once during the 3 p.m. hour and again during the 5 p.m. hour. The hour in which the least overall percentage of drowsy driving crashes occurred was the 9 p.m. hour. Only 1 percent of all drowsy driving crashes on U.S. 89 took place during this one hour time period.

Drowsy driving crashes typically occur more on weekends than during the week. Figure 4-20 indicates that for the years studied the most drowsy driving crashes took place on Saturdays. Of all drowsy driving crashes, 167 (19.0 percent) occurred on Saturday followed by Friday with 140 crashes (16.0 percent). On U.S. 89 the day in which the least number of drowsy driving crashes occurred was Monday with 98 crashes (11.2 percent). Also identified in Figure 4-20 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. This is included in the figure to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours. Specifically, 29.3 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. Of all drowsy driving crashes, 54 (6.2 percent) took place during the middle of the night or early morning hours on Saturday while 52 (5.9 percent) occurred on Monday.

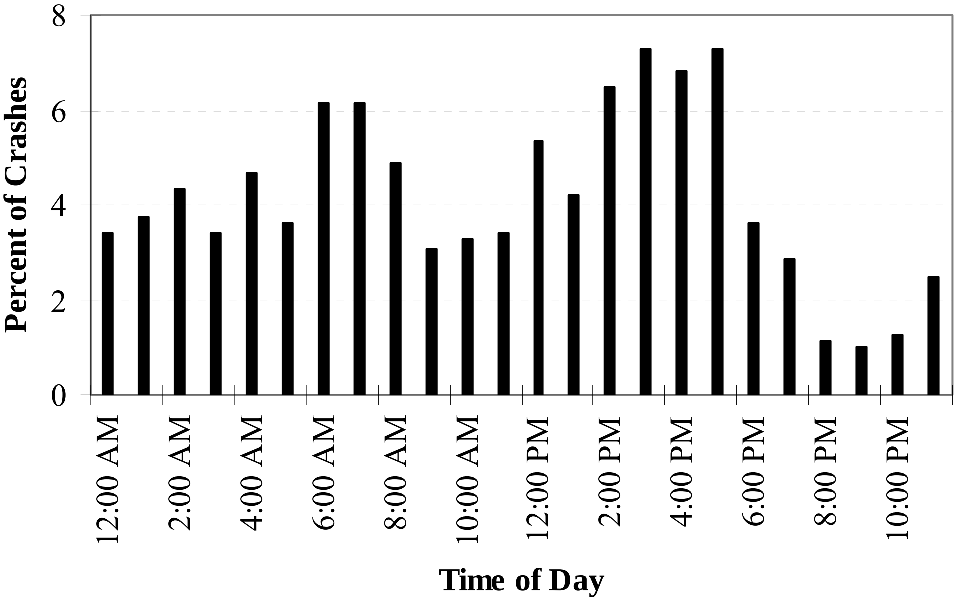


Figure 4-19. Histogram of drowsy driving crashes on U.S. 89.

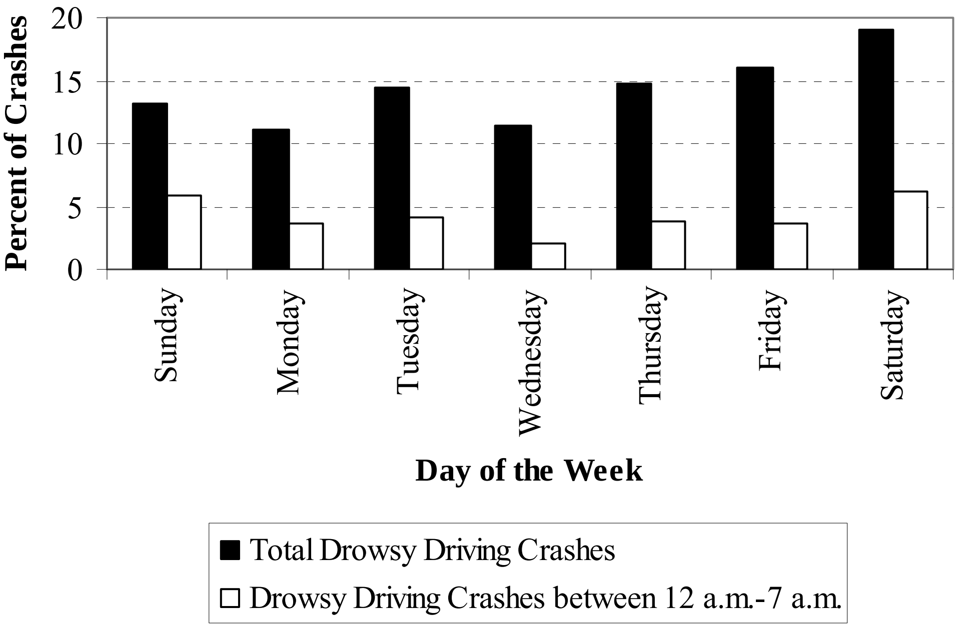


Figure 4-20. Drowsy driving crashes by day of the week on U.S. 89.

4.5.3 Vehicle Type, Object Struck, and Severity

Semi-trucks represented approximately 2 percent of all vehicles involved in drowsy driving crashes on U.S. 89. The most common vehicle type involved in this style of crash on U.S. 89 was the passenger car as outlined in Table 4-28. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 941 crashes, 64 more than the total number of crashes. In some cases, the police report indicated that two drivers were responsible for the crash.

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-29. The first and second most frequently hit objects were dirt embankment and fence, which were struck by 14.8 and 8.4 percent of drowsy drivers, respectively. The objects struck by drowsy drivers were more widespread along U.S. 89 than the Interstate freeways. This is likely due to the type of facility which is U.S. 89. No object was struck in 35.1 percent of the crashes.

Table 4-28. Vehicle Types of Drowsy Drivers on U.S. 89

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	832	88.4
Truck/Tractor and Trailer	22	2.3
Passenger Car/Pickup with Trailer	14	1.5
Single Unit Enclosed Box (Min. 2 Axles and 6 Tires)	5	0.5
Motorcycle	2	0.2
Dump Truck	1	0.1
No Vehicle Type Recorded	65	7.0
Total	941	100.0

Table 4-29. Objects Struck by Drowsy Drivers on U.S. 89

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Dirt Embankment/Ditch/Berm (Mountainside)	139	14.8
Fence	79	8.4
Delineator Post	68	7.2
Utility Pole	68	7.2
Sign Post	48	5.1
Tree/Shrubbery	46	4.9
Guardrail	36	3.8
Curb or Safety Island	29	3.1
Other	23	2.5
Bridge Culvert or Other Highway Structure	19	2.0
Building/Other Structure (Wall)	13	1.4
Rigid Barrier (Concrete)	13	1.4
Mailbox or Fire Hydrant	11	1.2
Guardrail End Section	7	0.7
Snow Embankment	4	0.4
Traffic Channelization Device	4	0.4
Domestic Animal	2	0.2
Crash Attenuator	1	0.1
Wild Animal	1	0.1
No Object Struck	330	35.1
Total	941	100.0

To determine if the distribution of drowsy driving crashes on U.S. 89 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis incorporated 681 crashes. Utah residents represented 78.7 percent of drivers responsible for the fatigue-related crashes in this study while 21.3 percent were recorded as out-of-state drivers.

The data in Table 4-30 are provided to determine whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. The first part of the table indicates a percentage for each severity type among solely persons involved in drowsy driving crashes while the second part gives a percentage for each severity level generated from all persons involved in all crashes on U.S. 89 from 1992-2004. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall with fewer persons able to escape such crashes with "No Injury." The top two severity levels, "Fatal" and "Broken Bones or Bleeding Wounds," accounted for 21.8 percent of all persons involved in drowsy driving crashes, more than three times that recorded for the same severity levels for all persons in all crashes on U.S. 89. The difference in severity between drowsy driving crashes and all crashes is smaller on this highway than the difference in severity on the Interstate freeways.

Table 4-30. Severity of Drowsy Driving Crashes Versus All Crashes on U.S. 89

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	1.8	0.4
Broken Bones or Bleeding Wound	20.0	6.4
Bruises and Abrasions	19.6	9.9
Possible Injury	20.2	23.8
No Injury	38.4	59.5
Total	100.0	100.0

4.5.4 Directional Distribution

In similar fashion to I-15, U.S. 89 also traverses an array of topography from a hot desert in the south to rugged mountainous regions in the north parts of Utah. For this reason the trends in directional distribution of drowsy driving crashes were calculated to determine if specific areas of the highway had more drowsy driving crashes in one direction than the other. Of the 877 drowsy driving crashes, 52.0 percent occurred in the northbound direction while the remaining 48.0 percent were in the southbound direction. Figure 4-21 illustrates the directional distribution from M.P. 0 to M.P. 250 while Figure 4-22 shows the same trends from M.P. 250 to M.P. 503.

In Figure 4-21, the overall directional split of drowsy driving crashes is relatively even between northbound and southbound directions with the exception of the area between M.P. 40 and M.P. 55. In Figure 4-22, a large decrease in crashes occurs near M.P. 355. This is one location in which U.S. 89 merges with I-15; therefore, no drowsy driving crashes were reported in this 5-mile segment.

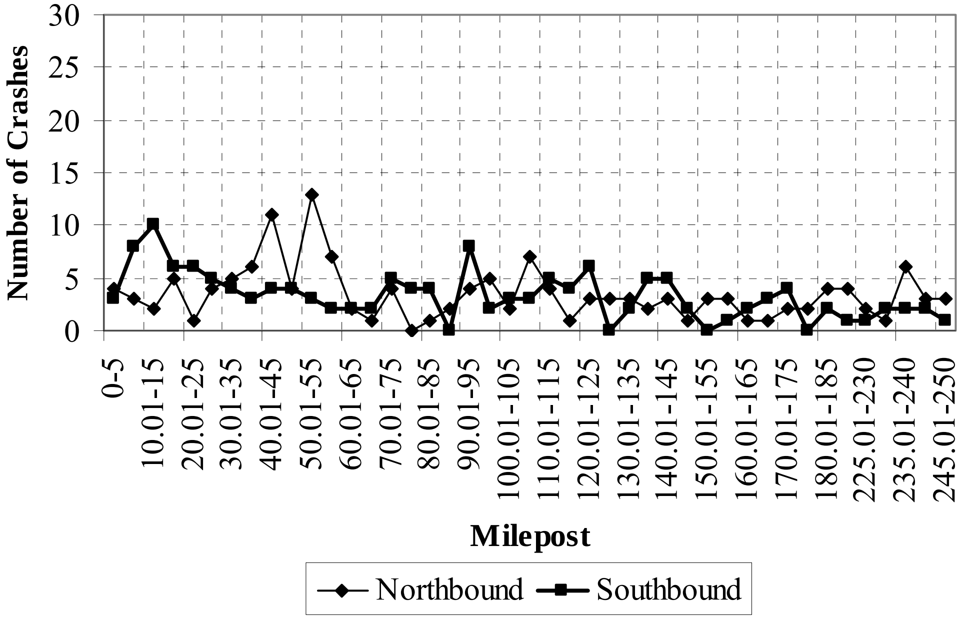


Figure 4-21. Directional distribution of drowsy driving crashes on U.S. 89 from M.P. 0 to M.P. 250.

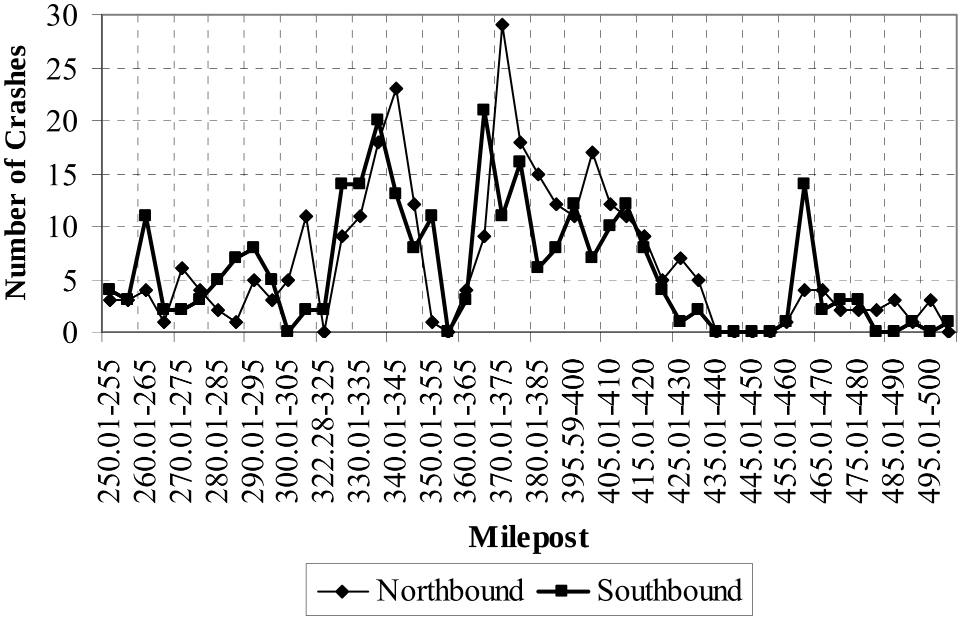


Figure 4-22. Directional distribution of drowsy driving crashes on U.S. 89 from M.P. 250 to M.P. 503.

4.6 United States Route 91

U.S. 91 begins just south of Brigham City, Utah and terminates 15 miles due north of Logan, Utah at the Idaho-Utah border. In total, U.S. 91 only covers 45 miles of highway in Utah. The 3-year crash rate analysis indicated that U.S. 91 has two critical corridors as identified in Table 4-31 and illustrated in Figure 4-23. Both the northbound and southbound corridors coincide with each other between M.P. 20 and M.P. 25.

Table 4-31. U.S. 91 Drowsy Driving Corridors

	Rural Area	
Area and Direction of Travel	**Northbound (NB)**	**Southbound (SB)**
Critical Crash Rate per Million VMT	0.222	0.100
M.P.	20 - 25	20 - 25

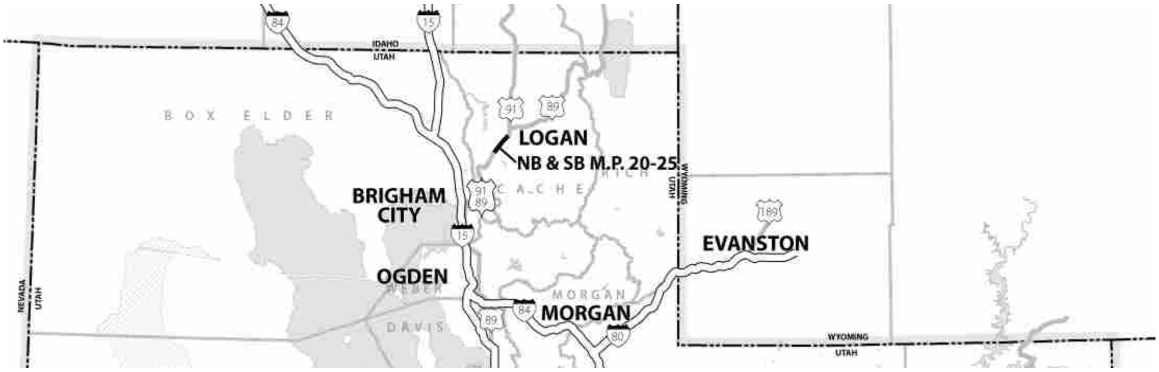


Figure 4-23. U.S. 91 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to fatigue and drowsy driving crashes. One mile intervals were scanned using a “floating segment” one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. The one critical corridor had two crashes attributed to a curve while the maximum number of crashes on a curve for all of U.S. 91 was six crashes near M.P. 26.

The critical corridor from M.P. 20-25 borders the city of Logan in the Cache Valley. As with all of U.S. 91 south of Logan, this section of roadway is a five-lane highway with a two-way left-turn lane separating the flow of traffic. The critical corridor passes through agricultural fields and appears to have no shifts in alignment which may increase the number of run-off-road crashes. One possible reason why this stretch of highway may be critical is the type of driver. The city of Logan is home to Utah State University (USU), which provides education to more than 23,000 students (USU 2007). As mentioned in the literature, young adults are most likely to be involved in a drowsy driving crash on a high-speed corridor (Stutts et al. 2005; Knipling and Wang 1994). Although the increased number of young adults living in Logan may explain in part why more drowsy driving crashes have occurred from M.P. 20-25, this assumption cannot be validated since age is not one of the driver characteristics included in the UDOT crash database.

Various drowsy driving statistics were calculated for U.S. 91 for the years 1992-2004. During this time period, 179 (66.1 percent) drowsy driving crashes were reported as single-vehicle crashes while 92 crashes (33.9 percent) involved two or more vehicles.

Of the 271 drowsy driving crashes, 5 crashes (1.8 percent) were identified as fatal resulting in 13 fatalities. U.S. 91 had 128 fatalities in all types of crashes; therefore, drowsy driving fatalities represented 10.2 percent of all fatalities on this facility.

4.6.1 Run-Off-Roadway Crashes and Roadway Alignment

It is evident in Table 4-32 that the majority of fatigued drivers were involved in run-off-road crashes since 64.9 percent of drivers ran off the roadway. Outside of run-off-road crashes, 28.0 percent of crashes involved two vehicles, which may be attributed to the type of facility. As indicated, U.S. 91 mainly consists of a five-lane cross-section with a two-way left-turn lane in the middle. Not having a barrier separating the flow of traffic may explain the higher MV-MV crash results.

Roadway alignment as indicated previously plays an important role in the location of drowsy driving crashes. Table 4-33 identifies how drowsy driving crashes related to roadway alignment for the years 1992-2004. Of the 271 drowsy driving crashes, 206 (76.0 percent) occurred on stretches which were “Straight and Level” while 9.2 percent of the crashes occurred in locations where a curve was present.

Table 4-32. U.S. 91 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Right	118	43.6
MV-MV	76	28.0
Ran Off Roadway-Left	54	19.9
MV-Fixed Object	15	5.5
Other Non-Collision	4	1.5
Ran Off Roadway-Thru Median	4	1.5
Total	271	100.0

Table 4-33. Drowsy Driving Correlation to Roadway Alignment on U.S. 91

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	206	76.0
Grade Straight	37	13.7
Curve Grade	12	4.4
Curve Level	12	4.4
Hillcrest Straight	2	0.7
Curve Hillcrest	1	0.4
Dip Straight	1	0.4
Total	271	100.0

4.6.2 Time of Day and Day of Week

The two peaks that are generally characteristic of drowsy driving crashes occur in the morning and in the afternoon. The drowsy driving crashes which occurred on U.S. 91 did not follow the normal morning and evening peak, but rather the crashes were widespread throughout the day. No well defined morning peak is illustrated in Figure 4-24 since a steady number of crashes took place between the hours of 5 a.m. and 11 a.m. The afternoon peak was 20 crashes and occurred twice, during both the 3 p.m. and 4 p.m. hours.

Generally, drowsy driving crashes occur more on weekends than during the week. Figure 4-25 indicates that for the years studied the most drowsy driving crashes on U.S. 91 occurred on Tuesdays in contrast to the other facilities studied where the most crashes occurred on Saturday. Also identified in Figure 4-25 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. This is included in the figure to visualize the number of crashes occurring during normal sleep-time hours versus those crashes occurring during the day and evening hours. Specifically, 29.9 percent of drowsy driving crashes on this facility occurred between 12 a.m. and 7 a.m. Of all drowsy driving crashes, 16 (5.9 percent) took place during the middle of the night or early morning hours on Monday while 15 (5.5 percent) occurred on Saturday.

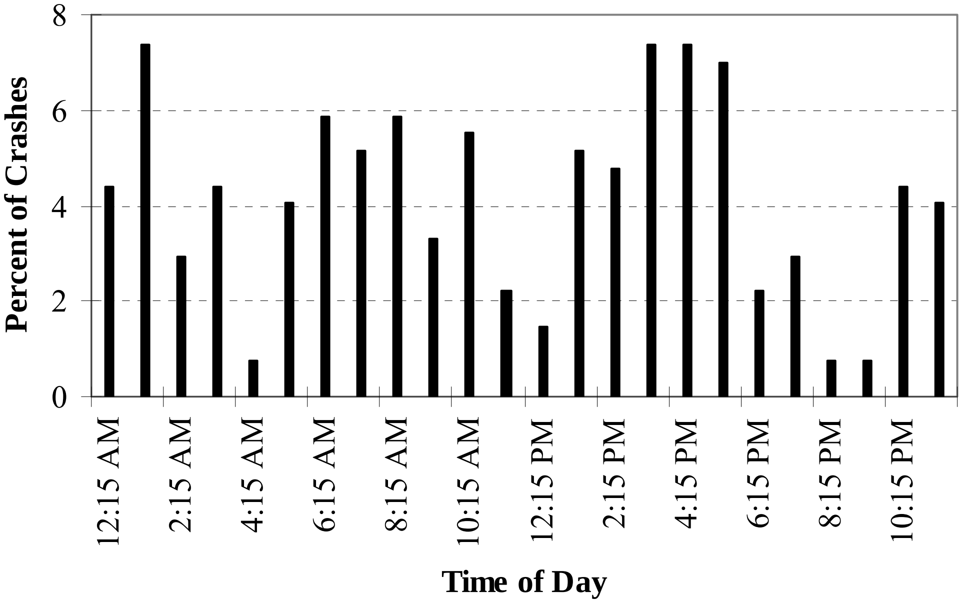


Figure 4-24. Histogram of drowsy driving crashes on U.S. 91.

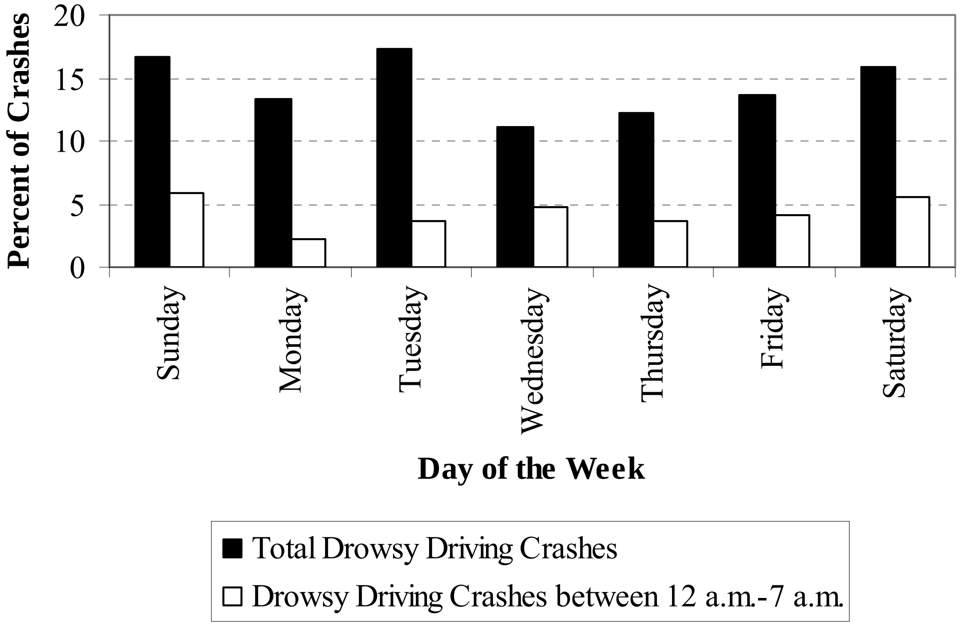


Figure 4-25. Drowsy driving crashes by day of the week on U.S. 91.

4.6.3 Vehicle Type, Object Struck, and Severity

Semi-trucks only represented approximately 0.7 percent of all vehicles involved in drowsy driving crashes on U.S. 91. The most common vehicle type involved in this style of crash was the passenger car as outlined in Table 4-34. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 288 crashes, 16 more than the total number of crashes as some cases the police report indicated that two drivers were responsible for the crash.

Table 4-34. Vehicle Types of Drowsy Drivers on U.S. 91

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	253	87.8
Passenger Car/Pickup with Trailer	4	1.4
Single Unit Enclosed Box (Min. 2 Axles and 6 Tires)	3	1.0
Truck/Tractor and Trailer	2	0.7
No Vehicle Type Recorded	26	9.1
Total	288	100.0

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-35. The first and second most frequently hit objects were dirt embankment and fence, which were struck by 14.2 and 11.5 percent of drowsy drivers on U.S. 91, respectively. The objects struck by drowsy drivers were more widespread along U.S. 91 than the Interstate freeways. This is likely linked to the functional classification of U.S. 91. Since this highway traverses through urban areas, it seems reasonable that more utility poles, sign posts, and curbs would be stuck as a result of drowsy driving. In 35.8 percent of the crashes, no object was struck by a vehicle.

Table 4-35. Objects Struck by Drowsy Drivers on U.S. 91

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Dirt Embankment/Ditch/Berm (Mountainside)	41	14.2
Fence	33	11.5
Utility Pole	30	10.4
Delineator Post	19	6.6
Sign Post	19	6.6
Other	9	3.1
Tree/Shrubbery	9	3.1
Mailbox or Fire Hydrant	8	2.8
Curb or Safety Island	7	2.4
Snow Embankment	4	1.4
Bridge Culvert or Other Highway Structure	2	0.7
Crash Attenuator	2	0.7
Building/Other Structure (Wall)	1	0.3
Rigid Barrier (Concrete)	1	0.3
No Object Struck	103	35.9
Total	288	100.0

To determine if the distribution of drowsy driving crashes on U.S. 91 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis incorporated 206 crashes. Utah residents represented 87.9 percent of drivers responsible for the fatigue-related crashes in this study while 12.1 percent were recorded as out-of-state drivers.

The data in Table 4-36 are provided to determine whether drowsy driving crashes are more severe in nature when compared to all types crashes combined. The first part of the table indicates a percentage for each severity type among persons involved in drowsy driving crashes while the second part gives a percentage for each severity level generated from all persons involved in all crashes. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall. The difference in severity between drowsy driving crashes and all crashes is smaller on this highway than the difference in severity on the Interstate freeways.

Table 4-36. Severity of Drowsy Driving Crashes Versus All Crashes on U.S. 91

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	3.3	0.6
Broken Bones or Bleeding Wound	14.6	6.0
Bruises and Abrasions	13.8	8.9
Possible Injury	16.7	18.8
No Injury	51.6	65.7
Total	100.0	100.0

4.6.4 Directional Distribution

The directional distribution of crashes was evaluated and is shown in Figure 4-26. Of the 271 drowsy driving crashes, 71.6 percent occurred heading northbound while the remaining 28.4 percent were in the southbound direction. M.P. 20 to M.P. 25 had the largest difference in the directional distribution of drowsy driving crashes, which was 46.

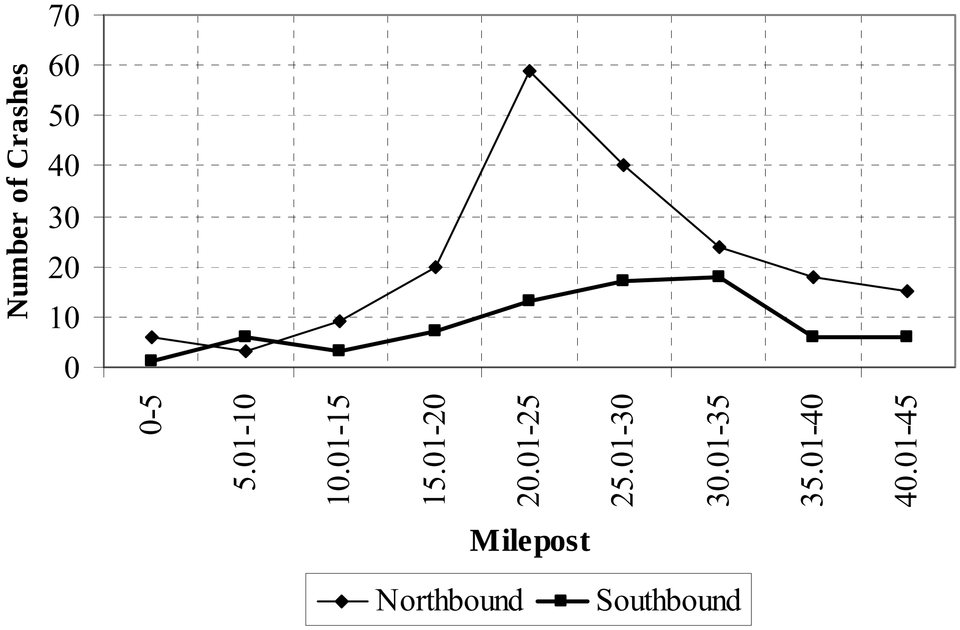


Figure 4-26. Directional distribution of drowsy driving crashes on U.S. 91.

4.7 State Route 36

S.R. 36, which is mostly a rural highway, begins 25 miles northwest of Nephi, Utah and terminates at its junction with I-80 approximately 10 miles north of Tooele, Utah. In total, S.R. 36 only traverses slightly more than 65 miles of Utah. Only two critical corridors were located on S.R. 36. Table 4-37 identifies the M.P. and direction of travel for these corridors while Figure 4-27 illustrates the corridors on a Utah state map.

Table 4-37. S.R. 36 Drowsy Driving Corridors

Area and Direction of Travel	**Rural Area**	
	Northbound (NB)	**Southbound (SB)**
Critical Crash Rate per Million VMT	1.318	0.225
M.P.	0 - 5	--
	--	25 – 30

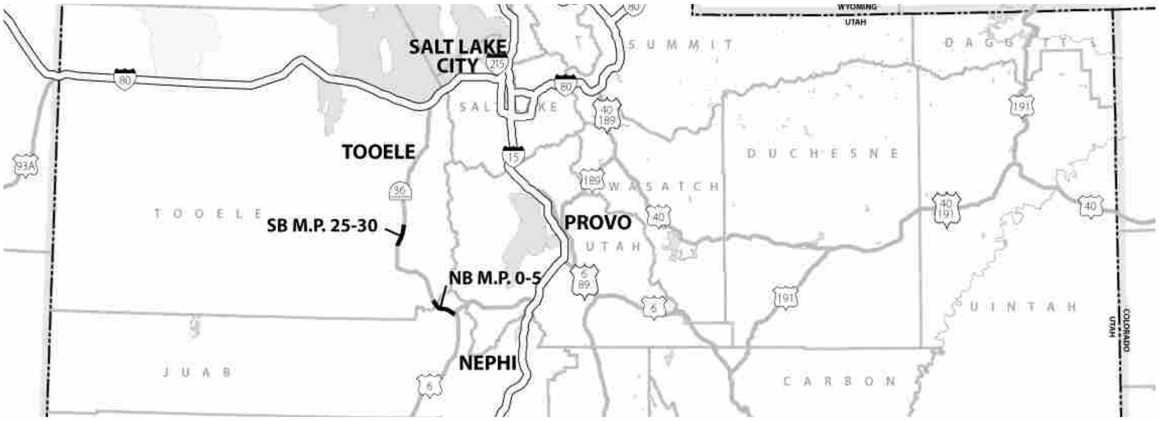


Figure 4-27. S.R. 36 drowsy driving corridors.

The roadway alignment in each critical corridor was analyzed to determine if specific curves in the alignment contributed to fatigue and drowsy driving crashes. One mile intervals were scanned using a “floating segment” one-half mile in length to determine the number of crashes which were reported to have occurred on any given curve. Only one drowsy driving crash occurred between M.P. 0 and M.P. 5 on a curve while none took place on a curve from M.P. 25-30. For comparison purposes, only five crashes on a curve for all of S.R. 36 occurred from 1992-2004.

The critical crash rates for both northbound and southbound directions are drastically different as indicated in Table 4-37. The crash rate calculated for northbound M.P. 0-5 was 2.10. This high crash rate can likely be attributed to the extremely low AADT since only two drowsy driving crashes occurred in this 5-mile segment regardless of roadway alignment over the three years of data studied. The AADT in the area is approximately 350 vehicles per day throughout the year. The southbound corridor consisting of M.P. 25-30 was determined critical, but only included one drowsy driving crash in three years. Again this is partly due to a low AADT, but also due to very few drowsy driving crashes in the other rural sectors of the highway thus affecting the critical crash rate as calculated in Equation 3-3 in Section 3.2.2.2.

Many drowsy driving crashes occurred on S.R. 36 over the years, but these crashes were concentrated on the highway between Tooele (M.P. 51) and the junction of S.R. 36 with I-80 (M.P. 66). It is believed that many of the crashes on this 15-mile stretch were caused by commuters who live in the area near Tooele and commute to Salt Lake City everyday. This is based on the fact that of the 66 drowsy driving crashes between M.P. 51 and M.P. 66, 51 crashes (77 percent) were in the southbound direction, the direction that commuters would have been traveling at the end of the workday. The peak hour of drowsy driving crashes in this 15-mile corridor was between 4 p.m. and 5 p.m. with approximately 14 percent of the drowsy driving crashes in the southbound direction occurring in this one hour. Although this section of highway did have a large number of drowsy driving crashes, it was not deemed critical. This is likely attributed to the high AADT in this 15-mile stretch of S.R. 36.

Various drowsy driving statistics were calculated for S.R. 36 for the years 1992-2004. During this time period, 73 (80.2 percent) drowsy driving crashes were reported as single-vehicle crashes while 18 crashes (19.8 percent) involved two or more vehicles. Of the 91 drowsy driving crashes, 2 crashes (2.2 percent) were identified as fatal resulting in 4 fatalities. S.R. 36 had 53 fatalities in all types of crashes; therefore, drowsy driving fatalities represented 7.5 percent of all fatalities on this facility.

4.7.1 Run-Off-Roadway Crashes and Roadway Alignment

Table 4-38 indicates that the majority of fatigued drivers were involved in run-off-road crashes. Besides the run-off-road crashes, 16.5 percent of crashes involved two vehicles. This may be attributed to the fact that S.R. 36 is proportionately a two-lane two-way rural road with a low AADT volume, which may explain the why no "Ran Off Road-Thru Median" crashes were reported.

Table 4-38. S.R. 36 Drowsy Driving Crash Consequences

Crash Consequence	Number of Crashes	Percent of Total Crashes
Ran Off Roadway-Right	48	52.7
Ran Off Roadway-Left	23	25.3
MV-MV	15	16.5
MV-Fixed Object	3	3.3
MV-Animal (Wild)	1	1.1
Other Non-Collision	1	1.1
Total	91	100.0

Table 4-39. Drowsy Driving Correlation to Roadway Alignment on S.R. 36

Alignment Type	Number of Crashes	Percent of Total Crashes
Straight and Level	67	73.6
Grade Straight	10	11.0
Curve Level	9	9.9
Curve Grade	4	4.4
Hillcrest Straight	1	1.1
Total	91	100.0

Roadway alignment as indicated previously has a critical role in the location of drowsy driving crashes. Table 4-39 identifies how drowsy driving crashes related to roadway alignment for the years 1992-2004. S.R. 36 begins with a curvilinear alignment for 19 miles before becoming relatively straight for the remaining 47 miles of highway. This may be the reason why only 13 crashes (14.3 percent) occurred where a curve was present. Of the 91 crashes identified in Table 4-39, 67 (73.6 percent) crashes occurred on stretches which were “Straight and Level.”

4.7.2 Time of Day and Day of Week

Generally drowsy driving crashes exhibit two peak hours in a 24 hour period—one in the morning and one in the afternoon. As with U.S. 91, the drowsy driving crashes which occurred on S.R. 36 did not follow this trend, but rather the crashes were widespread throughout the day. No morning peak is illustrated in Figure 4-28 as a relatively constant number of crashes took place throughout the morning hours. The afternoon peak is easily discernable in Figure 4-28 as it occurred during the 4 p.m. hour reaching a maximum of 14 crashes.

Drowsy driving crashes more frequently occur on weekends than during the week, but the crash data for S.R. 36 indicates that this typical trend was not followed. Figure 4-29 indicates that for the years studied the largest number of drowsy driving crashes occurred on Saturday. Of all drowsy driving crashes, 17 (18.7 percent) occurred on Saturday followed by Tuesday with 16 crashes (17.6 percent). On S.R. 36 the day in which the least number of drowsy driving crashes occurred was Thursday with 7 crashes (7.7 percent). Also identified in Figure 4-29 are the number of fatigue-related crashes by day which occurred between the hours of 12 a.m. and 7 a.m. Of drowsy driving crashes on this facility, 25.3 percent occurred between the hours of 12 a.m. and 7 a.m. For drowsy driving crashes that occurred between the hours of 12 a.m. and 7 a.m., 6 (6.6 percent) took place during the middle of the night or early morning hours on Saturday while 5 crashes (5.5 percent) occurred on Sunday morning. No drowsy driving crashes were reported to have occurred on any Wednesday morning during the years studied.

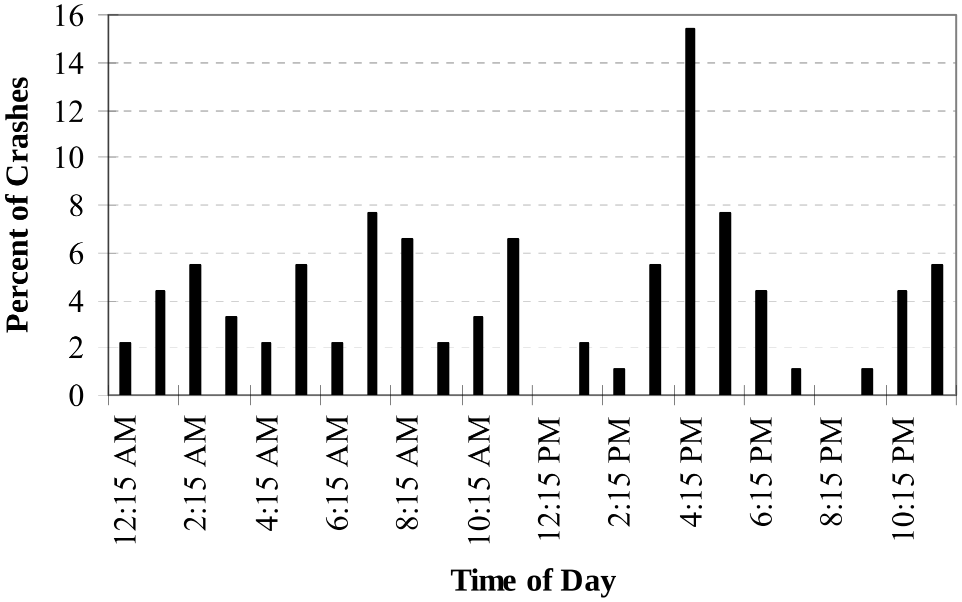


Figure 4-28. Histogram of drowsy driving crashes on S.R. 36.

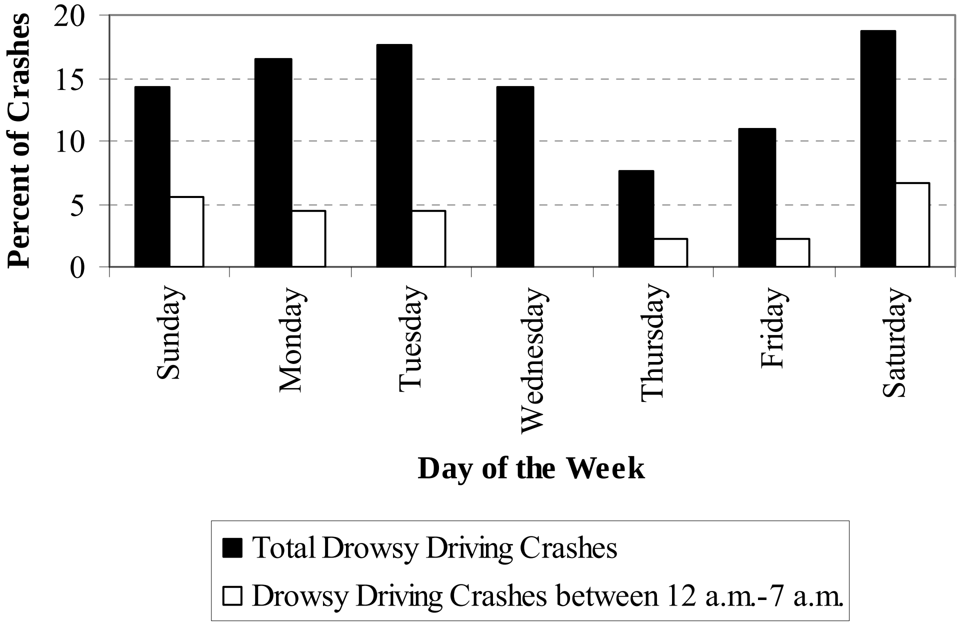


Figure 4-29. Drowsy driving crashes by day of the week on S.R. 36.

4.7.3 Vehicle Type, Object Struck, and Severity

Semi-trucks represented approximately 1.1 percent of all vehicles involved in drowsy driving crashes on S.R. 36. As has been identified from the results of other highways in this chapter, the most common vehicle type involved in drowsy driving crashes was the passenger car as outlined in Table 4-40. The total number of vehicles in which a driver was responsible for a crash or partially responsible for a drowsy driving crash summed to 94 crashes, 3 vehicles more than the total number of crashes as some cases the police report indicated that two drivers were responsible for the crash.

Table 4-40. Vehicle Types of Drowsy Drivers on S.R. 36

Vehicle Type of Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Passenger Car/Pickup	86	91.4
Passenger Car/Pickup with Trailer	1	1.1
Truck/Tractor and Trailer	1	1.1
No Vehicle Type Recorded	6	6.4
Total	94	100.0

A number of objects along a highway which drivers hit, and which are recorded in the UDOT crash database, are listed in Table 4-41. The first and second most frequently hit objects on S.R. 36 were fences and utility poles, which were struck by 18.1 and 16.0 percent of drowsy drivers, respectively. None of the other highway results in this chapter identified a utility pole as one of the most frequently hit objects. This is likely due to the rural area of that S.R. 36 spans. Also hit frequently was a dirt embankment or mountainside, which occurred in almost 15 percent of the drowsy driving crashes. No object was struck in 31.9 percent of the crashes.

Table 4-41. Objects Struck by Drowsy Drivers on S.R. 36

Object Struck by Person(s) Responsible for Crash	Number of Vehicles	Percent of Vehicles
Fence	17	18.1
Utility Pole	15	16.0
Dirt Embankment/Ditch/Berm (Mountainside)	14	14.9
Delineator Post	7	7.4
Tree/Shrubbery	3	3.2
Curb or Safety Island	2	2.1
Sign Post	2	2.1
Bridge Culvert or Other Highway Structure	1	1.1
Building/Other Structure (Wall)	1	1.1
Other	1	1.1
Wild Animal	1	1.1
No Object Struck	30	31.8
Total	94	100.0

To determine if the distribution of drowsy driving crashes on S.R. 36 was skewed towards Utah residents more than out-of-state visitors, license plate data from police reports were analyzed for the timeframe 1996-2004. This analysis incorporated 62 crashes. Utah residents represented 98.4 percent of drivers responsible for the fatigue-related crashes in this study while 1.6 percent were recorded as out-of-state drivers.

Severity of drowsy driving crashes as indicated in the literature review tends to be worse than other crashes. Table 4-42 indicates a percentage for each severity type among solely persons involved in drowsy driving crashes as well as a percentage for each severity level generated from all persons involved in all crashes on S.R. 36 from 1992-2004. As noted, drowsy driving crashes yielded a greater percentage of fatalities when compared to fatalities of all crashes on this highway. Furthermore, severity levels of persons involved in drowsy driving crashes were worse overall with fewer persons able to escape such crashes with “No Injury.”

Table 4-42. Severity of Drowsy Driving Crashes Versus All Crashes on S.R. 36

Severity	Percent of Persons Involved in Drowsy Driving Crashes	Percent of Persons Involved in All Crashes
Fatal	3.5	1.1
Broken Bones or Bleeding Wound	18.4	8.7
Bruises and Abrasions	15.8	8.6
Possible Injury	17.5	17.0
No Injury	44.8	64.6
Total	100.0	100.0

4.7.4 Directional Distribution

The trends in directional distribution of drowsy driving crashes were calculated and are illustrated in Figure 4-30. Of the 91 drowsy driving crashes, 37.8 percent occurred in the northbound direction while the 62.2 percent were in the southbound direction. A large increase in crashes is identifiable following M.P. 50 near Tooele.

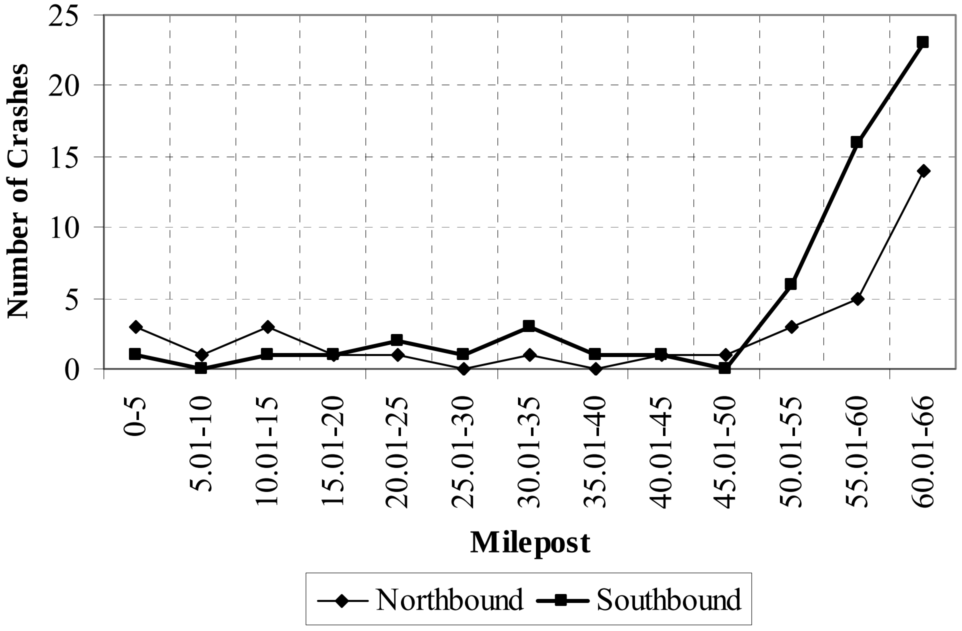


Figure 4-30. Directional distribution of drowsy driving crashes on S.R. 36.

4.8 Critical Corridor Summary

The previous sections discussed the critical corridor results as well as drowsy driving trends and statistics for each Interstate freeway, U.S. Route, and S.R. highway containing critical corridors. Statistics included: drowsy driving crash consequences, roadway alignment impact, time of day and day of week of drowsy driving crashes, vehicle type and object struck in drowsy driving crashes, and a comparison of the severity of drowsy driving crashes versus all crashes. Table 4-43 is provided to easily compare a few of the most important statistics from the various facilities studied.

Table 4-43. Drowsy Driving Crash Summary

Facility	Drowsy Driving Crashes	Single-vehicle Crashes		Fatal Crashes		Run-Off-Road Crashes		Crashes on Curves	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent
I-15	3,883	3,194	82.3	147	3.8	2,924	75.3	898	23.1
I-70	899	864	96.1	75	8.3	781	86.9	312	34.7
I-80	922	818	88.7	57	6.2	735	79.7	230	24.9
I-84	160	143	89.4	6	3.8	124	77.5	65	40.6
U.S. 89	877	628	71.6	18	2.1	567	64.7	157	17.9
U.S. 91	271	179	66.1	5	1.8	176	64.9	25	9.2
S.R. 36	91	73	80.2	2	2.2	71	78.0	13	14.3
Total	7,103	5,899	83.0	310	4.4	5,378	75.7	1,700	23.9

4.9 Under-Reported Drowsy Driving Crashes

As identified through the literature, it is believed that drowsiness as a primary factor in crashes where the driver fell asleep is under-reported because in many cases no evidence suggests the driver fell asleep behind the wheel (McCartt et al. 2000). Using the crash data obtained from the UDOT crash database, the percent of total crashes in which sleep or fatigue were not identified as primary contributors was estimated for several highways. The data used to determine whether or not drowsiness may have been a causal factor in a crash were: time of day, primary contributor, secondary contributor, crash result, vehicle type, and crash severity. These crash characteristics were identified in the literature and in this chapter as those most representative of drowsy driving crashes.

All crashes reported in six 5-mile corridors were reviewed; two corridors from each of the following freeways: I-15, I-70, and I-80. In judging each crash, more weight was given to time of day, crash result, primary contributor, and secondary contributor, while the other characteristics typical of drowsy driving crashes were used in a supporting role. Of the 582 crashes reviewed, police officers cited a secondary contributor in 150 (25.8 percent) crashes of which 13 crashes were designated as asleep, fatigue, or ill. If the reporting officer cited asleep, fatigue, or ill as a secondary contributor and no evidence of alcohol was identified in the crash report, then the crash was assumed to be caused by a drowsy driver. In cases where a secondary contributor was not recorded, the crash results along with the time of day were used as a method to gage whether a crash may have been fatigue-related.

Crashes which occurred between the hours of 11 p.m. and 7 a.m. and which the driver ran off the roadway were generally considered drowsy driving crashes unless alcohol or some physical car problem such as defective tires was indicated in the police report. Other crashes which were possibly caused by drowsy driving included crashes in which the police report outlined excessive speed coupled with a severe crash result such as a fatality or broken bones.

The results of this analysis are outlined in Table 4-44. Under-reported drowsy driving crashes were estimated at a minimum to be approximately 8 percent with a possible maximum of 18 percent. Even with the enormous amounts of data available in the UDOT crash database, it is possible that these values are still conservative. Until police officers are trained to recognize drowsy driving crashes and until drivers involved in crashes are willing to admit their sleepiness behind the wheel, it is estimated that drowsy driving crashes will continue to be under-reported.

Table 4-44. Estimated Percentage of Under-reported Drowsy Driving Crashes

Facility	Critical Corridor	Estimated Percentage of Under-reported Drowsy Driving Crashes
I-15	M.P. 90 – 95	15
	M.P. 190 – 195	14
I-70	M.P. 135 – 140	18
	M.P. 160 – 165	8
I-80	M.P. 35 – 40	17
	M.P. 70 – 75	18

4.10 Results Summary

The corridors most prone to drowsy driving crashes during the 3-year analysis encompassing the years 2002-2004 were identified and illustrated on Utah state maps. Discussion of drowsy driving statistics for each facility was given. Statistics for each roadway included: drowsy driving crash results, roadway alignment impact, time of day and day of week of drowsy driving crashes, vehicle type and object struck in drowsy driving crashes, and a comparison of the severity of drowsy driving crashes versus all crashes. Brief discussion was provided regarding curves in roadway alignment which may be considered dangerous based upon the number of crashes at a given location. To determine which type(s) of countermeasures may be suitable for the drowsy driving corridors discussed in this chapter, a detailed review of the existing drowsy driving countermeasures employed by UDOT was undertaken and is presented in Chapter 5

5 EXISTING COUNTERMEASURES

Over the past decade the state of Utah has taken a proactive approach to reduce crashes, specifically fatalities, on all Utah highways. In order to accomplish this goal, UDOT has implemented several countermeasures to prevent drivers from causing serious crashes. Four existing countermeasures undertaken by UDOT are discussed in this chapter as well as other countermeasures considered by UDOT but not yet implemented. The first existing countermeasure is aimed directly at drowsy drivers through drowsy driving freeway signage. The purpose of these signs is to warn drivers of the adverse affects of driving while drowsy. The second countermeasure discussed relates to rumble strips, which UDOT has added to miles of highway as a physical means to prevent drivers from drifting out of lanes and running off of highways. The third countermeasure outlined is the use of cable barriers placed in between opposing traffic patterns to prevent vehicles from crossing the median into on-coming traffic. The final countermeasure used by UDOT to help reduce drowsy driving crashes is that of a rest area. Other countermeasures not yet implemented by UDOT are also provided. In conjunction with the drowsy driving countermeasures mentioned, the results of two before-after crash rate analyses are provided. The first before-after analysis discusses the safety effectiveness of the drowsy driving freeway signage while the second analysis illustrates the effect on drowsy driving crashes before and after the installation of the Grassy Mountain rest area.

5.1 Drowsy Driving Freeway Signage

Utah is known for having beautiful national parks and scenic byways, but as with all states, Utah has miles of monotonous highway corridors. In an effort to reduce the number of drowsy driving crashes, UDOT has installed drowsy driving freeway signage on three Interstates, namely I-80, I-70 and I-15.

5.1.1 Interstate 80

The first 100 miles of I-80 seems to encompass some of the flattest land in the world. Long, straight stretches of highway coupled with a barren desert landscape have long posed a problem to travelers who traverse this corridor of freeway. In the early years of this decade, the UHP approached UDOT with a proposal to add signage to I-80 cautioning drivers to be aware of drowsy driving. This proposal came as consequence of UHP officers having years of experience investigating crash scenes in which drivers seemed to have fallen asleep at the wheel or suffered from severe fatigue.

UDOT reacted to officer requests and in April 2004 the work of installing drowsy driving signs throughout the first 100 miles of I-80 was underway. Installation of three series of signs, each series consisting of three signs, and one single drowsy driving sign was completed on July 21, 2004. The location and caption of each sign is outlined in Table 5-1 while an illustration of each sign is provided in Figure 5-1. Figure 5-2 illustrates the location of all drowsy driving signs, rest areas, and view areas on Interstates 15, 70, 80, and 84. A detailed analysis of the safety effectiveness of the signs on I-80 will be discussed in Section 5.2.

Table 5-1. Location and Caption of Drowsy Driving Signs on I-80

Direction	M.P.	Sign Caption
Eastbound	26.3	Drowsy Driving Causes Crashes
	26.6	Drowsy Drivers Next Exit 15 Miles
	26.8	Drowsy Drivers Pull Over If Necessary
	49.5	Drowsy Driving Causes Crashes
	49.8	Drowsy Drivers Next Exit 5 Miles
	50.0	Drowsy Drivers Pull Over If Necessary
Westbound	46.0	Drowsy Drivers Pull Over If Necessary
	46.3	Drowsy Drivers Next Exit 5 Miles
	46.6	Drowsy Driving Causes Crashes
	95.0	Drowsy Driving Causes Crashes

a)

b)

c)

(Photos by Grant Schultz 2007)

Figure 5-1. Typical examples of drowsy driving signage on I-80.

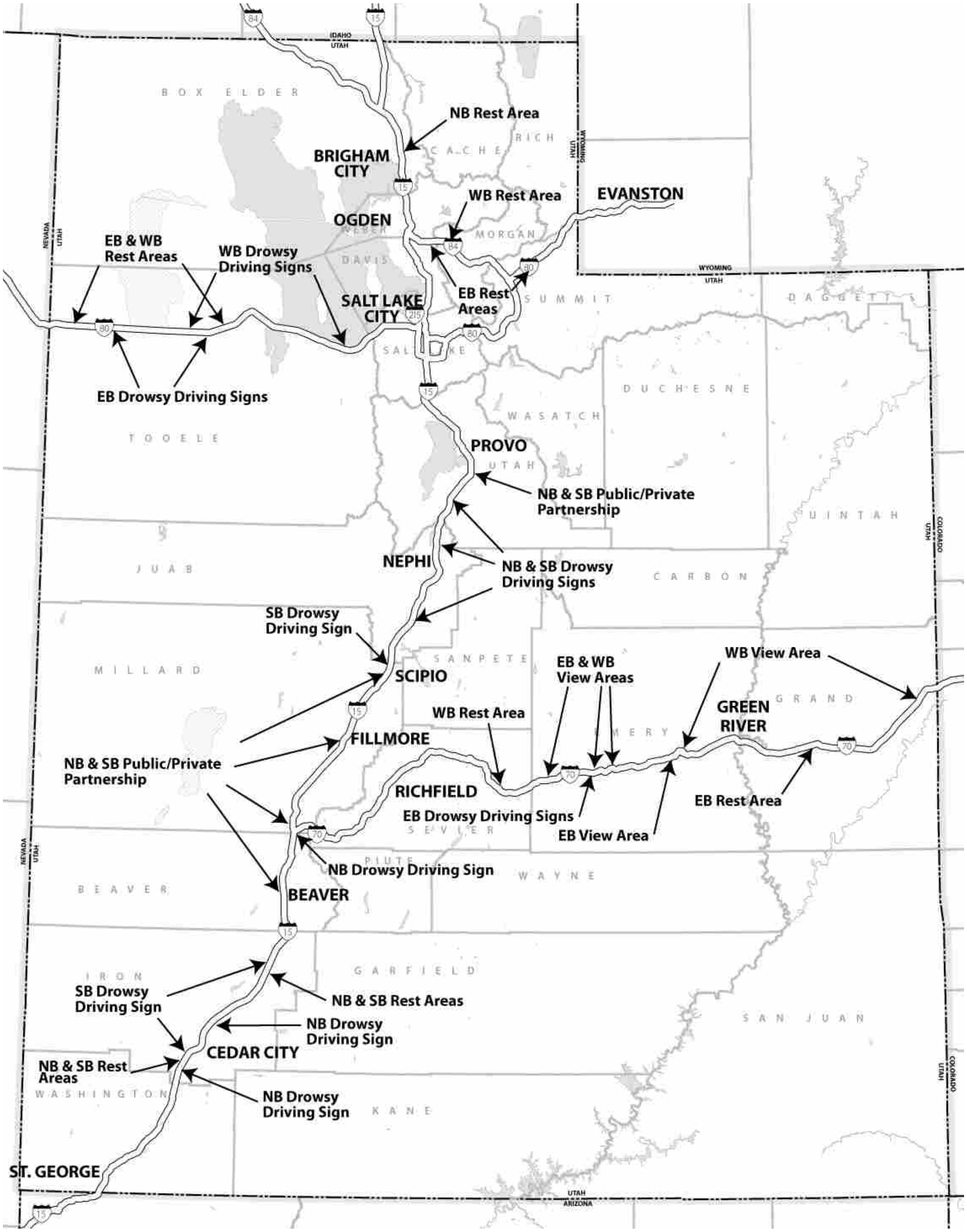


Figure 5-2. Location of drowsy driving signage, rest areas, and view areas on I-15, I-70, I-80, and I-84.

5.1.2 Interstate 70

I-70 was the second Interstate freeway in Utah to have drowsy driving signs posted along one corridor. Installation of the 3-sign series was completed in late February 2005. The signs are located in the eastbound direction 50 miles west of Green River as identified in Figure 5-2. Table 5-2 identifies the location and sign caption of each drowsy driving sign. The signs are exactly the same as those installed along I-80 as depicted in Figure 5-1. The second sign in the series indicates an exit 2 miles down road, which is the Eagle Canyon view area at M.P. 115.5. The view area has parking and restrooms for public use.

Table 5-2. Location and Caption of Drowsy Driving Signs on I-70

Direction	M.P.	Sign Caption
Eastbound	113.1	Drowsy Drivers Pull Over If Necessary
	113.5	Drowsy Drivers Next Exit 2 Miles
	114.0	Drowsy Driving Causes Crashes

5.1.3 Interstate 15

I-15 is the most recent Interstate freeway in Utah to have drowsy driving signs posted along various corridors. Unlike I-70 and I-80, the drowsy driving signage on I-15 does not appear in 3-sign sets, but rather single signs placed at many locations. The signs are approximately 10 feet in length and 5 feet tall. The sign caption for all 12 signs reads "Drowsy Drivers Use Next Exit." This sign caption is different than for the drowsy driving signs posted on I-70 and I-80. In similar fashion to those signs posted along I-70, the I-15 signs are located near rest areas or rural off ramps thus encouraging drowsy drivers to exit immediately rather than continue driving as indicated in Figure 5-2. The Kannara and Lunt Park rest areas are located at M.P. 45 and 88, respectively. The signs posted at northbound M.P. 68 and 133 as well as southbound M.P. 189 correspond to public/private rest areas where UDOT and local service stations provide amenities, including restrooms, water fountains, and gasoline. All of the signs are located south of Salt Lake City in rural areas. Table 5-3 identifies the M.P., location description, and date of installation of each sign while Figure 5-3 illustrates a typical drowsy driving sign along I-15.

Table 5-3. M.P., Location, and Date of Installation of Drowsy Driving Signs on I-15

Direction	M.P.	Description of Location	Date of Installation
Northbound	43	Before Kannaraville Rest Area	1/9/07
	68	Before Summit Truck Stop	2/21/07
	133	Before Cove Fort Chevron Rest Area	12/8/06
	205	Before Mills Exit	10/31/06
	232	Before Mona Exit	10/31/06
	247	Before Payson Exit	12/6/06
Southbound	51	Before Kannaraville Rest Area	1/8/07
	93	Before Lunt Park Rest Area	12/12/06
	189	Before Scipio Eagles Landing Rest Area	12/14/06
	208	Before Mills Exit	10/31/06
	234	Before Mona Exit	10/31/06
	249	Before Payson Exit	12/6/06

(Photo by Hunter Young 2007)

Figure 5-3. Typical drowsy driving signage on I-15.

5.2 I-80 Before-After Crash Studies

To determine the effectiveness of the drowsy driving freeway signage as well as the effectiveness of the rest area located at M.P. 54, two before-after crash rate analyses were conducted. The results of each analysis are discussed in the subsections that follow. The first subsection provides background as to time related trends before and after the installation of the signs. The second subsection discusses the traditional before-after analysis for the drowsy driving signs while the third subsection identifies the effectiveness of the signs using a modified traditional before-after analysis. The fourth subsection uses comparison groups as the basis for predicting the "after" crash rate had the drowsy driving signs not been implemented. Lastly, the fifth subsection identifies the traditional before-after analysis for drowsy driving crashes near the rest area at M.P. 54.

5.2.1 Time Trend Background

To aid in visualizing any time related trends before and after the installation of the drowsy driving signs, crash rates in the 10 miles directly following each series of signs were calculated. Figure 5-4 illustrates the crash rates for eastbound I-80 for M.P. 15-25 as well as M.P. 25-35 following the signs. The same information is provided for the signs near M.P. 50 in Figure 5-5. Figure 5-6 shows the crash rates for westbound I-80 for M.P. 35-45 and for M.P. 45-55 following the signs. The same information is provided in Figure 5-7 surrounding the single sign located at M.P. 95. From these figures, it can be determined if the crash rates after the drowsy driving signs were installed were regressing toward the mean or if a sharp change in the crash rate occurred which may be partly attributed to the signs themselves.

The crash rates in all of the following figures verify that crash rates are extremely volatile. From Figure 5-4, it can be seen that the crash rates from eastbound M.P. 25-35 are higher on average than those from M.P. 15-25. This may be due to the fact that drivers may have stopped to rest in Wendover or at the Salt Flats rest area at M.P. 10 and then become drowsier with more time behind the wheel. Similar fluctuations in crash rates occurred at all locations studied, but specifically in the vicinity of M.P. 50.

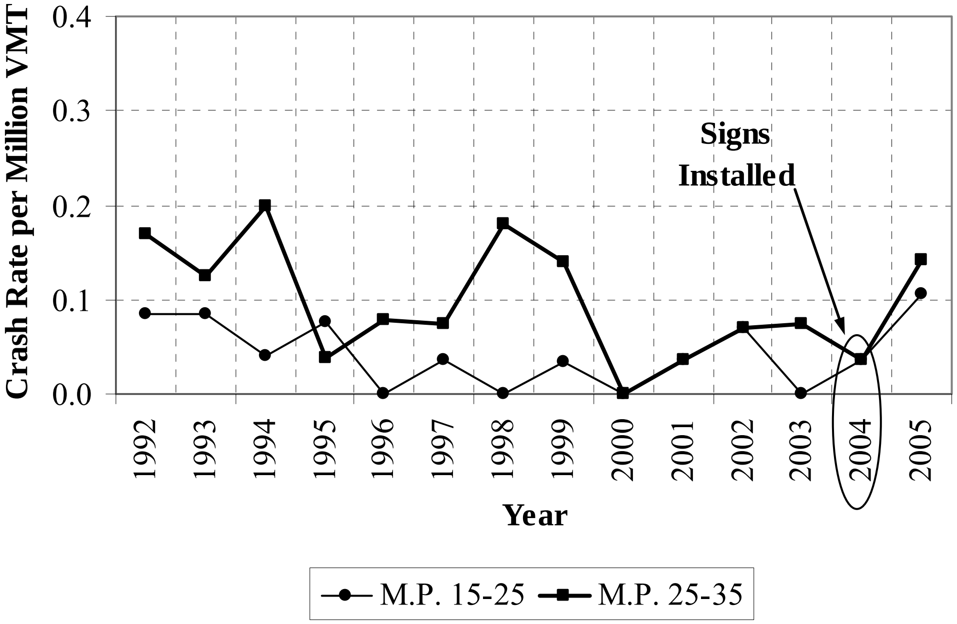


Figure 5-4. Eastbound I-80 crash rates for M.P. 15-25 and M.P. 25-35.

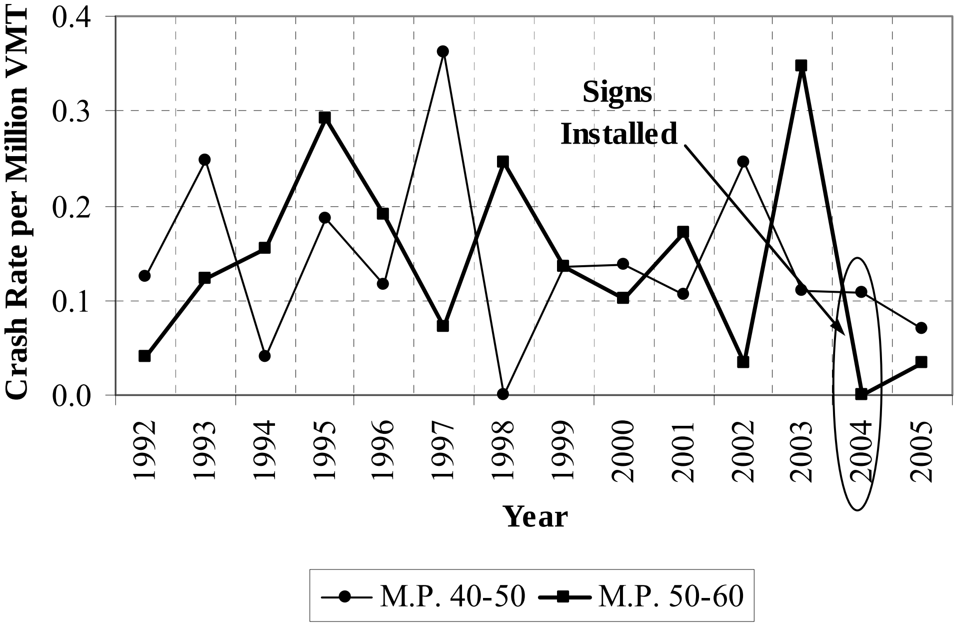


Figure 5-5. Eastbound I-80 crash rates for M.P. 40-50 and M.P. 50-60.

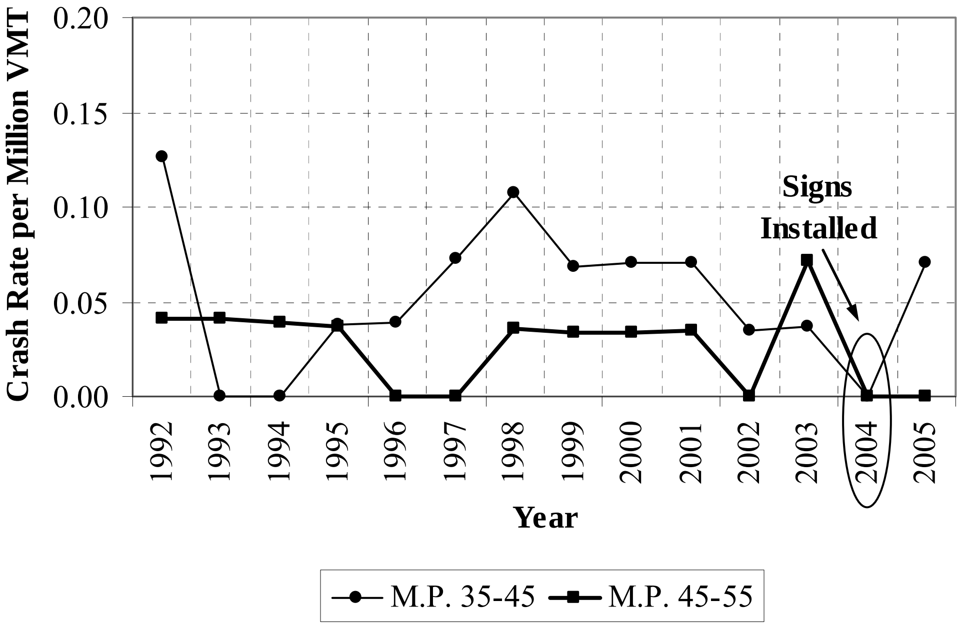


Figure 5-6. Westbound I-80 crash rates for M.P. 35-45 and M.P. 45-55.

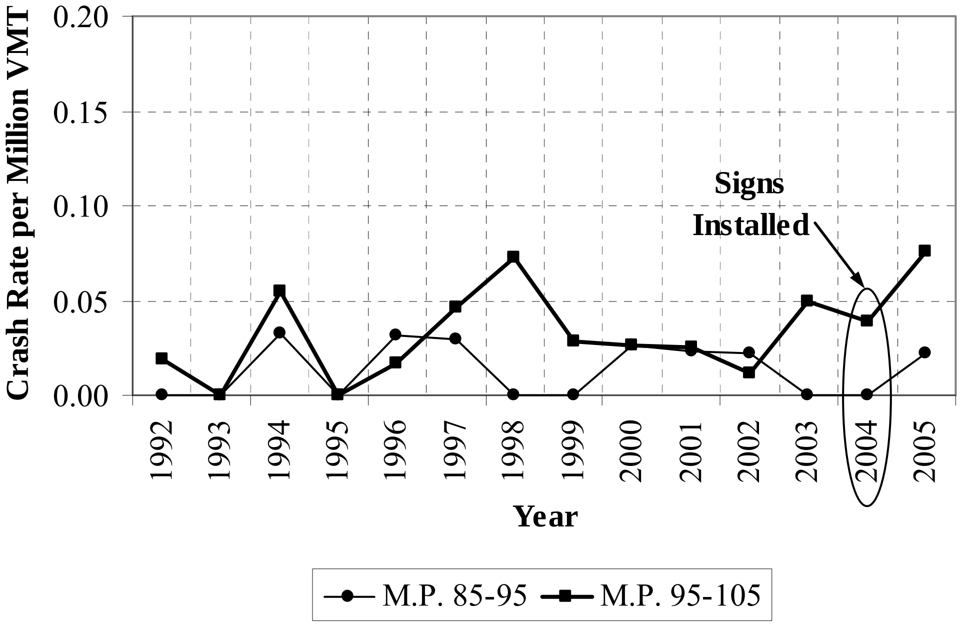


Figure 5-7. Westbound I-80 crash rates for M.P. 85-95 and M.P. 95-105.

5.2.2 Traditional Before-After Crash Rate Analysis of Drowsy Driving Signs

As discussed in Section 3.5, a before-after crash analysis of drowsy driving crashes for I-80 west of Salt Lake City was conducted for this research. The “before” timeframe includes drowsy driving crashes from August 21, 2002 through December 31, 2003 while the “after” time period incorporates the time period of August 21, 2004 through December 31, 2005. Figure 5-8 illustrates the before-after crash rate analysis for eastbound I-80 along with the location of the drowsy driving signage for comparison purposes.

Figure 5-8 presents several interesting trends based upon the short timeframe analysis conducted. The first series of drowsy driving signs appears near M.P. 26 for eastbound travelers while the second series of signs appears near M.P. 50, only four miles before the Grassy Mountain rest area. The pre-sign crash rate from M.P. 50 to M.P. 60 was consistently near 0.50 crashes per million VMT, but the “after” analysis indicates that in the 10 miles following the drowsy driving signage the crash rate decreased significantly. In fact, in the 10-mile corridor after the drowsy driving signs at eastbound M.P. 50 there was a 90 percent reduction in the drowsy driving crash rate (80.5 percent reduction in the number of crashes) whereas for the 10-mile corridor following the signs at M.P. 26 there was only a 2 percent reduction in the crash rate (No reduction in the number of crashes).

Figure 5-8 indicates that 15 miles following the second series of freeway signage the crash rate increased drastically during the “after” period. From approximately M.P. 70 to M.P. 85, the drowsy driving crash rate steadily increased followed by a sharp decrease in the crash rate from M.P. 85 to M.P. 100. The drowsy driving crash rate during the “before” time period however was relatively consistent with a mean crash rate of 0.1 drowsy driving crashes per million VMT. It is possible that whatever effect the drowsy driving signs have on a driver are temporary and quickly forgotten, especially 15 miles down the highway.

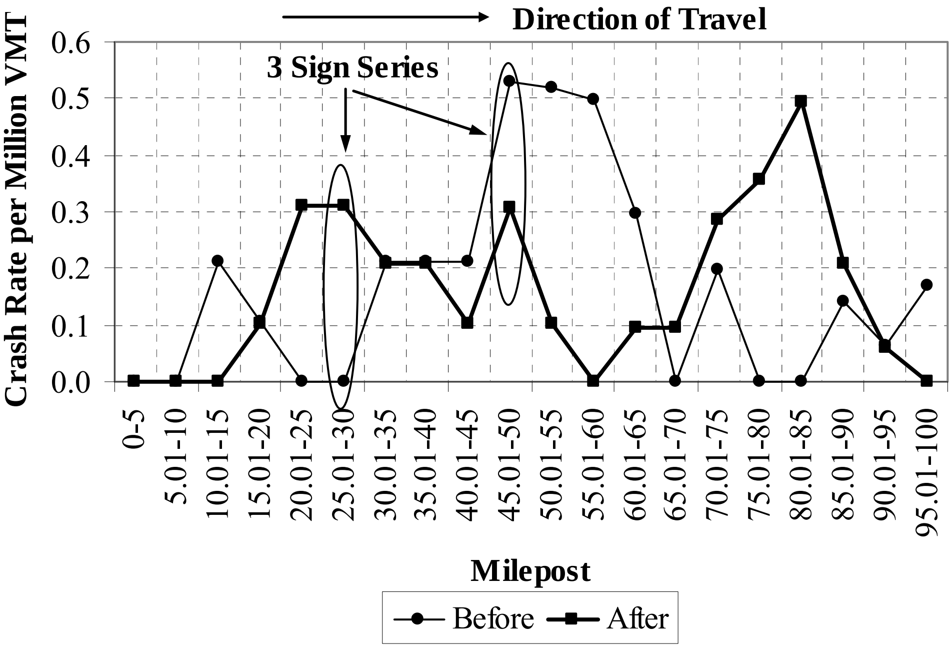


Figure 5-8. Eastbound I-80 before-after drowsy driving crash rate analysis for drowsy driving signage.

Figure 5-9 illustrates the before-after crash rate analysis for westbound I-80 along with the location of the drowsy driving signage from Figure 5-1 at M.P 46; the single sign located at M.P. 95 corresponds to Figure 5-1a. Figure 5-9 indicates that the westbound I-80 drowsy driving crash rate did not fluctuate nearly as much as the eastbound traffic previously discussed. The “after” analysis identifies a relatively flat trend in the fatigue-related crash rate beginning at M.P. 15 and ending at M.P. 90. This trend is drastically different than that outlined in the “after” period for the eastbound traffic during the same stretch of highway.

The 3-sign series in the westbound direction is located at M.P. 46, 5 miles from the nearest freeway off-ramp. Little reduction in the drowsy driving crash rate resulted in the vicinity of the drowsy driving signs, although very little room for improvement was available for the time period studied. At M.P. 95 stands one drowsy driving sign. No crashes occurred in this area in the “before” or “after” time period. In the 5-mile corridor following the signs, the crash rate decreased from 0.213 to 0.103 crashes per million VMT, a 51.6 percent reduction in crash rate but only a difference of one actual crash.

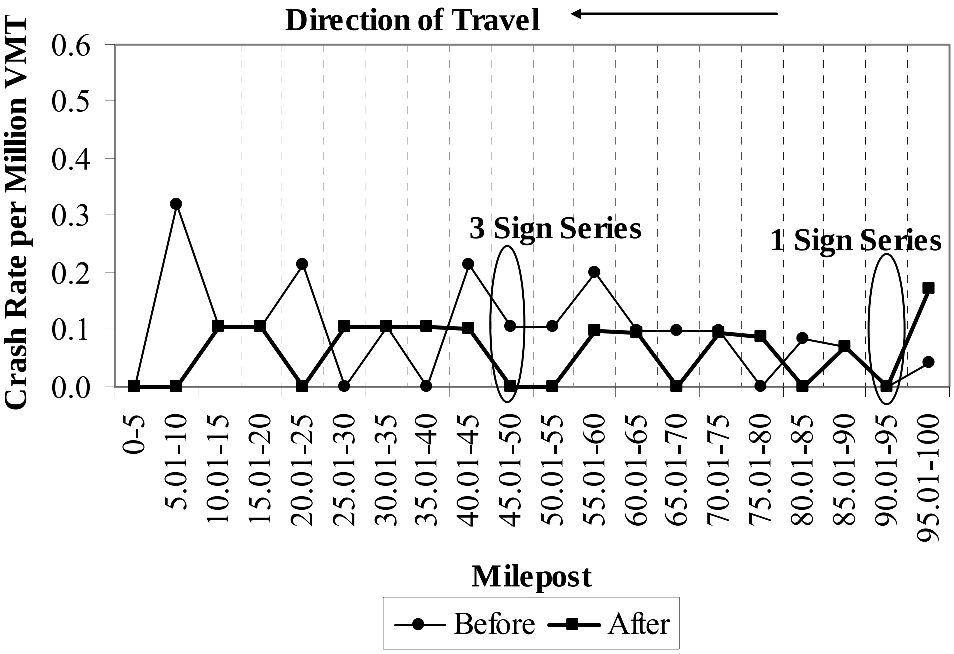


Figure 5-9. Westbound I-80 before-after drowsy driving crash analysis for drowsy driving signage.

Crash data of any type varies considerably from year to year; therefore, no concrete conclusions can be established from either Figure 5-8 or Figure 5-9. Although some observational trends were identified within the scope of this traditional before-after analysis, to determine the effectiveness of the signs required that an estimation of the number of crashes following sign installation be made and used as a benchmark rather than assuming that the number of crashes during the "before" time period is what would have occurred during the "after" period had the signs not been installed. Hauer (1997) indicates that "this way of predicting reflects a naive and usually unrealistic belief that the passage of time (from the 'before" to the 'after' period) was not associated with changes that affected the safety of the entity under scrutiny" (pp. 73). For this reason the modified traditional before-after analysis and comparison group studies were conducted.

It should also be noted from the traditional before-after method that the change in the number of crashes reflects not only the effect of the drowsy driving signage, but also the effect of factors such as traffic, weather, driver behavior, police report accuracy, and other possibly unknown factors. It is not known what part of the change can be attributed to the drowsy driving signs and what part is due to the various other influences outlined. Furthermore, it should be noted that the change in the number of crashes may be due to the spontaneous regression to the mean and not necessarily due to the drowsy driving signage.

5.2.3 Modified Traditional Before-After Crash Rate Analysis

Hauer (1997) provides a method for estimating the number of crashes which may have occurred during the "after" timeframe had the signs not been implemented. To generate this predicted value, the drowsy driving crashes in the two 10-mile corridors following each series of drowsy driving signage were combined to calculate the percent change in drowsy driving crashes in both the eastbound and westbound directions. In both Table 5-4 and Table 5-5 are the estimated parameters and estimates of the standard deviations for eastbound and westbound I-80, respectively. The parameters are defined as follows (Hauer 1997):

($\hat{\lambda}$) = estimated number of crashes in "after" period,
($\hat{\pi}$) = estimated predicted number of crashes in "after" period had the drowsy driving sign treatment not been applied,
($\hat{\delta}$) = the reduction in the expected frequency of drowsy driving crashes ($\hat{\pi}$ - $\hat{\lambda}$),
($\hat{\theta}$) = the estimated index of effectiveness ($\hat{\lambda}/\hat{\pi}$),
Percent Reduction = 100(1-$\hat{\theta}$), and
($\hat{\sigma}$) = standard deviation of random variable

Combining the drowsy driving crashes from eastbound M.P. 27 to M.P. 37 and from M.P. 50 to M.P. 60, it was determined that 5 crashes occurred during the after period while the predicted number of crashes was calculated to be 9.2 crashes. Therefore, the reduction was estimated to be 46.4 percent with a standard deviation of 24.8 percent. The calculations for determining the predicted number of crashes during the "after" period had the treatment not been applied are located in Appendix B.

Table 5-4. Summary of Estimated Values for Eastbound I-80

Estimates of Parameters			Estimates of Standard Deviations		
$\hat{\lambda}$	5	crashes	$\hat{\sigma}\{\hat{\lambda}\}$	2.2	crashes
$\hat{\pi}$	9.2	crashes	$\hat{\sigma}\{\hat{\pi}\}$	1.2	crashes
$\hat{\delta}$	4.2	crashes	$\hat{\sigma}\{\hat{\delta}\}$	2.6	crashes
$\hat{\theta}$	0.536		$\hat{\sigma}\{\hat{\theta}\}$	0.248	
Percent Reduction	46.4 %				

The actual number of crashes during the "after" time period (8/21/04 to 12/31/05) combining the drowsy driving crashes from westbound M.P. 37 to M.P. 47 and from M.P. 85 to M.P. 95 was 3 crashes while the predicted number of crashes was calculated to be 3.0 crashes. Therefore, the reduction in crashes was zero, but as explained hereafter, it was estimated that the percent reduction was 5.3 percent with a standard deviation of 57.5 percent.

Table 5-5. Summary of Estimated Values for Westbound I-80

Estimates of Parameters			Estimates of Standard Deviations		
$\hat{\lambda}$	3	crashes	$\hat{\sigma}\{\hat{\lambda}\}$	1.7	crashes
$\hat{\pi}$	3.0	crashes	$\hat{\sigma}\{\hat{\pi}\}$	0.7	crashes
$\hat{\delta}$	0.0	crashes	$\hat{\sigma}\{\hat{\delta}\}$	1.9	crashes
$\hat{\theta}$	0.947		$\hat{\sigma}\{\hat{\theta}\}$	0.575	
Percent Reduction	5.3 %				

Although the change in crashes from the "before" to the "after" time period was determined to be zero, a percent reduction was calculated. Hauer (1997) indicates that even if the estimated "after" number of crashes ($\hat{\lambda}$) and estimated predicted number of crashes ($\hat{\pi}$) are unbiased estimates of the *actual* number of "after" crashes (λ) and *actual* number of crashes had the signs not be installed (π), respectively, the ratio of (λ / π) is a biased estimate of the index of effectiveness (θ). To compensate for the bias index of effectiveness, an adjustment was made with an approximately unbiased estimator for the index of effectiveness as given by Equation 5-1 (Hauer 1997).

$$\hat{\theta} = \frac{\left(\hat{\lambda} / \hat{\pi}\right)}{\left[1 + \left(VAR(\hat{\pi}) / (\hat{\pi})^2\right)\right]} \tag{5-1}$$

where: $\hat{\theta}$ = estimated index of effectiveness ($\hat{\lambda} / \hat{\pi}$),

$\hat{\lambda}$ = estimated number of crashes in "after" period,

$\hat{\pi}$ = estimated predicted number of crashes in "after" period had the drowsy driving sign treatment not been applied, and

VAR ($\hat{\pi}$) = estimated variance of $\hat{\pi}$.

The estimated variance of $\hat{\pi}$ in Equation 5-1 was determined using Equation 5-2 (Hauer 1997).

$$\text{VAR}(\hat{\pi}) = \sum r_d(j)^2 K(j) \tag{5-2}$$

where: VAR ($\hat{\pi}$) = estimated variance of $\hat{\pi}$,

$r_d(j)$ = ratio of durations, and

K(j) = number of drowsy driving crashes in each "before" time period.

The ratio of durations in Equation 5-2 was determined using Equation 5-3 (Hauer 1997).

$$r_d(j) = \frac{D_a}{D_b} \tag{5-3}$$

where: D_a = duration of after period for entity j, and

D_b = duration of before period for entity j.

5.2.4 Comparison Group Before-After Crash Rate Analysis

According to Hauer (1997), "it is customary to account for the influence of all [causal] factors by making use of the comparison group device" (pp. 115). The purpose of using a comparison group is fairly straight forward. It is a method of prediction that takes into account "unrecognized, and/or unmeasured, and/or ill-understood factors" (Hauer 1997, pp. 115). The term comparison group stems from the fact that drivers in the data used for this analysis were not assigned at random to read and/or implement the actions outlined in the captions of the drowsy driving signage. As such, this study was purely observational and a comparison group, not a control group, was utilized.

Hauer (1997) provides a four-step procedure to calculating a percent reduction in the number of drowsy driving crashes. To begin, comparison groups were selected and incorporated the following sections of highway: southbound I-15 M.P. 0-20, southbound I-15 M.P. 168-188, eastbound I-70 M.P. 130-150, and westbound I-80 M.P. 0-20. Each comparison group consisted of 20 miles since each group was compared to 20 miles of drowsy driving data on I-80 (two 10-mile corridors following the location of the drowsy driving signage). The comparison groups used in the analyses were selected for two reasons. First, the mean of the estimated odds ratio for each group was "close" to 1 and second, the corridors are similar in topography and roadway alignment to those corridors studied on I-80.

The comparison groups served two purposes. First, as a means of comparing drowsy driving trends from one location in the state to those of I-80 and second, as a means to help calculate the variance of the predicted "after" number of crashes ($\hat{\pi}$). The number of drowsy driving crashes for time periods beginning on August 21st and ending on December 31st of the following year for the years studied were calculated after which the actual odds ratio (ω) was sought using Equation 5-4 (Hauer 1997).

$$\omega = \frac{r_C}{r_T} \tag{5-4}$$

where: r_C = the ratio of the expected accident counts for the comparison group, and

r_T = the ratio of the expected accident counts for the treatment group.

Equations 5-5 and 5-6 define the variable r_C and r_T from Equation 5-4 as given by Hauer (1997).

$$r_C = \frac{\nu}{\mu} \tag{5-5}$$

where: r_C = the ratio of the expected accident counts for the comparison group,

ν = expected crash count of comparison group during "after" time, and

μ = expected crash count of comparison group during "before" time.

$$r_T = \frac{\lambda}{\kappa} \tag{5-6}$$

where: r_T = the ratio of the expected accident counts for the treatment group,

λ = expected crash count of treatment group during "after" time, and

κ = expected crash count of treatment group during "before" time.

With insufficient data to determine the actual odds ratio, an approximate unbiased estimate of the odds ratio (o) for a given year was calculated using Equation 5-7 (Hauer 1997). Table 5-6 is provided as an example of the composite number of crashes from the four comparison groups used to calculate the variance of the predicted "after" number of crashes ($\hat{\pi}$). The mean of the estimated odds ratio is 0.959.

$$o = \frac{\left[(K \times N) \big/ (L \times M) \right]}{\left[1 + \left(\frac{1}{L} \right) + \left(\frac{1}{M} \right) \right]} \tag{5-7}$$

where: o = approximate unbiased estimate of odds ratio (ω)

K = crash count of treatment group during “before” time,

N = crash count of comparison group during “after” time,

L = crash count of treatment group during “after” time, and

M = crash count of comparison group during “before” time.

Table 5-6. Summary of Odds Ratios and Variance of Omega

Group	**Number of Crashes**		**Odds Ratio (*o*)**
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**Sum of Groups 1-4**	
8/21/92 - 12/31/93	6	19	
8/21/94 - 12/31/95	11	21	0.527
8/21/96 - 12/31/97	6	26	1.869
8/21/98 - 12/31/99	11	27	0.502
8/21/00 - 12/31/01	8	34	1.490
8/21/02 - 12/31/03	13	25	0.409
8/21/04 - 12/31/05	5	30	2.516
Mean of Odds Ratios			0.959
Sample Variance			0.452
K	55	M	152
L	5	N	30
Overall Odds Ratio			1.799
VAR(ω)			0.19

VAR(ω) for eastbound I-80 was 0.19 while for westbound I-80 it was less than zero; therefore, 0.00 was used for VAR(ω) for the westbound direction. Using a spreadsheet, $\hat{\lambda}$, $\hat{\pi}$, $\hat{\delta}$, $\hat{\theta}$, and a percent reduction in drowsy driving crashes were calculated for both eastbound and westbound I-80 and are summarized in Appendix B.

For eastbound I-80, the index of effectiveness was calculated to be 0.371; therefore, the percent reduction is assumed to be 62.9 percent. Westbound I-80 yielded an index of effectiveness of 0.776, thus the percent reduction in drowsy driving crashes for the 20 miles studied is 22.4 percent.

A *t*-ratio was calculated for both eastbound and westbound directions and used in conjunction with a *t*-distribution table to determine whether or not the reduction in crashes was statistically significant. The *t*-ratio was determined using Equation 5-8 (Ramsey and Schafer 2002).

$$t = \frac{o_{overall} - 1.0}{\sqrt{\frac{s_{before}^2}{n_{after}}}} \tag{5-8}$$

where: t = t-ratio,

$o_{overall}$ = overall odds ratio for time periods,

s_{before}^2 = sample variance of "before" time period, and

n_{after} = sample size of "after" time period.

Using a one-sided *t*-distribution table with four degrees of freedom, it was determined that the *p*-value for the 20 miles of highway analyzed in the eastbound direction was 0.15 while in the westbound direction of I-80 it was not calculated due to a negative *t*-ratio. Neither corridor was statistically significant.

5.2.5 Drowsy Driving Signage Before-After Crash Rate Analysis Summary

Three before-after methods were discussed in the previous subsections to determine the effectiveness of the drowsy driving freeway signage. The methods incorporated were the traditional method, the modified traditional method, and the comparison group method. The results of each method are outlined in Table 5-7.

Table 5-7. Summary of Drowsy Driving Signage Before-After Analyses

Method	Reduction in Number of Crashes (%)		Standard Deviation (%)		Number of Crashes Reduced	
	EB	WB	EB	WB	EB	WB
Traditional	45.0	12.5	52.6	25.0	9.0	0.0
Modified Traditional	46.4	5.3	24.8	57.5	4.2	0.0
Comparison Group	62.9	22.4	19.9	46.4	5.8	0.5

5.2.6 Traditional Before-After Crash Rate Analysis at Milepost 54 Rest Area

In addition to the drowsy driving signage crash rate analysis discussed, a before-after crash rate analysis of drowsy driving crashes west of Salt Lake City was conducted in the vicinity of the Grassy Mountain rest area as illustrated in Figure 5-2. The impact of the Grassy Mountain rest area at M.P. 54, which was constructed in 2000, is shown in Figure 5-10. The location of the rest area is identified as well for comparison purposes. Figure 5-10 demonstrates that the crash rate for the "before" timeframe of 1997-1999 as well as the "after" time period of 2001-2003. During the first 25 to 30 miles the crash rates are relatively low, but quickly increase from M.P. 25 to a peak near M.P. 50. The corridor directly following the rest area did demonstrate a decrease in the drowsy driving crash rate although it was not large. From M.P. 60 to M.P. 65, the crash rate was higher during the "after" period even though the overall trend during the "after" period showed a decrease in the crash rate. As seen in Figure 5-10, a large difference was identified between the "before" and "after" time periods in the vicinity of M.P. 70 to M.P. 85. Figure 5-11 represents the drowsy driving crash rate for westbound I-80 from M.P. 0 to M.P. 100. Westbound I-80 yielded more conservative crash rates for the 5-mile segments studied compared to the eastbound crash rates.

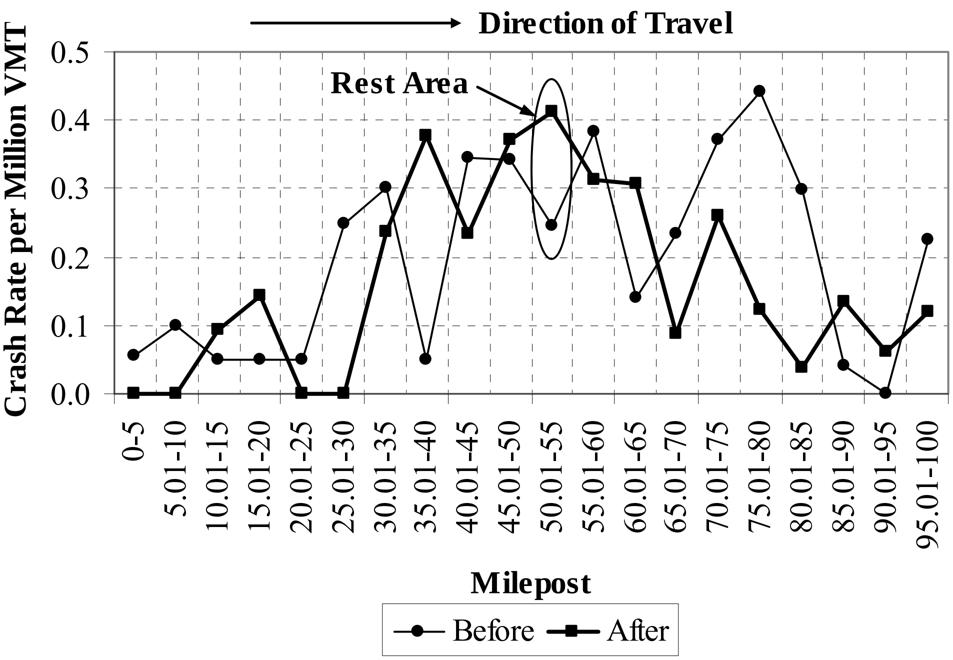


Figure 5-10. Eastbound drowsy driving crash rate analysis for M.P. 54 rest area.

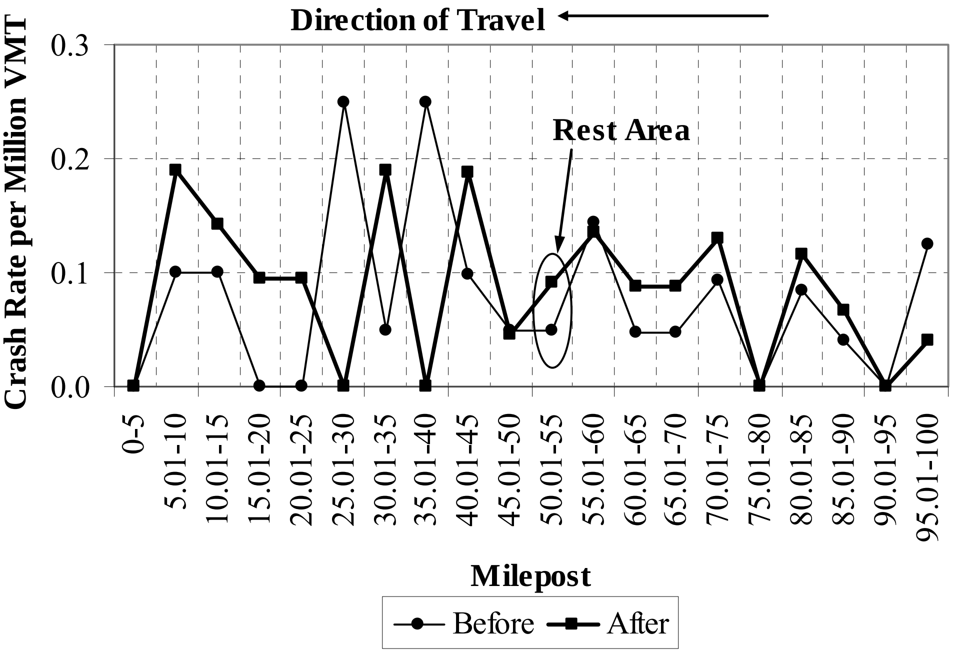


Figure 5-11. Westbound drowsy driving crash rate analysis for M.P. 54 rest area.

In the vicinity of the rest area and directly downstream, no drastic reduction in drowsy driving crash rates is noticeable. In fact, the “after” period crash rates for most segments supersede the “before” crash rates. The most notable trend occurred in the “after” time period as the crash rate increased as drivers approached and traversed the Salt Flats area prior to entering Wendover, Utah on the Nevada border. Crash rates in the vicinity following each rest area have been calculated to verify any trends. Figure 5-12 illustrates the crash rates for eastbound I-80 for the 10-mile segments before (M.P. 45-55) and after (M.P. 55-65) the rest area. The same information for westbound crash rates is provided in Figure 5-13 where the before segment is M.P. 55-65 while the after segment is M.P. 45-55.

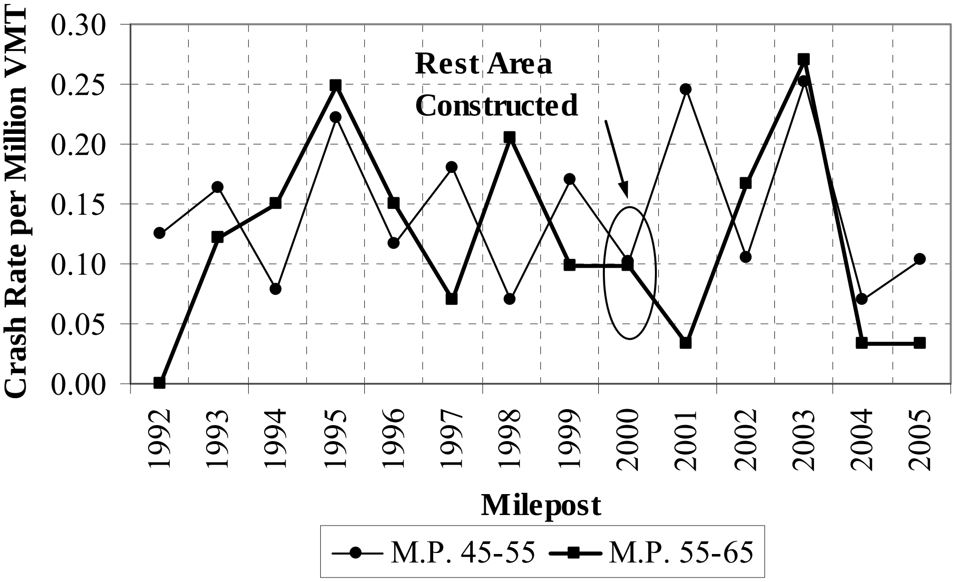


Figure 5-12. Eastbound I-80 crash rates for M.P. 45-55 and M.P. 55-65.

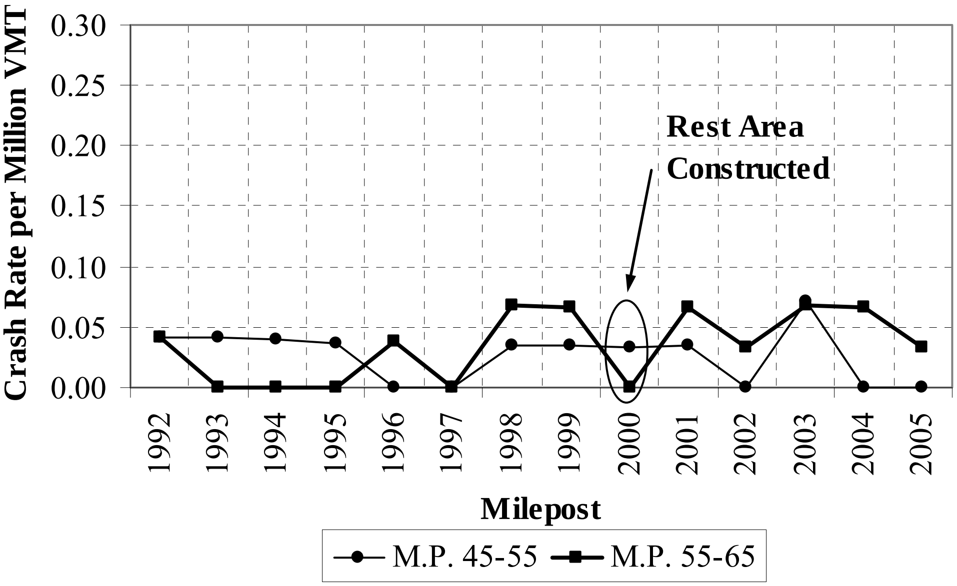


Figure 5-13. Westbound I-80 crash rates for M.P. 45-55 and M.P. 55-65.

5.3 Rumble Strips

Fatigue driving is one reason that many motorists have run-off-road crashes. The three specific run-off-road types of crashes as mentioned in Chapter 4 include "Ran Off Roadway-Thru Median," "Ran Off Roadway-Right," and "Ran Off Roadway-Left." Of the 38,648 run-off-road crashes in Utah on Interstate freeways, U.S. Routes, and S.R. highways from 1992-2004, 8,263 (21.4 percent) were caused by drivers who were asleep, fatigued, or ill. Of the 8,263 drowsy driving crashes in which the driver ran off the roadway, 393 fatalities resulted, or 9 percent of all fatalities across Utah occurred in run-off-road crashes. Furthermore, of the 472 drowsy driving caused fatalities, 83 percent occurred in run-off-road crashes. To reduce the number of run-off-road crashes and fatalities, UDOT implemented a policy that all Interstate highways are to have rumble strips installed. No formal policy has been established for U.S. routes or S.R. highways. Rumble strips on these highways must be justified through crash history data or engineering experience.

UDOT currently uses five types of rumble strips, namely continuous, skip, rolled, concrete-edge, and concrete-full. Approximately 77 percent of Interstates in Utah have rumble strips, although only 63 percent of the rumble strips are in “acceptable” or “marginal” condition according to Roland Stanger (Personal communication, June 11, 2007) of the FHWA. The number of miles and type of rumble strip for the Interstate freeways are outlined according to direction of travel in Table 5-8. No similar rumble strip inventory is available for U.S. routes or S.R. highways. The rumble strip inventory as summarized in Table 5-8 was conducted in May 2004. No rumble strip inventory has been conducted since May 2004, but it was determined that approximately 100 miles of shoulder rumble strip has been added to I-70 since the May 2004 inventory. I-215 is a belt route encircling much of Salt Lake City; therefore, the designation of “Inside Lanes” and “Outside Lanes” is used in Table 5-8. “Inside Lanes” encompasses southbound M.P. 0-6, westbound 6-14, northbound 14-27, and eastbound 27-29. “Outside Lanes” is exactly the opposite directions using the same M.P. markers.

According to the number of miles of rumble strip identified in Table 5-8, I-80 had the highest percentage of roadway with rumble strips as of May 2004. Approximately 90 percent of I-80 had rumble strips while the Interstate freeway with the least percentage of roadway with rumble strips was I-84 with approximately 64 percent.

Cheng et al. (1994) evaluated the effectiveness of rumble strips on highway shoulders in Utah from a safety perspective and concluded that highway segments with continuous rumble strips on asphalt near the travel lane had lower crash rates than highway segments with concrete discontinuous rumble strips offset from the travel lane. Furthermore, they reported that the discontinuous design proved to be less effective in alerting drivers to potentially dangerous driving patterns. Along with a reduction in run-off-road crashes, the severity of the crashes studied also diminished (Cheng et al 1994).

Table 5-8. Rumble Strip Summary for Interstate Freeways (Roland Stanger, personal communication, June 11, 2007)

	Number of Miles									
	I-15		I-70		I-80		I-84		I-215	
Rumble Strip Type	Northbound	Southbound	Eastbound	Westbound	Eastbound	Westbound	Eastbound	Westbound	Inside Lanes	Outside Lanes
Continuous	131.9	131.5	12.7	14.0	33.5	26.3	0.0	0.0	0.0	0.0
Skip	32.8	32.1	18.7	18.5	25.0	27.6	7.7	7.7	0.0	0.0
Rolled	72.8	76.2	88.5	67.9	80.2	92.6	16.1	8.4	0.0	0.0
Concrete-edge	82.1	73.5	42.8	41.5	34.0	34.2	31.3	31.1	20.0	20.0
Concrete-full	2.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	321.6	325.4	162.7	141.9	172.7	180.7	55.1	47.2	20.0	20.0

5.4 Cable Median Barrier

Another mitigation technique implemented by UDOT in late 2003 was the addition of cable barriers in the median between opposing directions of travel. The cable barrier has been installed mostly in urban areas where high traffic volumes in opposing directions have posed the greatest threat to cross-over crashes. As of August 2005, cable median barrier had been installed on I-215 in Salt Lake County, four locations in Utah County, and one location in Southern Utah (Braceras 2005). Although the cable median barriers installed do not specifically aid in the prevention of drowsy driving crashes similar to the drowsy driving freeway signage and rumble strips, they drastically reduce the probability of head-on collisions as a result of crossing the median into oncoming traffic and thus reduce the severity of many crashes.

For example, in the years prior to the cable being installed in Utah County, an average of five fatalities and 22 serious injuries occurred. In the year and a half following installation of the cable median barrier, only one serious injury and no fatalities were reported (Braceras 2005). Figure 5-14 illustrates a typical section of cable median barrier in Utah after having been struck by a vehicle.

(Source: Stutts et al. 2005)

Figure 5-14. Example of cable median barrier in Utah.

5.5 Rest Areas

The state of Utah has many locations where drivers can relax and take a break from the monotony of driving long distances. Utah has 63 locations where drivers can use a restroom, stretch, take photos, buy food, and obtain tourists information about Utah. Of the 63 facilities which comprise the rest facility system, five are welcome centers, five are public/private partnership rest areas, six are public/public facilities, 10 are view areas, 13 are port-of-entry facilities, and 24 are rest areas. The rest areas are separated into two categories. First, traditional state owned and maintained facilities and second, public/private rest areas in which private businesses and UDOT enter into a partnership to provide amenities to traveling motorists 24-hours a day 365 days a year (UDOT 2006b). Utah has five public/private rest areas, all of which are located in rural areas on the I-15 corridor south of Salt Lake City as previously shown in Figure 5-2. Figure 5-15 illustrates the freeway signage used to denote a public/private partnership rest area.

Of the 39 rest area, welcome center, and view area facilities currently in operation, 10 are less than 10 years old while of the remaining 29 rest areas, welcome centers, and view areas, 25 are over 25 years old (UDOT 2007b). Although the overall condition of these facilities is deteriorating, the state of Utah has a maintenance contract with a private company to ensure that the facilities operate in a clean, safe, and efficient manner. Currently roadside facilities such as parking areas, view areas with no services, pull-outs, points of interest, and brake check areas are not recognized as official elements of the highway rest facility system.

(Source: UDOT 2007b)

Figure 5-15. Example of the freeway signage denoting a public/private rest area.

Only the locations of rest areas and view areas on Interstates 15, 70, 80, and 84 were illustrated previously in Figure 5-2 from Section 5.1.1 while Table 5-9 summarizes the location and type of facility for each welcome center, rest area, and view area for all Interstates as well as for U.S. 89 since these are the highways on which drowsy driving corridors were located in Chapter 4.

Table 5-9. Rest Area Summary

Highway	Location of Facility	Type of Facility
I-15	NB M.P. 3	St. George Welcome Center
	NB & SB M.P. 45	Kanarraville Rest Area
	NB & SB M.P. 88	Lunt Park Rest Area
	NB & SB M.P. 112	Public/Private Partnership
	NB & SB M.P. 135	Public/Private Partnership
	NB & SB M.P. 167	Public/Private Partnership
	NB & SB M.P. 188	Public/Private Partnership
	NB & SB M.P. 262	Public/Private Partnership
	NB M.P. 363	Perry Rest Area
	SB M.P. 369	Brigham City Welcome Center
I-70	WB M.P. 84	Ivie Creek Rest Area
	EB & WB M.P. 102	Sand Bench View Area
	EB & WB M.P. 114	Devil's Canyon View Area
	EB & WB M.P. 120	Ghost Rocks View Area
	EB & WB M.P. 141	Black Dragon View Area
	EB M.P. 144	Spotted Wolf View Area
	EB M.P. 180	Crescent Juntion Rest Area
	WB M.P. 180	Thompson Welcome Center
	WB M.P. 225	Harley Dome View Area
I-80	EB & WB M.P. 10	Salt Flats Rest Area
	EB & WB M.P. 54	Grassy Mountain Rest Area
	EB & WB M.P. 170	Echo Canyon Resta Area/Welcome Center
I-84	EB M.P. 91	Weber Canyon Rest Area
	WB M.P. 94	Mountain Green Rest Area
U.S. 89	NB & SB M.P. 495	Bear Lake Overlook
	NB & SB M.P. 184	Hoover Rest Area
	NB & SB M.P. 95	Shingle Creek Rest Area

5.6 Other Countermeasures

Through discussion with the UDOT TAC, it was determined that other countermeasures not currently in place in Utah and/or not specifically identified in the literature review of Chapter 2 may be considered for future use. These countermeasures include in-lane pavement markings, enforcement of seat belt laws as well as other pertinent laws, variable message signs, and the use of radar as a means to set off radar detectors in vehicles thus capturing the attention of drivers.

The pavement marking technique would supplement the current drowsy driving highway signage and possibly read "AVOID FATIGUE DRIVING" in the middle of the travel lane. The intention of the markings is to command drivers' respect and help them realize the serious nature of drowsy driving. Besides pavement markings, a continued emphasis by law enforcement agencies to promote safe driving and the use of seat belts is necessary in order to save lives. The total number of fatalities in Utah on Interstates, U.S. Routes, and S.R. highways from 1992 to 2004 stemming from drowsy driving crashes was 1,643 of which 771 persons (46.9 percent) were reported to have not used their seat belt. Furthermore, of the 7,026 persons involved in drowsy driving crashes which sustained broken bones or bleeding wounds, 1,934 (27.5 percent) did not use their seat belt. It is imperative that the current NHTSA "CLICK IT OR TICKET" campaign nationwide continue in an effort to reduce the severity of all crashes, including drowsy driving crashes. Other possibilities may include a greater emphasis on public reporting of erratic driving which may be attributed to drowsy drivers.

UDOT currently has 69 variable message signs, also referred to as electronic roadway signs, which are used throughout the state to relay up-to-the-minute information to motorists already on the highway (UDOT 2007c). These signs could be employed as a method to alert drivers of drowsy driving or encourage drowsy drivers to pull off of the road immediately. The final mitigation technique mentioned was the use of radar to possibly wake up drowsy drivers via in-vehicle radar detectors. To better understand how widespread the use of radar detectors is among drivers, two questions regarding radar detectors were included as part of an observational survey conducted and summarized in detail in Chapter 6. Although the radar detector method of capturing drivers' attention appears conceivable, it was determined from the results of the survey that more than 97 percent of surveyed drivers did not have radar detectors in their vehicles.

5.7 Existing Countermeasures Summary

Four existing countermeasures undertaken by UDOT were discussed in this chapter. First, discussion was provided on drowsy driving freeway signage on Interstates 15, 70, and 80. The purpose of these signs is to warn drivers of the adverse affects of driving while fatigued. Second, rumble strips were discussed as a physical means to prevent drivers from drifting out of lanes and running off of highways. Third, the use of cable barriers placed in between opposing traffic patterns to prevent vehicles from crossing the median into on-coming traffic was given. Fourth, the role of rest areas with a summary of the location of rest areas on Interstates 15, 70, 80, and 84 as well as U.S. 89 was given followed by a discussion of countermeasures not yet implemented by UDOT to reduce drowsy driving crashes. The results of two before-after crash rate analyses were presented. The existing countermeasures discussed in this chapter form the basis of the drowsy driving countermeasures to be recommended in the critical corridors as discussed in Chapter 7.

6 PUBLIC SURVEY: DROWSY DRIVING

To maintain safety and order on highways, traffic engineers must understand and interpret drivers' reactions toward traffic control devices. A public survey was written and implemented to evaluate the feelings and concerns of drivers with respect to the drowsy driving freeway signage that UDOT has implemented and which was discussed in Chapter 5. Questions in the survey were designed to decipher drivers' opinions about drowsy driving, and specifically along the I-80 corridor. The background and results of the public survey are discussed in detail in this chapter. Also, the results of 14 Chi-Square tests are presented followed by discussion on the limitations of the survey.

6.1 Public Survey Background

Surveys were conducted at the westbound Salt Flats rest area at M.P. 10 as illustrated in Figure 6-1 as well as at the eastbound Grassy Mountain rest area at M.P. 54 as illustrated in Figure 6-2. The rest areas were chosen as appropriate sites for the survey for two reasons. First, each rest area is located downstream of at least one 3-sign series of drowsy driving signage and second, the travel patterns exhibited by drivers in the region. Eastbound drivers are required to cover longer distances between major urbanized areas, which intuitively results in longer travel times. Both rest areas have various amenities, including restrooms, picnic tables, water fountains, and telephone services. Truck parking is also available for semi-trailer trucks and recreational vehicles.

The questionnaire was divided into two sections. The first portion of the survey was used to determine why drivers stopped to use the rest area facilities and if the drowsy driving signs along the freeway had any impact on the drivers' decision to stop. The second part of the survey was aimed at understanding drowsy driving characteristics such as the average number of people in the vehicle when the driver was drowsy, the consequences, if any, of the driver's drowsiness, the types of countermeasures implemented by drivers to maintain an alert state of mind, and the frequency of how often one drives while drowsy. The questionnaire form used in the survey consisted of two sides with the front side shown in Figure 6-3 and the backside in Figure 6-4.

a)

b)

(Photos by Hunter Young and Grant Schultz 2007)

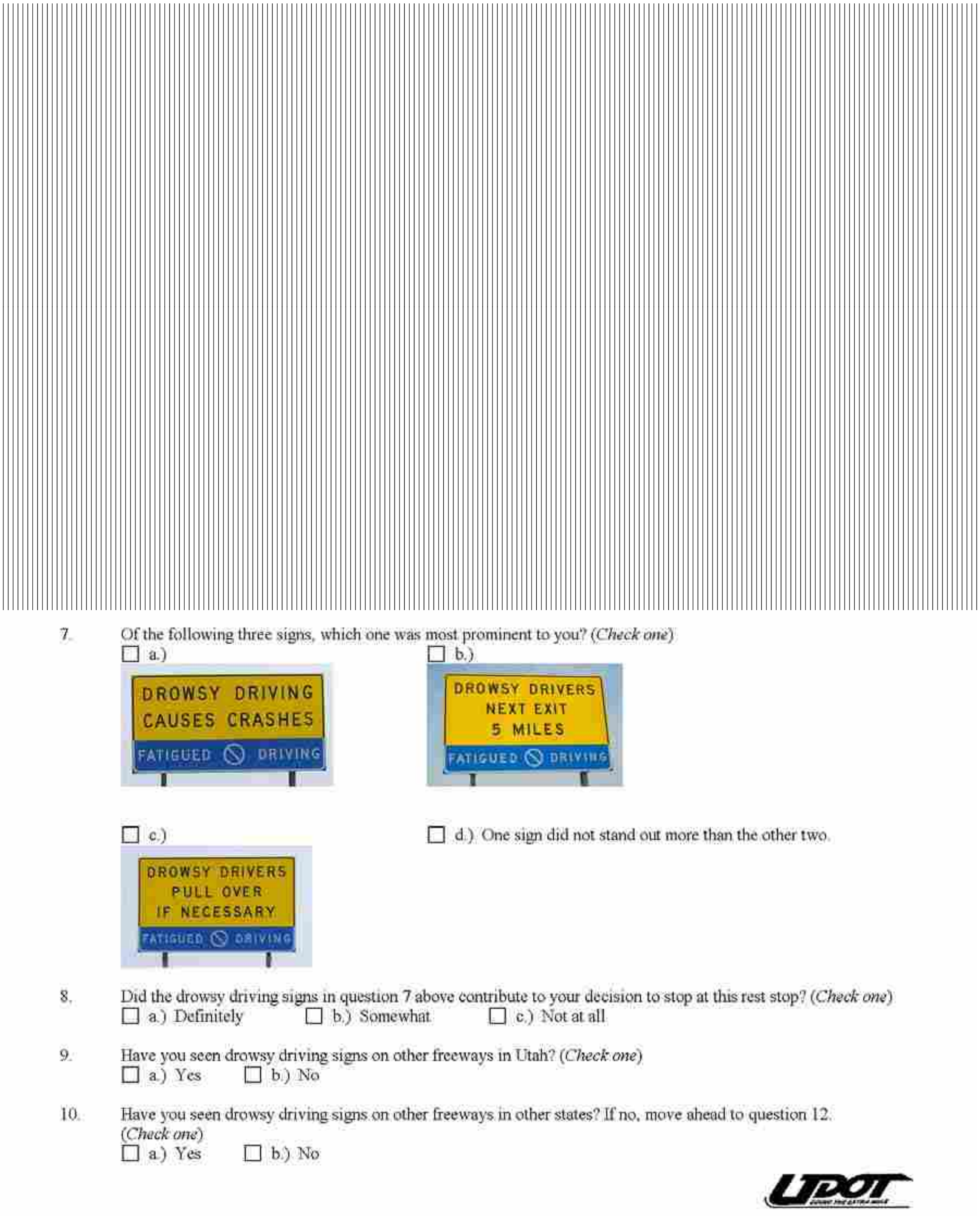
Figure 6-1. I-80 westbound Salt Flats rest area at M.P. 10.

a)

b)

(Photos by Hunter Young 2007)

Figure 6-2. I-80 eastbound Grassy Mountain rest area at M.P. 54.



7. Of the following three signs, which one was most prominent to you? (*Check one*)

☐ a.)

☐ b.)

☐ c.)

☐ d.) One sign did not stand out more than the other two.

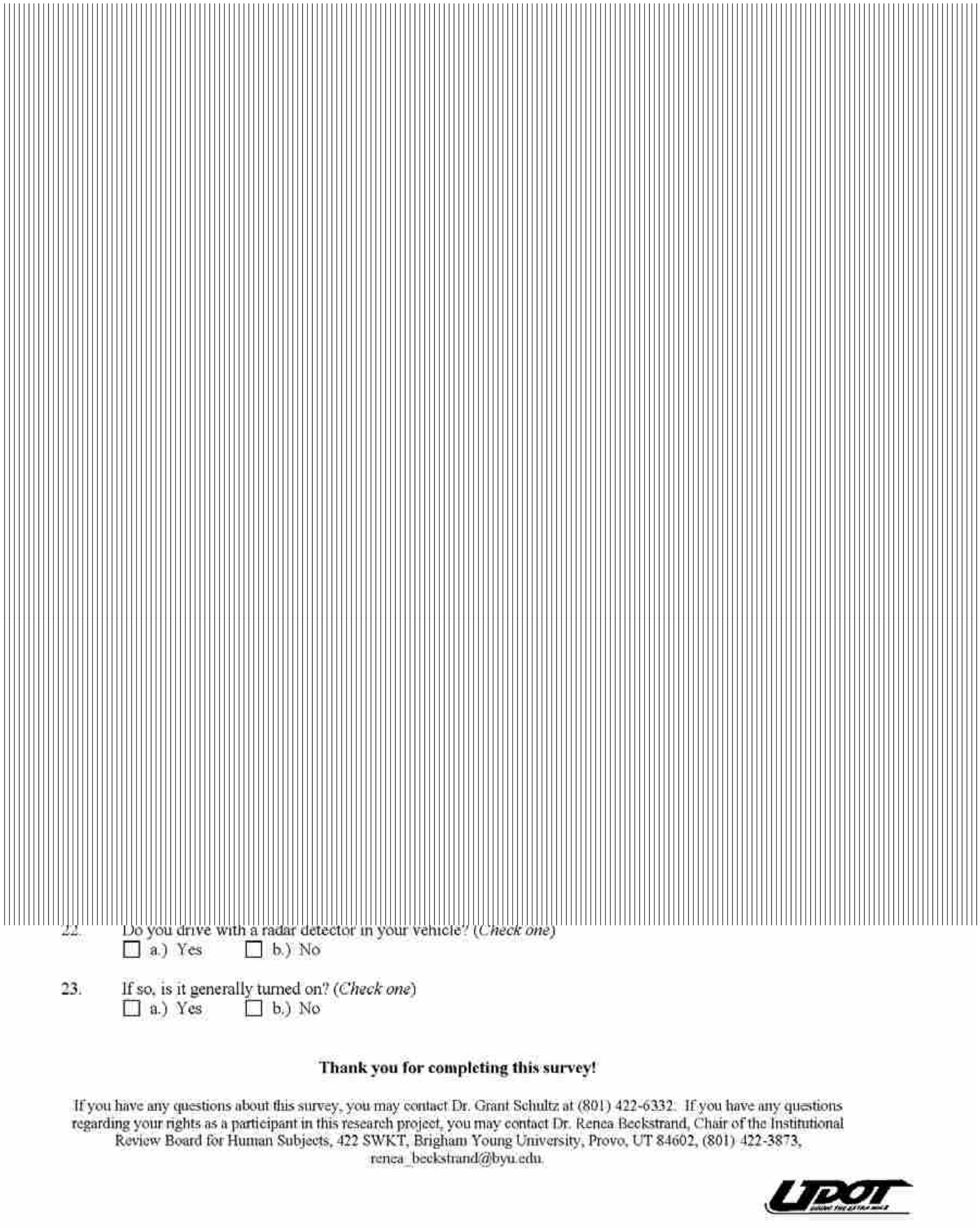
8. Did the drowsy driving signs in question 7 above contribute to your decision to stop at this rest stop? (*Check one*)
☐ a.) Definitely ☐ b.) Somewhat ☐ c.) Not at all

9. Have you seen drowsy driving signs on other freeways in Utah? (*Check one*)
☐ a.) Yes ☐ b.) No

10. Have you seen drowsy driving signs on other freeways in other states? If no, move ahead to question 12. (*Check one*)
☐ a.) Yes ☐ b.) No

UDOT

Figure 6-3. Drowsy driving public survey (front side).



22. Do you drive with a radar detector in your vehicle? (*Check one*)
☐ a.) Yes ☐ b.) No

23. If so, is it generally turned on? (*Check one*)
☐ a.) Yes ☐ b.) No

Thank you for completing this survey!

If you have any questions about this survey, you may contact Dr. Grant Schultz at (801) 422-6332. If you have any questions regarding your rights as a participant in this research project, you may contact Dr. Renea Beckstrand, Chair of the Institutional Review Board for Human Subjects, 422 SWKT, Brigham Young University, Provo, UT 84602, (801) 422-3873, renea_beckstrand@byu.edu.

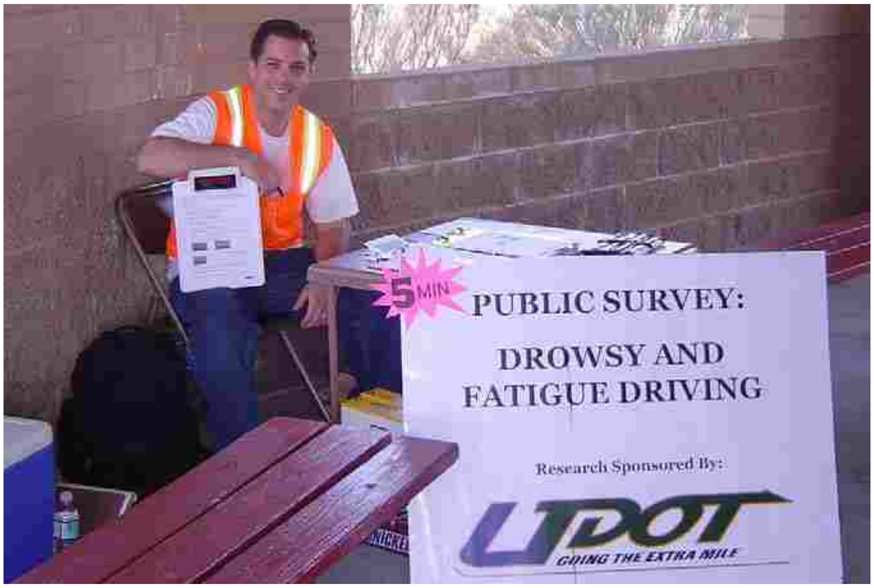
UDOT

Figure 6-4. Drowsy driving public survey (backside).

Once the survey was written and revised, dates were established on which to conduct the survey. In order for the surveys to yield meaningful results, 200 completed surveys at each of the two rest areas were sought. This goal was completed over a span of four days, specifically Monday, April 30, 2007 through Thursday, May 3, 2007, during which time 405 surveys were completed. All drivers who exited their vehicles were approached and asked to complete the survey. As an incentive for filling out the survey, participants were offered a bottle of water or a candy bar. To grasp drivers' attention and provide professional service, a sign was made indicating the purpose of the survey as illustrated in Figure 6-5. Table 6-1 summarizes pertinent data of the survey information.

Table 6-1. Drowsy Driving Public Survey Information

Location	Day of Week	Beginning Time	Ending Time	Number of Completed Surveys
WB M.P. 10	Monday	11:45 a.m.	7:15 p.m.	104
WB M.P. 10	Tuesday	8:00 a.m.	4:30 p.m.	100
EB M.P. 54	Tuesday	5:15 p.m.	7:30 p.m.	25
EB M.P. 54	Wednesday	8:30 a.m.	8:00 p.m.	142
EB M.P. 54	Thursday	8:15 a.m.	11:45 a.m.	34



(Photo by Grant Farnsworth 2007)

Figure 6-5. Drowsy driving public survey sign.

6.2 Public Survey Results

Of the 405 people surveyed, 331 (81.7 percent) were male while 74 (18.3 percent) were female. Of those surveyed, none were under 18, 25 (6.2 percent) were between the ages of 18 and 25, 57 (14.1 percent) were between the ages of 26 and 35, 114 (28.1 percent) were between the ages of 36 and 50, and 209 (51.6 percent) were over the age of 50. Table 6-2 and Table 6-3 summarize the gender and age of the participants, respectively.

Of those surveyed, 378 (93.3 percent) indicated that they drive a motor vehicle everyday, 17 (4.2 percent) only drive a few times a week, seven (1.7 percent) said they only drive a few times a month, while three (0.7 percent) said they rarely drive. Of those surveyed, 25 (6.2 percent) indicated that they drive everyday on I-80 in Utah, 47 (11.6 percent) a few times a week, 125 (30.9 percent) a few times a month, and 208 (51.4 percent) rarely drive on I-80 in Utah. In addition, 176 (43.5 percent) said that they usually travel alone on I-80 while the complement, 229 (56.5 percent), indicated that they drive with at least one other person in the vehicle.

Table 6-2. Gender Summary of Survey Participants

Gender	Responses	Percentage
Male	331	81.7
Female	74	18.3
Total	405	100.0

Table 6-3. Age Summary of Survey Participants

Age	Responses	Percentage
16-17	0	0.0
18-25	25	6.2
26-35	57	14.1
36-50	114	28.1
>50	209	51.6
Total	405	100.0

6.2.1 Drowsy Driving Freeway Signage Results

The data provided in Table 6-4 identifies the reasons for which rest area patrons stopped. To quantify the number of people whose decision to stop at a rest area due to drowsiness was influenced by the drowsy driving signage, the number of drivers who indicated feeling sleepy/drowsy as a reason for stopping was identified from Table 6-4. The total percentages for both westbound and eastbound driver responses sums to more than 100 percent as drivers were permitted to select multiple reasons for stopping.

Table 6-4. Drivers' Reasons for Stopping at a Rest Area

Why did you stop at this rest stop?	Westbound M.P. 10		Eastbound M.P. 54		Total	
	Responses	Percentage	Responses	Percentage	Responses	Percentage
Use restroom	154	75.5	163	81.1	317	78.3
Stretch	88	43.1	102	50.7	190	46.9
Take photos	24	11.8	1	0.5	25	6.2
Felt drowsy	16	7.8	29	14.4	45	11.1
Eat	4	2.0	7	3.5	11	2.7
Walk the dog	4	2.0	3	1.5	7	1.7
Work	3	1.5	0	0.0	3	0.7
No reason	2	1.0	1	0.5	3	0.7
Smoke	1	0.5	1	0.5	2	0.5
Check engine	1	0.5	0	0.0	1	0.2
Use phone	0	0.0	2	1.0	2	0.5
Check trailer load	0	0.0	1	0.5	1	0.2
Wash face	0	0.0	1	0.5	1	0.2
Access trunk	0	0.0	1	0.5	1	0.2
Caravan stopped	0	0.0	1	0.5	1	0.2
Check tires	0	0.0	1	0.5	1	0.2
Total	297	145.7	314	156.2	611	150.9

To determine how the drowsy driving signs may have played a role in a driver's decision to stop before taking the survey, the following question was asked, "Did you see any yellow-blue drowsy driving signs along the freeway? If no, move ahead to question 9." Since more signs are posted in the eastbound direction, the results are summarized by direction of travel in Table 6-5. The vast majority of all survey participants saw the drowsy driving signs. Those persons who did see the signage were then asked if the signs contributed to their decision to stop at one of the rest areas. Table 6-6 includes the responses of how survey participants answered this question.

Table 6-5. Driver Visual Contact Results with Drowsy Driving Signage

Did you see any drowsy driving signs?	Westbound M.P. 10		Eastbound M.P. 54		Total	
	Responses	Percentage	Responses	Percentage	Responses	Percentage
Yes	190	93.1	197	98.0	387	95.6
No	14	6.9	4	2.0	18	4.4
Total	204	100.0	201	100.0	405	100.0

Table 6-6. Drowsy Driving Sign Impact on Drivers' Decision to Stop at a Rest Area

Did the signs contribute to your decision to stop?	Westbound M.P. 10		Eastbound M.P. 54		Total	
	Responses	Percentage	Responses	Percentage	Responses	Percentage
Definitely	11	5.8	22	11.2	33	8.5
Somewhat	43	22.6	54	27.4	97	25.1
Not at all	136	71.6	121	61.4	257	66.4
Total	190	100.0	197	100.0	387	100.0

Of those surveyed, 130 indicated that the drowsy driving signs "definitely" or "somewhat" contributed to the driver's decision to exit the freeway and take a break from behind the wheel. This represents slightly more than 32 percent of the 405 people who completed the survey. It is interesting to note that eastbound drivers had 22 more participants identify the signs as a contributing factor to stopping. Three possible reasons for this large difference include: 1) eastbound drivers pass six drowsy driving signs compared to only three or four signs for westbound travelers, 2) the rest area at which the surveys were conducted is only 4 miles down the road of the drowsy driving signs and with only a few minutes of travel time between the signs and the rest area it is possible that more patrons exited the freeway because of the proximity of the two sites, and

3) eastbound drivers usually cover longer distances between major urbanized areas and in many cases travel from California and Nevada before reaching the rest area site.

Although 68 percent of participants who answered the question in Table 6-6 either did not see the signs or responded "not at all," the public sentiment regarding the signage was positive. Many rest area patrons expressed the feeling that the signs would contribute to their decision to stop if they were drowsy. This opinion is reasonable considering the time of day in which the surveys were conducted.

One question the researchers sought to answer was "how many people who acknowledged they were drowsy at the time of the survey also indicated that their decision to stop was influenced by the drowsy driving signage?" From Table 6-4, 16 westbound drivers felt drowsy while in the opposing direction 29 drivers felt drowsy. Table 6-7 shows how the signs contributed to these drowsy drivers' decisions to stop.

Table 6-7. Drowsy Drivers' Reaction to Drowsy Driving Signage

Of drivers who cited drowsiness as one reason for stopping, did the signs contribute to their decision to stop?	**Westbound M.P. 10**		**Eastbound M.P. 54**		**Total**	
	Responses	**Percentage**	**Responses**	**Percentage**	**Responses**	**Percentage**
Definitely	1	6.3	9	31.0	10	22.2
Somewhat	8	50.0	14	48.3	22	48.9
Not at all	5	31.3	6	20.7	11	24.4
Did not see signs	2	12.4	0	0.0	2	4.5
Total	16	100.0	29	100.0	45	100.0

From Table 6-7 it can be deduced that 56.3 percent of westbound travelers and 79.3 percent of eastbound travelers who were drowsy cited the signs as a "definite" or "somewhat" definite contributing factor in their decision to stop at the rest areas. The final survey question regarding the signage was asked to determine if any one of the three signs was more prominent than the other two, or if all three signs simply had the same overall effect on drivers. Of the 387 participants who responded to this question, 165 participants (42.6 percent) indicated that the first sign of the 3-sign series (Figure 5-1a) was most prominent; 42 participants (10.9 percent) responded that the second sign (Figure 5-1b) stood out the most while 88 participants (22.7 percent) identified the third sign (Figure 5-1c) as the most prominent. The remaining 92 participants (23.8 percent) felt that one sign did not stand out more than another.

Overall, the drowsy driving signs yielded positive responses both in the statistics provided from the surveys as well as through verbal communication between the investigators and rest area patrons.

6.2.2 General Drowsy Driving Results

The second portion of the survey was aimed at determining how many of the surveyed participants have driven drowsy, the consequences of having driven drowsy, and what do the participants do to keep themselves awake while driving drowsy. Of the 405 completed surveys, 304 participants (75.1 percent) admitted to driving drowsy at some point in their lives while 101 participants (24.9 percent) indicated that they had never driven while drowsy. The latter percentage seemed higher than expected but in large measure may be attributed to how one defines driving while drowsy as this terminology may have different meaning depending on the driver. Four follow-up questions were asked to the 304 people who answered affirmatively to driving drowsy at least once in their life. Table 6-8 indicates how people responded to the question, “How many people, including yourself, were usually in the vehicle at the time(s) you were driving drowsy?” The results from this question collaborate well with drowsy driving crash statistics, which indicate that the vast majority of these types of crashes occur when the driver is the only person in the vehicle. In this observational study, 60.5 percent of drivers indicated that they were alone at the time(s) they drove drowsy.

Table 6-8. Number of People in Vehicle at Time of Drowsy Driving

How many people, including yourself, were usually in the vehicle at the time(s) you were driving drowsy?	Responses	Percentage
1	184	60.5
2	92	30.3
3	15	4.9
4	12	3.9
>4	1	0.4
Total	304	100.0

From this data, the researchers wanted to determine the result of each driver having driven while drowsy. Table 6-9 contains the consequences of those drivers who drove drowsy. Survey participants were asked to indicate all consequences that applied to them, pending a driver drove drowsy on multiple occasions. For this reason the percentages sum to more than 100 percent. The largest response identified was "no consequence." Of those who answered this question, 62.5 percent never had a consequence while another 108 of 304 (35.5 percent) participants cited "drifted out of lane" as the consequence of their drowsy driving episode. It was deduced from these results that the overwhelming majority of drowsy driving experiences do not result in a physical crash although the potential for being in a crash does exists.

Table 6-9. Consequences of Survey Participants' Drowsy Driving

What was the consequence of your driving drowsy?	Responses	Percentage
No consequence	190	62.5
Drifted out of lane	108	35.5
Ran off the road	11	3.6
Other	4	1.2
Hit a fixed object	3	1.0
Hit another vehicle	1	0.3
Total	317	104.1

The final two survey questions related to how drowsy drivers remain alert behind the wheel, as in Table 6-10, and approximately how often those surveyed drive drowsy as outlined in Table 6-11. Drivers were asked to identify all drowsy driving countermeasures which they have employed in the past. For this reason the number of responses is greater than the 304 persons answering this question.

Table 6-10. In-Car Drowsy Driving Countermeasures

If you do feel sleepy or drowsy when driving, how to you stay alert?	**Responses**	**Percentage**
Stop driving	179	58.9
Listen to the radio/CD	178	58.6
Open window/turn on AC	178	58.6
Drink caffeinated beverage	168	55.3
Talk to passenger/yourself	103	33.9
Eat something	76	25.0
Slap/hit yourself	49	16.1
Smoke	41	13.5
Eat ice	2	0.7
Stop and exercise	2	0.7
Sing to oneself	2	0.7
Put wet rag on or splash water on face	2	0.7
Talk to someone on the CB radio	1	0.3
Total	981	323.0

Table 6-11. Frequency of Using In-Car Drowsy Driving Countermeasures

From the drowsy driving countermeasures in question 18, how often do you do these things to stay alert when driving?	**Responses**	**Percentage**
1-3 times per year	196	64.5
4-6 times per year	36	11.8
7-9 times per year	15	4.9
>9 times per year	57	18.8
Total	304	100.0

As indicated in Table 6-10, drowsy drivers resort to a host of methods to maintain themselves alert behind the wheel. The most popular methods include: opening a window or turning on the air conditioning, listening to the radio, drinking a caffeinated beverage, and stop driving. Of the 304 people who responded to the question posed in Table 6-11, 64.5 percent indicated that they incorporate the drowsy driving countermeasures discussed in Table 6-10 one to three times per year. Surprisingly, the second highest percentage was from those indicating that they use these measures more than nine times per year.

6.3 Chi-Square Tests Results

Survey questions were compared and analyzed using the Chi-square test procedure. The Chi-square test is useful in determining if a correlation exists between drivers' responses to two questions. For example, the test indicates if a male answered a particular question differently compared to a female; however, the test does not specifically identify what that relationship is. The Chi-square test only suggests that substantial evidence of a correlation exists by comparing the actual frequency observed to an expected frequency (Ramsey and Schafer 2002). All Chi-square tests were performed using SAS statistical analysis software with the aid of personnel in the Center for Statistical Consultation and Collaborative Research. The final results of the analyses are provided in Appendix C, where a summary of the results is presented here.

One of the fundamental assumptions associated with the Chi-square test is that each cell used in the analysis should have a value greater than or equal to five. Due to the limited number of responses to some questions, this assumption was not always satisfied, nor was any response from two possible answers combined in an effort to meet this assumption. After performing 14 Chi-Square tests, a few relationships were found with five of the test yielding statistically significant results. The results of the 14 comparisons are discussed in detail in the following subsections.

6.3.1 Relationships with Gender

Of the five Chi-square tests with statistically significant outcomes, only one involved a relationship with gender (question 1). The relationship encountered gender with whether or not the drowsy driving signs contributed to the driver's decision to stop at one of the rest areas (question 8). The results of this analysis yielded a *p*-value of 0.041. From the test, an observation was made that females are more likely to "definitely" stop at a rest stop compared to males. Although approximately the same percentage of both males and females (66 percent) indicated that the drowsy driving signs contributed "not at all" to their decision to stop, only 7 percent of the males responded that the signs "definitely" played a role in their decision to stop compared to 15 percent of the female responses. For this analysis, being female described more drivers that "definitely" pulled off of the freeway due to the drowsy driving freeway signage. The results of this test are located in Appendix C.

Six other comparisons were made with gender, none of which had significant results. Gender was compared to: whether or not the drowsy driving signs were seen along the freeway (question 6), whether or not one of the three drowsy driving signs was more prominent than the others (question 7), the number of hours one drives between stops (question 12), the number of hours the driver slept the night before his/her current trip (question 13), the number of hours of sleep on an average night (question 14), and whether or not a driver has ever driven drowsy (question 15).

For question 6, no significance was calculated as to whether being male or female played a role in a driver seeing the drowsy driving signs as indicated by a *p*-value of 0.153. The vast majority of both genders indicated seeing the freeway signs. Very similar results were outlined in Table 6-5 independent of gender. Male versus female responses for question 7 dealing with whether one drowsy driving sign stood out more than the others were fairly similar. Approximately 11 percent of each gender indicated that the sign caption "Drowsy Drivers Next Exit 5 Miles" was most prominent to them. This sign caption was the least prominent of the three signs when separated by gender. The greatest spread between male and female responses was in the category of "One sign did not stand out more than the other two." More than 25 percent of males indicated no preference among the sign captions while only 16 percent of females indicated no preference.

Question 12 asked how many hours a driver drives between stops. No significant difference was determined as the *p*-value associated with this question was 0.369. Of the male drivers, the most popular response (33 percent) was driving greater than three hours between stops followed by driving two hours between stops. More than 39 percent of the females indicated driving two hours between stops as the number one response followed by 30 percent driving about three hours.

Question 13 asked drivers how many hours they slept the night before their current trip. Although no statistically significant results were found with this question, which resulted in a *p*-value of 0.165, the difference in responses between the genders varied sharply. Responses indicated that slightly more than 43 percent of females slept five to seven hours with the second most frequent answer of 38 percent being seven to nine hours. The most popular male responses was the opposite with the most frequent response (45 percent) sleeping seven to nine hours followed by 28 percent indicating five to seven hours of sleep the night before their current trip. A total of 60 people surveyed (16 percent of males and 11 percent of females) responded having slept more than nine hours the night before their trip. These 60 people represent almost 15 percent of all drivers who completed the survey.

Question 14, which was very similar to question 13, asked how many hours of sleep one receives on an average night. As in question 13, the Chi-square test results had a *p*-value greater than 0.05, specifically 0.068. The results indicate that number of hours of sleep on an average night is close to being statistically different between males and females. Responses indicated that 46 percent of females sleep five to seven hours on average with the second most frequent answer of 45 percent being seven to nine hours. The male order of most popular responses was again the opposite with the most frequent response (54 percent) sleeping seven to nine hours followed by 31 percent indicating five to seven hours of sleep on average every night. In contrast to question 13, no females indicated that an average night of sleep consisted of five or less hours whereas 5 percent of males responded that they sleep less than five hours on average.

The final Chi-square test with gender was used to determine if a driver had ever driven while drowsy (question 15). Males and females who responded affirmatively were 77 percent and 75 percent, respectively. With a *p*-value of 0.666, the test strongly indicates that gender is not significant in whether or driver has ever driven while drowsy.

6.3.2 Relationships with Age

Of the five Chi-square tests with statistically significant outcomes, four involved a relationship with age (question 1). Those relationships with age included which drowsy driving sign was most prominent (question 7), the number of hours one drives between stops (question 12), the number of hours slept the night before one's current trip (question 13), and whether one has ever driven while drowsy (question 15).

The results of comparing age with which drowsy driving sign was most prominent (question 7) yielded a statistically significant *p*-value of 0.006. The most prominent drowsy driving sign varied drastically by age group. For the 18-25 year old group, "Drowsy Drivers Pull Over If Necessary" stood out the most with 39 percent of the respondents choosing this option. This particular age group only marked the option "One sign did not stand out more than the other two" 4 percent of the time thereby indicating that the youngest group preferred one of the three signs over the other two. Of the 26-35 year old group, 54.6 percent preferred the sign "Drowsy Driving Causes Crashes." This was also the most frequently reported answer for the age groups of 36-50 (41.0 percent) and greater than 50 (41.2 percent). Almost 31 percent of drivers 26-35 cited "Drowsy Drivers Pull Over If Necessary" as the most prominent.

The two oldest age groups, the 36-50 and greater than 50 age groups, had more respondents indicate that they had no preference between the three signs. Specifically, 26 percent of the 36-50 age bracket responded that they had no preference in one sign while 29 percent of those surveyed who were over 50 years old indicated the same. The overall trend in the responses was that the younger the age of the respondent the more the sign "Drowsy Drivers Pull Over If Necessary" was cited while the older the age of the respondent the more the sign "Drowsy Driving Causes Crashes" was preferred. Only 11 percent of the 387 responses to this question cited "Drowsy Drivers Next Exit 5 Miles" as the sign which stood out the most. This was verified through conversation between survey respondents and those administering the survey. Multiple remarks were made indicating that the sign “Drowsy Drivers Next Exit 5 Miles” sends drivers the wrong message, the message to keep going. Several survey participants mentioned that more emphasis should be aimed to get drowsy drivers off of the highway immediately rather than encouraging them to continue in a fatigued state for another 5 miles or more behind the wheel.

Question 12 asked how many hours a driver drives between stops. The test indicated significant results with a *p*-value of 0.027. Three of the four groups, namely the 18-25, 26-35, and 36-50 age brackets, responded driving more than three hours between stops while those drivers over 50 years of age cited stopping every two hours as the most frequent response. In the 26-35 year old group, 42 percent of drivers identified driving greater than three hours between stops as compared to only 25 percent of drivers over 50 years of age. The general trend from this test indicates that as drivers become older they are less likely to drive greater lengths of time between stops. This may likely be due to physical discomforts or a desire to stretch one’s muscles more often.

Question 13 asked drivers how many hours they slept the night before their current trip. The results were widespread and yielded a *p*-value of 0.008. The first and second most frequent responses of all four age brackets was sleeping seven to nine hours and five to seven hours of sleep, respectively. Of the drivers in the age group of 18-25, 12 percent responded sleeping less than three hours the night before their current trip. By comparison, only 0.5 percent of drivers over 50 cited sleeping less than three hours. It is theorized that lifestyle is the most likely reason that more young adults slept less than three hours. Similarly, 14 percent of 26-35 year old drivers indicated sleeping only between three to five hours the night before their current trip. In contrast to young drivers who slept less, 49 percent of drivers over 50 cited sleeping seven to nine hours the night before their current trip.

The final Chi-square test with age which yielded statistical significance was used to determine if a driver had ever driven while drowsy (question 15). The *p*-value associated with the results was 0.006. Slightly more than half (52 percent) of those 18-25 years old answered affirmatively to having ever driven while drowsy while more than 72 percent of drivers age 50 and greater responded affirmatively. For those drivers between 26-50 years old, 82 percent indicated having driven drowsy at some point while behind the wheel. Although the results from this analysis proved to be statistically significant, they may not be practically important. The survey question was asked in such a way that the results are what could have been anticipated. One might reason that the older a driver is and the more driving exposure one has, the greater the probability of having at least one drowsy driving episode at some point in time. Furthermore, 25 percent of drivers responded negatively implying that they have never driven while drowsy. While for some drivers this may be true, the question of how one defines drowsy driving very easily could have changed the outcome to this question.

Three other comparisons were made with age, none of which had significant results. Age was compared to: whether or not the drowsy driving signs were seen along the freeway (question 6), whether or not the drowsy driving signs contributed to the driver's decision to stop at one of the rest areas (question 8), and the number of hours of sleep on an average night (question 14).

For question 6, no significance was calculated as to whether age played a role in a driver seeing the drowsy driving signs as indicated by a *p*-value of 0.106. The range of percentages based upon age of those indicating that they did see the drowsy driving signs was 92 to 98 percent. Only 18 of the 405 survey participants responded in the negative.

Age was not determined to be a factor in whether or not a driver's decision to stop at the rest area was influenced by the drowsy driving signage (question 8). For the four age brackets, very little difference in how survey participants responded was detected as indicated by a *p*-value of 0.987. Approximately 66 percent of all age groups said that the drowsy driving signs did not contribute to their decision to stop at one of the rest areas while the remaining 34 percent cited that the signs "definitely" or "somewhat" contributed to their decision to stop.

Question 14, which was very similar to question 13, asked how many hours of sleep one receives on an average night. Again, no significant difference was determined by comparing age groups as denoted by a *p*-value of 0.090. For both the age groups 26-35 and 36-50 years old, sleeping seven to nine hours each night was the most frequent response with 42 percent cited this answer. This response increased to 56 percent and 60 percent for the 18-25 and greater than 50 year old groups, respectively. The second most frequent answer for all age groups was sleeping five to seven hours on an average night. Only 10 percent said that they sleep more than nine hours most nights.

After performing 14 Chi-Square tests, several correlations were found with five of the test yielding statistically significant results. Table 6-12 summarizes the Chi-Square tests conducted and their associated *p*-values. The statistically significant questions and *p*-values are identified in bold print according to gender and age.

Table 6-12. Chi-Square Test Summary

	***p*-value**	
Survey Question	**Gender**	**Age**
Did you see any yellow-blue drowsy driving signs?	0.153	0.106
Which drowsy driving sign was most prominent to you?	0.393	**0.006**
Did the signs contribute to your decision to stop at the rest area?	**0.041**	0.987
On average, how many hours do you drive between stops?	0.369	**0.027**
How many hours did you sleep the night before your current trip?	0.165	**0.008**
How many hours on average do you sleep each night?	0.068	0.090
Have you ever driven while drowsy?	0.666	**0.006**

6.4 Survey Limitations

The public survey overall was successful in understanding drivers' opinions about drowsy driving and the role that the drowsy driving freeway signage played in drivers' decisions to stop at one of the rest areas. However, the survey was not perfect. If it were possible to conduct a similar survey again a question would be added to differentiate truck drivers and passenger vehicles drivers as their driving habits can be drastically different. As for the survey questions actually administered, some needed clarification. Question 13 asked how many hours one slept the night before his/her current trip. This was interpreted as the number of hours one slept the night prior to leaving home, which may have been several days, when the intention was to determine how many hours one slept the night before the survey was administered.

Question 15 asked whether or not a driver had ever driven while drowsy. As indicated previously, the probability that one has had a drowsy driving episode is a function of time behind the wheel, which is in most cases related to age. To yield more meaningful results, the question would be changed to include a finite time period. For example, have you driven drowsy in the past 12 months? This type of question would place all drivers on the same level when answering this question since the responses would be independent of age.

Question 19 asked drivers how often they employ certain in-car drowsy driving countermeasures. The possible choices ranged from one time per year to greater than nine times per year. The answer choices assume that a driver has some type of drowsy driving episode at least once per year, which is not true of all drivers. To enhance the accuracy of this question, the answer choices should include "other" as an option thereby allowing drivers to specify how often they use in-car countermeasures to maintain alertness while driving.

Lastly, the persons administering the surveys wore bright orange vests to make a professional impression upon drivers. However, a number of truck drivers were suspicious of the survey administrators indicating concern for those questions dealing with the number of hours of sleep one receives. For fear of being reported to the police, truck drivers may have provided inaccurate information regarding how much sleep they receive each night for fear of being cited. Thus the results of questions 13 and 14 may be slightly skewed depending on the accuracy of the information provided.

6.5 Public Survey: Drowsy Driving Summary

The results of a public survey conducted at two rest areas along I-80 west of Salt Lake City were discussed. A total of 405 surveys were completed by drivers stopping at the rest areas. Of those surveyed, 130 indicated that the drowsy driving signs "definitely" or "somewhat" contributed to the driver's decision to exit the freeway and take a break from behind the wheel. This represents slightly more than 32 percent of survey participants. After performing 14 Chi-Square tests, several correlations were found with five of the test yielding statistically significant results. Only one significant correlation involved a relationship with gender (question 1). The relationship encountered with gender was whether or not the drowsy driving signs contributed to the driver's decision to stop at one of the rest areas (question 8). The four remaining statistically significant relationships were correlated with age and included which drowsy driving sign was most prominent (question 7), the number of hours one drives between stops (question 12), the number of hours slept the night before one's current trip (question 13), and whether one has ever driven while drowsy (question 15). Following discussion of the Chi-Square analyses, the limitations of the survey were provided to as a guide from which to learn. Understanding the effectiveness of the signs as outlined in this chapter sets the stage for future recommendations of drowsy driving signage as identified in the following chapter.

7 EVALUATION OF CANDIDATE SITES

Through the literature review (Chapter 2) and study of existing drowsy driving countermeasures in the state of Utah (Chapter 5), various tools have been discussed which may be useful in reducing the number of drowsy driving crashes statewide. These countermeasures form the basis of the tools which may be implemented on any one of the 41 drowsy driving critical corridors discussed in Chapter 4. The following sections discuss each critical corridor with the purpose of outlining which countermeasures currently exist in each corridor to prevent drowsy driving crashes. Following the inventory of drowsy driving countermeasures, limited recommendations of countermeasures are discussed. The recommendations provided in this chapter reflect the view of the authors and not the official views or policies of UDOT.

7.1 Interstate 15

Seven of the nine critical corridors on I-15 are located in rural areas of which two corridors have both northbound and southbound directions that coincide. Many of these rural corridors already have some type of countermeasure to help reduce drowsy driving crashes. Besides the rural segments identified in Chapter 4, two critical corridors on I-15 are located in the urban area north and south of Salt Lake City. Cable median barrier and rumble strips are currently in place throughout the critical corridor from M.P. 255-260 while in the Ogden area from M.P. 340-345 only rumble strips exists. No possible future countermeasures for the Springville/Provo area (M.P. 255-260) are proposed at this time; however, cable median barrier is one possible countermeasure which could be installed for M.P. 340-345 if UDOT justified such a course of action through a study of crash history. Existing countermeasures along with possible mitigation techniques in or near the drowsy driving corridors have been outlined for both the rural and urban areas in Table 7-1.

One countermeasure not identified in Table 7-1 is the possible use of variable message signs to occasionally warn drowsy drivers to exit a facility immediately. Considering that the two urban critical corridors are located at the extreme ends of the urban area and that some of the drowsy driving crashes occurred in the late afternoon due to commuters returning home after a long work day, this mitigation technique warrants further investigation by UDOT.

Table 7-1. Existing and Future Drowsy Driving Countermeasures on I-15

M.P.	Direction of Travel	Existing Countermeasures	Possible Mitigation Techniques
0 – 5	NB	None	Shoulder Rumble Strips; Drowsy Driving Sign before Welcome Center; Cable Median Barrier from M.P. 2-5
80 – 85	SB	Shoulder Rumble Strips	None Recommended
90 – 95	NB & SB	Shoulder Rumble Strips; Drowsy Driving Sign at SB M.P. 89	Drowsy Driving Sign NB Direction Before Lunt Park Rest Area
170 – 175	SB	Shoulder Rumble Strips	None Recommended
185 – 195	SB	Shoulder Rumble Strips; Drowsy Driving Sign at SB M.P. 189	Drowsy Driving Sign NB Direction Before Scipio Rest Area
190 – 200	NB	Shoulder Rumble Strips	Fix Edge Drop Off
255 – 260	SB	Shoulder Rumble Strips; Cable Median Barrier	None Recommended
340 – 345	NB	None	Shoulder Rumble Strips; Cable Median Barrier

To determine other possible contributing factors in drowsy driving crashes, data gathered from site visits to critical corridors by engineers from Horrocks Engineers was investigated. Site visits were conducted on I-15 from M.P. 80 to M.P. 120 as well as from M.P. 188 to M.P. 223. Within the drowsy driving corridor of southbound M.P. 80 to M.P. 85, the rumble strips were filled in during the last chip seal project (Horrocks

Engineers 2006). It is recommended that the rumble strips be reevaluated to determine if they are currently effective or should be reinstalled anew. For both northbound and southbound from M.P. 90 to M.P. 95, the site visits did not reveal any immediate concerns with edge drop off or sharp clear zone slopes in need of flattening.

In contrast to the good roadway conditions located from M.P. 90 to M.P. 95, the site visits incorporating M.P. 188 to M.P. 223 yielded several locations where edge drop off and steep clear zone slopes are currently a concern. At southbound M.P. 194.9 is located a 1-in. edge drop off while in the northbound direction from M.P. 194.2 to M.P. 199.2 is located an edge drop off ranging from 1-in. to 4-in. The 4-in. edge drop off was recorded at M.P. 198.0 and is illustrated in Figure 7-1. Besides edge drop off as one concern in this area, Horrocks Engineers (2006) identified that the fill slope on the outside of the highway could be flattened to enable a driver to safely reenter the highway despite a clear zone of 30 feet. The specific area in which UDOT may consider flattening the clear zone slope is at northbound M.P. 196.1 and is shown in Figure 7-2.

(Photo by Brian Christensen 2006)

Figure 7-1. Example of edge drop off on NB I-15 between M.P. 194 to M.P. 199.

(Photo by Brian Christensen 2006)

Figure 7-2. Example of steep clear zone slope on NB I-15 between M.P. 194 and M.P. 199.

7.2 Interstate 70

From Chapter 4, it was determined that I-70 has seven critical corridors. All seven of the corridors currently have discontinuous shoulder rumble strips as the only type of countermeasure. Although not located in a particular critical corridor, a series of three drowsy driving is signs located near eastbound M.P. 114. This series of signage has resulted in an increase in drivers stopping at the Eagle Canyon view area according to UDOT. Table 7-2 outlines the existing and possible future mitigation techniques for the critical corridors of I-70. No site visits were conducted on I-70, but UDOT's Roadview Explorer program was used to identify possible areas of concern.

It was determined that several areas of I-70 may be prime candidates for drowsy driving countermeasures. It is recommended that near the city of Green River, transverse rumble strips be considered as a means to wake up drowsy drivers before passing the main exit at M.P. 160. It is also recommended that UDOT consider adding in-lane pavement markings for drivers to read while traveling.

Table 7-2. Existing and Future Drowsy Driving Countermeasures on I-70

M.P.	Direction of Travel	Existing Countermeasures	Possible Mitigation Techniques
20 – 25	WB	Shoulder Rumble Strips	Drowsy Driving Sign before Joseph; Cable Median Barrier
95 – 100	WB	Shoulder Rumble Strips	Cable Median Barrier from M.P. 96-97
125 – 135	WB	Shoulder Rumble Strips	None Recommended
135 – 140	EB	Shoulder Rumble Strips	Drowsy Driving Sign EB before Black Dragon View Area with In-lane Pavement Markings to “Avoid Fatigue Driving”
155 – 160	EB	Shoulder Rumble Strips	Transverse Rumble Strips near M.P. 159 before Green River
160 – 165	WB	Shoulder Rumble Strips	Drowsy Driving Sign Before Green River with Transverse Rumble Strips near M.P. 161
225 – 232	EB	Shoulder Rumble Strips	Drowsy Driving Sign Before Harley Dome View Area

7.3 Interstate 80

In similar fashion to I-70, I-80 also has seven critical corridors. Of these corridors, eastbound I-80 has three critical corridors, all of which are relatively close to each other. The drowsy driving signs indicate that drivers should exit the freeway at M.P. 41 at which location drivers can rest. After conducting a site visit to the exit, it was evident from the amount of trash on the off- and on-ramps that the location is being used by both passenger vehicles as well as large semi-trailer trucks. Therefore, it is recommended that UDOT consider construction of a rest area or view area with minimal amenities. Such amenities could strictly be limited to include passenger and truck parking in a paved parking lot, garbage dumpsters, and possibly lighting for drowsy drivers to feel comfortable sleeping during nighttime or early morning hours. This course of action is to provide a location for sleepy drivers to pull off of the highway between the rest areas at M.P. 10 and M.P. 54 and to minimize the volume of litter thrown out of vehicles currently using the ramps as an area to take a brake from driving. This countermeasure along with other potential drowsy driving mitigation techniques are outlined in Table 7-3.

Table 7-3. Existing and Future Drowsy Driving Countermeasures on I-80

M.P.	Direction of Travel	Existing Countermeasures	Possible Mitigation Techniques
5 – 10	WB	Shoulder Rumble Strips	Drowsy Driving Sign before Salt Flats Rest Area with Transverse Rumble Strips near M.P. 11
20 – 25	WB	Shoulder Rumble Strips	None Recommended
30 – 35	WB	Shoulder Rumble Strips	None Recommended
35 – 40	EB	Shoulder Rumble Strips	Modified Rest Area at Knolls Exit; In-lane Pavement Markings to "Avoid Fatigue Driving"
45 – 50	EB	Shoulder Rumble Strips; Drowsy Driving Signs	Transverse Rumble Strips before Signage
60 – 65	EB	Shoulder Rumble Strips	None Recommended
70 – 75	WB	Shoulder Rumble Strips	Drowsy Driving Sign before Rowley Jct. at M.P. 77

7.4 Interstate 84

The two critical corridors located on I-84 coincide with each other from M.P. 110 to M.P. 115. Although this one stretch of highway was deemed critical, a total of only 10 drowsy driving crashes were recorded between 1992-2004; therefore, it is not recommended that any drowsy driving countermeasure be implemented in this area in addition to the current rumble strips unless justified by UDOT. Continued monitoring of I-84 is recommended to identify if these corridors become worse over time.

7.5 United States Route 89

On U.S. 89, eight of the 12 critical corridors are located in extremely rural areas of Utah. Table 7-4 indicates the existing and possible future drowsy driving countermeasures for the critical corridors. Not identified in Table 7-4, but recommended for all rural areas of U.S. 89 is the use of wider longitudinal edge line pavement markings to help delineate the edge of the highway. An 8-inch edge line width as shown previously in Figure 2-6 is recommended.

Table 7-4. Existing and Future Drowsy Driving Countermeasures on U.S. 89

M.P.	Direction of Travel	Existing Countermeasures	Possible Mitigation Techniques
5 – 10	NB	None	Drowsy Driving Sign before Visitor Center; Centerline Rumble Strips
55 – 60	NB	None	Centerline Rumble Strips; Replace Guardrails
90 – 95	SB	Shoulder Rumble Strips	Drowsy Driving Sign before Shingle Creek Rest Area; Centerline Rumble Strips; Replace Guardrails
105 – 110	NB	None	Centerline Rumble Strips
115 – 125	SB	None	Centerline Rumble Strips
140 – 145	NB & SB	None	View Area and Drowsy Driving Sign with Transverse Ruble Strips near M.P. 141 at S.R. 20 Junction
180 – 185	SB	None	Drowsy Driving Sign before Hoovers Rest Area
325 – 330	NB & SB	None	None Recommended
340 – 353	SB	None	None Recommended
370 – 375	NB	None	None Recommended

Currently, only one portion of one critical corridor has shoulder rumble strips. The one section of rumble strips is found near M.P. 95 and is likely due to a lack of available space since in many locations within critical corridors very little shoulder room exist to install this type of countermeasure. This was verified through site visits conducted by Horrocks Engineers. It was determined during the visits that the right shoulder width of U.S. 89 in both directions from M.P. 0 to M.P. 108 ranges from a minimum of 0 feet to a maximum of 15 feet with an average right shoulder width of 5 feet (Horrocks Engineers 2007). It is therefore recommended that UDOT consider installing centerline rumble strips throughout appropriate areas from M.P. 0 to M.P. 131 to help reduce the number of run-off-road crashes.

This recommendation is based upon the fact that from the Arizona-Utah border to Panguitch (M.P. 0 to M.P. 131), 211 drowsy driving crashes occurred from 1992 to 2004. Of these, 64 drowsy driving crashes (30.3 percent) were "Ran Off Roadway-Left" crashes indicating that approximately one-third of drowsy drivers crossed over the centerline into oncoming traffic before leaving the highway. Furthermore, 126 crashes (59.7 percent) were "Ran Off Roadway-Right" crashes. With such a high percentage of drowsy driving crashes resulting in vehicles drifting off of the roadway to the right, it is recommended that the guardrails in the critical corridor of northbound M.P. 55 to M.P. 60 be replaced along with the "Texas turn-downs." An example of the current guardrails is provided in Figure 7-3.

(Photo by Brian Christensen 2006)

Figure 7-3. Typical example of current guardrail with "Texas turn-down."

7.6 United States Route 91

U.S. 91 has two critical corridors which coincide with each other between M.P. 20 and M.P. 25. Although this section of the highway does not have shoulder rumble strips, this particular countermeasure may not be the ideal solution due to noise complaints which may arise from residents who live along the route. An educational awareness countermeasure through a single drowsy driving sign is a potential countermeasure which UDOT may consider installing near M.P. 16 along with transverse rumble strips as motorists first enter the Cache valley. M.P. 16 is suggested since it is located away from residents' homes and before drivers arrive at the critical corridor at M.P. 20.

7.7 State Route 36

As identified in Chapter 4, S.R. 36 has two critical corridors. Neither corridor has rumble strips due to the extremely narrow shoulders. Also discussed in Chapter 4 was the low AADT on most portions of S.R. 36. Several 5-mile segments had inflated crash rates as a result of the low volume of traffic on the majority of this highway. The crash rates were not practical or consistent with crash rates calculated for other Utah highways. Further study by UDOT of drowsy driving on S.R. 36 is necessary before implementation of any countermeasure should be considered.

7.8 Evaluation of Candidate Sites Summary

Each of the 41 critical corridors outlined in Chapter 4 were in this chapter along with possible recommendations for drowsy driving countermeasures. It was determined that most of the critical corridors on Interstates have one type of rumble strip while the critical corridors on U.S. and S.R. highways do not have rumble strips. Possible drowsy driving countermeasures identified in this chapter include: shoulder and centerline rumble strips, additional drowsy driving highway signage, cable median barrier, clearing brush back to create wider shoulders, flattening slopes near shoulders, and using variable message boards in Salt Lake City to promote staying alert behind the wheel. Each countermeasure discussed should be implemented and justified by UDOT on a case-by-case basis to ensure safety on Utah highways and save lives.

8 CONCLUSIONS

The preceding chapters have outlined the background of drowsy and fatigue driving in the state of Utah as well as around the world. The analysis procedure using the UDOT crash database has been set forth as was the method for determining which 5-mile segments of highway were most prone to drowsy driving during the years 2002-2004. The results indicate 41 critical corridors distributed over eight highway facilities, the majority of which are located on I-15, I-70, and I-80. This chapter provides conclusions and outlines future research possibilities aimed at reducing drowsy driving crashes.

8.1 Conclusions

The results of the research indicate that drowsy driving occurs in both rural and urbanized areas alike. Although drowsy driving crashes represent only 3 percent of all crashes in Utah, they are responsible for approximately 11 percent of all fatalities on Interstates, U.S. Routes, and S.R. highways. While several critical corridors were discovered in urban settings, the majority of the corridors are located in very rural areas with speed limits in excess of 55 mph. The drowsy driving statistics calculated from Utah highways reaffirm many drowsy driving statistics outlined in the literature. For example, drowsy driving crashes typically had two peaks—one in the morning hours near 7 a.m. and one in the mid to late afternoon near 4 p.m. Along with time of day, it was determined that more drowsy driving crashes occurred on weekends than during the middle of the week. Other statistics from Utah highways identified drowsy driving crashes as more severe in nature. For example, on Interstate freeways approximately 6 percent of drowsy driving crashes ended in at least one fatality whereas in all crashes on these facilities combined less than 2 percent of crashes yielded a fatality. It was also estimated from six 5-mile sections of crash data in Chapter 4 that drowsy driving crashes in Utah may be under-reported by as much as 18 percent.

Drowsy driving freeway signage was one specific drowsy driving countermeasure discussed in detail in Chapter 5. The signage is currently found on I-15, I-70, and I-80. The results of a crash rate analysis before and after installation of drowsy driving signs on I-80 west of Salt Lake City yielded promising results in helping to reduce drowsy driving crashes. Three before-after methods were outlined to calculate the effectiveness of the drowsy driving signs for the crash data available following sign installation. It was determined that the eastbound percent reduction in drowsy driving crashes ranged from 45 percent to a high of 63 percent while the westbound direction ranged from 5 percent to 22 percent. Again, the change in the number of crashes reflects not only the effect of the drowsy driving signage, but also the effect of factors such as traffic, weather, driver behavior, police report accuracy, and other possibly unknown factors. It is not known what part of the change can be attributed to the drowsy driving signs and what part is due to the various other influences mentioned.

Besides the drowsy driving signage analysis discussed, a crash rate analysis before and after the construction of the Grassy Mountain rest area yielded positive results for the eastbound direction thus indicating that the rest area may help reduce the number of drowsy driving crashes. In the westbound direction no conclusions could be drawn in light of the volatile change in crash rate between consecutive 5-mile sections. Also identified in Chapter 5 were the effectiveness of rumble strips and cable median barrier in Utah both of which help reduce run-off-road crashes significantly.

Chapter 6 discussed a public survey conducted at two rest areas on I-80 as a supplement to determining the effectiveness of the drowsy driving freeway signage west of Salt Lake City. It was determined that of the 387 surveyed drivers who saw the drowsy driving freeway signs, 33.6 percent indicated that the signs “definitely” contributed or “somewhat” contributed to their decision to stop at one of the two rest areas where surveys were conducted. Also calculated from the survey was the effect that the signs had on drivers who admitted that one reason for stopping at one of the rest areas was drowsiness. Of the 45 people who cited feeling drowsy as a reason for stopping, 32

(71.1 percent) indicated that the drowsy driving signs “definitely” or “somewhat” contributed to their decision to stop.

Using the results of the public survey, 14 Chi-square tests were conducted to determine trends using gender and age. It was determined that the only significant relationship with gender was whether or not the drowsy driving signs contributed to the driver’s decision to stop at one of the rest areas. Other statistically significant results identified trends with age. These included which drowsy driving sign was most prominent, the number of hours one drives between stops, the number of hours slept the night before one’s current trip, and whether one has ever driven while drowsy.

Based upon the results of Chapter 4, appropriate drowsy driving countermeasures were outlined in Chapter 7. The recommended countermeasures include: additional shoulder and centerline rumble strips, cable median barrier, replacement of some guardrail, and drowsy driving highway signage. Drowsy driving countermeasures not yet implemented but which should be considered by UDOT are transverse rumble strips, wider longitudinal pavement markings, in-lane pavement markings indicating “AVOID FATIGUE DRIVING,” minimizing edge drop off, flattening slopes in clear zones, and adding a modified rest area at M.P. 41 on I-80 where motorists can rest and empty trash in appropriate containers.

8.2 Future Research

Future research is highly recommended for the area of drowsy and fatigue driving in the state of Utah. As the population of Utah continues to increase with time so will the number of drowsy driving crashes. The critical corridors discussed in Chapter 4 may see an increase in length or even become obsolete altogether due to reconstruction of roadway alignments, traffic volume increases, and land use changes. It is recommended that UDOT continue to monitor the safety impacts of the drowsy driving freeway signage currently in place. Furthermore, future research will be necessary to statistically determine the effectiveness of the signage on I-15 and I-70 as well as reevaluate the effectiveness of the signage on I-80. The results of such a study would be essential to properly reassess the purpose and need of the freeway signs.

Additional future research may be necessary to identify other drowsy driving countermeasures which may currently be unproven in reducing drowsy driving crashes. Examples of such countermeasures may include midlane rumble strips on highways with narrow shoulders such as U.S. 89 or the use of in-vehicle countermeasures such as eye-closure monitors or tracking devices that detect lane drift. Other countermeasures which should be considered include transverse rumble strips and wider lane markers to more easily delineate the edge of the outside lanes. It is also recommended that an in-depth study of run-off-road crashes be conducted to determine where cable median barrier may be appropriate where not recommended as part of this research.

REFERENCES

Åkerstedt, T. and Kecklund, G. (2001). Age, Gender, and Early Morning Highway Accidents. *Journal of Sleep Research*, 10(2), pp. 105-110.

American Automobile Association (AAA). (2004). Foundation for Traffic Safety. Survey of U.S. and Canadian Police Officers about The Public's Drowsy Driving Behavior. <http://www.aaafoundation.org/pdf/PoliceDD.pdf> (May 29, 2007).

Anderson, D., Glazer, C., and Perrett, G. (2005). UDOT Data Almanac User's Manual, Utah Department of Transportation, Research and Development Division, Salt Lake City, UT.

Beirness, D.J., Simpson, H.M., and Desmond K. (2005). The Road Safety Monitor 2004: Drowsy Driving, *Traffic Injury Research Foundation*, <www.trafficinjuryresearch.com/publications/PDF_publications/RSM_Drowsy_Driving_2004.pdf> (June 13, 2007).

Braceras, C. (2005). Utah Demonstrates That Cable Barriers Virtually Eliminate Cross-Over Crashes. AASHTO-NCHRP Project 17-18 *Lifelines*, 2(2), pp. 1-4.

Brown, I.D. (1994). Driver Fatigue. *The Journal of the Human Factors and Ergonomics Society*, 36(2), pp. 298-314.

Brown, I.D. (1997). Prospects for Technological Countermeasures Against Driver Fatigue. *Accident Analysis and Prevention*, 29(4), pp. 525-531.

California Department of Transportation (Caltrans) (2007). Safety Roadside Rest Area System, *California Department of Transportation*, <http://www.dot.ca.gov/hq/LandArch/srra/index.htm> (June 4, 2007).

Carskadon, M. (1990). Adolescent Sleepiness: Increased Risk in a High-Risk Population. *Alcohol, Drugs, and Driving*, 5(4)/6(1), pp. 317-328.

Chandler, B. (2007). Eliminating Cross-Median Fatalities: Statewide Installation of Median Cable Barrier in Missouri. *TR News*, 248(1), pp. 29-31.

Cheng, E., Gonzalez, E., and Christensen, M. (1994). Application and Evaluation of Rumble Strips on Highways. *Utah Department of Transportation (UDOT)*, <http://safety.fhwa.dot.gov/roadway_dept/docs/ application.pdf> (June 1, 2007).

Cheng, W. and Washington, S.P. (2005). Experimental Evaluation of Hotspot Identification Methods. *Accident Analysis and Prevention*, 37(5), pp. 870-881.

Colten, H.R. and Altevogt, B.M. (2006). *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*. Committee on Sleep Medicine and Research, Board on Health Sciences Policy, National Academies Press, Washington, DC.

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., Bailey, J., and Jackson, R. (2002). Driver Sleepiness and Risk of Serious Injury to Car Occupants: Population-Based Case Control Study. *British Medical Journal* (BMJ), 324(1125), pp. 1-5.

Council on Scientific Affairs (CSA). (1986). Alcohol and the Driver. *The Journal of the American Medical Association* (JAMA), 255(4), pp. 522-527.

Cummings, P., Koepsell, T., Moffat, J., and Rivara, F. (2001). Drowsiness, Countermeasures to Drowsiness, and the Risk of a Motor Vehicle Crash. *Injury Prevention*, 7, pp. 194-199.

Dinges, D. (1995). An Overview of Sleepiness and Accidents*.* *Journal of Sleep Research*, 4(2), pp. 4-14.

Dinges, D. and Kribbs, N. (1991). "Performing While Sleepy: Effects of Experimentally-Induced Sleepiness." In Monk, T. *Sleep, Sleepiness, and Performance*. John Wiley and Sons, New York.

Federal Highway Administration (FHWA). (2002). "Boosting Roadway Safety with Rumble Strips." <http://www.tfhrc.gov/focus/may02/rumble.htm> (June 1, 2007).

Federal Highway Administration (FHWA). (2001). Traffic Monitoring Guide, FHWA, United States Department of Transportation Office Highway Policy Information, Washington, DC.

Federal Highway Administration (FHWA) Wyoming Division Office. (1997). Shoulder Rumble Strips—Effectiveness and Current Practice. <http://safety.fhwa.dot.gov/ roadway_dept/ rumble/states /state_wyom.htm> (June 1, 2007).

Folkard, S. (1997). Black Times: Temporal Determinants of Transport Safety. *Accident Analysis and Prevention*, 29(4), pp. 417-430.

Gates, T.J. and Hawkins, H.G. (2002). The Use of Wider Longitudinal Pavement Markings. Texas Transportation Institute, Report No. 02-0024-1. The Texas A&M University System, College Station.

Gengo, F. and Manning, C. (1990). A Review of the Effects of Antihistamines on Mental Processes Related to Automobile Driving. *The Journal of Allergy and Clinical Immunology*, 86(6), pp. 1034-1039.

Gillberg, M., Kecklund, G., Axelsson, J., and Åkerstedt, T. (1994). Counteracting Sleepiness with a Short Nap. *Journal of Sleep Research,* 3(Supplement 1), pp. 90.

Griffith, M.S. (1999). Safety Evaluation of Rolled-In Continuous Shoulder Rumble Strips Installed on Freeways. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1665*. TRB, National Research Council, Washington, DC, pp. 28-34.

Harwood, D.W. (1993). National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 191: Use of Rumble Strips to Enhance Safety, Transportation Research Board, National Research Council, Washington, DC.

Hauer, E. (1997). *Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety*, 1st Ed. Elsevier Science Ltd., Tarrytown, NY.

Horne, J.A. and Reyner, L.A. (1996). Counteracting Driver Sleepiness: Effects of Napping, Caffeine, and Placebo. *The International Journal of the Society for Psychophysiological Research*, 33(3), pp. 306-309.

Horne, J.A. and Reyner, L.A. (1995). Sleep Related Vehicle Accidents. *British Medical Journal* (BMJ), 310(6979), pp. 565-567.

Horne, J.A. and Reyner, L.A. (1999). Vehicle Accidents Related to Sleep: A Review. *Occupational and Environmental Medicine*, 56, pp. 289-294.

Horrocks Engineers. (2007). Roadway Safety Assessment, U.S.-89; M.P. 0 to M.P. 108, Draft Report of Findings, Utah Department of Transportation.

Horrocks Engineers. (2006). Roadway Safety Assessment, I-15; M.P. 80 to M.P. 120.1, Report of Findings, Utah Department of Transportation.

Hummer, J.E. (2000). "Traffic Accident Studies." *Manual of Transportation Engineering*. Institute of Transportation Engineers, Washington, DC, pp. 191-218.

Knipling, R.R. and Wang, J-S. (1994). Crashes and Fatalities Related to Driver Drowsiness/Fatigue. Research Note from the Office of Crash Avoidance Research. National Highway Traffic Safety Administration (NHTSA), Washington, DC, pp. 1-8.

Kroemer, K. and Grandjean, E. (1997). *Fitting the Task to the Human: A Textbook of Occupational Ergonomics,* 5th Ed. Taylor and Francis, Bristol, PA.

Lyznicki, J.M., Doege, T.C., Davis, R.M., and Williams, M.A. (1998). Sleepiness, Driving, and Motor Vehicle Crashes. *The Journal of the American Medical Association* (JAMA), 279(23), pp. 1908-1913.

Main Roads Western Australia. (2007a). Fatigue: Driver Fatigue Kills. <http://www.mainroads.wa.gov.au/NR/mrwa/run/start.asp> (May 31, 2007).

Main Roads Western Australia. (2007b). A Guide to Roadside Amenities and Rest Areas. <http://www.mainroads.wa.gov.au/NR/mrwa/run/start.asp> (May 31, 2007).

Marvin, R.R. and Clark, D.J. (2003). An Evaluation of Shoulder Rumble Strips in Montana. Federal Highway Administration (FHWA) Report No. FHWA/MT-03-008/8157, Washington, DC.

Maycock, G. (1996). Sleepiness and Driving: The Experience of U.K. Car Drivers. *Journal of Sleep Research*, 5(4), pp. 229-237.

McCartt, A.T., Ribner, S.A., Pack, A.I., and Hammer, M.C. (1996). The Scope and Nature of the Drowsy Driving Problem in New York State. *Accident Analysis and Prevention*, 28(4), pp. 511-517.

McCartt, A.T., Rohrbaugh, J.W., Hammer, M.C., and Fuller, S.Z. (2000). Factors Associated with Falling Asleep at the Wheel Among Long-Distance Truck Drivers. *Accident Analysis and Prevention*, 32(4), pp. 493-504.

McClanahan, D., Albin, R., and Milton, J. (2004). “Washington State Cable Median Barrier In-Service Study.” (CD-ROM), Transportation Research Board 83rd Annual Meeting, TRB, National Research Council, Washington, DC.

McConnell, C.F., Bretz, K.M., and Dwyer, W.O. (2003). Falling Asleep at the Wheel: A Close Look at 1,269 Fatal and Serious Injury-Producing Crashes. *Behavioral Sleep Medicine*, 1(3), pp. 171-183.

McGee, H.W. and Hanscom, F.R. (2006). Low-Cost Treatments for Horizontal Curve Safety. Federal Highway Administration (FHWA) Report No. FHWA-SA-07-002, Washington, DC.

Mignot, E. (1998). Genetic and Familial Aspects of Narcolepsy. *Neurology, Official Journal of the American Academy of Neurology*, 50(Supplement 1), pp. S16-S22.

Mignot, E. (2005). Narcolepsy. <http://www.sleepfoundation.org/site/c.huIXKjM0IxF/b.2419563/k.25DA/Narcolepsy.htm> (May 29, 2007).

Miles, J.D., Carlson, P.J., Pratt, M.P., and Thompson, T.D. (2005). Traffic Operational Impacts of Transverse, Centerline, and Edgeline Rumble Strips. Texas Transportation Institute, Report No. 0-4472-2. The Texas A&M University System, College Station.

Minnesota Department of Transportation (Mn/DOT) (2006). Office of Traffic, Safety, and Operations, Mn/DOT Web site. <http://www.dot.state.mn.us/trafficeng/safety/rumble/index.html> (June 14, 2007).

Mitler, M.M. (1989). Snoozing Almost Worse than Boozing. *Traffic Safety*. 89(2), pp. 17-18.

Mitler, M.M., Miller, J.C., Lipsitz, J.J., Walsh, J.K., and Wylie, C.D. (1997). The Sleep of Long-Haul Truck Drivers. *The New England Journal of Medicine*, 337(11), pp. 755-761.

Morrisey, M., Grabowski, D., Dee, T., and Campbell, C. (2006). The Strength of Graduated Drivers License Programs and Fatalities Among Teen Drivers and Passengers. *Accident Analysis and Prevention*, 38(1), pp. 135-141.

Naitoh, P. (1992). Minimal Sleep to Maintain Performance: Search for Sleep Quantum in Sustained Operations, *Naval Health Research Center*, <http://stinet.dtic.mil/oai/oai?&verb=getRecord&metadataPrefix=html&identifier=ADA223815> (May 31, 2007).

National Heart, Lung, and Blood Institute (NHLBI). (2003). 2003 National Sleep Disorders Research Plan. <http://www.nhlbi.nih.gov/health/prof/sleep/res_plan/sleep-rplan.pdf> (June 14, 2007).

National Highway Traffic Safety Administration (NHTSA). (1998). Expert Panel on Driver Fatigue and Sleepiness, National Center on Sleep Disorders Research/ "Drowsy Driving and Automobile Crashes." <http://www.nhlbi.nih.gov/health/prof/sleep/drsy_drv.pdf> (May 30, 2007).

National Sleep Foundation (NSF). (2005). 2005 Sleep in America Poll. <http://www.kintera.org/atf/cf/{F6BF2668-A1B4-4FE8-8D1AA5D39340D9CB}/2005_summary_of_findings.pdf> (May 29, 2007).

National Sleep Foundation (NSF). (2007). How Much Sleep Do We Really Need? <http://www.sleepfoundation.org/site/c.huIXKjM0IxF/b.2417325/k.3EAC/How_Much_Sleep_Do_We_Really_Need.htm> (May 29, 2007).

National Sleep Foundation (NSF). (2006). Sleep Apnea. <http://www.sleepfoundation.org/site/c.huIXKjM0IxF/b.2464479/apps/nl/content3.asp?content_id={8075528C-88C1-4A26-A944-CA88EB298E2B}&notoc=1> (May 29, 2007).

Neuman, T., Pfefer, R., Slack, K., Hardy, K., Council, F., McGee, H., Prothe, L., and Eccles, K. (2003). National Cooperative Highway Research Program (NCHRP) Report No. 500. Guidance for Implementation of the AASHTO Strategic Highway Safety Plan. Volume 6: A Guide for Addressing Run-Off-Road Collisions, Transportation Research Board, Washington, DC.

Nguyen, L., Jauregui, B., and Dinges, D. (1998). Changing Behaviors to Prevent Drowsy Driving and Promote Traffic Safety: Review of Proven, Promising, and Unproven Techniques, *American Automobile Association Foundation for Traffic Safety*, <http://aaafoundation.org/pdf/drowsydriving.pdf> (May 31, 2007).

Noyce, D.A. and Elango, V.V. (2004). Safety Evaluation of Centerline Rumble Strips Crash and Driver Behavior Analysis. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1862*. TRB, National Research Council, Washington, DC, pp. 44-53.

Outcalt, W. (2001). Centerline Rumble Strips. Colorado Department of Transportation (CDOT) Report No. CDOT-DTD-R-2001-8, Colorado Department of Transportation, Denver, CO.

Pack, A.I, Pack, A.M., Rodgman, E., Cucchiara, A., Dinges D.F., and Schwab, C.W. (1995). Characteristics of Crashes Attributed to the Driver Having Fallen Asleep. *Accident Analysis and Prevention*, 27(6), pp. 769-775.

Pratt, M., Miles, J., and Carlson, P. (2006). Evaluation of Operational Impacts of Installation of Centerline and Edge Line Rumble Strips. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1973*. TRB, National Research Council, Washington, DC, pp. 80-88.

Presser, H.B. (1989). Can We Make Time for Children? The Economy, Work Schedules, and Child Care: Population Association of America, 1989 Presidential Address. *Demography*, 26(4), pp. 523-543.

Presser, H.B. (1995). Job, Family, and Gender: Determinants of Nonstandard Work Schedules Among Employed Americans in 1991. *Demography*, 32(4), pp. 577-598.

Ramsey, F.L., and Schafer, D.W. (2002). *The Statistical Sleuth: A Course in Methods of Data Analysis,* 2nd Ed., Duxbury Thompson Learning, Pacific Grove, CA.

Ray, W.A., Fought, R.L., and Decker, M.D. (1992). Psychoactive Drugs and the Risk of Injurious Motor Vehicle Crashes in Elderly Drivers. *American Journal of Epidemiology*, 136(7), pp. 873-883.

Reyner, L.A. and Horne, J.A. (1998). Evaluation of "In-Car" Countermeasures to Sleepiness: Cold Air and Radio. *Sleep*, 21(1), pp. 46-51.

Roehrs, T., Beare, D., Zorick, F., and Roth, T. (1994). Sleepiness and Ethanol Effects on Simulated Driving. *Alcoholism Clinical Experimental Research*, 18(1), pp. 154-158.

Roehrs, T., Carskadon, M., Dement, W., and Roth, T. (2000). "Daytime Sleepiness and Alertness." In Kryger, M., Roth, T., and Dement, W. *Principles and Practice of Sleep Medicine,* 3rd Ed. W.B. Saunders Company, Philadelphia, pp. 43-52.

Royal, D. (2003). National Survey of Distracted and Drowsy Driving, Attitudes and Behaviors: 2002, National Highway Traffic Safety Administration (NHTSA), <http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/surveydistractive03/HS809566v1.pdf> (May 29, 2007).

Russell, E.R. and Rys, M.J. (2005). National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 339: Centerline Rumble Strips, Transportation Research Board, National Research Council, Washington, DC.

Sagberg, F., Jackson, P., Krüger, H-P., Muzet, A., and Williams, A. (2004). Fatigue, Sleepiness, and Reduced Alertness as Risk Factors in Driving, *Institute of Transport Economics*, <http://www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2004/739-2004/739-2004-2.pdf> (May 31, 2007).

Sagberg, F. (1999). Road Accidents Caused by Drivers Falling Asleep. *Accident Analysis and Prevention*, 31(6), pp. 639-649.

Saito, M. and Richards, S. (2005). Evaluation of Recent Traffic and Safety Initiatives, Volume III: Centerline Rumble Strips on Rural, Two-Way, Undivided Highways, UDOT Report No. UT-05.12, Department of Civil and Environmental Engineering, Brigham Young University, Provo, UT.

Schultz, G.G. and Braley, K.T. (2007). A Prioritization Process for Access Management Implementation in Utah, UDOT Report No. UT-07.05, Department of Civil and Environmental Engineering, Brigham Young University, Provo, UT.

Schultz, G.G. and Lewis, J.S. (2006). Assessing the Safety Benefits of Access Management Techniques, UDOT Report No. UT-06.08, Department of Civil and Environmental Engineering, Brigham Young University, Provo, UT.

Smiley, A. (2002). Fatigue and Driving. In Dewar, R.E. and Olson, P.L. (Editors). *Human Factors in Traffic Safety*. Lawyers and Judges, Tucson, AZ. pp. 143-175.

Stern, J., Boyer, D., and Schroeder, D. (1994). Blink Rate: A Possible Measure of Fatigue. *The Journal of the Human Factors and Ergonomics Society*, 36(2), pp. 285-297.

Stutts, J., Knipling, R., Pfefer, R., Neuman, T., Slack, K., and Hardy, K. (2005). National Cooperative Highway Research Program (NCHRP) Report No. 500. Guidance for Implementation of the AASHTO Strategic Highway Safety Plan. Volume 14: A Guide for Reducing Crashes Involving Drowsy and Distracted Drivers, Transportation Research Board, National Research Council, Washington, DC.

Stutts, J.C., Wilkins, J.W., Osberg, J.S., and Vaughn, B.V. (2003). Driver Risk Factors for Sleep-Related Crashes. *Accident Analysis and Prevention*, 35(3), pp. 321-331.

Stutts, J.C., Wilkins, J.W., and Vaughn, B.V. (1999). Why Do People Have Drowsy Driving Crashes? Input from Drivers Who Just Did. *American Automobile Association Foundation for Traffic Safety*. <http://www.aaafts.org/pdf/ sleep.pdf> (May 29, 2007).

Terán-Santos, J., Jiménez-Gómez, A., and Cordero-Guevara, J. (1999). The Association between Sleep Apnea and the Risk of Traffic Accidents. *The New England Journal of Medicine*, 340(11), pp. 847-851.

Turner-Fairbank Highway Research Center (TFHRC). (2007). *TFHRC Web site*. <http://www.tfhrc.gov/pubrds/03nov/11.htm> (June 1, 2007).

Utah Department of Transportation (UDOT). (2005). "AADT History—2005-1986." <http://www.udot.utah.gov/main/f?p=100:pg:5222177903867411132::::V,T:, 531> (May 29, 2007).

Utah Department of Transportation (UDOT). (2006b). "Public and Private Minimum Requirements" Web site. *Utah Department of Transportation*, <http://www.udot.utah.gov/main/f?p=100:pg:3143427725244953600:::1:T,V:1408> (June 25, 2007).

Utah Department of Transportation (UDOT). (2007a). "Utah Department of Transportation "Road Viewer" Web site." *Utah Department of Transportation*, <http://www.roadview.udot.utah.gov/> (May 29, 2007).

Utah Department of Transportation (UDOT). (2007b). Utah Statewide Rest Area Plan. Utah Department of Transportation, Salt Lake City, UT.

Utah Department of Transportation (UDOT). (2007c). “Variable Message Signs” Web site. *Utah Department of Transportation*, <http://www.udot.utah.gov/main/f?p=100:pg:3365330835871978670:::1:T,V:263,3672> (July 1, 2007).

Utah Department of Transportation (UDOT). (2006a). “Zero Fatalities: A Goal We Can All Live With” Web site. *Utah Department of Transportation*, <http://www.zerofatalities.com> (June 6, 2007).

Utah State University (USU). (2007). “About Utah State University” Web site. <http://www.usu.edu/about/> (June 11, 2007).

Williamson, A.M., Feyer, A.-M., and Friswell, R. (1996). The Impact of Work Practices on Fatigue in Long Distance Truck Drivers. *Accident Analysis and Prevention*, 28(6), pp. 709-719.

Wolfson, A.R. and Carskadon, M.A. (1998). Sleep Schedules and Daytime Functioning in Adolescents. *Child Development*, 69(4), pp. 875-887.

Wood, N. E. (1994). “Shoulder Rumble Strips: A Method to Alert “Drifting” Drivers.” Presented at the Transportation Research Board 73rd Annual Meeting, TRB, National Research Council, Washington, DC.

Wylie, C.D., Schultz, T., Miller, J.C., Mitler, M.M., and Mackie, R.R. (1996). Commercial Motor Vehicle Driver Fatigue and Alertness Study: Technical Summary. Federal Highway Administration (FHWA) Report No. FHWA-MC-97-001, Washington, DC.

Young, T., Palta, M., Dempsey, J., Skatrud, J., Weber, S., and Badr, S. (1993). The Occurrence of Sleep-Disordered Breathing Among Middle-Aged Adults. *The New England Journal of Medicine,* 328(17), pp. 1230-1235.

Zeitz, R. (2003). Low-Cost Solutions Yield Big Savings. *Public Roads*, 67(3), pp. 48-50.

APPENDIX A: 3-, 5-, AND 13-YEAR ANALYSIS RESULTS

Table A-1. I-15 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	**0.312**	0.087
	5.01-10	0.066	0.019
	10.01-15	0.072	0.092
	15.01-20	0.052	0.139
	20.01-25	0.041	0.102
	25.01-30	0.040	0.180
	30.01-35	0.174	0.194
	35.01-40	0.178	0.059
	40.01-45	0.080	0.080
	45.01-50	0.020	0.080
	50.01-55	0.136	0.097
	55.01-60	0.090	0.036
	60.01-65	0.036	0.018
	65.01-70	0.199	0.119
	70.01-75	0.041	0.082
	75.01-80	0.114	0.023
	80.01-85	0.183	**0.251**
	85.01-90	0.253	0.115
	90.01-95	**0.412**	**0.229**
	95.01-100	0.112	0.067
	100.01-105	0.246	0.090
	105.01-110	0.000	0.069
	110.01-115	0.119	0.167
	115.01-120	0.139	0.186
	120.01-125	0.185	0.000
	125.01-130	0.158	0.090
	130.01-135	0.080	0.000
	135.01-140	0.225	0.000
	140.01-145	0.065	0.000
	145.01-150	0.033	0.163
	150.01-155	0.163	0.163
	155.01-160	0.064	0.095
	160.01-165	0.184	0.092
	165.01-170	0.178	0.148
	170.01-175	0.059	**0.206**
	175.01-180	0.062	0.062
	180.01-185	0.089	0.000
	185.01-190	0.147	**0.265**
	190.01-195	**0.425**	**0.227**
	195.01-200	**0.453**	0.198

Table A-1. Continued

	Milepost	Northbound	Southbound
Rural	200.01-205	0.113	0.057
	205.01-210	0.286	0.115
	210.01-215	0.086	0.058
	215.01-220	0.201	0.115
	220.01-225	0.133	0.133
	225.01-230	0.148	0.055
	230.01-235	0.030	0.076
	235.01-240	0.090	0.015
	240.01-245	0.044	0.015
	245.01-250	0.038	0.038
	250.01-255	0.026	0.044
Urban	255.01-260	0.018	**0.061**
	260.01-265	0.054	0.029
	265.01-270	0.037	0.048
	270.01-275	0.046	0.043
	275.01-280	0.034	0.040
	280.01-285	0.010	0.050
	285.01-290	0.033	0.030
	290.01-295	0.036	0.044
	295.01-300	0.034	0.020
	300.01-305	0.021	0.012
	305.01-310	0.018	0.016
	310.01-315	0.042	0.027
	315.01-320	0.034	0.019
	320.01-325	0.024	0.024
	325.01-330	0.056	0.016
	330.01-335	0.052	0.008
	335.01-340	0.056	0.007
	340.01-345	**0.088**	0.009
Rural	345.01-350	0.043	0.057
	350.01-355	0.042	0.042
	355.01-360	0.017	0.026
	360.01-365	0.087	0.011
	365.01-370	0.030	0.045
	370.01-375	0.031	0.062
	375.01-380	0.000	0.019
	380.01-385	0.027	0.082
	385.01-390	0.115	0.077
	390.01-395	0.040	0.119
	395.01-401	0.000	0.036

Table A-2. I-70 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Eastbound**	**Westbound**
Rural	0-5	0.000	0.148
	5.01-10	0.000	0.000
	10.01-15	0.145	0.073
	15.01-20	0.430	0.072
	20.01-25	0.197	**0.393**
	25.01-30	0.481	0.267
	30.01-35	0.429	0.054
	35.01-40	0.182	0.122
	40.01-45	0.076	0.152
	45.01-50	0.397	0.072
	50.01-55	0.200	0.133
	55.01-60	0.108	0.072
	60.01-65	0.075	0.151
	65.01-70	0.076	0.076
	70.01-75	0.082	0.123
	75.01-80	0.057	0.057
	80.01-85	0.171	0.000
	85.01-90	0.181	0.302
	90.01-95	0.070	0.210
	95.01-100	0.000	**0.505**
	100.01-105	0.144	0.216
	105.01-110	0.216	0.072
	110.01-115	0.216	0.000
	115.01-120	0.144	0.000
	120.01-125	0.288	0.072
	125.01-130	0.216	**0.505**
	130.01-135	0.288	**0.360**
	135.01-140	**0.505**	0.072
	140.01-145	0.360	0.072
	145.01-150	0.146	0.219
	150.01-155	0.467	0.078
	155.01-160	**0.629**	0.063
	160.01-165	0.462	**0.528**
	165.01-170	0.057	0.057
	170.01-175	0.285	0.057
	175.01-180	0.171	0.114
	180.01-185	0.272	0.109
	185.01-190	0.054	0.107
	190.01-195	0.055	0.164
	195.01-200	0.000	0.109
	200.01-205	0.163	0.163
	205.01-210	0.163	0.163
	210.01-215	0.382	0.109
	215.01-220	0.281	0.056
	220.01-225	0.225	0.169
	225.01-232	**0.494**	0.000

Table A-3. I-80 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	Eastbound	Westbound
Rural Area	0-5	0.000	0.000
	5.01-10	0.000	**0.191**
	10.01-15	0.143	0.143
	15.01-20	0.096	0.143
	20.01-25	0.048	**0.191**
	25.01-30	0.000	0.000
	30.01-35	0.239	**0.191**
	35.01-40	**0.383**	0.000
	40.01-45	0.288	0.096
	45.01-50	**0.335**	0.048
	50.01-55	0.233	0.047
	55.01-60	0.270	0.135
	60.01-65	**0.356**	0.089
	65.01-70	0.089	0.133
	70.01-75	0.266	**0.177**
	75.01-80	0.122	0.041
	80.01-85	0.037	0.150
	85.01-90	0.128	0.032
	90.01-95	0.028	0.000
	95.01-100	0.097	0.058
	100.01-105	0.102	0.073
	105.01-110	0.084	0.117
Urban Area	110.01-115	0.070	0.035
	115.01-120	0.000	0.013
	120.01-125	0.007	0.004
	125.01-130	0.021	0.034
Rural Area	130.01-135	0.042	0.025
	135.01-140	0.034	0.026
	140.01-145	0.045	0.009
	145.01-150	0.087	0.052
	150.01-155	0.125	0.025
	155.01-160	0.055	0.028
	160.01-165	0.057	0.057
	165.01-170	0.055	0.000
	170.01-175	0.027	0.027
	175.01-180	0.053	0.053
	180.01-185	0.134	0.080
	185.01-190	0.057	0.113
	190.01-197	0.283	0.057

Table A-4. I-84 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Eastbound**	**Westbound**
Urban	0-5	0.000	0.056
	5.01-10	0.000	0.048
	10.01-15	0.178	0.133
	15.01-20	0.000	0.000
	20.01-25	0.042	0.085
	25.01-30	0.041	0.124
	30.01-35	0.000	0.000
	35.01-42	0.202	0.081
	81.04-85	0.000	0.026
	85.01-90	0.027	0.082
	90.01-95	0.196	0.028
	95.01-100	0.000	0.030
	100.01-105	0.135	0.000
	105.01-110	0.000	0.000
	110.01-115	**0.237**	**0.142**
	115.01-120	0.194	0.000

Table A-5. I-215 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Inside Lanes**	**Outside Lanes**
Urban	0-5	0.047	0.047
	5.01-10	0.015	0.024
	10.01-15	0.029	0.015
	15.01-20	0.025	0.008
	20.01-25	0.032	0.052
	25.01-30	0.047	0.031

Table A-6. U.S. 89 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	0.000	0.133
	5.01-10	**0.350**	0.350
	10.01-15	0.000	0.176
	15.01-20	0.176	0.176
	20.01-25	0.000	0.176
	25.01-30	0.176	0.176
	30.01-35	0.000	0.176
	35.01-40	0.176	0.000
	40.01-45	0.176	0.176
	45.01-50	0.000	0.176
	50.01-55	0.175	0.000
	55.01-60	**0.473**	0.158
	60.01-65	0.000	0.074
	65.01-70	0.000	0.098
	70.01-75	0.101	0.406
	75.01-80	0.000	0.101
	80.01-85	0.000	0.308
	85.01-90	0.173	0.000
	90.01-95	0.000	**0.854**
	95.01-100	0.285	0.285
	100.01-105	0.000	0.000
	105.01-110	**0.552**	0.000
	110.01-115	0.000	0.254
	115.01-120	0.000	**0.606**
	120.01-125	0.000	**0.523**
	125.01-130	0.000	0.000
	130.01-135	0.180	0.090
	135.01-140	0.000	0.151
	140.01-145	**0.485**	**0.485**
	145.01-150	0.000	0.000
	150.01-155	0.292	0.000
	155.01-160	0.000	0.000
	160.01-165	0.213	0.000
	165.01-170	0.000	0.000
	170.01-175	0.290	0.290
	175.01-180	0.000	0.000
	180.01-185	0.257	**0.515**
	185.01-191.74	0.257	0.000
	225.36-230	0.049	0.000
	230.01-235	0.000	0.093
	235.01-240	0.101	0.000
	240.01-245	0.000	0.000
	245.01-250	0.000	0.000

Table A-6. Continued

	Milepost	Northbound	Southbound
Rural	250.01-255	0.096	0.000
	255.01-260	0.060	0.000
	260.01-265	0.175	0.233
	265.01-270	0.085	0.085
	270.01-275	0.266	0.000
	275.01-280	0.084	0.084
	280.01-285	0.000	0.080
	285.01-290	0.000	0.405
	290.01-295	0.000	0.274
	295.01-300	0.000	0.151
	300.01-305	0.152	0.000
	305.01-312.8	0.304	0.304
	322.28-325	0.000	0.058
Urban	325.01-330	**0.116**	**0.116**
	330.01-335	0.068	0.068
	335.01-340	0.041	0.020
	340.01-345	0.047	0.028
	345.01-353	0.035	**0.088**
	362.01-370	0.044	0.058
	370.01-375	**0.104**	0.013
	375.01-380	0.014	0.068
	380.01-385	0.041	0.010
	385.01-389.5	0.013	0.039
	395.6-400	0.011	0.000
	400.01-405	0.046	0.011
	405.01-410	0.029	0.029
	410.01-415	0.013	0.052
	415.01-420	0.041	0.014
	420.01-425	0.031	0.031
	425.01-430	0.031	0.031
	430.01-435	0.041	0.021
	435.01-440	0.000	0.000
	440.01-445	0.000	0.000
	445.01-450	0.000	0.000
	450.01-455	0.000	0.000
	455.01-460	0.000	0.000
	460.01-465	0.029	0.059
	465.01-470	0.052	0.052
	470.01-475	0.069	0.000
	475.01-480	0.000	0.080
	480.01-485	0.000	0.000
Rural	485.01-490	0.000	0.000
	490.01-495	0.000	0.000
	495.01-500	0.160	0.000
	500.01-503	0.000	0.000

Table A-7. U.S. 91 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	0.020	0.020
	5.01-10	0.047	0.023
	10.01-15	0.024	0.000
	15.01-20	0.140	0.047
	20.01-25	**0.284**	**0.122**
	25.01-30	0.076	0.022
	30.01-35	0.055	0.055
	35.01-40	0.056	0.056
	40.01-45	0.082	0.041

Table A-8. S.R. 36 3-Year (2002-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	**2.100**	0.000
	5.01-10	0.000	0.000
	10.01-15	0.976	0.000
	15.01-20	0.000	0.000
	20.01-25	0.482	0.000
	25.01-30	0.000	**0.401**
	30.01-35	0.401	0.000
	35.01-40	0.000	0.000
	40.01-45	0.000	0.000
	45.01-50	0.000	0.000
	50.01-55	0.030	0.030
	55.01-60	0.013	0.039
	60.01-66	0.015	0.089

Table A-9. I-15 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	Northbound	Southbound
Rural	0-5	**0.293**	0.076
	5.01-10	0.059	0.018
	10.01-15	0.052	0.111
	15.01-20	0.055	0.154
	20.01-25	0.103	0.103
	25.01-30	0.038	**0.214**
	30.01-35	0.147	0.147
	35.01-40	0.150	0.075
	40.01-45	0.063	0.100
	45.01-50	0.013	0.050
	50.01-55	0.133	0.073
	55.01-60	0.072	0.024
	60.01-65	0.048	0.036
	65.01-70	0.150	0.088
	70.01-75	0.039	0.065
	75.01-80	0.101	0.029
	80.01-85	0.129	**0.287**
	85.01-90	0.159	0.188
	90.01-95	**0.374**	**0.216**
	95.01-100	0.139	0.056
	100.01-105	0.194	0.069
	105.01-110	0.071	0.071
	110.01-115	0.150	0.150
	115.01-120	0.087	**0.204**
	120.01-125	0.130	0.043
	125.01-130	0.143	0.086
	130.01-135	0.168	0.000
	135.01-140	0.220	0.040
	140.01-145	0.100	0.020
	145.01-150	0.020	0.101
	150.01-155	0.143	0.123
	155.01-160	0.099	0.079
	160.01-165	0.190	0.133
	165.01-170	0.146	0.146
	170.01-175	0.036	0.181
	175.01-180	0.058	0.038
	180.01-185	0.075	0.000
	185.01-190	0.111	**0.203**
	190.01-195	**0.422**	**0.211**
	195.01-200	**0.281**	**0.193**

Table A-9. Continued

	Milepost	Northbound	Southbound
Rural	200.01-205	0.123	0.123
	205.01-210	**0.268**	0.071
	210.01-215	0.234	0.054
	215.01-220	0.252	0.108
	220.01-225	0.200	0.100
	225.01-230	0.128	0.082
	230.01-235	0.039	0.077
	235.01-240	0.077	0.019
	240.01-245	0.057	0.028
	245.01-250	0.080	0.064
	250.01-255	0.022	0.044
Urban	255.01-260	0.019	**0.065**
	260.01-265	0.050	0.029
	265.01-270	0.032	0.044
	270.01-275	0.040	0.050
	275.01-280	0.040	0.042
	280.01-285	0.013	0.051
	285.01-290	0.029	0.023
	290.01-295	0.032	0.048
	295.01-300	0.031	0.022
	300.01-305	0.019	0.012
	305.01-310	0.021	0.021
	310.01-315	0.037	0.029
	315.01-320	0.034	0.026
	320.01-325	0.034	0.022
	325.01-330	**0.076**	0.015
	330.01-335	0.058	0.025
	335.01-340	0.047	0.016
	340.01-345	**0.067**	0.006
Rural	345.01-350	0.047	0.089
	350.01-355	0.045	0.055
	355.01-360	0.031	0.031
	360.01-365	0.065	0.020
	365.01-370	0.036	0.054
	370.01-375	0.046	0.046
	375.01-380	0.012	0.035
	380.01-385	0.033	0.083
	385.01-390	0.094	0.047
	390.01-395	0.024	0.097
	395.01-401	0.022	0.044

Table A-10. I-70 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	Eastbound	Westbound
Rural	0-5	0.000	0.091
	5.01-10	0.000	0.000
	10.01-15	0.132	0.088
	15.01-20	0.389	0.086
	20.01-25	0.233	0.272
	25.01-30	0.412	0.190
	30.01-35	0.325	0.065
	35.01-40	0.149	0.112
	40.01-45	0.093	0.163
	45.01-50	0.290	0.156
	50.01-55	0.166	0.125
	55.01-60	0.111	0.111
	60.01-65	0.070	0.093
	65.01-70	0.071	0.071
	70.01-75	0.051	0.152
	75.01-80	0.140	0.035
	80.01-85	0.105	0.070
	85.01-90	0.112	0.299
	90.01-95	0.087	0.219
	95.01-100	0.000	**0.407**
	100.01-105	0.136	0.136
	105.01-110	0.181	0.045
	110.01-115	0.136	0.045
	115.01-120	0.181	0.045
	120.01-125	0.271	0.181
	125.01-130	0.226	**0.452**
	130.01-135	0.362	0.271
	135.01-140	**0.543**	0.045
	140.01-145	**0.452**	0.090
	145.01-150	0.137	0.182
	150.01-155	0.425	0.047
	155.01-160	**0.533**	0.038
	160.01-165	0.330	**0.371**
	165.01-170	0.100	0.133
	170.01-175	0.266	0.033
	175.01-180	0.133	0.166
	180.01-185	0.162	0.194
	185.01-190	0.161	0.129
	190.01-195	0.098	0.131
	195.01-200	0.065	0.229
	200.01-205	0.229	0.131
	205.01-210	0.132	0.132
	210.01-215	0.331	0.132
	215.01-220	0.238	0.136
	220.01-225	0.204	0.102
	225.01-232	0.399	0.050

Table A-11. I-80 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Eastbound**	**Westbound**
Rural Area	0-5	0.000	0.030
	5.01-10	0.000	0.115
	10.01-15	0.086	0.115
	15.01-20	0.086	0.143
	20.01-25	0.029	**0.258**
	25.01-30	0.000	0.057
	30.01-35	0.172	**0.172**
	35.01-40	0.258	0.029
	40.01-45	0.228	0.142
	45.01-50	**0.339**	0.057
	50.01-55	**0.278**	0.056
	55.01-60	0.243	0.108
	60.01-65	0.239	0.080
	65.01-70	0.079	0.079
	70.01-75	**0.290**	0.132
	75.01-80	0.197	0.025
	80.01-85	0.115	0.092
	85.01-90	0.119	0.040
	90.01-95	0.035	0.018
	95.01-100	0.119	0.036
	100.01-105	0.097	0.079
	105.01-110	0.081	0.081
Urban Area	110.01-115	0.058	0.029
	115.01-120	0.000	0.012
	120.01-125	0.008	0.005
	125.01-130	0.026	0.031
Rural Area	130.01-135	0.031	0.026
	135.01-140	0.032	0.021
	140.01-145	0.051	0.011
	145.01-150	0.054	0.065
	150.01-155	0.077	0.031
	155.01-160	0.069	0.052
	160.01-165	0.053	0.035
	165.01-170	0.034	0.000
	170.01-175	0.016	0.033
	175.01-180	0.033	0.082
	180.01-185	0.097	0.097
	185.01-190	0.102	0.153
	190.01-197	0.250	0.067

Table A-12. I-84 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Eastbound**	**Westbound**
Rural	0-5	0.034	0.034
	5.01-10	0.028	0.028
	10.01-15	0.101	0.101
	15.01-20	0.025	0.025
	20.01-25	0.024	0.072
	25.01-30	0.023	**0.117**
	30.01-35	0.000	0.000
	35.01-42	**0.209**	0.093
	81.04-85	0.017	0.033
	85.01-90	0.034	0.051
	90.01-95	0.134	0.050
	95.01-100	0.000	0.018
	100.01-105	0.079	0.059
	105.01-110	0.048	0.024
	110.01-115	0.134	0.107
	115.01-120	0.152	0.000

Table A-13. I-215 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Inside Lanes**	**Outside Lanes**
Urban	0-5	0.042	0.042
	5.01-10	0.009	0.031
	10.01-15	0.029	0.029
	15.01-20	0.030	0.016
	20.01-25	0.029	0.040
	25.01-30	0.041	0.029

Table A-14. U.S. 89 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	Northbound	Southbound
Rural	0-5	0.082	0.164
	5.01-10	0.210	0.315
	10.01-15	0.000	0.106
	15.01-20	**0.423**	0.211
	20.01-25	0.000	0.211
	25.01-30	0.106	0.211
	30.01-35	0.000	0.106
	35.01-40	0.211	0.106
	40.01-45	0.317	0.317
	45.01-50	0.106	0.211
	50.01-55	0.210	0.105
	55.01-60	**0.386**	0.096
	60.01-65	0.000	0.045
	65.01-70	0.064	0.064
	70.01-75	0.132	0.264
	75.01-80	0.000	0.066
	80.01-85	0.000	0.191
	85.01-90	0.101	0.000
	90.01-95	0.178	**0.711**
	95.01-100	**0.534**	0.178
	100.01-105	0.000	0.351
	105.01-110	**0.486**	0.000
	110.01-115	0.000	0.311
	115.01-120	0.000	**0.472**
	120.01-125	0.103	0.308
	125.01-130	0.000	0.000
	130.01-135	0.110	0.055
	135.01-140	0.092	0.184
	140.01-145	0.295	**0.443**
	145.01-150	0.000	0.177
	150.01-155	0.177	0.000
	155.01-160	0.000	0.000
	160.01-165	0.122	0.000
	165.01-170	0.000	0.000
	170.01-175	0.170	0.170
	175.01-180	0.000	0.000
	180.01-185	0.311	0.311
	185.01-191.74	**0.466**	0.000
	225.36-230	0.057	0.000
	230.01-235	0.000	0.055
	235.01-240	0.059	0.029
	240.01-245	0.055	0.055
	245.01-250	0.070	0.000

Table A-14. Continued

	Milepost	Northbound	Southbound
Rural	250.01-255	0.118	0.000
	255.01-260	0.037	0.037
	260.01-265	0.108	0.144
	265.01-270	0.052	0.052
	270.01-275	0.166	0.083
	275.01-280	0.107	0.107
	280.01-285	0.000	0.050
	285.01-290	0.000	0.251
	290.01-295	0.000	**0.422**
	295.01-300	0.000	0.179
	300.01-305	0.090	0.000
	305.01-312.78	0.270	0.180
	322.28-325	0.000	0.036
Urban	325.01-330	0.071	**0.071**
	330.01-335	0.062	**0.083**
	335.01-340	0.029	0.033
	340.01-345	0.051	0.029
	345.01-350	0.026	0.026
	350.01-355	0.000	0.064
	355.01-360	0.000	0.000
	360.01-365	0.011	0.011
	365.01-370	0.022	0.029
	370.01-375	**0.100**	0.036
	375.01-380	0.022	0.067
	380.01-385	0.025	0.006
	385.01-389.53	0.031	0.031
	395.59-400	0.020	0.027
	400.01-405	0.055	0.028
	405.01-410	0.018	0.036
	410.01-415	0.023	0.039
	415.01-420	0.033	0.017
	420.01-425	0.055	0.018
	425.01-430	0.038	0.019
	430.01-435	0.038	0.013
	435.01-440	0.000	0.000
	440.01-445	0.000	0.000
	445.01-450	0.000	0.000
	450.01-455	0.000	0.000
	455.01-460	0.000	0.000
	460.01-465	0.018	**0.072**
	465.01-470	0.064	0.032
Rural	470.01-475	0.046	0.046
	475.01-480	0.000	0.112
	480.01-485	0.000	0.000
	485.01-490	0.094	0.000
	490.01-495	0.103	0.000
	495.01-500	0.096	0.000
	500.01-503	0.000	0.138

Table A-15. U.S. 91 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	0.026	0.013
	5.01-10	0.028	0.028
	10.01-15	0.029	0.029
	15.01-20	0.155	0.070
	20.01-25	**0.323**	**0.087**
	25.01-30	0.073	0.033
	30.01-35	0.085	0.042
	35.01-40	0.103	0.034
	40.01-45	0.127	0.025

Table A-16. S.R. 36 5-Year (2000-2004) Crash Rate Analysis

	Crash Rate per Million Vehicle-Miles Traveled		
	Milepost	**Northbound**	**Southbound**
Rural	0-5	**1.287**	0.000
	5.01-10	0.598	0.000
	10.01-15	0.590	0.000
	15.01-20	0.000	0.000
	20.01-25	0.364	0.000
	25.01-30	0.000	**0.316**
	30.01-35	0.316	**0.316**
	35.01-40	0.000	0.000
	40.01-45	0.000	0.000
	45.01-50	0.000	0.000
	50.01-55	0.036	0.036
	55.01-60	0.018	0.055
	60.01-66	0.029	0.077

Table A-17. Northbound I-15 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.09	0.00	0.15	0.00	0.20	0.19	0.12	0.24	0.24	0.28	0.32	0.26	0.36
	5.01-10	0.00	0.00	0.04	0.04	0.00	0.11	0.07	0.00	0.07	0.03	0.09	0.09	0.03
	10.01-15	0.00	0.05	0.00	0.14	0.00	0.00	0.00	0.04	0.04	0.00	0.06	0.03	0.12
	15.01-20	0.00	0.09	0.08	0.08	0.07	0.00	0.00	0.13	0.06	0.06	0.05	0.05	0.05
	20.01-25	0.34	0.00	**0.59**	0.10	0.18	0.16	0.23	0.00	0.14	0.27	0.06	0.00	0.06
	25.01-30	**0.45**	0.21	0.10	0.09	0.09	0.16	0.30	0.00	0.00	0.07	0.06	0.00	0.06
	30.01-35	0.00	0.21	0.19	0.09	0.00	0.31	0.07	0.14	0.00	0.19	0.13	0.29	0.11
	35.01-40	0.11	0.00	0.00	0.28	0.17	0.08	0.15	0.28	0.14	0.07	0.25	0.23	0.06
	40.01-45	0.00	0.31	**0.48**	0.09	0.26	0.39	0.22	0.29	0.07	0.00	0.06	0.06	0.11
	45.01-50	0.00	0.21	0.10	0.09	0.09	0.16	0.07	0.21	0.00	0.00	0.00	0.06	0.00
	50.01-55	0.00	0.20	0.19	0.00	0.25	0.00	0.07	0.07	0.20	0.06	0.24	0.12	0.06
	55.01-60	0.00	0.00	0.21	0.00	0.00	0.00	0.16	0.15	0.00	0.07	0.16	0.05	0.05
	60.01-65	0.22	0.00	0.10	0.00	0.17	0.00	0.15	0.00	0.00	0.13	0.00	0.11	0.00
	65.01-70	0.00	0.33	0.00	0.00	0.09	0.00	0.07	0.21	0.07	0.07	0.28	0.19	0.12
	70.01-75	0.35	**0.43**	**0.71**	**0.58**	0.18	0.25	0.16	0.00	0.07	0.00	0.06	0.00	0.06
	75.01-80	0.38	0.23	0.11	0.10	0.20	**0.63**	0.17	0.00	0.00	0.15	0.00	0.20	0.14
	80.01-85	0.12	0.33	0.21	0.10	0.29	0.09	**0.42**	0.08	0.00	0.08	0.14	0.07	0.35
	85.01-90	**0.47**	0.00	0.21	0.10	0.10	0.37	0.17	0.24	0.00	0.00	0.14	**0.47**	0.14
	90.01-95	0.12	0.33	**0.42**	**0.40**	**0.49**	**0.92**	0.26	0.32	0.32	0.30	**0.49**	**0.47**	0.27
	95.01-100	**0.55**	0.10	0.10	0.19	0.00	0.09	0.24	**0.46**	0.30	0.07	0.07	0.20	0.07
	100.01-105	0.33	0.00	0.20	0.29	0.18	**0.69**	0.00	**0.76**	0.00	0.21	0.35	0.13	0.26
	105.01-110	0.11	0.11	**0.41**	**0.40**	0.10	0.00	0.25	0.16	0.23	0.15	0.00	0.00	0.00
	110.01-115	0.13	0.12	0.11	0.32	0.21	0.10	0.09	0.00	0.33	0.08	0.14	0.07	0.14
	115.01-120	0.12	0.11	0.11	0.10	0.00	0.09	0.00	0.25	0.00	0.00	0.00	0.07	0.34
	120.01-125	0.37	**0.46**	0.11	0.00	0.00	0.00	0.26	0.32	0.00	0.08	0.14	0.14	0.28
	125.01-130	0.00	0.11	0.32	0.21	0.20	0.00	0.09	0.16	0.08	0.15	0.20	0.14	0.14
	130.01-135	0.14	0.00	0.25	0.12	**0.68**	0.21	0.30	0.38	0.37	0.26	0.16	0.00	0.08
	135.01-140	0.16	**0.60**	0.00	**0.40**	**0.51**	**0.48**	0.11	0.32	0.11	0.31	0.28	0.29	0.10
	140.01-145	0.32	0.30	0.14	0.14	0.00	0.12	0.11	0.22	0.11	0.21	0.09	0.10	0.00
	145.01-150	0.00	0.15	0.14	0.14	0.13	0.00	0.34	0.22	0.00	0.00	0.00	0.10	0.00
	150.01-155	0.16	**0.45**	0.29	0.00	0.26	0.00	0.11	**0.54**	0.22	0.00	0.20	0.20	0.10
	155.01-160	0.00	0.14	0.13	0.00	0.36	0.34	**0.43**	0.00	0.22	0.10	0.09	0.00	0.10
	160.01-165	**0.56**	0.39	0.12	0.12	0.23	**0.64**	0.10	0.19	0.10	0.29	0.27	0.28	0.00
	165.01-170	0.30	0.14	0.00	0.13	0.12	0.11	0.11	0.10	0.20	0.00	0.00	0.27	0.26
	170.01-175	**0.61**	0.14	0.14	0.13	**0.49**	0.23	0.11	0.10	0.00	0.00	0.18	0.00	0.00
	175.01-180	**0.50**	0.16	0.15	0.14	0.27	0.00	0.00	0.11	0.00	0.10	0.19	0.00	0.00
	180.01-185	0.16	0.29	**0.55**	0.13	0.00	0.23	0.11	0.21	0.10	0.00	0.18	0.09	0.00
	185.01-190	0.30	0.00	0.27	0.00	0.36	0.34	0.21	0.00	0.00	0.10	0.09	0.27	0.09
	190.01-195	**0.43**	0.27	0.25	0.00	0.23	**0.53**	0.30	0.39	**0.47**	0.36	**0.52**	0.17	**0.58**
	195.01-200	**0.71**	**0.40**	**0.62**	0.24	**0.45**	**0.43**	0.00	0.29	0.00	0.00	0.35	**0.69**	0.33

Table A-17. Continued

Rural	200.01-205	0.28	**0.40**	0.12	0.35	0.11	0.11	0.20	0.10	0.09	0.18	0.09	0.09	0.17
	205.01-210	0.15	**0.42**	0.13	0.12	0.00	0.11	0.10	**0.40**	0.10	0.37	0.17	**0.60**	0.09
	210.01-215	0.15	0.14	0.13	0.37	0.12	**0.78**	**0.42**	0.10	**0.59**	0.38	0.09	0.09	0.09
	215.01-220	0.00	**0.43**	0.39	0.12	0.35	**0.67**	0.11	0.31	0.20	**0.47**	0.09	0.09	**0.43**
	220.01-225	0.14	0.00	0.12	0.35	0.23	0.32	0.20	0.19	**0.66**	0.00	0.16	0.00	0.24
	225.01-230	**0.43**	0.00	0.09	0.00	0.00	0.08	**0.53**	0.15	0.07	0.12	0.11	0.22	0.11
	230.01-235	0.00	0.09	0.08	0.15	0.22	0.14	0.00	0.06	0.06	0.05	0.00	0.09	0.00
	235.01-240	0.09	0.18	0.00	0.30	0.14	0.07	0.13	0.06	0.06	0.05	0.00	0.18	0.09
	240.01-245	0.27	**0.43**	0.24	0.15	0.36	0.20	0.00	0.00	0.06	0.10	0.04	0.00	0.09
	245.01-250	0.08	0.07	0.13	0.18	0.17	0.05	0.00	0.09	0.17	0.12	0.00	0.12	0.00
	250.01-255	0.21	0.20	0.05	0.04	0.12	0.04	0.10	0.00	0.00	0.03	0.03	0.03	0.03
Urban	255.01-260	0.00	**0.17**	**0.12**	0.08	**0.11**	0.00	0.02	0.04	0.02	0.02	0.02	0.00	0.04
	260.01-265	0.02	0.02	0.02	0.06	**0.09**	0.02	0.05	0.03	0.03	0.06	0.05	0.05	0.06
	265.01-270	0.02	0.02	0.09	0.06	0.04	0.04	0.05	0.06	0.05	0.00	0.04	0.04	0.02
	270.01-275	0.09	0.08	0.03	0.04	0.08	0.04	0.04	0.01	0.02	0.04	0.07	0.03	0.04
	275.01-280	0.04	0.04	**0.10**	0.08	0.07	0.06	0.03	0.07	0.07	0.03	0.03	0.04	0.03
	280.01-285	**0.10**	0.00	0.08	0.00	0.07	0.04	0.06	0.03	0.02	0.01	0.00	0.02	0.01
	285.01-290	0.04	0.03	0.05	0.04	0.04	0.01	0.07	0.04	0.04	0.00	0.03	0.04	0.04
	290.01-295	0.01	0.04	0.04	0.07	0.08	**0.09**	0.04	0.07	0.01	0.04	0.02	0.04	0.05
	295.01-300	0.01	0.01	0.02	0.05	0.01	0.03	0.03	0.03	0.03	0.02	0.04	0.04	0.02
	300.01-305	0.00	0.04	0.01	0.04	0.02	0.03	0.05	0.05	0.02	0.01	0.05	0.01	0.01
	305.01-310	0.01	0.01	0.04	0.02	0.03	0.01	0.02	0.02	0.04	0.02	0.02	0.01	0.02
	310.01-315	0.02	0.04	0.04	0.01	0.01	0.06	0.01	0.03	0.03	0.03	0.04	0.06	0.03
	315.01-320	0.00	0.06	0.00	0.02	0.04	0.02	0.02	0.05	0.04	0.03	0.06	0.02	0.02
	320.01-325	0.06	0.01	0.01	0.04	0.06	0.00	0.01	0.01	0.04	0.06	0.02	0.04	0.02
	325.01-330	**0.12**	0.07	0.03	**0.11**	0.06	0.05	0.00	0.09	0.04	**0.18**	**0.09**	0.03	0.05
	330.01-335	0.08	0.05	0.08	0.02	0.06	0.08	0.04	0.00	0.08	0.05	0.04	0.08	0.03
	335.01-340	0.02	0.03	0.06	0.08	0.03	0.03	0.06	0.02	0.02	0.04	0.04	0.08	0.05
	340.01-345	0.00	0.06	0.07	0.05	0.05	0.02	0.05	0.03	0.04	0.03	0.06	**0.13**	0.07
Rural	345.01-350	0.13	0.09	0.08	0.12	0.00	0.00	0.09	0.02	0.04	0.06	0.02	0.04	0.07
	350.01-355	0.04	0.04	0.13	0.12	0.00	0.03	0.00	0.00	0.00	0.10	0.02	0.00	0.11
	355.01-360	0.00	0.04	0.07	0.03	0.09	0.09	0.06	0.05	0.08	0.03	0.02	0.03	0.00
	360.01-365	0.00	0.00	0.05	0.13	0.04	0.08	0.04	0.11	0.03	0.03	0.06	0.13	0.07
	365.01-370	0.00	0.00	0.06	0.06	0.11	0.00	0.00	0.05	0.00	0.09	0.04	0.00	0.05
	370.01-375	0.00	0.00	0.07	0.06	0.06	0.17	0.11	0.00	0.09	0.05	0.00	0.00	0.10
	375.01-380	0.09	0.09	0.08	0.07	0.07	0.21	0.00	0.00	0.06	0.00	0.00	0.00	0.00
	380.01-385	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.08	0.00	0.08	0.00
	385.01-390	0.00	0.00	0.00	0.29	0.00	0.13	0.13	0.00	0.00	0.12	0.12	0.23	0.00
	390.01-395	0.21	0.00	0.16	0.00	0.15	0.00	0.00	0.13	0.00	0.00	0.12	0.00	0.00
	395.01-400.59	0.00	0.00	0.29	0.00	0.13	0.00	0.12	0.00	0.00	0.11	0.00	0.00	0.00

Table A-18. Southbound I-15 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rural	0-5	0.00	0.00	0.15	0.00	0.00	0.26	0.12	0.06	0.00	0.11	0.21	0.00	0.05
	5.01-10	0.00	0.00	0.00	0.04	0.00	0.07	0.03	0.10	0.03	0.00	0.00	0.03	0.03
	10.01-15	0.05	0.10	0.15	0.28	0.22	0.04	0.12	0.04	0.08	0.20	0.06	0.12	0.09
	15.01-20	0.19	0.18	**0.42**	0.16	0.15	0.07	0.00	0.19	0.06	0.29	0.05	0.21	0.15
	20.01-25	0.11	**0.31**	**0.49**	**0.38**	**0.44**	0.08	0.15	0.15	0.00	0.20	0.19	0.12	0.00
	25.01-30	0.11	0.21	0.10	0.09	0.09	0.08	0.15	0.22	0.21	**0.33**	0.26	0.11	0.18
	30.01-35	0.11	0.00	**0.48**	0.18	0.00	0.00	0.15	0.14	0.00	0.13	0.13	0.23	0.22
	35.01-40	0.00	0.10	0.10	0.09	0.26	0.00	0.07	0.21	0.14	0.07	0.13	0.06	0.00
	40.01-45	0.00	0.21	0.19	0.00	0.09	0.16	0.07	**0.36**	0.07	0.20	0.00	0.12	0.11
	45.01-50	0.11	0.10	0.19	0.09	0.00	0.08	0.07	0.29	0.00	0.00	0.06	0.06	0.12
	50.01-55	0.11	0.00	0.00	0.00	0.08	0.00	0.14	0.00	0.00	0.06	0.12	0.06	0.11
	55.01-60	0.00	0.00	0.00	0.00	0.18	0.00	0.08	0.00	0.00	0.00	0.05	0.00	0.05
	60.01-65	0.11	0.22	0.10	0.19	0.26	0.00	0.08	0.07	0.07	0.07	0.00	0.06	0.00
	65.01-70	0.11	**0.44**	0.19	0.09	0.26	0.23	0.15	0.07	0.07	0.00	0.22	0.06	0.06
	70.01-75	**0.46**	**0.65**	0.10	0.10	**0.72**	**0.49**	0.23	0.15	0.00	0.07	0.06	0.12	0.06
	75.01-80	0.13	**0.47**	**0.44**	0.10	0.20	0.27	0.17	0.08	0.00	0.08	0.07	0.00	0.00
	80.01-85	0.24	**0.45**	**0.32**	0.20	**0.29**	**0.36**	**0.34**	0.08	**0.40**	**0.30**	**0.35**	0.20	0.21
	85.01-90	0.24	0.00	**0.64**	**0.51**	**0.29**	0.18	0.17	0.08	0.00	**0.61**	0.00	0.07	0.28
	90.01-95	0.12	0.22	0.21	0.20	**0.59**	0.09	0.17	**0.32**	0.16	0.23	0.21	0.20	0.27
	95.01-100	**0.33**	0.00	0.10	0.29	0.00	0.09	0.24	0.15	0.00	0.07	0.07	0.13	0.00
	100.01-105	0.22	0.00	0.00	0.00	0.00	0.09	0.00	0.15	0.00	0.07	0.00	0.20	0.07
	105.01-110	0.23	0.11	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.00	0.07	0.07	0.07
	110.01-115	0.00	**0.36**	0.00	0.00	0.00	0.10	0.09	0.26	0.08	0.16	0.29	0.15	0.07
	115.01-120	0.00	0.00	0.22	0.00	**0.40**	0.00	0.00	**0.33**	0.16	**0.30**	0.14	0.21	0.21
	120.01-125	0.00	0.00	0.00	0.20	0.10	0.09	0.26	0.24	0.08	0.15	0.00	0.00	0.00
	125.01-130	0.00	0.11	0.00	0.10	0.00	0.18	0.00	0.00	0.08	0.08	0.27	0.00	0.00
	130.01-135	0.14	0.26	0.00	0.12	0.23	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	135.01-140	**0.31**	0.00	0.00	0.13	0.00	0.24	**0.45**	0.11	0.11	0.10	0.00	0.00	0.00
	140.01-145	**0.32**	0.00	**0.43**	0.00	0.13	0.12	0.11	**0.32**	0.11	0.00	0.00	0.00	0.00
	145.01-150	0.00	0.00	0.14	0.00	0.13	0.00	0.11	**0.32**	0.00	0.00	**0.29**	0.10	0.10
	150.01-155	0.00	**0.30**	0.14	0.00	0.13	0.12	0.23	0.11	0.11	0.00	0.20	0.10	0.19
	155.01-160	0.15	0.00	0.13	0.00	0.12	0.00	0.11	0.10	0.00	0.10	0.09	0.00	0.19
	160.01-165	0.14	0.13	0.12	0.12	0.11	0.00	0.20	0.09	0.21	0.19	0.09	0.09	0.09
	165.01-170	0.15	0.00	0.27	0.25	0.00	0.11	0.21	0.00	0.00	0.28	0.09	0.18	0.17
	170.01-175	0.15	0.00	**0.41**	0.00	0.00	0.23	0.00	0.21	0.20	0.09	0.27	0.18	0.17
	175.01-180	**0.50**	0.16	0.15	0.00	0.13	0.13	0.00	**0.33**	0.00	0.00	0.09	0.00	0.09
	180.01-185	0.16	**0.29**	0.14	0.13	0.00	0.12	0.00	0.11	0.00	0.00	0.00	0.00	0.00
	185.01-190	0.15	0.00	0.00	0.00	**0.36**	0.00	0.11	0.00	0.10	0.10	**0.45**	0.18	0.17
	190.01-195	**0.86**	**0.40**	**0.37**	0.00	0.23	**0.43**	0.00	0.19	0.19	0.18	**0.35**	0.09	0.25
	195.01-200	0.14	**1.07**	0.12	0.24	**0.34**	0.21	0.10	0.19	**0.38**	0.00	0.17	0.00	**0.41**

Table A-18. Continued

Rural	200.01-205	0.00	0.13	**0.74**	0.12	**0.34**	**0.32**	0.00	0.29	**0.38**	0.09	0.09	0.00	0.08
	205.01-210	0.15	0.28	0.26	0.00	0.23	0.11	0.10	**0.30**	0.00	0.00	0.00	**0.34**	0.00
	210.01-215	0.15	**0.43**	0.13	0.00	0.00	0.00	0.11	**0.51**	0.10	0.00	0.00	0.09	0.09
	215.01-220	0.00	0.29	0.26	0.00	0.00	0.00	0.00	**0.61**	0.00	0.19	0.26	0.09	0.00
	220.01-225	0.14	0.27	0.00	0.12	0.11	0.00	**0.30**	0.00	0.00	0.08	0.08	0.24	0.08
	225.01-230	0.00	0.21	0.09	**0.35**	0.00	0.08	0.00	0.07	0.07	0.18	0.11	0.00	0.06
	230.01-235	0.09	0.18	0.00	0.00	0.07	0.07	0.19	**0.31**	0.06	0.10	0.05	0.14	0.05
	235.01-240	0.09	0.09	0.08	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.04
	240.01-245	0.00	0.09	0.16	0.22	0.07	0.20	0.06	0.06	0.00	0.10	0.00	0.04	0.00
	245.01-250	0.00	0.00	0.07	0.06	0.11	0.00	0.14	0.09	0.09	0.12	0.12	0.00	0.00
	250.01-255	0.05	0.00	0.00	0.13	0.00	0.11	0.10	0.06	0.06	0.03	0.06	0.05	0.03
Urban	255.01-260	0.00	0.03	**0.09**	0.06	0.00	0.02	0.05	0.02	0.04	**0.10**	0.06	0.04	**0.09**
	260.01-265	0.07	0.00	0.04	0.00	0.02	0.05	0.03	0.01	0.01	0.04	0.01	0.02	0.05
	265.01-270	0.06	**0.09**	0.09	**0.09**	**0.10**	**0.10**	**0.09**	0.04	0.06	0.01	0.04	**0.10**	0.00
	270.01-275	0.05	**0.10**	**0.11**	**0.11**	0.08	**0.14**	0.02	0.03	0.04	0.08	0.02	0.05	0.06
	275.01-280	**0.10**	**0.15**	0.08	0.03	0.06	0.06	0.07	0.07	0.04	0.06	0.05	0.01	0.06
	280.01-285	**0.10**	**0.22**	**0.13**	**0.12**	0.06	**0.15**	0.07	**0.10**	0.07	0.03	0.08	0.02	0.05
	285.01-290	0.04	0.03	0.05	0.01	0.04	0.01	0.00	0.02	0.02	0.00	0.04	0.04	0.02
	290.01-295	0.07	0.04	0.01	0.06	0.05	0.02	0.01	0.02	0.03	0.07	0.06	0.03	0.04
	295.01-300	0.01	0.04	0.02	0.04	0.01	0.03	0.05	0.00	0.02	0.03	0.02	0.00	0.04
	300.01-305	0.02	0.03	0.02	0.01	0.03	0.01	0.02	0.00	0.02	0.01	0.02	0.01	0.01
	305.01-310	0.02	0.02	0.04	0.01	0.04	0.02	0.00	0.00	0.07	0.02	0.01	0.01	0.03
	310.01-315	0.05	0.02	0.03	0.00	0.03	0.06	0.00	0.03	0.03	0.04	0.03	0.04	0.02
	315.01-320	0.03	0.05	0.04	0.02	0.01	0.06	0.01	0.03	0.05	0.02	0.00	0.03	0.03
	320.01-325	0.06	0.04	0.01	0.01	0.00	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04
	325.01-330	0.02	0.02	0.03	0.02	0.05	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.02
	330.01-335	0.04	0.05	0.03	0.06	0.00	0.02	0.01	0.06	0.06	0.05	0.01	0.00	0.01
	335.01-340	0.03	0.05	0.03	0.00	0.00	0.01	0.00	0.00	0.03	0.02	0.00	0.01	0.01
	340.01-345	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.01
Rural	345.01-350	0.00	0.03	0.03	0.00	0.00	0.02	0.05	0.15	0.17	0.10	0.06	0.04	0.07
	350.01-355	0.04	0.00	0.00	0.03	0.15	0.06	0.06	0.16	0.05	0.10	0.07	0.05	0.00
	355.01-360	0.04	0.04	0.00	0.06	0.06	0.06	0.03	0.00	0.08	0.00	0.02	0.03	0.03
	360.01-365	0.00	0.00	0.14	0.13	0.04	0.00	0.04	0.00	0.07	0.00	0.00	0.00	0.03
	365.01-370	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.09	0.09	0.00	0.05
	370.01-375	0.00	0.00	0.07	0.00	0.11	0.11	0.11	0.05	0.05	0.00	0.09	0.05	0.05
	375.01-380	0.00	0.09	0.00	0.07	0.14	0.00	0.07	0.19	0.06	0.06	0.06	0.00	0.00
	380.01-385	0.13	0.00	0.00	0.00	0.10	0.10	0.10	0.09	0.17	0.00	0.16	0.08	0.00
	385.01-390	0.00	0.00	0.00	0.15	0.00	0.13	0.13	0.00	0.00	0.00	0.12	0.12	0.00
	390.01-395	0.00	0.18	0.00	0.15	0.15	0.14	0.00	0.00	0.00	0.12	0.00	0.24	0.12
	395.01-400.59	**0.36**	0.00	0.29	0.00	0.00	0.00	0.12	0.00	0.12	0.00	0.00	0.00	0.11

Table A-19. Eastbound I-70 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.36	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.01-10	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.01-15	0.34	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.44	0.00
	15.01-20	**0.65**	0.31	0.32	0.31	0.29	0.27	0.00	0.23	0.22	0.43	**0.64**	0.44	0.21
	20.01-25	**0.58**	**0.55**	0.27	0.00	0.25	0.00	0.21	0.41	0.39	0.19	0.19	0.40	0.00
	25.01-30	0.25	0.47	**0.66**	0.00	**0.60**	0.37	0.35	0.33	0.16	0.46	0.15	**0.64**	**0.67**
	30.01-35	0.00	0.00	0.42	0.00	0.43	0.40	0.37	0.00	0.34	0.00	0.31	0.50	0.48
	35.01-40	0.00	0.28	0.51	0.00	0.00	0.47	0.22	0.21	0.20	0.00	0.00	0.19	0.35
	40.01-45	0.21	**0.57**	0.18	0.34	0.00	0.15	0.14	0.00	0.12	0.12	0.23	0.00	0.00
	45.01-50	0.20	0.00	0.00	**0.65**	0.16	0.00	0.14	0.00	0.12	0.11	**0.54**	0.45	0.21
	50.01-55	0.19	0.17	0.00	0.15	0.00	0.14	0.26	0.24	0.11	0.11	0.20	0.10	0.29
	55.01-60	0.00	0.00	0.00	0.00	0.16	0.00	0.14	0.13	0.12	0.12	0.22	0.11	0.00
	60.01-65	0.21	0.19	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.11	0.00	0.11
	65.01-70	0.00	0.00	0.36	0.00	0.00	0.31	0.00	0.00	0.00	0.12	0.00	0.12	0.11
	70.01-75	0.23	0.00	0.39	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00
	75.01-80	0.32	0.29	**0.81**	0.26	0.49	0.23	0.21	0.00	0.37	0.18	0.00	0.17	0.00
	80.01-85	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.17
	85.01-90	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.38	0.17
	90.01-95	0.00	0.00	0.00	**0.66**	0.32	0.00	0.00	0.50	0.00	0.23	0.00	0.00	0.20
	95.01-100	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100.01-105	0.00	0.00	0.00	0.00	0.33	0.31	0.00	0.26	0.00	0.24	0.22	0.22	0.00
	105.01-110	0.00	0.00	0.00	0.35	0.00	**0.92**	0.00	0.00	0.00	0.24	0.22	0.22	0.21
	110.01-115	0.00	0.00	0.35	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.42
	115.01-120	0.00	0.37	0.35	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.22	0.21
	120.01-125	0.00	0.00	0.35	0.00	0.33	0.00	0.00	0.00	0.25	0.24	0.22	0.44	0.21
	125.01-130	0.40	0.37	0.00	0.35	**1.31**	0.31	0.28	0.00	0.00	0.48	0.22	0.00	0.42
	130.01-135	0.40	0.37	0.00	0.00	0.00	0.00	**0.87**	0.26	0.25	**0.71**	0.00	0.22	**0.64**
	135.01-140	0.40	**0.74**	0.00	0.35	0.00	**0.63**	0.00	**0.80**	**0.74**	0.47	0.43	0.44	**0.64**
	140.01-145	0.00	0.00	0.35	**0.70**	**0.67**	0.31	0.29	0.53	0.25	**0.95**	0.22	0.00	**0.85**
	145.01-150	0.39	0.36	0.34	0.00	0.00	0.31	0.00	0.26	0.00	0.24	0.00	0.22	0.22
	150.01-155	0.34	0.30	0.31	**1.27**	0.31	0.29	0.27	0.00	0.25	0.47	0.45	0.23	**0.73**
	155.01-160	**0.54**	0.00	0.25	0.00	0.25	0.00	0.43	0.41	0.20	**0.56**	**0.55**	**0.76**	**0.58**
	160.01-165	0.00	0.00	0.28	0.29	0.00	0.00	0.50	0.23	0.00	0.21	**0.65**	0.37	0.39
	165.01-170	0.22	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.16	0.16	0.17	0.00	0.00
	170.01-175	0.00	0.00	0.40	0.00	0.41	0.00	0.00	0.00	0.33	0.16	0.34	0.17	0.35
	175.01-180	0.00	0.00	0.20	0.20	0.41	0.00	0.00	0.00	0.16	0.00	0.34	0.17	0.00
	180.01-185	0.23	0.21	0.00	0.40	0.20	0.00	0.18	0.00	0.00	0.00	0.48	0.16	0.17
	185.01-190	0.00	0.00	0.00	0.00	0.00	0.20	0.18	0.34	0.33	0.32	0.00	0.16	0.00
	190.01-195	0.24	0.45	0.21	0.00	0.00	0.40	0.37	0.00	0.00	0.32	0.00	0.17	0.00
	195.01-200	0.00	0.45	0.21	0.20	0.20	0.00	0.18	0.00	0.33	0.00	0.00	0.00	0.00
	200.01-205	0.00	0.45	0.21	**0.61**	0.20	0.20	0.18	0.17	0.33	0.32	0.30	0.17	0.00
	205.01-210	0.00	0.45	**0.86**	**0.61**	0.21	0.00	0.19	0.00	0.00	0.16	0.16	0.33	0.00
	210.01-215	0.48	0.00	0.43	0.00	0.00	0.00	0.00	0.17	0.34	0.17	**0.78**	0.17	0.17
	215.01-220	0.00	0.46	0.22	0.42	0.21	0.41	0.00	0.18	0.00	0.34	0.48	0.35	0.00
	220.01-225	0.48	0.23	0.22	0.21	0.43	0.41	0.00	0.35	0.18	0.17	0.00	0.35	0.35
	225.01-232	0.13	0.13	0.24	0.12	0.24	0.23	0.00	0.00	0.00	0.37	0.43	0.47	0.20

Table A-20. Westbound I-70 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.22
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.01-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22
	15.01-20	0.00	0.31	0.00	**1.22**	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.00
	20.01-25	0.00	0.28	**0.55**	0.00	0.25	0.00	0.00	0.00	0.19	0.00	**0.58**	0.20	0.39
	25.01-30	**0.50**	0.00	0.22	**0.42**	0.40	**0.56**	0.00	0.17	0.16	0.00	0.31	**0.48**	0.00
	30.01-35	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.18	0.17	0.00	0.16	0.00	0.00
	35.01-40	0.00	0.28	0.00	0.25	0.00	0.00	**0.67**	0.21	0.20	0.00	0.18	0.00	0.18
	40.01-45	0.21	**0.95**	0.18	0.00	0.33	0.15	0.29	0.26	0.25	0.12	0.11	0.35	0.00
	45.01-50	0.00	0.00	0.00	0.32	0.32	0.15	0.00	0.00	0.36	0.23	0.22	0.00	0.00
	50.01-55	0.00	0.34	0.00	0.15	0.15	0.00	0.00	0.00	0.11	0.11	0.20	0.20	0.00
	55.01-60	0.39	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.35	0.00	0.11	0.11
	60.01-65	0.00	0.00	0.36	0.00	0.00	0.15	0.00	0.26	0.00	0.00	0.11	0.11	0.22
	65.01-70	0.00	0.00	0.00	0.34	0.17	0.31	0.00	0.00	0.13	0.00	0.12	0.12	0.00
	70.01-75	0.00	0.21	0.00	0.00	0.18	0.17	0.00	0.00	0.27	0.13	0.37	0.00	0.00
	75.01-80	0.32	**0.57**	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
	80.01-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00
	85.01-90	0.34	0.31	0.29	**0.55**	0.00	0.00	0.23	0.00	0.40	0.19	0.38	0.38	0.17
	90.01-95	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.24	0.23	0.21	0.21	0.20
	95.01-100	0.40	0.37	0.00	0.00	0.00	0.31	0.00	0.26	0.00	**0.48**	**0.87**	0.00	**0.64**
	100.01-105	0.00	0.00	0.00	0.35	0.33	0.00	0.00	**0.52**	0.00	0.00	0.22	0.22	0.21
	105.01-110	0.00	0.37	0.00	**0.69**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
	110.01-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00
	115.01-120	0.40	0.00	0.35	0.00	0.00	0.00	0.28	0.00	0.25	0.00	0.00	0.00	0.00
	120.01-125	0.00	0.00	0.00	0.00	0.00	**0.92**	0.00	0.26	**0.49**	0.24	0.00	0.00	0.21
	125.01-130	0.40	0.37	0.00	0.00	0.00	0.31	0.00	0.26	0.00	**0.72**	**0.44**	**0.87**	0.21
	130.01-135	0.00	0.00	0.00	0.00	0.33	**0.62**	0.00	0.00	0.00	0.24	**0.87**	0.22	0.00
	135.01-140	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.22	0.00
	140.01-145	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.22	0.00	0.00
	145.01-150	0.00	0.36	0.00	0.00	0.00	0.31	0.29	0.26	0.00	0.24	0.00	0.22	**0.43**
	150.01-155	0.00	0.00	**0.62**	0.00	0.00	0.00	0.00	**0.51**	0.00	0.00	0.00	0.00	0.24
	155.01-160	0.27	0.00	0.00	0.00	0.25	0.00	0.00	0.41	0.00	0.00	0.00	0.19	0.00
	160.01-165	0.00	0.00	0.28	0.29	**0.86**	0.00	0.25	0.23	0.23	0.00	**0.43**	0.37	**0.77**
	165.01-170	0.00	0.00	0.20	0.00	0.21	0.19	0.18	0.00	0.33	0.16	0.00	0.17	0.00
	170.01-175	0.00	0.20	0.00	0.00	0.21	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
	175.01-180	**0.66**	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.16	0.00	0.17	0.17
	180.01-185	0.00	0.21	0.20	0.00	0.00	0.19	0.18	0.00	0.16	**0.47**	0.16	0.16	0.00
	185.01-190	**0.48**	0.23	0.00	0.00	0.00	0.00	0.00	0.17	0.16	0.16	0.15	0.00	0.17
	190.01-195	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.17	0.35
	195.01-200	0.00	**0.67**	0.00	0.20	0.20	0.00	0.00	0.17	0.17	**0.64**	0.15	0.00	0.17
	200.01-205	0.24	0.22	0.21	0.00	0.00	0.00	0.18	0.00	0.00	0.16	0.15	0.33	0.00
	205.01-210	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.17	0.00	0.16	0.33	0.00
	210.01-215	0.00	0.00	**0.43**	0.00	0.00	0.20	0.19	0.00	0.17	0.17	0.16	0.00	0.17
	215.01-220	0.00	0.00	0.00	**0.42**	0.00	0.21	0.00	0.36	0.00	**0.51**	0.00	0.00	0.18
	220.01-225	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.35	0.00
	225.01-232	0.00	0.13	0.00	0.12	0.24	0.12	0.21	0.00	0.10	0.09	0.00	0.00	0.00

Table A-21. Eastbound I-80 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rural Area	0-5	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.00	0.00	0.00	0.00	0.00	0.00
	10.01-15	0.17	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.28	0.00	0.14
	15.01-20	0.17	0.34	0.16	0.15	0.00	0.00	0.00	0.14	0.00	0.14	0.28	0.00	0.00
	20.01-25	0.17	0.00	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.14
	25.01-30	0.34	**0.50**	0.16	0.00	0.32	0.00	0.29	**0.42**	0.00	0.00	0.00	0.00	0.00
	30.01-35	0.34	0.00	**0.64**	0.15	0.00	0.29	**0.43**	0.14	0.00	0.14	0.28	0.29	0.14
	35.01-40	**0.85**	**0.67**	0.00	0.00	0.32	0.00	0.14	0.00	0.00	0.14	**0.84**	0.15	0.14
	40.01-45	0.17	0.33	0.16	0.30	0.31	**0.87**	0.00	0.14	0.28	0.00	**0.56**	0.15	0.14
	45.01-50	0.33	**0.66**	0.00	**0.45**	0.16	**0.58**	0.00	**0.41**	0.27	**0.42**	**0.42**	0.29	0.29
	50.01-55	0.17	0.00	0.31	**0.45**	0.31	0.14	0.28	0.27	0.14	**0.55**	0.00	**0.71**	0.00
	55.01-60	0.00	**0.49**	0.30	**0.72**	**0.45**	0.14	**0.69**	0.27	0.27	0.14	0.14	**0.68**	0.00
	60.01-65	0.00	0.00	0.30	0.28	0.15	0.14	0.14	0.13	0.13	0.00	**0.53**	**0.40**	0.13
	65.01-70	0.16	0.00	0.15	0.00	0.30	**0.41**	0.13	0.13	0.00	0.13	0.13	0.00	0.13
	70.01-75	0.16	0.31	0.00	0.00	0.15	**0.55**	0.13	0.39	0.26	**0.39**	0.13	0.27	**0.40**
	75.01-80	**0.44**	**0.44**	0.14	0.13	**0.55**	0.26	0.39	**0.62**	0.25	0.38	0.00	0.00	0.37
	80.01-85	0.14	0.00	0.27	0.00	0.26	0.25	0.37	0.24	**0.48**	0.00	0.11	0.00	0.00
	85.01-90	0.13	**0.40**	**0.40**	0.12	0.13	0.12	0.00	0.00	0.11	0.10	0.09	0.19	0.10
	90.01-95	0.12	0.12	0.13	0.00	0.25	0.00	0.00	0.00	0.00	0.09	0.00	0.09	0.00
	95.01-100	0.34	0.17	0.26	0.25	0.00	0.22	0.21	0.21	0.26	0.06	0.11	0.17	0.00
	100.01-105	0.27	0.13	0.00	0.12	0.06	0.00	0.05	0.05	0.09	0.09	0.08	0.13	0.09
	105.01-110	0.15	0.07	0.00	0.07	0.06	0.06	0.11	0.06	0.16	0.00	0.05	0.10	0.11
Urban Area	110.01-115	**0.12**	**0.16**	0.00	0.05	**0.14**	0.05	**0.13**	0.08	0.04	0.04	0.10	0.03	0.07
	115.01-120	0.03	0.00	0.00	0.02	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	120.01-125	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0.00
	125.01-130	0.00	**0.13**	0.09	0.00	0.00	0.00	0.03	0.06	0.00	0.07	0.04	0.00	0.02
Rural Area	130.01-135	0.07	0.03	0.00	0.03	0.00	0.00	0.00	0.06	0.00	0.03	0.05	0.03	0.05
	135.01-140	0.00	0.07	0.06	0.03	0.00	0.08	0.03	0.03	0.06	0.00	0.08	0.03	0.00
	140.01-145	0.04	0.04	0.04	0.07	0.00	0.00	0.06	0.00	0.06	0.06	0.05	0.03	0.05
	145.01-150	0.08	0.16	0.14	0.00	0.00	0.06	0.06	0.06	0.00	0.00	0.05	0.11	0.10
	150.01-155	0.11	0.00	0.29	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.08	0.15
	155.01-160	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.10	0.09	0.08	0.08	0.00
	160.01-165	0.00	0.00	0.23	0.00	0.00	0.10	0.00	0.00	0.00	0.09	0.00	0.09	0.09
	165.01-170	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00
	170.01-175	0.00	0.00	0.00	0.10	0.10	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.08
	175.01-180	0.00	0.00	0.00	0.00	0.10	0.00	0.09	0.00	0.00	0.00	0.16	0.00	0.00
	180.01-185	0.12	0.22	0.00	0.10	0.00	0.00	0.00	0.08	0.08	0.00	0.23	0.08	0.08
	185.01-190	0.12	0.33	0.11	0.10	0.20	0.19	0.28	0.09	0.17	0.17	0.00	0.09	0.09
	190.01-197	0.00	0.16	0.08	0.38	0.38	0.21	0.21	0.26	0.19	0.12	0.23	0.20	0.20

Table A-22. Westbound I-80 13-Year (1992-2004) Crash Rate Analysis

	Milepost	Crash Rate per Million Vehicle-Miles Traveled												
		1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural Area	0-5	0.19	0.00	0.18	0.00	0.17	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
	5.01-10	0.17	0.00	0.00	0.00	0.00	0.15	0.00	0.14	0.00	0.00	0.14	**0.44**	0.00
	10.01-15	0.00	0.00	0.00	0.15	0.00	0.00	0.00	**0.28**	0.00	0.14	0.14	0.15	0.14
	15.01-20	0.17	0.00	0.16	**0.30**	0.00	0.00	0.00	0.00	**0.29**	0.00	**0.28**	0.00	0.14
	20.01-25	0.00	0.00	0.16	**0.30**	0.00	0.00	0.00	0.00	**0.73**	0.00	0.00	**0.29**	**0.29**
	25.01-30	**0.51**	**0.84**	**0.32**	0.00	0.00	**0.29**	0.14	**0.28**	**0.29**	0.00	0.00	0.00	0.00
	30.01-35	0.17	0.00	0.16	0.15	0.16	0.00	0.00	0.14	0.15	0.14	**0.28**	0.15	0.14
	35.01-40	**0.34**	0.00	0.00	0.00	0.00	**0.29**	**0.29**	0.14	0.15	0.00	0.00	0.00	0.00
	40.01-45	0.17	0.00	0.00	0.15	0.16	0.00	0.14	0.14	0.14	**0.28**	0.14	0.15	0.00
	45.01-50	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.15	0.00
	50.01-55	0.17	0.16	0.16	0.15	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.14	0.00
	55.01-60	0.16	0.00	0.00	0.00	0.00	0.00	0.14	**0.27**	0.00	0.14	0.00	**0.27**	0.13
	60.01-65	0.00	0.00	0.00	0.00	0.15	0.00	0.14	0.00	0.00	0.13	0.13	0.00	0.13
	65.01-70	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.13	0.00	0.00	**0.26**	0.00	0.13
	70.01-75	0.00	0.00	0.00	0.00	0.15	0.14	0.13	0.00	0.13	0.00	**0.26**	0.14	0.13
	75.01-80	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
	80.01-85	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.12	0.00	0.00	0.22	0.11	0.11
	85.01-90	0.00	0.00	0.13	0.00	0.13	0.12	0.00	0.00	0.00	0.10	0.09	0.00	0.00
	90.01-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
	95.01-100	0.09	0.00	0.09	0.00	0.00	0.07	**0.28**	0.00	0.00	0.00	0.06	0.06	0.06
	100.01-105	0.00	0.00	0.12	0.00	0.06	0.11	0.05	0.09	0.09	0.09	0.00	0.13	0.09
	105.01-110	0.08	0.07	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.05	0.05	**0.24**	0.05
Urban Area	110.01-115	0.00	0.00	**0.10**	**0.15**	0.00	0.05	**0.08**	0.00	0.00	0.04	0.00	0.07	0.04
	115.01-120	0.03	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.04	0.00
	120.01-125	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00
	125.01-130	0.05	0.00	0.00	0.00	0.05	**0.07**	0.00	0.03	0.05	0.00	0.06	0.00	0.04
Rural Area	130.01-135	0.04	0.03	0.03	0.03	0.00	0.00	0.03	0.06	0.00	0.05	0.07	0.00	0.00
	135.01-140	0.04	0.04	0.10	0.03	0.06	0.03	0.00	0.03	0.03	0.00	0.05	0.00	0.03
	140.01-145	0.00	0.04	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.03
	145.01-150	0.08	0.08	0.14	0.06	0.06	0.00	0.00	0.00	0.06	0.11	0.00	0.11	0.05
	150.01-155	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.07	0.00	0.00
	155.01-160	0.13	0.00	0.00	0.00	0.21	0.19	0.00	0.10	0.10	0.09	0.00	0.08	0.00
	160.01-165	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.09	0.00
	165.01-170	0.12	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	170.01-175	0.00	0.00	0.10	0.20	0.20	0.00	0.18	0.00	0.08	0.00	0.08	0.00	0.00
	175.01-180	0.12	0.11	0.00	0.00	0.00	0.19	0.18	0.00	0.08	0.17	0.08	0.08	0.00
	180.01-185	0.12	0.00	0.00	0.00	0.10	0.00	0.00	0.08	**0.25**	0.00	0.08	0.00	0.16
	185.01-190	0.12	0.00	0.00	**0.31**	0.00	**0.28**	0.09	0.09	0.08	**0.34**	0.08	0.18	0.09
	190.01-197	0.09	0.08	0.00	0.00	0.00	0.07	0.00	0.06	0.06	0.06	0.00	0.00	0.13

Table A-23. Eastbound I-84 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	**0.48**	0.00	**0.21**	0.00	**0.20**	0.00	0.19	0.18	0.18	0.00	0.00	0.00	0.00
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.13	0.00	0.13	0.00	0.00	0.00
	10.01-15	0.00	0.00	0.00	0.00	**0.28**	0.00	0.00	0.12	0.00	0.00	**0.23**	0.15	0.15
	15.01-20	0.17	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.12	0.00	0.00	0.00	0.00
	20.01-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.14
	25.01-30	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
	30.01-35	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	35.01-42	0.00	**0.22**	0.00	0.00	0.19	0.09	0.00	0.08	0.00	**0.31**	0.14	**0.20**	0.10
	81.04-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
	85.01-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09	0.00	0.00
	90.01-95	0.00	0.00	0.00	0.00	0.11	**0.21**	0.18	0.00	0.00	0.08	**0.25**	0.08	**0.25**
	95.01-100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100.01-105	0.00	0.00	0.00	0.13	0.00	0.11	0.00	**0.20**	0.00	0.00	0.10	**0.21**	0.10
	105.01-110	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.11	0.00	**0.22**	0.00	0.00	0.00
	110.01-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	**0.24**	**0.31**	0.15
	115.01-120	0.00	0.00	0.00	**0.20**	0.19	0.00	0.00	0.17	0.17	0.00	**0.49**	0.00	0.15

Table A-24. Westbound I-84 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	**0.21**	0.00	0.00	**0.38**	0.00	0.00	0.00	0.00	0.00	0.17	0.00
	5.01-10	**0.39**	**0.37**	0.00	0.16	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
	10.01-15	0.18	0.00	**0.31**	**0.30**	0.14	0.00	0.00	0.12	0.00	0.12	**0.34**	0.00	0.00
	15.01-20	0.17	0.16	0.00	**0.29**	0.14	0.00	0.00	**0.24**	0.00	0.11	0.00	0.00	0.00
	20.01-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.10	0.14	0.00
	25.01-30	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.22**	0.00	0.10	0.14	0.14
	30.01-35	0.00	0.00	0.14	0.13	0.13	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.00
	35.01-42	0.12	0.00	0.00	0.10	0.00	0.00	0.00	0.08	0.08	0.08	0.00	**0.20**	0.00
	81.04-85	0.00	0.00	0.00	0.15	0.00	0.14	0.00	0.12	0.00	0.11	0.09	0.00	0.00
	85.01-90	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.16
	90.01-95	0.00	0.00	0.00	0.00	0.11	0.00	0.09	0.00	0.00	0.17	0.08	0.00	0.00
	95.01-100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
	100.01-105	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	**0.19**	0.00	0.00	0.00
	105.01-110	0.00	0.00	0.00	0.00	0.14	0.00	0.11	0.00	0.11	0.00	0.00	0.00	0.00
	110.01-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12	0.16	0.15
	115.01-120	0.00	0.00	0.00	0.00	**0.19**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-25. Inner Lanes I-215 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Urban	0-5	0.03	0.02	0.02	0.00	**0.11**	0.02	0.05	0.07	0.07	0.00	**0.09**	0.04	0.02
	5.01-10	0.05	**0.09**	0.02	0.06	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.00
	10.01-15	0.06	0.05	0.06	0.01	0.02	0.02	0.03	0.03	0.00	0.06	0.04	0.02	0.02
	15.01-20	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.03	0.01	0.04	0.03
	20.01-25	0.00	0.03	0.02	0.02	0.00	0.00	0.00	0.03	0.05	0.00	0.06	0.04	0.00
	25.01-30	0.00	0.00	0.04	0.04	0.04	0.06	0.02	**0.08**	0.04	0.05	**0.13**	0.00	0.03

Table A-26. Outer Lanes I-215 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Urban	0-5	0.03	0.02	0.00	0.02	0.02	0.04	**0.07**	0.00	0.02	0.05	**0.07**	0.06	0.02
	5.01-10	0.00	0.00	**0.10**	0.02	0.06	0.02	0.00	0.02	0.05	0.03	0.03	0.00	0.04
	10.01-15	0.04	0.03	0.01	0.02	0.05	0.04	0.04	0.02	**0.07**	0.03	0.01	0.02	0.01
	15.01-20	0.06	0.00	0.04	0.01	0.04	0.01	0.03	**0.07**	0.02	0.03	0.01	0.01	0.00
	20.01-25	0.03	0.05	0.00	0.02	0.02	0.00	0.00	0.00	0.05	0.00	0.06	0.04	0.06
	25.01-30	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.02	0.05	0.05	0.03	0.03

Table A-27. Northbound U.S. 89 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	**0.69**	0.00	0.00	0.00	0.61	0.58	0.42	0.00	0.00	0.00	0.00
	5.01-10	**0.70**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.54	0.00
	10.01-15	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00
	15.01-20	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.52	**1.07**	0.00	0.54	0.00
	20.01-25	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25.01-30	**0.70**	**0.66**	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.53
	30.01-35	0.00	**1.32**	0.63	0.00	0.00	0.00	0.56	0.53	0.00	0.00	0.00	0.00	0.00
	35.01-40	0.00	**1.32**	0.00	0.00	0.00	0.57	0.56	0.00	0.52	0.00	0.51	0.00	0.00
	40.01-45	0.00	**0.66**	**1.26**	**1.24**	0.00	**1.15**	0.00	0.53	0.52	0.53	0.00	0.54	0.00
	45.01-50	0.00	0.00	0.00	0.00	**1.20**	0.57	0.00	0.00	0.00	0.53	0.00	0.00	0.00
	50.01-55	**0.69**	0.00	0.62	**1.22**	**1.18**	0.57	0.56	**1.57**	0.00	0.53	0.00	0.00	0.53
	55.01-60	0.00	**1.12**	0.00	0.00	0.00	0.00	0.47	0.00	0.49	0.00	0.48	0.47	0.46
	60.01-65	0.00	0.00	0.00	0.26	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	65.01-70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00
	70.01-75	0.46	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00	0.31	0.00
	75.01-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	80.01-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00
	85.01-90	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
	90.01-95	0.00	0.00	**1.65**	0.00	**0.75**	0.00	0.00	0.00	**0.95**	0.00	0.00	0.00	0.00
	95.01-100	0.00	0.00	0.00	**0.79**	0.00	0.00	**0.78**	0.00	**0.95**	**0.94**	0.00	**0.92**	0.00
	100.01-105	0.00	0.00	0.00	0.00	0.00	0.00	**1.58**	0.00	0.00	0.00	0.00	0.00	0.00
	105.01-110	**0.85**	0.00	0.00	**0.78**	**0.75**	0.00	0.00	**0.79**	0.00	**0.78**	0.00	**0.89**	**0.86**
	110.01-115	0.00	**0.77**	**1.65**	**0.78**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	115.01-120	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	120.01-125	0.00	0.00	0.00	0.00	0.47	0.00	0.47	0.00	0.00	0.55	0.00	0.00	0.00
	125.01-130	0.00	0.47	0.00	0.00	0.00	0.00	0.37	0.36	0.00	0.00	0.00	0.00	0.00
	130.01-135	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
	135.01-140	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00
	140.01-145	0.00	0.00	0.00	0.00	0.00	**0.79**	0.00	0.00	0.00	0.00	**1.47**	0.00	0.00
	145.01-150	**1.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	150.01-155	0.00	**0.96**	0.00	0.00	0.00	0.00	0.00	**0.89**	0.00	0.00	**0.89**	0.00	0.00
	155.01-160	**1.02**	0.00	0.00	0.00	0.00	**1.90**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	160.01-165	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.67**
	165.01-170	0.00	0.00	0.00	0.00	**0.78**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	170.01-175	0.00	0.00	0.00	**0.99**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.95**
	175.01-180	0.00	0.00	0.00	**1.75**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	180.01-185	0.00	0.00	**0.79**	**0.77**	0.00	0.00	0.00	0.00	0.00	**0.79**	0.00	0.00	**0.77**
	185.01-191.74	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.57	0.59	0.00	0.00	0.57
	225.36-230	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.16	0.00
	230.01-235	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	235.01-240	0.00	0.00	0.00	0.00	0.00	0.32	0.30	0.00	0.00	0.00	0.14	0.00	0.15
	240.01-245	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.21	0.21	0.00	0.00	0.00	0.00
	245.01-250	0.00	0.00	0.00	0.37	0.00	0.37	0.00	0.00	0.00	0.35	0.00	0.00	0.00

Table A-27. Continued

Rural	250.01-255	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.30	0.00	0.00	0.29
	255.01-260	0.00	0.00	0.00	0.00	0.19	0.00	0.18	0.00	0.00	0.00	0.00	0.16	0.00
	260.01-265	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.17	0.16
	265.01-270	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00
	270.01-275	0.57	0.00	**0.95**	0.00	0.46	0.00	0.00	0.00	0.00	0.00	**0.77**	0.00	0.00
	275.01-280	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.30	0.00	0.28	0.00	0.27	0.00
	280.01-285	0.00	0.00	0.38	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	285.01-290	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	290.01-295	0.00	**0.69**	**1.22**	0.00	0.53	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	295.01-300	0.00	**0.69**	0.00	0.55	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00
	300.01-305	0.00	0.00	0.00	0.00	**1.07**	0.00	0.00	**0.82**	0.00	0.00	0.46	0.00	0.00
	305.01-312.78	0.00	**0.88**	0.39	0.00	**1.03**	0.00	0.29	0.26	0.00	0.29	0.00	0.29	0.30
	322.28-325	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban	325.01-330	0.00	**0.18**	0.09	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.07	**0.21**	0.07
	330.01-335	0.00	0.00	0.00	0.06	0.00	0.00	**0.17**	0.05	0.11	0.00	**0.15**	0.00	0.05
	335.01-340	0.08	0.03	0.02	0.02	0.00	0.02	0.07	0.02	0.02	0.00	0.08	0.02	0.02
	340.01-345	0.00	**0.13**	0.04	0.04	**0.15**	0.04	0.09	0.03	0.09	0.03	0.03	0.08	0.03
	345.01-350	0.00	0.00	0.00	**0.17**	0.06	0.05	**0.15**	0.05	0.05	0.00	0.04	0.00	0.04
	350.01-355	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
	355.01-360	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	360.01-365	0.00	0.06	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.07	0.00
	365.01-370	0.00	0.04	0.04	0.04	0.00	0.03	0.06	0.00	0.03	0.00	0.00	0.08	0.00
	370.01-375	0.00	0.10	0.06	0.07	0.07	0.09	0.05	0.03	0.09	0.11	**0.16**	0.08	0.08
	375.01-380	0.04	0.00	0.07	0.07	0.10	0.06	0.05	0.09	0.06	0.00	0.00	0.00	0.04
	380.01-385	0.05	0.00	0.00	0.04	0.00	0.10	0.06	**0.13**	0.00	0.00	0.00	0.06	0.06
	385.01-389.53	0.00	0.00	0.10	0.00	0.00	**0.14**	0.09	0.04	0.00	**0.13**	0.04	0.00	0.00
	395.59-400	0.00	0.00	0.09	0.05	0.09	0.04	0.08	0.00	0.04	0.04	0.00	0.04	0.00
	400.01-405	0.04	0.04	0.04	0.00	**0.16**	0.00	0.07	0.00	0.04	0.10	0.00	0.04	0.11
	405.01-410	0.04	0.00	0.07	0.00	0.07	0.00	0.03	0.09	0.00	0.00	0.06	0.00	0.03
	410.01-415	0.10	0.00	0.09	0.05	0.09	0.04	0.00	0.00	0.08	0.00	0.00	0.00	0.04
	415.01-420	0.06	0.00	0.00	0.00	0.00	0.00	0.09	0.08	0.04	0.00	0.04	0.08	0.00
	420.01-425	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.09	0.09	0.00	0.09	0.00
	425.01-430	**0.13**	**0.12**	**0.23**	0.00	0.00	0.00	0.10	0.00	0.00	0.10	0.09	0.00	0.00
	430.01-435	0.00	0.00	**0.15**	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.06	0.06
	435.01-440	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	440.01-445	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	445.01-450	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	450.01-455	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	455.01-460	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	460.01-465	**0.14**	0.00	0.00	**0.12**	**0.12**	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
	465.01-470	0.00	**0.33**	0.00	**0.30**	0.00	0.00	0.00	0.00	0.00	**0.17**	**0.16**	0.00	0.00
Rural	470.01-475	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.19
	475.01-480	0.00	0.00	0.00	0.00	0.44	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00
	480.01-485	0.00	0.00	0.50	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00
	485.01-490	0.00	0.62	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.47	0.00	0.00	0.00
	490.01-495	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00
	495.01-500	0.00	0.00	0.00	0.00	0.00	**0.65**	0.57	0.00	0.00	0.00	0.00	0.47	0.00
	500.01-503	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-28. Southbound U.S. 89 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.43	0.00	0.00	0.35
	5.01-10	**0.70**	**0.66**	0.00	0.00	0.60	0.58	0.00	0.53	0.52	0.00	0.00	0.54	0.53
	10.01-15	**0.70**	0.00	0.00	0.00	**1.20**	**1.15**	0.56	**1.58**	0.00	0.00	0.51	0.00	0.00
	15.01-20	0.00	**0.66**	0.00	0.00	**1.20**	0.00	0.00	0.53	0.52	0.00	0.00	0.54	0.00
	20.01-25	0.00	0.00	0.00	0.00	0.00	0.57	0.00	**1.58**	0.52	0.00	0.00	0.00	0.53
	25.01-30	**0.70**	**0.66**	0.00	0.00	0.00	0.00	0.00	0.53	0.52	0.00	0.51	0.00	0.00
	30.01-35	**0.70**	0.00	0.00	0.00	**1.20**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
	35.01-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.06**	0.52	0.00	0.00	0.00	0.00
	40.01-45	0.00	0.00	**0.63**	0.00	0.00	0.00	0.00	0.00	**1.05**	0.00	0.51	0.00	0.00
	45.01-50	0.00	**0.66**	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.53	0.00	0.54	0.00
	50.01-55	0.00	0.00	**0.62**	0.00	0.00	0.00	0.00	0.52	0.00	0.53	0.00	0.00	0.00
	55.01-60	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.48	0.00	0.00
	60.01-65	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
	65.01-70	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
	70.01-75	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.61**	0.31	0.30
	75.01-80	0.00	0.00	**0.82**	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00
	80.01-85	0.00	0.54	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.45
	85.01-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	90.01-95	0.00	**0.77**	**0.82**	0.00	0.00	**0.80**	0.00	**0.75**	**0.95**	0.00	**0.91**	**1.83**	0.00
	95.01-100	0.00	**0.77**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.76**
	100.01-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.76**	0.00	**1.78**	0.00	0.00	0.00
	105.01-110	0.00	**0.77**	**0.83**	**0.78**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	110.01-115	0.00	0.00	**2.48**	0.00	0.00	0.00	0.00	0.00	0.00	**0.80**	**0.77**	0.00	0.00
	115.01-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.63**	**1.21**	0.00	0.60
	120.01-125	0.00	0.00	0.00	0.00	**0.94**	0.48	0.00	0.00	0.00	0.00	0.00	**1.07**	0.51
	125.01-130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	130.01-135	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.28	0.00
	135.01-140	0.00	0.00	0.50	0.00	0.50	0.00	0.00	0.47	0.00	0.47	0.45	0.00	0.00
	140.01-145	0.00	**0.83**	0.00	0.00	0.00	**0.79**	0.00	0.00	0.00	**0.76**	0.00	**0.70**	**0.75**
	145.01-150	0.00	0.00	0.00	0.00	0.00	0.00	**0.93**	0.00	0.00	**0.92**	0.00	0.00	0.00
	150.01-155	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	155.01-160	0.00	**0.96**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	160.01-165	0.00	**0.67**	0.00	**0.64**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	165.01-170	0.00	**1.03**	0.00	0.00	**0.78**	0.00	0.00	**0.80**	0.00	0.00	0.00	0.00	0.00
	170.01-175	0.00	0.00	**0.99**	0.00	0.00	**0.80**	0.00	**0.82**	0.00	0.00	0.00	**0.85**	0.00
	175.01-180	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	180.01-185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.58**	0.00
	185.01-191.74	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	225.36-230	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	230.01-235	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00
	235.01-240	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.14	0.00	0.00	0.00
	240.01-245	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00
	245.01-250	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00

Table A-28. Continued

Rural	250.01-255	0.34	0.00	0.00	0.28	0.27	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
	255.01-260	0.00	0.00	0.00	0.00	0.19	0.18	0.00	0.00	0.19	0.00	0.00	0.00	0.00
	260.01-265	0.00	0.00	0.39	0.39	0.20	0.38	0.00	0.00	0.00	0.00	0.19	0.51	0.00
	265.01-270	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
	270.01-275	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
	275.01-280	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.31	0.00	0.00	0.00	0.23
	280.01-285	**0.86**	0.00	0.00	0.00	0.00	0.30	0.00	0.27	0.00	0.00	0.00	0.26	0.00
	285.01-290	0.00	**0.69**	0.00	0.55	0.53	0.00	0.45	0.00	0.00	0.00	**0.91**	0.00	0.33
	290.01-295	0.00	**0.69**	0.00	0.00	0.00	0.51	0.45	0.00	0.43	**0.89**	**0.91**	0.00	0.00
	295.01-300	0.00	0.00	0.00	0.55	0.53	0.00	0.00	0.41	0.00	0.44	0.46	0.00	0.00
	300.01-305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	305.01-312.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.30
	322.28-325	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00
Urban	325.01-330	0.09	0.09	0.09	0.00	**0.27**	0.00	**0.17**	0.08	0.00	0.00	**0.13**	0.07	**0.14**
	330.01-335	0.00	0.00	0.00	0.00	**0.19**	0.00	0.06	0.11	0.11	0.11	0.10	0.05	0.05
	335.01-340	0.00	0.10	0.02	0.07	0.00	0.00	0.05	0.04	0.04	0.06	0.00	0.06	0.00
	340.01-345	0.00	0.00	0.08	0.04	0.00	0.07	0.06	0.03	0.06	0.00	0.00	0.00	0.09
	345.01-350	0.00	0.00	0.06	**0.17**	0.06	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.04
	350.01-355	0.09	**0.17**	0.08	0.00	0.08	**0.15**	0.00	0.00	0.00	0.00	0.07	**0.20**	0.10
	355.01-360	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	360.01-365	0.06	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00
	365.01-370	0.04	**0.20**	0.08	**0.12**	0.11	0.03	0.06	0.00	0.00	0.04	0.00	0.08	0.04
	370.01-375	0.00	0.06	0.00	0.07	0.00	0.00	0.03	0.03	0.11	0.00	0.00	0.04	0.00
	375.01-380	0.04	0.00	0.03	0.00	0.03	0.06	0.05	0.00	0.06	0.07	0.08	0.00	**0.12**
	380.01-385	0.05	0.00	0.04	0.04	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00
	385.01-389.53	0.00	0.00	0.05	0.00	0.05	0.05	0.00	0.04	0.04	0.00	0.00	0.09	0.04
	395.59-400	**0.14**	0.05	0.05	0.05	0.04	0.00	0.04	0.00	0.08	0.08	0.00	0.00	0.00
	400.01-405	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.04	0.04	0.07	0.03	0.00	0.00
	405.01-410	0.00	0.00	0.00	0.04	0.00	0.07	0.00	0.03	0.06	0.03	0.06	0.03	0.00
	410.01-415	0.00	0.00	0.04	0.05	0.04	0.08	0.08	0.00	0.00	0.04	0.03	0.04	0.09
	415.01-420	**0.12**	0.00	0.00	0.05	0.00	0.09	0.05	0.00	0.04	0.00	0.00	0.04	0.00
	420.01-425	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.09	0.00	0.00	0.00	0.09	0.00
	425.01-430	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
	430.01-435	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
	435.01-440	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	440.01-445	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	445.01-450	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	450.01-455	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	455.01-460	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
	460.01-465	**0.14**	**0.26**	0.00	**0.12**	**0.12**	**0.35**	**0.23**	0.00	0.00	**0.19**	0.09	0.09	0.00
	465.01-470	0.00	**0.33**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.16**	0.00	0.00
Rural	470.01-475	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00
	475.01-480	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.37	0.00	0.21	0.00
	480.01-485	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	485.01-490	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	490.01-495	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00
	495.01-500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	500.01-503	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.69**	0.00	0.00	0.00	0.00

Table A-29. Northbound U.S. 91 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.09	0.08	0.00	0.00	0.00	0.07	0.07	0.00	0.07	0.00	0.00	0.06
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.14
	10.01-15	0.00	0.10	0.00	0.16	0.17	0.00	0.08	0.07	0.07	0.00	0.00	0.00	0.07
	15.01-20	0.00	0.30	0.00	0.00	0.17	0.16	0.07	0.07	0.21	0.14	0.07	0.14	0.21
	20.01-25	0.22	0.30	**0.44**	**0.41**	**0.38**	**0.35**	**0.34**	0.19	**0.39**	**0.39**	**0.31**	0.18	**0.36**
	25.01-30	0.18	0.00	0.15	0.04	0.12	0.27	0.19	0.18	0.07	0.07	0.13	0.07	0.03
	30.01-35	0.06	0.17	0.05	0.20	0.00	0.19	0.05	0.00	0.09	0.18	0.00	0.04	0.13
	35.01-40	0.21	0.00	0.11	**0.33**	**0.32**	0.20	0.00	0.10	0.27	0.09	0.00	0.00	0.16
	40.01-45	0.14	0.14	0.00	0.12	0.12	0.22	0.11	**0.32**	**0.36**	0.00	0.00	0.11	0.11

Table A-30. Southbound U.S. 91 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
	5.01-10	**0.29**	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.07	0.00	0.07	0.00	0.00
	10.01-15	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.15**	0.00	0.00	0.00
	15.01-20	0.00	0.00	0.00	0.00	0.00	0.08	0.07	0.00	0.14	0.07	0.07	0.07	0.00
	20.01-25	0.00	**0.20**	0.00	0.08	0.08	0.00	0.00	0.13	0.06	0.00	0.12	0.06	**0.18**
	25.01-30	0.00	0.08	0.08	0.12	0.04	0.08	0.04	0.04	0.07	0.03	0.03	0.03	0.00
	30.01-35	0.12	0.06	**0.15**	0.10	0.10	0.05	0.10	0.00	0.00	0.04	0.04	0.12	0.00
	35.01-40	**0.21**	0.00	0.00	0.11	0.00	0.00	0.10	0.00	0.00	0.00	0.08	0.00	0.08
	40.01-45	0.00	0.00	0.00	0.12	**0.24**	0.00	0.00	**0.21**	0.00	0.00	0.12	0.00	0.00

Table A-31. Northbound S.R. 36 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	0.00	0.00	0.00	**3.61**	0.00	0.00	0.00	0.00	**2.97**	**3.01**	0.00
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.01**	0.00	0.00	0.00	0.00
	10.01-15	0.00	0.00	0.00	**3.38**	**3.38**	0.00	0.00	0.00	0.00	0.00	0.00	**2.85**	0.00
	15.01-20	0.00	**3.05**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20.01-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**2.82**	0.00	0.00
	25.01-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30.01-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**2.85**	0.00
	35.01-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40.01-45	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	45.01-50	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50.01-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.09	0.00	0.00
	55.01-60	0.00	0.00	0.00	0.10	0.00	0.07	0.07	0.00	0.06	0.00	0.04	0.00	0.00
	60.01-66	0.09	0.10	0.36	0.00	0.00	0.11	0.05	0.10	0.09	0.00	0.04	0.00	0.00

Table A-32. Southbound S.R. 36 13-Year (1992-2004) Crash Rate Analysis

		Crash Rate per Million Vehicle-Miles Traveled												
	Milepost	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Rural	0-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.35**	0.00	0.00	0.00	0.00	0.00
	5.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.01-15	0.00	0.00	0.00	0.00	0.00	0.00	**3.14**	0.00	0.00	0.00	0.00	0.00	0.00
	15.01-20	0.00	**3.05**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20.01-25	0.00	0.00	**3.43**	0.00	0.00	0.00	**3.14**	0.00	0.00	0.00	0.00	0.00	0.00
	25.01-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**2.82**	0.00	0.00
	30.01-35	0.00	**3.05**	0.00	0.00	0.00	**3.23**	0.00	0.00	**3.01**	0.00	0.00	0.00	0.00
	35.01-40	0.00	0.00	0.00	0.00	0.00	**1.61**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40.01-45	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	45.01-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50.01-55	0.00	0.00	0.11	0.11	0.00	0.10	0.00	0.09	0.09	0.00	0.00	0.00	0.09
	55.01-60	0.11	0.12	0.42	0.10	0.00	0.14	0.00	0.06	0.18	0.00	0.04	0.00	0.08
	60.01-66	0.09	0.10	0.18	0.34	0.06	0.05	0.10	0.15	0.09	0.00	0.07	0.04	0.11

APPENDIX B: BEFORE-AFTER ANALYSES

Table B-1. Number of Drowsy Driving Crashes on Eastbound I-80 from M.P. 27-37 and from M.P. 50-60 for Modified Traditional Before-After Analysis

		Number of Crashes	
	Time Period	**EB M.P. 27-37**	**EB M.P. 50-60**
Before	8/21/92 - 12/31/93	3	3
	8/21/94 - 12/31/95	3	8
	8/21/96 - 12/31/97	2	4
	8/21/98 - 12/31/99	2	9
	8/21/00 - 12/31/01	1	7
	8/21/02 - 12/31/03	3	10
After	8/21/04 - 12/31/05	4	1

Table B-2. Predicted Number of "After" Crashes Calculations for Eastbound I-80 for Modified Traditional Before-After Analysis

Direction and M.P.	Number of Before TimePeriods	Number of After Time Periods	Accidents Before (K)	Accidents After (L)	r_d	r_d*K	r_d^2*K
EB M.P. 27-37	6	1	14	4	0.17	2.33	0.39
EB M.P. 50-60	6	1	41	1	0.17	6.83	1.14
Sums				5		9.2	1.5

Table B-3. Number of Drowsy Driving Crashes on westbound I-80 from M.P. 37-47 and from M.P. 85-95 for Modified Traditional Before-After Analysis

	Time Period	Number of Crashes	
		WB M.P. 37-47	WB M.P. 85-95
Before	8/21/92 - 12/31/93	1	0
	8/21/94 - 12/31/95	1	1
	8/21/96 - 12/31/97	2	2
	8/21/98 - 12/31/99	2	0
	8/21/00 - 12/31/01	3	2
	8/21/02 - 12/31/03	3	1
After	8/21/04 - 12/31/05	2	1

Table B-4. Predicted Number of "After" Crashes Calculations for Westbound I-80 for Modified Traditional Before-After Analysis

Direction and M.P.	Number of Before TimePeriods	Number of After Time Periods	Accidents Before (K)	Accidents After (L)	r_d	r_d*K	r_d^2*K
WB M.P. 85-95	6	1	6	1	0.17	1.00	0.17
WB M.P. 37-47	6	1	12	2	0.17	2.00	0.33
Sums				3		3.0	0.5

Table B-5. Eastbound I-80 with Comparison Group of EB I-70 M.P. 130-150

Group	**Number of Crashes**		**Odds Ratio (*o*)**
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**EB I-70 M.P. 130-150**	
8/21/92 - 12/31/93	6	5	
8/21/94 - 12/31/95	11	4	0.338
8/21/96 - 12/31/97	6	5	1.618
8/21/98 - 12/31/99	11	8	0.676
8/21/00 - 12/31/01	8	13	1.788
8/21/02 - 12/31/03	13	5	0.205
8/21/04 - 12/31/05	5	10	3.714
Mean of Odds Ratios			0.925
Sample Variance			0.537
K	55	M	40
L	5	N	10
VAR(ω)			0.19

Table B-6. Eastbound I-80 with Comparison Group of SB I-15 M.P. 0-20

Group	**Number of Crashes**		**Odds Ratio (*o*)**
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**SB I-15 M.P. 0-20**	
8/21/92 - 12/31/93	6	6	
8/21/94 - 12/31/95	11	10	0.723
8/21/96 - 12/31/97	6	14	2.026
8/21/98 - 12/31/99	11	10	0.335
8/21/00 - 12/31/01	8	16	1.796
8/21/02 - 12/31/03	13	11	0.371
8/21/04 - 12/31/05	5	13	2.380
Mean of Odds Ratios			1.05
Sample Variance			0.647
K	55	M	67
L	5	N	13
VAR(ω)			0.34

Table B-7. Eastbound I-80 with Comparison Group of SB I-15 M.P. 168-188

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**SB I-15 M.P. 168-188**	
8/21/92 - 12/31/93	6	6	
8/21/94 - 12/31/95	11	3	0.217
8/21/96 - 12/31/97	6	6	2.444
8/21/98 - 12/31/99	11	6	0.434
8/21/00 - 12/31/01	8	3	0.532
8/21/02 - 12/31/03	13	4	0.582
8/21/04 - 12/31/05	5	5	2.241
Mean of Odds Ratios			0.842
Sample Variance			0.822
K	55	M	28
L	5	N	5
VAR(ω)			0.37

Table B-8. Eastbound I-80 with Comparison Group of WB I-80 M.P. 0-20

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**WB I-80 M.P. 0-20**	
8/21/92 - 12/31/93	6	2	
8/21/94 - 12/31/95	11	4	0.686
8/21/96 - 12/31/97	6	1	0.324
8/21/98 - 12/31/99	11	3	0.783
8/21/00 - 12/31/01	8	2	0.629
8/21/02 - 12/31/03	13	5	0.976
8/21/04 - 12/31/05	5	2	0.743
Mean of Odds Ratios			0.679
Sample Variance			0.057
K	55	M	17
L	5	N	2
VAR(ω)			0.00

Table B-9. Eastbound I-80 with Composite Comparison Group of Groups 1-4

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**EB I-80 M.P. 27-37 & 50-60**	**Sum of Groups 1-4**	
8/21/92 - 12/31/93	6	19	
8/21/94 - 12/31/95	11	21	0.527
8/21/96 - 12/31/97	6	26	1.869
8/21/98 - 12/31/99	11	27	0.502
8/21/00 - 12/31/01	8	34	1.490
8/21/02 - 12/31/03	13	25	0.409
8/21/04 - 12/31/05	5	30	2.516
Mean of Odds Ratios			0.959
Sample Variance			0.452
K	55	M	152
L	5	N	30
Overall Odds Ratio			1.799
VAR(ω)			0.19

Table B-10. Eastbound I-80 Comparison Group Results with Data from Table C-9

INPUT:		
	Treatment	Comparison
Accident Count "Before" =	55	152
Accident Count "After" =	5	30
Variance of odds ratio =	0.19	
OUTPUT:		
Step 1:	Lambda-hat=	5
	$r_T = r_C =$	0.20
	pi-hat=	10.8
Step 2:	Var{lambda-hat}=	5.0
	Var{pi-hat}=	28.85
Step 3:	Delta-hat=	5.8
	Theta-hat=	0.371
Step 4:	Sigma{Delta-hat}=	5.82
	Sigma{Theta-hat}=	0.199

Table B-11. Westbound I-80 with Comparison Group of EB I-70 M.P. 130-150

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**WB I-80 M.P. 37-47 & 85-95**	**EB I-70 M.P. 130-150**	
8/21/92 - 12/31/93	1	5	
8/21/94 - 12/31/95	2	4	0.235
8/21/96 - 12/31/97	4	5	0.417
8/21/98 - 12/31/99	2	8	1.882
8/21/00 - 12/31/01	5	13	0.491
8/21/02 - 12/31/03	4	5	0.362
8/21/04 - 12/31/05	3	10	1.739
Mean of Odds Ratios			0.677
Sample Variance			0.462
K	18	M	40
L	3	N	10
VAR(ω)			0.00

Table B-12. Westbound I-80 with Comparison Group of SB I-15 M.P. 0-20

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**WB I-80 M.P. 37-47 & 85-95**	**SB I-15 M.P. 0-20**	
8/21/92 - 12/31/93	1	6	
8/21/94 - 12/31/95	2	10	0.500
8/21/96 - 12/31/97	4	14	0.519
8/21/98 - 12/31/99	2	10	0.909
8/21/00 - 12/31/01	5	16	0.492
8/21/02 - 12/31/03	4	11	0.655
8/21/04 - 12/31/05	3	13	1.106
Mean of Odds Ratios			0.615
Sample Variance			0.031
K	18	M	67
L	3	N	13
VAR(ω)			0.00

Table B-13. Westbound I-80 with Comparison Group of SB I-15 M.P. 168-188

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**WB I-80 M.P. 37-47 & 85-95**	**SB I-15 M.P. 168-188**	
8/21/92 - 12/31/93	1	6	
8/21/94 - 12/31/95	2	3	0.150
8/21/96 - 12/31/97	4	6	0.632
8/21/98 - 12/31/99	2	6	1.200
8/21/00 - 12/31/01	5	3	0.146
8/21/02 - 12/31/03	4	4	1.053
8/21/04 - 12/31/05	3	5	1.053
Mean of Odds Ratios			0.636
Sample Variance			0.242
K	18	M	28
L	3	N	5
VAR(ω)			0.00

Table B-14. Westbound I-80 with Comparison Group of WB I-80 M.P. 0-20

Group	Number of Crashes		Odds Ratio (*o*)
	Treatment Group	**Comparison Group**	
Time Periods	**WB I-80 M.P. 37-47 & 85-95**	**WB I-80 M.P. 0-20**	
8/21/92 - 12/31/93	1	2	
8/21/94 - 12/31/95	2	4	0.500
8/21/96 - 12/31/97	4	1	0.083
8/21/98 - 12/31/99	2	3	2.400
8/21/00 - 12/31/01	5	2	0.174
8/21/02 - 12/31/03	4	5	1.786
8/21/04 - 12/31/05	3	2	0.348
Mean of Odds Ratios			0.989
Sample Variance			1.087
K	18	M	17
L	3	N	2
VAR(ω)			0.14

Table B-15. Westbound I-80 with Composite Comparison Group of Groups 1-4

	Number of Crashes		
Group	**Treatment Group**	**Comparison Group**	**Odds Ratio (*o*)**
Time Periods	**WB I-80 M.P. 37-47 & 85-95**	**Sum of Groups 1-4**	
8/21/92 - 12/31/93	1	19	
8/21/94 - 12/31/95	2	21	0.356
8/21/96 - 12/31/97	4	26	0.477
8/21/98 - 12/31/99	2	27	1.350
8/21/00 - 12/31/01	5	34	0.407
8/21/02 - 12/31/03	4	25	0.718
8/21/04 - 12/31/05	3	30	1.165
Mean of Odds Ratios			0.662
Sample Variance			0.167
K	18	M	152
L	3	N	30
Overall Odds Ratio			0.884
VAR(ω)			0.00

Table B-16. Westbound I-80 Comparison Group Results with Data from Table C-15

INPUT:		
	Treatment	Comparison
Accident Count "Before" =	4	25
Accident Count "After" =	3	30
Variance of odds ratio =	0.00	
OUTPUT:		
Step 1:	Lambda-hat=	3
	$r_T = r_C =$	0.20
	pi-hat=	3.5
Step 2:	Var{lambda-hat}=	3.0
	Var{pi-hat}=	1.19
Step 3:	Delta-hat=	0.5
	Theta-hat=	0.776
Step 4:	Sigma{Delta-hat}=	2.05
	Sigma{Theta-hat}=	0.464

APPENDIX C: CHI-SQUARE TESTS RESULTS

Table C-1. Gender vs. Seeing the Drowsy Driving Signs

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Did you see the drowsy driving signs? (question 6)**		**Total**
	Yes	**No**	
Female	73 18.02 98.65 18.86	1 0.25 1.35 5.56	74 18.27
Male	314 77.53 94.86 81.14	17 4.2 5.14 94.44	331 81.73
Total	387 95.56	18 4.44	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	1	2.0397	0.1532
Likelihood Ratio Chi-Square	1	2.6256	0.1052
Continuity Adj. Chi-Square	1	1.2459	0.2643
Mantel-Haenszel Chi-Square	1	2.0347	0.1537
Phi Coefficient		-0.071	
Contingency Coefficient		0.0708	
Cramer's V		-0.071	

Table C-2. Age vs. Seeing the Drowsy Driving Signs

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Did you see the drowsy driving signs? (question 6)**		
	Yes	**No**	**Total**
18 - 25	23 5.68 92 5.94	2 0.49 8 11.11	25 6.17
26 - 35	55 13.58 96.49 14.21	2 0.49 3.51 11.11	57 14.07
36 - 50	105 25.93 92.11 27.13	9 2.22 7.89 50	114 28.15
> 50	204 50.37 97.61 52.71	5 1.23 2.39 27.78	209 51.6
Total	387 95.56	18 4.44	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	3	6.1296	0.1055
Likelihood Ratio Chi-Square	3	5.8274	0.1203
Mantel-Haenszel Chi-Square	1	2.1132	0.146
Phi Coefficient		0.123	
Contingency Coefficient		0.1221	
Cramer's V		0.123	

Table C-3. Gender vs. the Most Prominent Drowsy Driving Sign

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Which drowsy driving sign was most prominent to you? (question 7)**				**Total**
	Drowsy Drivers Next Exit 5 Miles	**Drowsy Drivers Pull Over If Necessary**	**Drowsy Driving Causes Crashes**	**No Preference**	
Female	8 2.07 10.96 19.05	17 4.39 23.29 19.32	36 9.3 49.32 21.82	12 3.1 16.44 13.04	73 18.86
Male	34 8.79 10.83 80.95	71 18.35 22.61 80.68	129 33.33 41.08 78.18	80 20.67 25.48 86.96	314 81.14
Total	42 10.85	88 22.74	165 42.64	92 23.77	387 100
Frequency Missing = 18					

Statistic	**DF**	**Value**	**Probability**
Chi-Square	3	2.9901	0.3931
Likelihood Ratio Chi-Square	3	3.1486	0.3693
Mantel-Haenszel Chi-Square	1	0.6866	0.4073
Phi Coefficient		0.0879	
Contingency Coefficient		0.0876	
Cramer's V		0.0879	

Table C-4. Age vs. the Most Prominent Drowsy Driving Sign

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Which drowsy driving sign was most prominent to you? (question 7)**				**Total**
	Drowsy Drivers Next Exit 5 Miles	**Drowsy Drivers Pull Over If Necessary**	**Drowsy Driving Causes Crashes**	**No Preference**	
18 - 25	5 1.29 21.74 11.9	9 2.33 39.13 10.23	8 2.07 34.78 4.85	1 0.26 4.35 1.09	23 5.94
26 - 35	3 0.78 5.45 7.14	17 4.39 30.91 19.32	30 7.75 54.55 18.18	5 1.29 9.09 5.43	55 14.21
36 - 50	12 3.1 11.43 28.57	23 5.94 21.9 26.14	43 11.11 40.95 26.06	27 6.98 25.71 29.35	105 27.13
> 50	22 5.68 10.78 52.38	39 10.08 19.12 44.32	84 21.71 41.18 50.91	59 15.25 28.92 64.13	204 52.71
Total	42 10.85	88 22.74	165 42.64	92 23.77	387 100.0
Frequency Missing = 18					

Statistic	**DF**	**Value**	**Probability**
Chi-Square	9	22.976	0.0063
Likelihood Ratio Chi-Square	9	25.312	0.0026
Mantel-Haenszel Chi-Square	1	9.4681	0.0021
Phi Coefficient		0.2437	
Contingency Coefficient		0.2367	
Cramer's V		0.1407	

Table C-5. Gender vs. How the Drowsy Driving Signs Contribute to Drivers' Decisions to Stop

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Did the drowsy driving signs contribute to your decision to stop? (question 8)**			
	Definitely	**Somewhat**	**Not at all**	**Total**
Female	11 2.84 15.07 33.33	13 3.36 17.81 13.4	49 12.66 67.12 19.07	73 18.86
Male	22 5.68 7.01 66.67	84 21.71 26.75 86.6	208 53.75 66.24 80.93	314 81.14
Total	33 8.53	97 25.06	257 66.41	387 100.0
Frequency Missing = 18				

Statistic	**DF**	**Value**	**Probability**
Chi-Square	2	6.4118	0.0405
Likelihood Ratio Chi-Square	2	5.946	0.0511
Mantel-Haenszel Chi-Square	1	5.5366	0.0186
Phi Coefficient		0.1287	
Contingency Coefficient		0.1277	
Cramer's V		0.1287	

Table C-6. Age vs. How the Drowsy Driving Signs Contributed to Drivers' Decisions to Stop

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Did the drowsy driving signs contribute to your decision to stop? (question 8)**			
	Definitely	**Somewhat**	**Not at all**	**Total**
18 - 25	2 0.52 8.7 6.06	6 1.55 26.09 6.19	15 3.88 65.22 5.84	23 5.94
26 - 35	5 1.29 9.09 15.15	13 3.36 23.64 13.4	37 9.56 67.27 14.4	55 14.21
36 - 50	11 2.84 10.48 33.33	26 6.72 24.76 26.8	68 17.57 64.76 26.46	105 27.13
> 50	15 3.88 7.35 45.45	52 13.44 25.49 53.61	137 35.4 67.16 53.31	204 52.71
Total	33 8.53	97 25.06	257 66.41	387 100.0
Frequency Missing = 18				

Statistic	**DF**	**Value**	**Probability**
Chi-Square	6	0.963	0.987
Likelihood Ratio Chi-Square	6	0.9477	0.9875
Mantel-Haenszel Chi-Square	1	0.1572	0.6918
Phi Coefficient		0.0499	
Contingency Coefficient		0.0498	
Cramer's V		0.0353	

Table C-7. Gender vs. Number of Hours Driven between Stops

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**On average, how many hours do you drive between stops? (question 12)**					**Total**
	0.5	**1**	**2**	**3**	**> 3**	
Female	1 0.25 1.35 50	5 1.23 6.76 17.24	29 7.16 39.19 21.32	22 5.43 29.73 19.64	17 4.2 22.97 13.49	74 18.27
Male	1 0.25 0.3 50	24 5.93 7.25 82.76	107 26.42 32.33 78.68	90 22.22 27.19 80.36	109 26.91 32.93 86.51	331 81.73
Total	2 0.49	29 7.16	136 33.58	112 27.65	126 31.11	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	4	4.2857	0.3687
Likelihood Ratio Chi-Square	4	4.0841	0.3947
Mantel-Haenszel Chi-Square	1	2.3013	0.1293
Phi Coefficient		0.1029	
Contingency Coefficient		0.1023	
Cramer's V		0.1029	

Table C-8. Age vs. Number of Hours Driven between Stops

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**On average, how many hours do you drive between stops? (question 12)**					
	0.5	**1**	**2**	**3**	**> 3**	**Total**
18 - 25	0 0 0 0	4 0.99 16 13.79	5 1.23 20 3.68	7 1.73 28 6.25	9 2.22 36 7.14	25 6.17
26 - 35	0 0 0 0	0 0 0 0	15 3.7 26.32 11.03	18 4.44 31.58 16.07	24 5.93 42.11 19.05	57 14.07
36 - 50	1 0.25 0.88 50	9 2.22 7.89 31.03	29 7.16 25.44 21.32	34 8.4 29.82 30.36	41 10.12 35.96 32.54	114 28.15
> 50	1 0.25 0.48 50	16 3.95 7.66 55.17	87 21.48 41.63 63.97	53 13.09 25.36 47.32	52 12.84 24.88 41.27	209 51.6
Total	2 0.49	29 7.16	136 33.58	112 27.65	126 31.11	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	12	23.05	0.0273
Likelihood Ratio Chi-Square	12	26.892	0.008
Mantel-Haenszel Chi-Square	1	8.5103	0.0035
Phi Coefficient		0.2386	
Contingency Coefficient		0.2321	
Cramer's V		0.1377	

Table C-9. Gender vs. Number of Hours Slept before Drivers' Current Trips

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**How many hours did you sleep the night before your current trip? (question 13)**					**Total**
	< 3	**3 - 5**	**5 - 7**	**7 - 9**	**> 9**	
Female	1 0.25 1.35 11.11	5 1.23 6.76 15.15	32 7.9 43.24 25.4	28 6.91 37.84 15.82	8 1.98 10.81 13.33	74 18.27
Male	8 1.98 2.42 88.89	28 6.91 8.46 84.85	94 23.21 28.4 74.6	149 36.79 45.02 84.18	52 12.84 15.71 86.67	331 81.73
Total	9 2.22	33 8.15	126 31.11	177 43.7	60 14.81	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	4	6.5005	0.1648
Likelihood Ratio Chi-Square	4	6.2989	0.1779
Mantel-Haenszel Chi-Square	1	2.4445	0.1179
Phi Coefficient		0.1267	
Contingency Coefficient		0.1257	
Cramer's V		0.1267	

Table C-10. Age vs. Number of Hours Slept before Drivers' Current Trips

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**How many hours did you sleep the night before your current trip? (question 13)**					**Total**
	< 3	**3 - 5**	**5 - 7**	**7 - 9**	**> 9**	
18 - 25	3 0.74 12 33.33	1 0.25 4 3.03	9 2.22 36 7.14	11 2.72 44 6.21	1 0.25 4 1.67	25 6.17
26 - 35	2 0.49 3.51 22.22	8 1.98 14.04 24.24	15 3.7 26.32 11.9	22 5.43 38.6 12.43	10 2.47 17.54 16.67	57 14.07
36 - 50	3 0.74 2.63 33.33	11 2.72 9.65 33.33	37 9.14 32.46 29.37	41 10.12 35.96 23.16	22 5.43 19.3 36.67	114 28.15
> 50	1 0.25 0.48 11.11	13 3.21 6.22 39.39	65 16.05 31.1 51.59	103 25.43 49.28 58.19	27 6.67 12.92 45	209 51.6
Total	9 2.22	33 8.15	126 31.11	177 43.7	60 14.81	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	12	26.732	0.0084
Likelihood Ratio Chi-Square	12	23.006	0.0277
Mantel-Haenszel Chi-Square	1	0.0018	0.9662
Phi Coefficient		0.2569	
Contingency Coefficient		0.2488	
Cramer's V		0.1483	

Table C-11. Gender vs. Number of Hours of Sleep Drivers Receive on an Average Night

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**On average, how many hours do you sleep each night? (question 14)**					**Total**
	< 3	**3 - 5**	**5 - 7**	**7 - 9**	**> 9**	
Female	0 0 0 0	0 0 0 0	34 8.4 45.95 24.82	33 8.15 44.59 15.64	7 1.73 9.46 17.5	74 18.27
Male	2 0.49 0.6 100	15 3.7 4.53 100	103 25.43 31.12 75.18	178 43.95 53.78 84.36	33 8.15 9.97 82.5	331 81.73
Total	2 0.49	15 3.7	137 33.83	211 52.1	40 9.88	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	4	8.7263	0.0683
Likelihood Ratio Chi-Square	4	11.519	0.0213
Mantel-Haenszel Chi-Square	1	0.3911	0.5317
Phi Coefficient		0.1468	
Contingency Coefficient		0.1452	
Cramer's V		0.1468	

Table C-12. Age vs. Number of Hours of Sleep Drivers Receive on an Average Night

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**On average, how many hours do you sleep each night? (question 14)**					**Total**
	< 3	**3 - 5**	**5 - 7**	**7 - 9**	**> 9**	
18 - 25	0 0 0 0	1 0.25 4 6.67	8 1.98 32 5.84	14 3.46 56 6.64	2 0.49 8 5	25 6.17
26 - 35	1 0.25 1.75 50	3 0.74 5.26 20	22 5.43 38.6 16.06	24 5.93 42.11 11.37	7 1.73 12.28 17.5	57 14.07
36 - 50	0 0 0 0	7 1.73 6.14 46.67	42 10.37 36.84 30.66	48 11.85 42.11 22.75	17 4.2 14.91 42.5	114 28.15
> 50	1 0.25 0.48 50	4 0.99 1.91 26.67	65 16.05 31.1 47.45	125 30.86 59.81 59.24	14 3.46 6.7 35	209 51.6
Total	2 0.49	15 3.7	137 33.83	211 52.1	40 9.88	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	12	18.933	0.0902
Likelihood Ratio Chi-Square	12	18.893	0.0911
Mantel-Haenszel Chi-Square	1	0.0202	0.8871
Phi Coefficient		0.2162	
Contingency Coefficient		0.2113	
Cramer's V		0.1248	

Table C-13. Gender vs. Driving while Drowsy

Gender (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Have you ever driven while drowsy? (question 15)**		
	Yes	**No**	**Total**
Female	57 14.07 77.03 18.75	17 4.2 22.97 16.83	74 18.27
Male	247 60.99 74.62 81.25	84 20.74 25.38 83.17	331 81.73
Total	304 75.06	101 24.94	405 100.0

Statistic	**DF**	**Value**	**Probability**
Chi-Square	1	0.1868	0.6656
Likelihood Ratio Chi-Square	1	0.1895	0.6633
Continuity Adj. Chi-Square	1	0.0804	0.7767
Mantel-Haenszel Chi-Square	1	0.1864	0.666
Phi Coefficient		-0.0215	
Contingency Coefficient		0.0215	
Cramer's V		-0.0215	

Table C-14. Age vs. Driving while Drowsy

Age (question 1) *Frequency* *Percent* *Row Percent* *Column Percent*	**Have you ever driven while drowsy? (question 15)**		
	Yes	**No**	**Total**
18 - 25	13 3.21 52 4.28	12 2.96 48 11.88	25 6.17
26 - 35	48 11.85 84.21 15.79	9 2.22 15.79 8.91	57 14.07
36 - 50	92 22.72 80.7 30.26	22 5.43 19.3 21.78	114 28.15
> 50	151 37.28 72.25 49.67	58 14.32 27.75 57.43	209 51.6
Total	304 75.06	101 24.94	405 100.0

Statistic	DF	Value	Probability
Chi-Square	3	12.472	0.0059
Likelihood Ratio Chi-Square	3	11.897	0.0077
Mantel-Haenszel Chi-Square	1	0.003	0.9564
Phi Coefficient		0.1755	
Contingency Coefficient		0.1728	
Cramer's V		0.1755	