# Investigating Critical Incidents, Driver Restart Period, Sleep Quantity, and Crash Countermeasures in Commercial Vehicle Operations Using Naturalistic Data Collection

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

**November 2016**

# FOREWORD

The Federal Motor Carrier Safety Administration (FMCSA) commissioned this on-road naturalistic driving (ND) study to investigate light-vehicle/heavy-vehicle (LV-HV) interactions and other safety issues related to commercial motor vehicle (CMV) crash risk. The primary goal of this report was to document the data collection effort and report on the investigated crashes, near-crashes, and crash-relevant conflicts from the HV driver's perspective in order to help determine functional countermeasures. Identifying these functional countermeasures is expected to assist in the development of effective technologies, enforcement strategies, training and education needs, and other specific countermeasures to reduce CMV crashes and their associated injuries and fatalities.

# NOTICE

# Technical Report Documentation Page

| 1. Report No.<br>**FMCSA-RRR-13-017** | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle<br>**Investigating Critical Incidents, Driver Restart Period, Sleep Quantity, and Crash Countermeasures in Commercial Vehicle Operations Using Naturalistic Data Collection** | | 5. Report Date<br>**November 2016**<br>6. Performing Organization Code |
| 7. Author(s)<br>**Blanco, Myra, Hickman, Jeffrey S., Olson, Rebecca L., Bocanegra, Joseph L., Hanowski, Richard J., Nakata, Akiko, Greening, Mike, Madison, Phillip, Holbrook, G. Thomas, and Bowman, Darrell** | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>**Virginia Technical Transportation Institute<br>3500 Transportation Research Plaza (0536)<br>Blacksburg, VA 24061** | | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No.<br>**DTFH61-01-C-00049, Task Order # 23** |
| 12. Sponsoring Agency Name and Address<br>**U.S. Department of Transportation<br>Federal Motor Carrier Safety Administration<br>1200 New Jersey Ave., SE<br>Washington, DC 20590** | | 13. Type of Report and Period Covered<br>**Final Report<br>December 2004–March 2008**<br>14. Sponsoring Agency Code<br>**FMCSA** |

15. Supplementary Notes
**This program was managed by Martin Walker at the Federal Motor Carrier Safety Administration (FMCSA).**


16. Abstract
**This report presents the final results of an on-road naturalistic driving data collection effort to investigate light-vehicle/heavy-vehicle (LV-HV) interactions and other safety issues related to commercial motor vehicle (CMV) crash risk. The three primary focus areas in this on-road study were work/rest parameters relating to driver fatigue and incident involvement, event causation, and LV-HV interaction and applicable functional countermeasures. The primary goal of this on-road study was to investigate crashes, near-crashes, and crash-relevant conflicts from the HV driver's perspective in order to help determine functional countermeasures. Identifying these functional countermeasures is expected to assist in the development of effective technologies, enforcement strategies, training and education programs, and other specific countermeasures to reduce CMV crashes and their associated injuries and fatalities.**

**More than 14,500 driving hours of valid data were collected during 2,200 driving shifts with almost 26,000 on-duty hours of activity recorded by drivers in daily activity registers. The instrumented trucks covered nearly 735,000 miles during recorded driving hours. Several research questions were addressed by using these data in addition to the LV-HV interactions and countermeasures. They evaluate aspects related to the restart period and sleep patterns with respect to safety-critical events (SCEs) that happened during the data collection. A total of 2,899 SCEs were identified by data analysts and analyzed in detail. These events comprise 13 crashes (8 of which are tire strikes), 61 near-crashes, 1,594 crash-relevant conflicts, 1,215 unintentional lane deviations, and 16 illegal maneuvers. In addition, the 65,000-plus hours of collected actigraphy data were analyzed to help address some of the research questions.**


| 17. Key Words<br>**CMV, commercial motor vehicle, countermeasures, crashes, naturalistic, restart period, sleep, work\rest** | | 18. Distribution Statement<br>**No restrictions** | |
|---|---|---|---|
| 19. Security Classif. (of this report)<br>**Unclassified** | 20. Security Classif. (of this page)<br>**Unclassified** | 21. No. of Pages<br>**225** | 22. Price |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

# SI* (MODERN METRIC) CONVERSION FACTORS

## Table of APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| In | inches | 25.4 | Millimeters | mm |
| Ft | feet | 0.305 | Meters | m |
| Yd | yards | 0.914 | Meters | m |
| Mi | miles | 1.61 | Kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.836 | square meters | $m^2$ |
| Ac | acres | 0.405 | Hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | 1000 L shall be shown in $m^3$ | |
| fl oz | fluid ounces | 29.57 | Milliliters | mL |
| Gal | gallons | 3.785 | Liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| | | **MASS** | | |
| Oz | ounces | 28.35 | Grams | g |
| Lb | pounds | 0.454 | Kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or “metric ton”) | Mg (or “t”) |
| | | **TEMPERATURE** | Temperature is in exact degrees | |
| °F | Fahrenheit | 5 × (F-32) ÷ 9<br>or (F-32) ÷ 1.8 | Celsius | °C |
| | | **ILLUMINATION** | | |
| Fc | foot-candles | 10.76 | Lux | lx |
| Fl | foot-Lamberts | 3.426 | candela/$m^2$ | cd/$m^2$ |
| | | **Force and Pressure or Stress** | | |
| Lbf | poundforce | 4.45 | Newtons | N |
| lbf/$in^2$ | poundforce per square inch | 6.89 | Kilopascals | kPa |

## Table of APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| Mm | millimeters | 0.039 | Inches | in |
| M | meters | 3.28 | Feet | ft |
| M | meters | 1.09 | Yards | yd |
| Km | kilometers | 0.621 | Miles | mi |
| | | **AREA** | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | $yd^2$ |
| Ha | hectares | 2.47 | Acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | Gallons | gal |
| $m^3$ | cubic meters | 35.314 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| G | grams | 0.035 | Ounces | oz |
| Kg | kilograms | 2.202 | Pounds | lb |
| Mg (or “t”) | megagrams (or “metric ton”) | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE** | Temperature is in exact degrees | |
| °C | Celsius | 1.8c + 32 | Fahrenheit | °F |
| | | **ILLUMINATION** | | |
| Lx | lux | 0.0929 | foot-candles | fc |
| cd/$m^2$ | candela/$m^2$ | 0.2919 | foot-Lamberts | fl |
| | | **Force & Pressure Or Stress** | | |
| N | newtons | 0.225 | Poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/$in^2$ |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

# TABLE OF CONTENTS

# LIST OF FIGURES (AND FORMULAS)

# LIST OF TABLES

# LIST OF ACRONYMS AND ABBREVIATIONS

| Acronym | Definition |
|---|---|
| 24HB | 24-hour block |
| AMI | Ambulatory Monitoring, Inc. |
| B | baseline event |
| BMI | body mass index |
| CB | Citizen's Band |
| CDL | commercial driver's license |
| CMV | commercial motor vehicle |
| CR | critical reason |
| DART | data analysis and reduction tool |
| DAS | Data Acquisition System |
| DDDI | Dula Dangerous Driving Index |
| DDWS | Drowsy Driver Warning System |
| DSP | duration of sleep period |
| FARS | Fatality Analysis Reporting System |
| FMCSA | Federal Motor Carrier Safety Administration |
| FOT | field operational test |
| ft | feet |
| *g* | vertical acceleration |
| GES | General Estimates System |
| GPS | Global Positioning System |
| HOS | hours-of-service |
| HV | heavy vehicle |
| Hz | hertz |
| ICF | Informed Consent Form |
| ID | identification |
| kHz | kilohertz |
| km/h | kilometers per hour |
| LCL | lower confidence limit |
| LED | light-emitting diode |
| LH | long-haul |
| LOS | level-of-service |
| L/SH | local/short-haul |
| LTCCS | Large Truck Crash Causation Study |

| Acronym | Definition |
| --- | --- |
| LV | light vehicle |
| MB | megabyte |
| mg | Milligram |
| MHz | megahertz |
| mi/h | miles per hour |
| ms | milliseconds |
| ND | naturalistic driving |
| NHTSA | National Highway Traffic Safety Administration |
| NTDS | Naturalistic Truck Driving Study |
| ODT | on-duty time |
| ODTSR | on-duty time since restart |
| PAR | police accident report |
| PC | personal computer |
| PVT | Psychomotor Vigilance Test |
| QC | quality control |
| rad | radians |
| SAE | Society of Automotive Engineers, Inc. |
| SAN | Storage Area Network |
| SB | sleeper berth |
| SCE | safety-critical event |
| SH | short-haul |
| SSR | sleep since restart |
| TB | terabyte |
| TDTSR | total driving time since restart |
| TSLSP | time since last sleep period |
| TTC | time-to-collision |
| TTSR | total time since restart |
| UCL | upper confidence limit |
| USDOT | U.S. Department of Transportation |
| VORAD | vehicle onboard radar |

# EXECUTIVE SUMMARY

The Federal Motor Carrier Safety Administration (FMCSA) commissioned an on-road naturalistic driving (ND) study to investigate light vehicle-heavy vehicle (LV-HV) interactions and other safety issues related to commercial motor vehicle (CMV) crash risk. As part of a comprehensive program, FMCSA delineated the Commercial Vehicle Data Collection and Countermeasure Assessment Research Project. This project has been divided into two phases:

- Phase I: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test (DDWS FOT) and Preparation for Phase II.
- Phase II: Study of Heavy-vehicle Crashes and Near-crashes in Support of Crash Reduction Countermeasures.

Phase I was completed prior to the start of this study (Phase II is hereafter referred to as the Naturalistic Truck Driving Study [NTDS]). Phase I served as a preliminary analysis of the investigation on HV safety events and/or their interactions with LVs that would inform data collection and analyses in the NTDS. The main objective of this on-road study was to collect ND data that could be used to investigate issues related to CMV crash risk. Three primary focus areas were evaluated in this report:

- Work/rest parameters relating to driver fatigue and incident involvement.
- Event causation and LV-HV interactions.
- Applicable functional countermeasures.

Naturalistic, or *in situ*, data collection is a proactive approach that involves drivers operating vehicles that have been instrumented with data collection equipment, including sensors and video cameras, to record driving performance data. A significant advantage of this approach is that instrumented vehicles can record what happened prior to, during, and after a crash or near-crash event. Knowledge of the events preceding a critical incident may make it possible to determine why the incident happened and what could be done to prevent similar incidents in the future.

## OBJECTIVES

### Research Design

This was an on-road driving study conducted during normal revenue-producing operations with no experimental manipulations. Each participant was observed for approximately 4 consecutive work weeks. The authors recruited 100 participants who had Class-A commercial driver's licenses (CDLs) and worked for 4 different trucking fleets, instrumenting 1–3 trucks from each trucking fleet (9 trucks total). The drivers' genders were 95 male, 5 female; they were 44.5 years old on average (age range: 21–73 years old), and more than 50 percent of all drivers had 5 years of experience or less as a CMV driver. After a participant finished 4 consecutive weeks of data collection, another participant started driving the instrumented truck. Line-haul (out-and-back)

and long-haul (LH) (out for approximately 1 week) operations were represented. Drivers volunteered for the study and were compensated for their participation.

### Data Collection

A diverse set of on-road driving and participant (non-driving) data were collected during the study, including driver input/performance measures (e.g., lane position, headway), five camera views in video, actigraphy (for sleep quantity), work/rest schedule and medication use in daily activity registers, and pre- and post-study questionnaires. The data acquisition system (DAS) instrumented in the trucks included four major components: sensors, vehicle network, incident box, and video cameras. Each component became active when the ignition system of the truck was initiated. Software integrated the collected electronic data into a specific DAS output file linked to the video. More than 14,500 driving hours of valid data (including more than 65,000 hours of actigraphy data from 97 drivers) were collected from approximately 2,200 driving shifts and 26,000 on-duty hours of daily activity register data from more than 735,000 miles of driving.

### Data Reduction

A specialized software program supported analyses of the collected on-road data. Data reduction started with identifying events of interest. The on-road data set was scanned for notable actions (e.g., hard braking, short time-to-collision [TTC], quick steering maneuvers), and potential events of interest were identified for validation (i.e., visual inspection of event). Valid events were classified as one of six safety-critical events (SCEs) (i.e., crash, crash—tire strike, near-crash, crash-relevant conflict, illegal maneuver, unintentional lane deviation) and analyzed in detail with an established coding directory. These events were operationally defined for this study as having elements identical to a crash scenario, with the exception that a successful evasive maneuver was also present.

Data collection was completed in May 2007. The following list provides an overview of the results of data reduction:

- 2,899 SCEs.
  - 13 crashes (8 were tire strikes).
  - 61 near-crashes.
  - 1,594 crash-relevant conflicts.
  - 1,215 unintentional lane deviations.
  - 16 illegal maneuvers.
- 456 baseline (control) events.

## CONCLUSIONS

The ND provided the opportunity to answer a myriad of research questions. Therefore, in addition to the data reduction effort undertaken to obtain the SCEs, several other data analyses were performed. The four main areas evaluated were:

- Restart Period and SCEs.
- Sleep Pattern and SCEs.
- Vehicle Interactions by Type of Maneuver.
- Functional Countermeasures.

The focus of these questions is SCEs, and all the data were calculated or evaluated taking into consideration SCEs or baseline events, as appropriate.

### Restart Period and Safety-critical Events

All of the analyses performed for this research question are focused on the restart period preceding the SCEs. The three main analyses were:

- Duration of the restart period.
- Relationship between SCEs and the restart period.
- Time from restart period to SCEs.

On average, the duration of the restart period before a SCE was 53 hours every 5 days. For the baseline events taken as a comparison, the duration of the restart averaged 58 hours. LH drivers had a shorter restart (48 hours) than the short-haul (SH) drivers (63 hours). The medium-haul drivers had an average restart of 53 hours. All three different types of operations took, on average, more than the 34-hour minimum of off-duty restart required by FMCSA under the current hours-of-service (HOS) regulations. Conversely, no relationship was found between the duration of the restart period and the SCEs. However, the results show that the number of SCEs is highest during the first day after restart.

### Sleep Patterns and Safety-critical Events

Based on the actigraphy data collected during the study, CMV drivers in the baseline events slept 6.6 hours (6.4–6.8 hours at the 95-percent confidence interval) on average during the 24 hours before the baseline event. For SCEs, CMV drivers had an average of 6.5 hours (6.4–6.6 hours at the 95-percent confidence interval) of sleep during the 24 hours before the SCE. In addition to the amount of sleep in the 24 hours preceding a SCE, the sleep during the restart period and the sleep since the restart were evaluated. On average, CMV drivers slept 1.1 hours more during their restart than during their regular workdays. The average sleep for CMV drivers since restart and 24 hours before a SCE is less than what they obtained during the restart period preceding the SCE. However, this difference represents only one-half hour less sleep during the 24 hours before a SCE. These results included all SCEs (i.e., at fault or not).

The amounts of sleep reported above reflected the sum of all the sleep periods inside a 24-hour period (i.e., one total sleep per SCE or baseline event). However, 8 hours of sleep in the last 24 hours might not always be taken in a single sleep period. The total sleep could be composed of two or more sleep periods. The analysis performed for this study showed that most of the sleep received 24 hours before a SCE or baseline event involved a single sleep period, but some drivers had their sleep divided into as many as four sleep periods. However, having three or more sleep periods was not predominant. The duration of the sleep period (all sleep periods in the last 24 hours), the amount of time since the last sleep period preceding the event of interest (only the first sleep period preceding an event), and the amount of time between sleep periods (only when there were multiple sleep periods within the last 24 hours) were also evaluated. The average durations of sleep periods 24 hours before a baseline event or a SCE were 5.1 hours and 5.0 hours, respectively. On average, drivers had a sleep period 7.0 hours before the baseline event and 7.8 hours before a SCE. When CMV drivers had multiple sleep periods in the 24 hours before a baseline event or SCE, these sleep periods were taken 5.2 hours and 5.1 hours apart, respectively.

**Vehicle Interactions**

As part of this study, interaction of other vehicles with the instrumented CMVs was assessed. Driver fault was determined by visual review of videos by researchers. Because the other vehicle with which the CMV interacted was not instrumented, it was difficult to determine precise fault or critical reasons (CRs) for the other driver. Nevertheless, of the 548 SCEs that involved 2 or more vehicles, CMV drivers were judged to be at fault 53.5 percent of the time, while other drivers were judged to be at fault 39.8 percent of the time (in 0.4 percent of the SCEs it was unknown who was at fault, and 6.4 percent of the SCEs were judged no-fault). The most frequent CRs assigned to the CMV drivers for SCEs involved internal distractions (57.1 percent), external distractions (11.4 percent), and drowsiness (8.9 percent). While it is not surprising that these types of factors would be prevalent CRs, the frequencies were much higher than anticipated. The current study found the most frequent CRs for other drivers involved in SCEs were other decision error (1.4 percent); aggressive driving—wanton, neglectful, or reckless behavior—(1.0 percent); other illegal maneuver (0.8 percent), apparent recognition error (0.7 percent); and too slow for traffic stream (0.7 percent). There were a total of 407 LV-HV interactions in this study. Of these, the HV driver was judged to be at fault in 235 safety-critical incidents, while the LV driver was judged to be at fault in 146 SCEs. The most frequently-assigned HV-driver CRs during LV-HV interactions were inadequate evasive action (35.9 percent), misjudgment of gap or other's speed (12.2 percent), internal distraction (11.4 percent), and inadequate surveillance (11.0 percent). Of the current study's 146 LV-HV interactions in which the LV driver was judged to be at fault, the most frequent CRs were other decision error (23.6 percent), aggressive driving behavior (18.8 percent), other illegal maneuver (13.9 percent), and too slow for traffic stream (10.4 percent).

This naturalistic approach allows researchers to evaluate vehicle interactions as they evolve and fills a void in driving safety research. Police accident reports (PARs) and crash investigations rely on eyewitness accounts. Such data are very helpful, but can suggest possible CRs for a crash that, in fact, may not be the real cause of the SCE. For example, in the case of rear-end events, following too closely might seem to be the most relevant CR during an investigation, but in most instances naturalistic research reveals that distraction tends to be the main CR for these types of events.

**Functional Countermeasures**

This study collected detailed information on a large number of SCEs. These events were operationally defined for this study as having elements identical to a crash scenario, with the exception that a successful evasive maneuver was also present. These types of events have two important features that the crash data do not. First, they occur much more frequently than crashes. Second, near-crash events are cases in which a driver successfully performed an evasive maneuver. Understanding these cases may give additional insight into the factors that enable drivers to be effective defensive drivers, as well as potential countermeasures to aid these drivers in crisis situations. This research effort assessed applicable functional countermeasures that can be used to inform the development by researchers of crash avoidance technologies, enforcement regulations, and safety management methods to prevent unsafe situations from arising and/or to improve the driver's response to the unsafe situation. The most frequent CMV functional countermeasures involved preventing "drift" lane departures (79.0 percent), increasing driver attention to forward visual scene (73.7 percent), improving general driver situation awareness and/or proactive/defensive driving (56.1 percent), and increasing driver alertness (14.4 percent). More than one countermeasure could be selected for each SCE; therefore, the total is more than 100 percent.

The most frequent countermeasures for other vehicles in the NTDS were improving general driver situation awareness and/or proactive/defensive driving (4.9 percent); improving driver night vision in the forward field (4.3 percent); increasing driver recognition/appreciation of specific highway crash threats—vehicle in right adjacent lane (1.1 percent); and increasing driver recognition/appreciation of specific highway crash threats—vehicle in left adjacent lane (1.0 percent).

[This page intentionally left blank.]

# 1. INTRODUCTION

## 1.1 BACKGROUND

Crashes involving large trucks constitute a significant risk to the driving public as well as an occupational risk to truck drivers. According to the Federal Motor Carrier Safety Administration (FMCSA) sponsored report, Large Truck and Bus Crash Facts 2010,[1] 275,000 large trucks (vehicles weighing more than 10,000 pounds) were involved in vehicle crashes; 3,484 of these crashes resulted in fatalities and 58,000 in injuries. A total of 3,675 people died (11 percent of all traffic-related fatalities) and an additional 80,000 were injured (4 percent of all traffic-related injuries). Of the fatalities that resulted from crashes involving large trucks, 76 percent were occupants of another vehicle, 10 percent were non-occupants, and 14 percent were truck occupants (drivers and passengers). Large trucks accounted for 4.3 percent of all registered vehicles in 2010,[2] yet represented 7.8 percent of all vehicles involved in fatal crashes.[1] The fatality rate per 100 million vehicle miles traveled was 1.1 for all vehicles and 1.3 for large trucks.[1]

These statistics can be misleading because commercial motor vehicle (CMV) drivers exhibit lower rates of most types of incidents and crash involvement per mile than drivers of light vehicles,[3] and drivers of light vehicles have been found to initiate a significant proportion of CMV crashes and their associated injures [4,5]. Large trucks are involved in a high percentage of crash-related fatalities (compared to passenger vehicles) and injure a higher percentage of people other than truck occupants because of the significant difference in weight between a large truck and a passenger vehicle.[6] Thus, increasing the safe driving practices of CMV drivers will help to make the roadways safer for all road users.

### 1.1.1 Traditional Approach to Crash Causation

The data to generate crash statistics usually come from police accident reports (PARs). Typically, after a crash occurs, law enforcement is notified and dispatched to the crash scene. The responding officer then collects data to complete the PAR. The data from the PAR are entered into a crash database that can be analyzed to produce the type of statistics presented above. These data allow researchers to learn about the scope of the large truck crash problem and the characteristics of various crash scenarios. This is a reactive approach—the solution is generated only after a large number of crashes (and possibly fatalities) have occurred. Additionally, data from PARs are limited to what the police officer observed and wrote; thus, PARs may not tell the whole story. In most cases, little is known about the driver's behavior leading up to a crash. For example, there is difficulty and uncertainty in assessing whether the driver involved in the crash was distracted, tired, or driving aggressively. Typically, PARs have codes for these behaviors, but it is unlikely that the officer can reliably attribute the crash to such factors after the fact. In an audit of the PARs filed for crashes involving large trucks in Oregon, Utah, and Florida, it was found that only a small percentage of these PARs (20 percent or less) contained zero reporting errors.[7] Frequent errors made by police across the three States included incorrect vehicle type/configuration, missing (or mismatched) diagrams and narratives, and incorrect carrier information.

Additionally, PARs vary by State, complicating comparisons across States and limiting the generalization of aggregated results. As a result, PARs are inherently deficient in providing information on the underlying causal factors in crashes. These errors and inconsistencies in PARs are alarming because these statistics are used to design and manage safety programs, set policy, and assess differential crash risk.

Although researchers can learn about the scope of the large truck crash problem with statistics generated from PARs, these statistics provide limited insight into the details of pre-crash events and driver behavior. Detailed pre-crash event information is important because it can identify potential causal factors and remedial measures to prevent future crashes (i.e., countermeasures). This level of understanding requires richer real-time data than possible with post-crash investigations. One benefit of expanding our understanding of crashes and near-crashes is the ability to recommend or develop countermeasures that are likely to mitigate future crashes. Therefore, if traffic safety research is going to take the next preventive step, it is important to acquire a more complete, in-depth understanding of why a crash occurred.

### 1.1.2 Naturalistic Data Collection

One approach that has been used by researchers involves naturalistic, or *in situ*, data collection efforts. *In situ* data collection involves drivers operating vehicles that have been instrumented with data collection equipment, including sensors and video cameras. Drivers operate these vehicles as part of their normal driving routines (e.g., delivery route). A major advantage of these studies is that they can record what happened prior to, during, and after a crash or near-crash event. The significant advantage of *in situ* data collection is that when we know the events preceding a critical incident, we can determine why the incident occurred and what might be done to prevent similar incidents in the future.

Determining the contributing factors of large truck crashes, near-crashes, and crash-relevant conflicts recorded in naturalistic data may help reduce fatalities, injuries, and their associated economic and social consequences. Reductions in crashes will be facilitated by investigating contributing factors within CMV operations as various factors influence CMV driver crash risk. Few studies have attempted to integrate all the interacting factors (e.g., personality, sensory-motor, driving behaviors, prior crash/violation rate) that may contribute to increased crash risk. In addition, most studies fail to account for exposure (i.e., hours of driving and traffic density). Finally, most previous studies used self-reports of prior crashes or retrospective records (such as PARs). As described above, these approaches have limitations.

Researchers currently have kernels of knowledge that suggest that certain factors are associated with an increase in crash risk; however, what they do not have is a comprehensive model on how these factors interact with each other. Further, all these factors have not been incorporated in one study, nor have they been studied under naturalistic driving (ND) conditions. It is certainly possible that some unknown determinant contributes to crash risk; thus, a ND study seems most appropriate to answer those questions.

### 1.1.3 Project Goal and General Requirements

FMCSA awarded a contract to the researchers to conduct an on-road ND study to investigate light-vehicle/heavy-vehicle (LV-HV) interactions and other safety issues related to CMV crash risk. The primary goal of this on-road study was to investigate crashes, near-crashes, and crash-relevant conflicts from the HV driver's perspective to help determine functional countermeasures (a functional countermeasure provides the main objective of the countermeasure and is not restricted by existing technology). Identifying these functional countermeasures will potentially drive the development of effective technologies, enforcement strategies, training and education to meet needs, and other specific countermeasures to reduce CMV crashes and their associated injuries and fatalities.

The main objective of this on-road study was to collect ND data that could be used to investigate issues related to CMV crash risk. More specifically, there were three primary focus areas to be evaluated in this report and future research efforts:(8)

- Work/rest parameters relating to driver fatigue and incident involvement.
- Event causation and LV-HV interactions.
- Applicable functional countermeasures.

Given the serious problem of large truck crashes, the potential safety benefits of identifying factors (such as work/rest parameters) associated with crash risk are great. However, up until this point, there have been no long-term, on-road studies that have assessed factors related to CMV crash risk. To perform these analyses, there were two general requirements associated with meeting the on-road study objectives:

- The evaluation occurred in a ND environment, and data were collected from actual truck drivers with a valid commercial driver's license (CDL) under normal operating conditions (i.e., actual revenue-producing delivery runs).
- The sample of CMV drivers participating in the on-road study was part of the target population to the greatest extent possible within the constraints of project resources.

### 1.1.4 Organization of this Report

As part of a comprehensive program, FMCSA delineated the Commercial Vehicle Data Collection and Countermeasure Assessment Research Project. This project has been divided into two phases:

- Phase I: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test (DDWS FOT) and Preparation for Phase II.
- Phase II: Study of Heavy-vehicle Crashes and Near-crashes in Support of Crash Reduction Countermeasures.

Phase II, hereafter referred to as the Naturalistic Truck Driving Study (NTDS), is the focus of this report study. The report is organized into seven sections:

1. Introduction.
2. Overview of Phase I.
3. Methods.

4. Data Management.
5. Research Questions and Data Analyses.
6. Results.
7. Conclusions.

Phase I was completed prior to the start of the current NTDS.(9) Phase I served as a preliminary analysis of the investigation on HV safety events and their interactions with LVs that would inform data collection and analyses in the NTDS. Section 2 of this report provides a brief overview of Phase I.

# 2. OVERVIEW OF PHASE I: PRELIMINARY ANALYSIS OF DATA COLLECTED IN THE DROWSY DRIVER WARNING SYSTEM FIELD OPERATIONAL TEST

The primary goal of the DDWS FOT was to determine the safety benefits and operational capabilities, limitations, and characteristics of the monitor to evaluate driver alertness. The FOT was conducted in a ND environment and data were collected from actual truck drivers driving commercial trucks. The DDWS FOT used instrumented vehicles to collect ND data to gain a better understanding of driving performance and the genesis of large-truck traffic crashes. Data collected during the study, but not specifically related to the functioning of the DDWS, were used to assess and improve knowledge of the fundamental aspects of CMV safety. The current section is focused on the data collected in the DDWS FOT between May 2004 and May 2005. These data came from 95 volunteer CMV driver participants and included approximately 50,000 hours of driving data. The following is an overview of the Phase I report.[9]

Four priority issues and study topics were selected for exploratory investigation and analysis in Phase I:

- Analysis of HV safety events, including LV-HV interactions.
- Countermeasure identification.
- Driving patterns and work/rest schedules.
- Correlates of driver risk.

To investigate these issues and lay the foundation for broader, more in-depth analyses, the Phase I analyses employed a database of classification variables used to compare four basic types of driving events: crashes (including tire strikes as a separate subcategory), near-crashes, crash-relevant conflicts (also termed safety-critical events [SCEs]), and baseline (control) events. Descriptions of each event type are listed in Table 1. The non-crash events were operationally defined for this study as having elements identical to a crash scenario, with the exception that a successful evasive maneuver was also present.

**Table 1. Description of SCE types.**

| Event Type | Description |
|---|---|
| Crash | Any contact with an object, either moving or fixed, at any speed. |
| Crash:<br>Tire Strike | Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated where the contact occurs on the truck's tire only. No damage occurs during these events (e.g., a truck is making a right turn at an intersection and runs over the sidewalk/curb with a tire). |
| Near-crash | Any circumstance that requires a rapid, evasive maneuver (e.g., hard braking, steering) by the subject vehicle or any other vehicle, pedestrian, pedalcyclist, or animal, in order to avoid a crash. |

| Event Type | Description |
|---|---|
| Crash-relevant Conflict | Any circumstance that requires a crash-avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, pedalcyclist, or animal that was less severe than a rapid evasive maneuver (as defined above), but greater in severity than a normal maneuver. A crash-avoidance response can include braking, steering, accelerating, or any combination of control inputs. |

The frequencies of these events in the dataset were as follows:

- Crashes: 14 + 14 tire strikes = 28 total.
- Near-crashes: 98.
- Crash-relevant conflicts: 789.
- Total SCEs (i.e., the sum of the above): 915.
- Baseline events: 1,072.

## 2.1 METHODS

Data analyzed in Phase I were recorded in a ND environment from CMVs during normal operations. The participant sample included two types of CMV operations (long-haul [LH] and line-haul). LH drivers typically had their full load delivered to a single destination. Delivery destinations varied but drivers reported approximately 460 miles driven per day. Line-haul operations involved drivers either picking up or delivering goods to/from multiple destinations. Participants in the DDWS FOT were assigned to either an experimental or a control group (the DDWS was active or passive, respectively); however, for the purposes of the Phase I study, data from these two groups were aggregated.

Forty-six trucks operated by three motor carriers were instrumented with data collection equipment. A data acquisition system (DAS) was installed in tractors to collect data continuously whenever the instrumented trucks were running and in motion. The DAS consisted of an encased unit housing a computer and external hard drive, dynamic sensors (e.g., a front-vehicle onboard radar [VORAD] and a lane-tracker), an interface with the existing vehicle network, an “incident box,” and video cameras. In addition, the DAS interfaced with the DDWS (also termed the driver fatigue monitor) and recorded data from it.

Two types of data were collected continuously by the vehicle instrumentation: video and dynamic sensor. Audio data were collected for up to 60 seconds each time the driver pressed a button. The four video camera views were forward road, driver’s face, rearward from the left side of the tractor, and rearward from the right side of the tractor. Low-level infrared lighting (not visible to the driver) illuminated the vehicle cab so drivers’ faces and hands could be viewed via the camera during nighttime driving.[10]

## 2.2 RESULTS

Most results were based on the data analysts' assessments of the video and dynamic sensor data for three types of SCEs: crashes (including tire strikes), near-crashes, and crash-relevant conflicts. The sum of these three event categories was termed "total SCEs." The data analysts recorded their assessments of the video and dynamic sensor data by using a data directory listing 54 variables and associated coding instructions and specific choices, or data elements. Highlights of the results are provided below for the four major analytic issues addressed in the study. Unless otherwise noted, these results are based on the analysis of total SCEs (i.e., crashes + tire strikes + near-crashes + crash-relevant conflicts). Below is a summary of pertinent results from Phase I.[9]

### 2.2.1 Issue 1: Analysis of Heavy-vehicle Safety Events

The analysis of safety events was accomplished through the application of the data directory to detected SCEs. Selected variables (related mostly to ambient conditions such as time-of-day, roadway type, and weather) were also coded for randomly selected baseline events. Highlights of the results were as follows:

- Of the observed SCEs, 64.8 percent involved two vehicles.
- When the critical reason (CR) was assigned to the instrumented truck, the most common reason was (in descending order):
  - Inadequate evasive action (14 percent).
  - Internal distraction (10.8 percent).
  - External distraction (6.2 percent).
  - Misjudgment of gap or other's speed (5.7 percent).
  - Too fast for conditions (5.4 percent).
- When the CR was assigned to the other vehicle (or V2), most commonly the reason was a failure in recognition (6 percent) or decision (1.7 percent).
- In 71 percent of multivehicle events, the instrumented truck was assigned the CR and thus was "at fault." However, this finding is not representative of all LV-HV conflicts, because the vehicle sensor suite and analysis routines captured a disproportionate number of events precipitated by instrumented trucks.

### 2.2.2 Issue 2: Countermeasure Identification

This analysis identified functional countermeasures for crashes. An applicable V1 functional countermeasure is one that would probably have prevented the event, either by preventing the unsafe condition from arising or by improving the driver response to the unsafe condition. The countermeasures listed are functional rather than device/method-specific; that is, they describe an intervention into the driving situation as opposed to a specific technology or method of intervention. Near-crashes and crash-relevant conflicts were analyzed "as if" a crash had occurred. More than one countermeasure for an event could be coded.

The most frequent instrumented truck (V1) countermeasures for all SCEs combined were:

- Increasing driver recognition of specific highway crash threats—stopped or decelerating vehicle(s) in lane ahead, traveling in same direction (18.8 percent).
- Increasing driver attention to forward scene (18.5 percent).
- Improving general driver situation awareness and/or defensive driving (13 percent).

The most frequent "other" vehicle (V2) countermeasures for SCEs were:

- Providing warning to prevent rear encroachment or tailgating by other vehicle (24.6 percent).
- Increasing driver recognition of specific highway crash threats—vehicle in left adjacent lane on highway (5.7 percent).
- Increasing driver recognition of specific highway crash threats—vehicle in left adjacent lane during merging maneuver (4.8 percent).

### 2.2.3 Issue 3: Driving Patterns and Work/Rest Schedules

Driving data from the DDWS FOT were used to investigate the driving patterns of the commercial drivers that participated in the study. Primarily, these data relate to day-of-week and time-of-day. In comparison to baseline events (the principal control or exposure measure), multivehicle SCEs were found to be more likely to occur on a Friday and less likely to occur on a Monday or Tuesday. This difference was not seen for single-vehicle events (i.e., involving the instrumented truck only). Although the work schedules of drivers in the study varied, most began their work weeks on Sunday evening or Monday morning, and finished on Friday or Saturday. Thus, one interpretation of this result is that it reflects cumulative fatigue across the end of the work week. However, this interpretation cannot be verified based on the dataset.

Regarding time-of-day, multivehicle events were more likely than baseline events to occur between the hours of 1 p.m. and 4:59 p.m., and less likely to occur between the hours of midnight and 5:59 a.m. Again, this was true only for multivehicle SCEs and not single-vehicle SCEs. The increased risk of a SCE during the afternoon hours probably reflects the increased traffic volumes and density of traffic seen in those hours.

### 2.2.4 Issue 4: Correlates of Driver Risk

Several studies over the past decade have shown that there are significant individual differences in crash and fatigue risk among commercial drivers. This study documented risk differences for the 95 drivers that participated over the course of the data collection, and gathered data on individual driver characteristics that might correlate with driver risk. Three principal metrics of driver risk were employed:

- Rate of involvement in "at-fault" SCEs (i.e., frequency of at-fault crashes + near-crashes + crash-relevant conflicts divided by the hours driving), 680 total.
- Rate of involvement in not-at-fault SCEs (i.e., frequency of not-at-fault crashes + near-crashes + crash-relevant conflicts divided by the hours driving), 235 total.

- Rate of involvement in high-driver-drowsiness SCEs regardless of fault (i.e., frequency of high-drowsiness crashes + near-crashes + crash-relevant conflicts divided by the hours driving), 127 total.

"High drowsiness" was defined as observer rating of drowsiness values greater than or equal to 40.

No significant differences were seen between experimental and control group rates for all these metrics; as a result, the data were aggregated across both groups for the driver risk analysis. To document and quantify differential risk, individual driver risk rates for each of these three metrics were calculated and arranged in descending order. Within each metric, the worst 15 drivers (15.8 percent of the 95 subjects) were compared to the middle 40 (42.1 percent) and the best 40 drivers (42.1 percent). A summary of the differential risk rates for these three metrics included:

- At-fault events (i.e., truck driver assigned CR; 680 total):
  - Worst 15 drivers: 11 percent of driving hours—38.2 percent of at-fault SCEs.
  - Middle 40 drivers: 46.7 percent of driving hours—54.1 percent of at-fault SCEs.
  - Best 40 drivers: 42.3 percent of driving hours—7.6 percent of at-fault SCEs.
- Not-at-fault events (i.e., other driver assigned CR; 235 total):
  - Worst 15 drivers: 14.6 percent of driving hours—43 percent of not-at-fault SCEs.
  - Middle 40 drivers: 50.4 percent of driving hours—51.9 percent of not-at-fault SCEs.
  - Best 40 drivers: 35 percent of driving hours—5.1 percent of not-at-fault SCEs.
- High-drowsiness events (i.e., observer rating of drowsiness greater than or equal to 40, includes both at-fault and not-at-fault SCEs; 127 total):
  - Worst 15 drivers: 14.6 percent of driving hours—69.3 percent of drowsy events.
  - Middle 40 drivers: 49.5 percent of driving hours—30.7 percent of drowsy events.
  - Best 40 drivers: 35.9 percent of driving hours—0 percent of drowsy events.

Another way of illustrating differential risk and safety significance of high-risk drivers is to calculate the relative exposure risk ratios for the worst drivers (the worst 15 in this case) compared to the remaining 80 drivers. These ratios were: at-fault involvement rates—5.0; not-at-fault involvement rates—4.4; and drowsy event involvement rates—13.2.

## 2.3 SUMMARY

The Phase I Commercial Vehicle Data Collection and Countermeasure Assessment project leveraged the instrumented-vehicle ND data collection from the DDWS FOT to obtain and analyze non-countermeasure-related data relevant to the genesis of large-truck traffic crashes. This data collection was the largest commercial transportation ND study ever undertaken, and is among the first to perform systematic analyses of SCEs and exposure risk analyses to quantify risks associated with various conditions and behaviors. A significant advantage of naturalistic data collection over post-hoc crash investigation is that it permits direct viewing of safety-significant events, including observable aspects of driver errors and other behaviors leading to the events. This includes unsafe pre-event behaviors such as speeding or tailgating, as well as specific driver errors resulting in incidents.

# 3. METHODS

## 3.1 APPARATUS

### 3.1.1 Data Acquisition System

The DAS and instrumentation package used in this study were designed, developed, and enhanced over the past decade. Previous versions of the system were used in several on-road studies. The system consisted of a computer that received and stored data from a network of sensors distributed to collect data of interest from the vehicle. Data were stored on the system's external hard drive, which could store several weeks of driving data before it needed replacement.

#### *3.1.1.1 System Capabilities*

Installed sensors included a box containing computer equipment for obtaining data from the vehicle network, an accelerometer box for longitudinal and lateral acceleration, a system that provided information on distance to lead vehicles, an incident box that allowed participants to flag incidents for the research team, a video-based lane-tracking system that measured lane-keeping behavior, and video recordings to validate any sensor-based findings. The video subsystem provided a continuous visual display of the events and situations that occurred in and around the truck and trailer while driving. There were five camera views monitoring the driver's face, forward road view, steering/dash, and left and right sides of the tractor-trailer to observe the traffic actions of other vehicles behind and around the truck. The video data were digital, with software-controllable video compression capability. This feature allowed synchronization, simultaneous display, and efficient archiving and retrieval of data. Additional system capabilities included system initialization equipment to automatically control system status, and a global positioning system (GPS) to collect information on vehicle position. Each of the sensor subsystems within the instrumented vehicle was independent of the others, resulting in confinement of sensor failures to the involved sensor only.

#### *3.1.1.2 Data Acquisition System Components—Main Data Acquisition System Unit*

The main DAS unit was mounted under the passenger seat for trucks without a sleeper berth and for trucks with sleeper berths but without an air-ride-equipped seat or an air conditioning unit under the seat (see Figure 1). For trucks with sleeper berths or limited room under the passenger seat, the main DAS unit was mounted in the side compartment (see Figure 2).

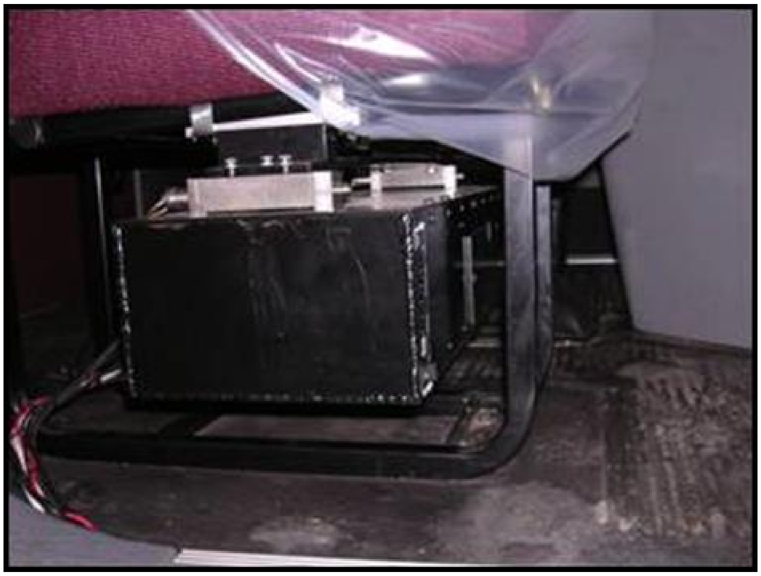


**Figure 1. Photo. The DAS unit installed under the passenger seat.**

**Figure 2. Grouped photo. The DAS unit mounted in a side compartment located on either side of the truck.**

#### *3.1.1.3 Secondary Data Acquisition System Components*

**Video Cameras/Incident Button.** Digital video cameras were used to record continuous video of the driver and driving environment. The face video camera and incident button were combined into a single unit (see Figure 3). A microphone was also instrumented as part of the incident box. In addition to inserting a flag in the data stream, pressing the incident button opened an audio channel for 60 seconds and allowed the driver to record verbal comments about the event.

The face camera/incident box device was mounted in one of two locations in the truck. The first location was at the top of the inside of the windshield near the center (see Figure 3). This location was selected to minimize obstruction of the driver's forward view by the device. The second location was the upper center of the windshield on the far left side in a vertical position (see Figure 4). In some of the trucks used in the study, the sun visors were large enough that in the down position they obstructed the view of the driver by the face camera. These visors were replaced with modified visors with a section of the visor cut out to ensure a clear view of the driver by the face camera, even with the visor in the down position.

The face camera was covered in a smoked Plexiglas sheet to obscure the view of the camera from the driver. The forward-view camera and the glare sensor were mounted near the face camera/incident button box (see Figure 3). A dome camera was mounted above and behind the driver's right shoulder to provide a view of the steering wheel and dash (see Figure 5). Two rear-facing side cameras were mounted above the outside rearview mirrors on each side of the truck to provide views similar to what the driver would see when using the rearview mirrors while driving (see Figure 6).

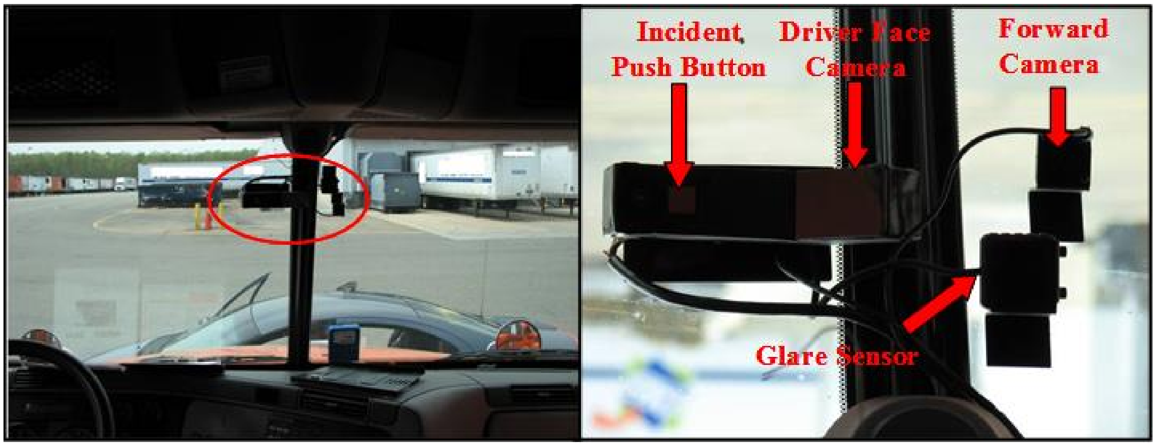



**Figure 3. Grouped photo. View of face camera/incident box, forward camera, and glare sensor location (left) and close-up (right).**


**Figure 4. Photo. Alternate position of the face camera/incident box.**


**Figure 5. Grouped photo. Dome camera mounted on roof of cab (left) and view from behind the dome camera (right).**

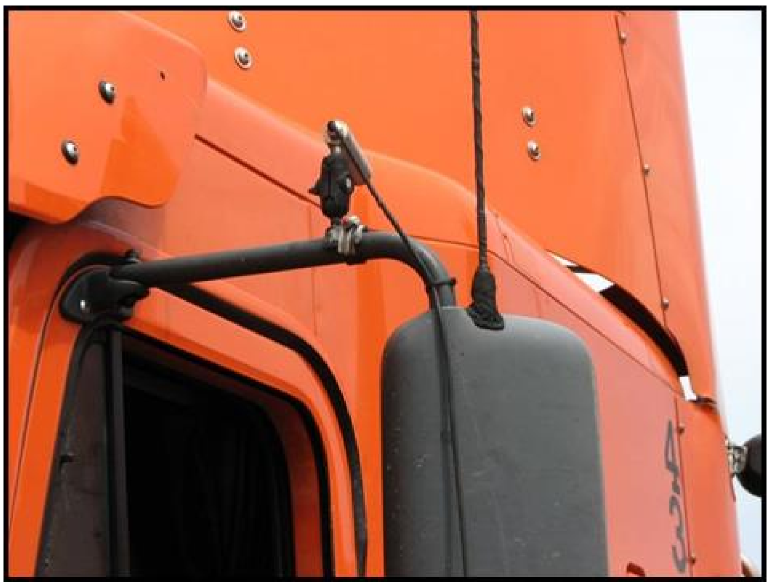


**Figure 6. Photo. A rear-facing side camera mounted on the outside rearview mirror.**

The five camera images were multiplexed into a single image (see Figure 7). The top left frame shows the driver's face camera view, the top right shows the forward camera view, the bottom right shows the left/right rear camera views in a split-quadrant format, and the bottom left shows the over-the-shoulder view from the dome camera. A timestamp was included in the video data. The frame number was used to time-synchronize the video and the truck/performance data. The digital video files did not contain continuous audio.


**Figure 7. Video images. Five camera images multiplexed into a single image.**

**Glare Sensor.** The outside ambient illumination level was recorded by a glare sensor mounted on the windshield near the face camera/incident box device, facing out (see Figure 3**,** left).

**Seat Acceleration.** An accelerometer was mounted on the underside of the driver's seat (see Figure 8). The accelerometer measured the vertical acceleration (*g*) of the driver's seat at a rate of 10 Hertz (Hz).


**Figure 8. Grouped photo. Seat accelerometer mounted on the driver's seat bracket (left) and close view of seat accelerometer (right).**

**Front VORAD.** A radar-based VORAD unit was installed on the front bumper of the truck (see Figure 9) to provide a measure of range to lead vehicles and objects. From the range measure, range rate and time-to-collision (TTC) can also be derived.


**Figure 9. Grouped photo. VORAD unit mounted on the front of the truck (left) and close view of VORAD unit mounted on the front of the truck (right).**

**Sound Level.** For measuring sound level, a detachable probe sound meter (see Figure 10) was mounted above and to the left of the driver's head near the driver's left ear. This device measured sound levels in decibels.


**Figure 10. Grouped photo. Sound level meter instrumented in the tractor (left) and close view of sound level meter (right).**

**GPS.** A GPS device was mounted on top of the truck to provide data on truck location. Data output included measures of latitude, longitude, altitude, horizontal and vertical velocity, heading, and status/strength of satellite signal acquisition, as well as time and date data.

**Lane-tracker.** A mobile tracker was included in the DAS. This device consisted of a single analog black-and-white camera, a personal computer (PC) with a frame grabber card, and an interface-to-vehicle network for obtaining ground speed (note that the "grabbed" video frames were not stored, but were processed algorithmically in real time to calculate the vehicle position relative to road lane markings). Once installed, the device's software automatically calibrated itself to determine camera position; no elaborate calibration procedure was required. Options for configuration of this device included 10 Hz on a 266 megahertz (MHz) PC or up to 30 Hz on an 800 MHz (or better) PC. The following variables were reported by this device:

- Distance from center of truck to left and right lane markings (estimated maximum error is < 6 inches, average error is < 2 inches.).
- Angular offset between truck centerline and road centerline (estimated maximum error is < 1 degree).
- Approximate road curvature.
- Confidence in reported values for each marking found.
- Marking characteristics, such as dashed versus solid and double versus single.
- Status information, such as in-lane or solid line crossed.

**Yaw Rate Sensor.** A yaw rate (gyro) sensor was installed in the main DAS unit to provide a measure of steering instability (i.e., jerky steering movements).

**X/Y Accelerometer.** Accelerometers instrumented in the truck were used to measure longitudinal (x) and lateral (y) accelerations.

**Vehicle Network.** The vehicle network refers to a from-the-factory, on-board data collection system. The format of messages and data collected by on-board microprocessors was defined by Society of Automotive Engineers, Inc. (SAE) J1587.(11) These microprocessors were installed on the vehicle at the truck manufacturing facility and not by the authors. Depending on the truck model, year, and manufacturer, there were several data network protocols or standards that were used, including those defined by SAE J1939, J1587, and J1708.(11,12,13) After assessing the data requirements associated with the current study, it was decided that the data defined by J1708 would be accessed. An interface was developed to access the data and bring it into the DAS dataset. Some of the measures accessed from the truck's vehicle network depended on the make, model, and year of the vehicle.

## 3.2 ACTIGRAPH AND PSYCHOMOTOR VIGILANCE TEST

### 3.2.1 Actigraphy Device

Each study participant was instructed to wear an actigraphy device (see Figure 11) on the wrist of his or her non-dominant hand. An actigraphy unit is a wristwatch-type activity-monitoring device used to assess a participant's sleep quantity and quality. The device was the approximate size and shape of a wristwatch, although somewhat bulkier and heavier. The actigraphy device collected data on the motion of the person wearing the device and stored the data as a function of time. The device was self-contained and made no electrical contact with the person wearing it.


**Figure 11. Grouped photo. Actigraphy device worn by participants.**

### 3.2.2 Psychomotor Vigilance Test

Researchers administered a Psychomotor Vigilance Test (PVT) to participants at each meeting throughout participation. The PVT model used in this study was the PVT-192 (see Figure 12). The PVT-192 is a portable device that measured the reaction time with which participants responded to a visual stimulus by pressing a response button.[14]


**Figure 12. Photo. PVT device used in the study.**

## 3.3 EXPERIMENTAL PROCEDURES: DATA ACQUISITION SYSTEM INSTALLATION AND REMOVAL, PARTICIPANT INTERVIEWS, QUESTIONNAIRES, AND TRAINING

### 3.3.1 Data Acquisition System Installation Procedures

Truck companies—also known as motor carriers—identified each truck to be instrumented for the study, and a time was scheduled for the initial installation of the entire DAS, as well as an operational check. The installation was conducted by a team of researchers in an enclosed area at the participating motor carrier. The DAS was installed in company-owned vehicles without any permanent vehicle modifications. To achieve this, customized brackets were developed for the sensors and equipment of the DAS, to make use of existing mounting holes in the frame of each vehicle. The brackets were designed individually based on bumper style, type of seat and dashboard, or placement of previously-installed units. On occasion, researchers were granted access to welders, cutting torches, or air-driven tools on site for bracket modification. Each installation was customized according to the make, model, and year of the vehicle.

Researchers completed installation of DAS components in 5–6 hours. The trucks were chosen by the company's management based on reliability and accessibility of the trucks to the participants. Sensors were mounted in the appropriate locations inside and outside the truck. All cables attached to the sensors were routed to the main DAS unit. All sensors were mounted as discreetly as possible and all cables were installed beneath ceiling panels, under floors and carpeting, and beneath plastic moldings and compartments in order to make as little change to the truck as possible.

Once the initial installation and operational checks were complete, data information was entered and verified for the motor carrier, location, individual truck identification (ID), and driver ID of interest. The drivers were asked to adjust their seats for normal driving and the DAS cameras were adjusted to proper orientation for each driver. These checks and adjustments were also done each time experimenters met with the drivers.

### 3.3.2 Data Acquisition System Removal Process

At the completion of the study, research personnel scheduled a time with each motor carrier for the removal of all DAS components from each truck. Removal of DAS components was completed in approximately 3 hours by a team of two to three people. Removal of the DAS was conducted with the intention of restoring the truck to its original condition, as if the installation of equipment had never taken place. The authors coordinated with each motor carrier to perform an acceptance inspection of the truck and verify that operation and configuration matched original pre-study specifications. All equipment installed in the truck was recovered.

### 3.3.3 Participants

Approval to conduct research with participants was granted by the Institutional Review Board at the Office of Research Compliance.

Drivers were recruited for the study at seven terminals from four different fleet companies. Research personnel and company management approached drivers. Recruitment flyers featuring study and contact information were also displayed at some terminals. Participation was voluntary. Interested drivers were contacted and met by personnel to assess the driver’s interest and availability for participation.

The initial meeting with participants included a brief description of the background and goals of the project. Meetings took place in private rooms at the company terminals. Interested participants were required to read thoroughly and sign an informed consent form (ICF) before engaging in any other study-related tasks. The ICF described the goals of the study in detail and outlined the expectations of the participant and researcher. The participants were required to grant or withhold their consent for the use of their data for presentation purposes, and to sign and date the final page of the form to confirm their willingness to participate in the study. Researchers made certain that the participants had a clear understanding of all sections described in the ICF by asking them if they had any questions and covering key points of the participant responsibilities in the study. There were two general restrictions on participation in the study:

- Participants must NOT have participated in the DDWS FOT study.
- Participants were required to show a valid CDL.

After a driver agreed to participate, researchers administered the initial contact form and pre-study questionnaires to the driver. Once the contact form and questionnaires were complete, researchers measured the participant’s height, weight, and wrist circumference and conducted vision and hearing tests. After this testing was complete, the participant was brought to the instrumented truck he or she would be driving for the duration of the study. Researchers explained the data collection equipment installed on the truck and answered any questions asked by the participant.

An actigraphy device was initialized by researchers and given to the participant to wear on his/her non-dominant wrist. If the standard watchband did not fit properly or if the participant found it uncomfortable, the band was replaced with a Velcro band, which offered a wider circumference and reduced the degree of contact between the actigraphy device itself and the skin. Participants were asked to wear the actigraphy device 24 hours a day, 7 days a week for the duration of their time in the study. Drivers were instructed to remove the device only when showering, washing dishes, swimming, or performing any other task in which the device might become submerged in water. Participants were asked to replace the device on their wrists as soon as possible after such activities, to minimize data loss.

Researchers issued a daily activity register to the participants and explained, in detail, how to complete entries. After explaining the daily log to participants, researchers administered the PVT to participants. The PVT was conducted in the driver’s seat of the tractor with the door closed, unless significant work had to be done to the DAS that required researchers to access the interior of the tractor. In this rare case, the passenger seat or sleeper berth was used. Before each test, the participant was instructed on how to use the PVT device. These instructions included using the same digit of the same hand for the entirety of the test, and reviewing the procedure to answer the pre-test and post-test questions that were presented. Once the PVT began, researchers closed the door of the vehicle in which the test was taking place and ensured the privacy of the participant for the duration of the test.

Participants were required to respond to a visual stimulus presented at a variable interval of 2,000–10,000 milliseconds (ms). The stimulus was a four-digit, red, light-emitting diode (LED) counter turning on and climbing in 1-ms intervals, beginning with zero. The participant was instructed to push the button as soon as he or she saw the numbers, at which point the numbers would stop climbing and display the reaction time in ms. After 1 second, the displayed number would clear and another stimulus would be presented during the random time interval. This process continued for the predetermined test time of 15 minutes. This task duration was selected because in previous tests, the results have been shown to be sensitive to sleep deprivation.(15) Both before and after the testing period, the device displayed the word “Sleepy?” with a scale directly below the word that allowed the user to input a subjective rating of his/her sleepiness at that moment. The scale read “No” at the left end and “Yes” at the right end. The rating was entered by first moving a cursor along the scale by pressing the left button, and then by pressing the right button to enter the rating. This information was recorded by the device, along with the PVT trial information. After the participant had completed the PVT, researchers answered any additional questions regarding the study.

### 3.3.4 Participant Debriefing

Participation ended after drivers had driven their instrumented truck for 4 consecutive work weeks. Meetings were arranged by researchers with participants to complete data collection. The meetings took place in private rooms at the company terminals.

During the debriefing, researchers administered the post-study questionnaires. Once these questionnaires were complete, researchers held a short oral debriefing interview with the participants. This interview lasted between 5 and 15 minutes, depending on the length of participants’ answers to the interview questions. The interviews were recorded on a digital sound recording device and later, after the researchers had returned, transcribed into a text document. After the interview, researchers administered a final PVT to participants in the driver’s seats of their instrumented trucks. Once the PVT was complete, data from the actigraphy device was downloaded and the daily activity registers from the participants were collected, with the strictest confidence. After answering any final questions and ensuring that all required data were collected, participants were compensated in cash for their participation. Participants were paid $75 per week of participation in the study and a bonus payment of $100 for completing all study requirements.

### 3.3.5 Participation Confidentiality

Drivers’ names were separated from the data and replaced with numbers as soon as data collection started. Participants’ privacy was protected with a Confidentiality Certificate from the Department of Health and Human Services. This confidentiality is provided for by the Public Health Services Act (§301(d), 42 U.S.C. 8241(d)). According to the Public Health Services Act, with this certificate, the researchers could not be forced (e.g., by court subpoena) to disclose information that might identify a participant in any Federal, State, or local civil, criminal, administrative, legislative, or other proceeding. The certificate indicates that all persons associated with the conduct of the research project were authorized to protect the privacy of the individuals who participated in that research from all persons not connected with the conduct of the research.

The video and other data from this study were stored in a secured area. Access to the digital video files was available only under the supervision of the Principal Investigator and lead researchers involved in the project. The video files were accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects. The video files will not be released to unauthorized individuals without the participants' written consent.

## 3.4 PARTICIPATING MOTOR CARRIERS

Four for-hire motor carriers participated in this study. A for-hire motor carrier transports goods for customers for a fee. The following paragraphs describe, in alphabetical order, the motor carriers that participated in this study, with a description of the fleet size and general operations of each.

### 3.4.1 Carrier A

Carrier A, based in Mount Crawford, VA, dispatches approximately 120 drivers. Drivers for Carrier A primarily carried U.S. Mail as freight. The drivers were dispatched on dedicated routes whereby they delivered to cities such as Roanoke, VA, Charlotte, NC, Richmond, VA, Pittsburgh, PA, and Washington, DC. After delivery to these cities, the freight was often picked up by another driver from the same company for delivery to more remote locations. A single driver was assigned to each tractor unit for these deliveries. Some of the routes required night driving and some required day driving, depending on the specifics of the freight delivery schedule. Drivers' route locations were often based on the region in which they lived, and some drivers rarely visited the Mount Crawford terminal.

### 3.4.2 Carrier B

Carrier B is based in Kernersville, NC. Its drivers also reported to distribution warehouses in High Point, NC, and Greensboro, NC. While drivers were employed through Carrier B, they were assigned to a particular warehouse and started and ended their routes there instead of in Kernersville. Carrier B employed 61 drivers and 7 onsite managers. The fleet size was 60 tractor units, but the company had plans to add 40 more in 2007. All trailers owned by Carrier B were 53-foot dry vans. Main freight types included mattresses, furniture, foam products, carpet, and corrugated products, but freight types were specific to individual customers. The tractor-trailer units were dispatched to each customer and were not used in any capacity other than carrying the specific products of the individual customer. Operating procedures varied by location to accommodate the specific demands of each customer.

### 3.4.3 Carrier C

Carrier C is based in Pittsburgh, PA, and operates 21 terminals in 7 States across the eastern United States. This carrier's Roanoke, VA, terminal had a fleet with 27 tractor-trailer units. These units carried freight primarily to and from other terminals (also operated by Carrier C) within a radius that allowed the drivers to return to Roanoke at the end of their shifts. Some drivers were dispatched to several locations within the city where the terminal was located to complete deliveries. Participants at the Roanoke terminal were dispatched to Baltimore, MD, Richmond, VA, and Charleston, WV. A "slip-seat" method was employed in which a single tractor unit was used in a 24-hour operation. Two drivers were often assigned to the same tractor, one driving during the day and one at night. Drivers at the terminal in Roanoke sometimes drove up to 600 miles per shift. Drivers were often assigned the same destination city for several shifts in a row before their assigned route changed to another city.

### 3.4.4 Carrier D

Carrier D is one of the largest freight carriers in North America, with terminals and distribution centers across the country. For this study, the Charlotte, NC, Henderson, NC, and Gordonsville, VA, terminals were used. The fleet size at the Charlotte, NC, terminal was 1,400 trucks, which carried mainly consumer goods, paper, raw products, and automotive supplies. The main trailer types were dry vans and rail or ocean-going containers. Both the company terminals in Henderson, NC, and Gordonsville, VA, were distribution centers for a large discount retail chain. At the Henderson, NC, terminal, the main types of goods carried were perishable groceries, requiring refrigerated trailers. The fleet size at Henderson was 80 tractors and 110 trailers. The terminal in Gordonsville, VA, had 142 tractor units (170 drivers) that carried dry groceries, frozen foods, dairy, deli products, meat, and fresh produce.

## 3.5 DATA RETRIEVAL

### 3.5.1 Video and Dynamic Sensor Data

To retrieve data collected from the instrumented vehicles, researchers met with participants at predetermined locations such as freight company terminals and truck stops. Typically, meetings were scheduled each week.


**Figure 13. Photo. Hard drive used for data collection.**

The hard drives used to store video, audio, and dynamic sensor data from the DAS were encased in metal shells with a computer interface on one end for communication with the DAS (see Figure 13). These hard drives were installed in a lockable bay interface on the DAS. During each meeting with a participant, personnel unlocked and removed the hard drive from the DAS and inserted a blank hard drive into the DAS drive bay. The blank drives were secured in the DAS by locking them in with a key and the DAS was checked to verify that the new hard drive was working correctly (i.e., the DAS booted up with the new hard drive installed).

After a hard drive was removed from the DAS, it was placed in a sealed envelope and labeled with identifying information, including the company's truck number, truck ID number, participant ID number, date of removal, and hard drive number. Once the hard drives were returned, the data were downloaded, processed, and stored. After the data were securely downloaded from the hard drive, the drive was reformatted and stored for future use.

### 3.5.2 Onsite Data Acquisition System Operation Verification

During each meeting with participants, researchers followed a specific protocol outlined in a field manual to assess the functionality of DAS components. This process consisted of visual verification of component security and connectivity with a subsequent operational verification once the hard drive was replaced. Personnel were equipped with a laptop suitcase that interfaced with the DAS, allowing the researcher to verify operation of each DAS component and perform calibrations of specific components if necessary.

In addition, researchers used a portable hard drive reader with a specialized viewing program to view collected video data from the hard drive in addition to verifying sensor operation throughout the collection period. This program allowed for a quality control check for inoperable or out-of-adjustment DAS components.

In each instance in which a driver completed participation in the study and a new driver began, the system header information was modified to correspond to the new driver and location designation. This ensured proper identification of data for each driver's study period. These data were written in the header of each recorded file.

### 3.5.3 Actigraphy Data

During each meeting with drivers, actigraphy data were downloaded. To download data from the actigraphy device, an actigraphy interface unit was used. The actigraphy device was placed on the interface in such a way that the four metal connector pins on the interface contacted the four receptacles on the actigraphy device. The interface was connected to a PC using a standard DB9 serial cable. Special software was used to download the data from the actigraphy device to the PC. The time taken to download the data from an actigraphy device was approximately 10 seconds for 1 month of data. The data were saved to the PC and given a file name that contained the four-digit participant number followed by the download date (####_mmddyy). Once the data were downloaded and verified, the actigraphy device was returned to the participant. The actigraphy data were processed and stored on a storage server.

### 3.5.4 Onsite Actigraphy Data Verification

Once the data were downloaded at each meeting with drivers, the file was viewed using software designed to verify that the participant was wearing the actigraphy device as instructed. The resulting graph contained a plot of motion (y-axis) vs. time (x-axis). Flat lines in the data graph (highlighted in Figure 14) corresponded to time periods during which the participant removed the actigraphy device from his or her wrist. If the data indicated that the participant had removed the actigraphy device for an extended period of time or a large aggregate sum of time, researchers were instructed to remind the participant to wear the unit as much as possible, with the exception of times when it could potentially be submerged in water (e.g., bathing, showering).

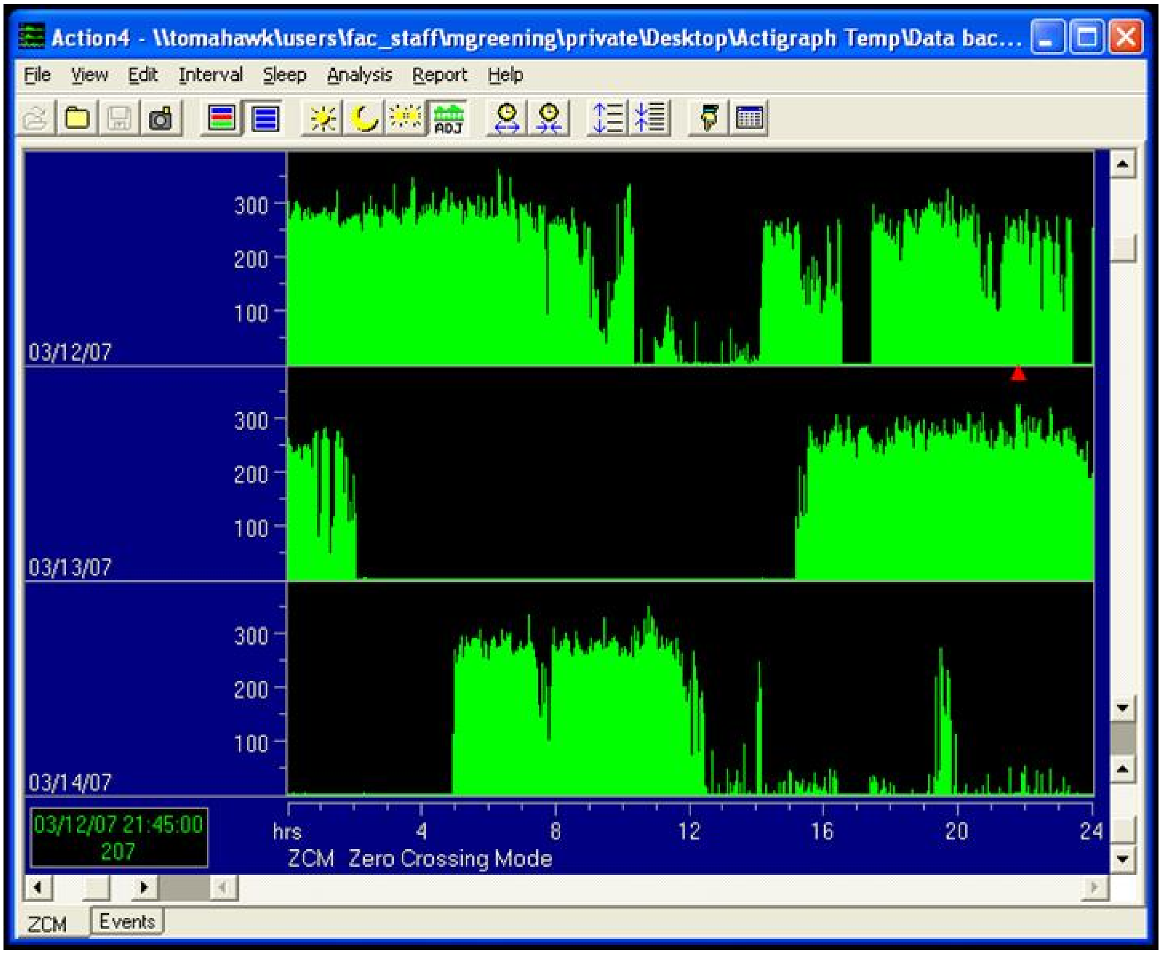



**Figure 14. Screenshot. Software displaying collected motion logger data from an actigraphy device; flat line indicates device was removed.**

### 3.5.5 Psychomotor Vigilance Test Data

A PVT was administered to participants at each meeting. PVT data were recorded to internal memory within the device itself and were later downloaded to a PC using a specially-designed software. The data were then processed and stored on a storage server.

### 3.5.6 Daily Activity Register Data

Personnel reviewed the driver's daily activity register at each meeting with a participant. If the daily activity register was incomplete, researchers requested that participants complete the missing portions retroactively and urged participants to complete future daily activity registers regularly. A new activity register was issued to the participant at the end of each meeting. Driver activity registers were processed and stored after each meeting.

## 3.6 RESEARCH DESIGN

Because this was an on-road driving study conducted under normal operations, there were no experimental manipulations. Each participant in this on-road study was observed for approximately 4 consecutive work weeks. As mentioned above, 100 participants were recruited from 4 different trucking fleets across 7 terminals and instrumented 1–3 trucks from each trucking fleet (9 trucks total). After a participant finished 4 consecutive weeks of data collection, another participant started driving the instrumented truck.

### 3.6.1 Dependent Measures Collected from the Data Acquisition System

What follows is a partial list of dependent variables collected from the DAS during the NTDS.

**Light Level:** The light level measured from a luminance meter.

**Sound Level:** Measure of the cab interior sound level in decibels, recorded by the DAS sound level meter.

**Temperature:** The ambient temperature of the air surrounding the vehicle recorded by the in-vehicle network communication system, reported in degrees Celsius (C°).

**Vehicle Speed:** Vehicle speed recorded from the in-vehicle network communication system in kilometers per hour (km/h).

**Throttle Position:** The position of the throttle pedal—recorded by the in-vehicle network communication system—in a normalized range of 0 to 1 (0 = pedal up, 1 = pedal down, fully pressed).

**Cruise Control Status:** Status of the vehicle velocity control system, recorded by the in-vehicle network communication system. System status was reported as “active” or “not active,” and the device also reported when the system switch was “on” or “off.”

**Vehicle Component Information:** Vehicle components recorded by the in-vehicle network communication system, measuring the presence and absence of right- and left-turn signal (1 = present, 2 = absent), brake usage (1 = brake was pressed, 0 = brake not pressed), headlight status (1 = headlights on, 0 = headlights off), and ignition signal (1 = on, 0 = off).

**Steering Angle:** Data collected from a transducer mounted on the steering column , which transmitted a variable signal representing the degrees of rotation of the steering wheel to the left or right using a straight-ahead, 0-degree reference point.

**Seat Acceleration:** Data collected from the accelerometer to receive Z-axis acceleration (vertical travel up and down) of the driver’s seat, reported in 1/100 *g*.

**Vehicle Angle:** Angle of vehicle with respect to the lane, measured in 1/100,000 radians (rad), recorded by the lane-tracker system.

**Lane Offset:** Distance of vehicle to the center of the lane. Measurements reported in 1/100 inch, recorded by the lane-tracker system.

**Lane Width:** Lane width measured in 1/100 inch, recorded by the lane-tracker system.

**Road Curvature:** Radius of road curvature was reported as the inverse of radius of road curvature reported in 1/100,000 feet (ft) and referred to as RhoInverse. This information was collected by the lane-tracker system.

**Road Incline:** The incline of the road with respect to baseline measured in 1/100,000 rad, recorded by the lane-tracker system.

**Left-lane Characteristics:** The lane-tracker system recorded characteristics in the lane immediately to the left and reported the type of line (0 = none, 1 = double, 2 = single), leftmost and rightmost line color (0 = light lines, 1 = dark lines), and contrast level in a range of 0–7 (0 being a sharp contrast between lines and background, and 7 being little contrast between lines and background).

- *Immediate Left Lane—Left Distance.* Distance from the lane's center to the left side of the marker measured in 1/100 inch, recorded by the lane-tracker system.
- *Immediate Left Lane—Right Distance.* Distance from the lane's center to the right side of the marker measured in 1/100 inch, recorded by the lane-tracker system.

**Right-lane Characteristics:** The lane-tracker system recorded characteristics in the immediate right lane and reported the type of line (0 = none, 1 = double, 2 = single), leftmost and rightmost line color (0 = light lines, 1 = dark lines), and contrast level in a range of 0–7 (0 being a sharp contrast between lines and background, and 7 being little contrast between lines and background).

- *Immediate Right Lane—Left Distance.* Distance from the lane's center to the left side of the marker measured in 1/100 inch recorded by lane-tracker system.
- *Immediate Right Lane—Right Distance.* Distance from the lane's center to the right side of the marker measured in 1/100 inch recorded by the lane-tracker system.

**Global Positioning System (GPS):** GPS recorded all location information which included latitude and longitude measured in degrees, altitude measured in 1/100 ft, horizontal and vertical velocity measured in 1/10 miles per hour (mi/h), vehicle heading measured in 1/10 degree, month reported in a range of 1 to 12, day of the month, hour of the day reported in a range of 0 to 24, and minute of the hour reported in a range of 0 to 59.

**Lateral Acceleration (Y Acceleration):** Data recorded by the system accelerometer, measuring acceleration readings reported in 1/100 *g* (positive = right; negative = left).

**Longitudinal Acceleration (X Acceleration):** Data recorded by the system accelerometer, measuring acceleration readings reported in 1/100 *g* (positive = accelerating; negative = braking).

**Rotation:** Data recorded from the gyro system to report rotation of the driver in degrees per second. A positive rotation rate is in a clockwise motion.

**Range to Target or Targets:** Distance measurement reported as 1/10 ft from vehicle to target object or target objects. Seven targets may be tracked at a time.

**Road and Lane Characteristics:** Size availability of road structure on both left and right sides of vehicle, measured by three video camera feeds, one located on left mirror, one located on right mirror, and one forward camera. Also included road characteristics such as junctions, interchanges, traffic flow, number of lanes, roadway alignment, roadway profile, surface condition, lane marker type, and traffic density.

**Participant Comments:** Audio comments recorded by participants by way of the incident box microphone. All audio clips are 60 seconds long and recorded in moving picture expert group audio layer 3 (mp3 format).

### 3.6.2 Dependent Measures Collected from the Participants

Several types of participant (non-driving) data were collected before, during, and after data collection in the instrumented vehicle. Table 2 lists the types of data collected from participants in the NTDS and shows when the data were collected.

**Table 2. Data collected from participants in NTDS.**

| Before | During | After |
|---|---|---|
| • Visual acuity *Conducted in Screening*<br>• Hearing level *Conducted in Screening*<br>• Height, weight, frame size *Conducted in Screening*<br>• Demographic *Questionnaire 1*<br>• Driving experience *Questionnaire 1*<br>• Driver Stress Inventory *Questionnaire 2*<br>• Risky driving propensity *Questionnaire 3*<br>• Life Stress Inventory *Questionnaire 4*<br>• Psychomotor vigilance *PVT* | • Sleep/awake data *Actigraphy device*<br>• On-/off-duty activities *Driver log*<br>• Medication/Caffeine use *Driver log*<br>• Psychomotor vigilance test (collected at driver meetings) *PVT*<br>• Load history *Load history* | • Reactivity to be observed *Questionnaire 5*<br>• Personal health *Questionnaire 6*<br>• Safety belt use *Questionnaire 7*<br>• Sleep hygiene *Questionnaire 8*<br>• Psychomotor vigilance *PVT*<br>• Comments on crash causation and prevention *Debriefing interviews* |

#### *3.6.2.1 Physiological Measures*

**Visual acuity:** Participants were informally tested for their normal or corrected-to-normal visual acuity with the Snellen acuity test. They were allowed to wear glasses or contact lenses if they normally wore them while driving.

**Hearing level:** Participants were tested at eight frequency levels (500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz). The outputs were the decibel levels of the tones produced at each frequency level to which participants responded.

**Height and weight:** During the screening, participants were instructed to step on the height or weight scale placed on a hard surface (not carpeted) for their height and weight measurements.

**Body Mass Index (BMI):** BMI is a measure of body fat based on height and weight that applies to adult men and women. The BMI was calculated for each participant based on his or her height and weight during the screening. The formula for obtaining BMI is (weight/height$^2$) × 703.(16) For adults more than 20 years old, BMI falls into one of four categories:

- BMI less than 18.5 is considered underweight.
- BMI between 18.5 and 24.9 is considered normal.
- BMI between 25 and 29.9 is considered overweight.
- BMI more than 30 is considered obese.

**Frame size:** Participants' frame size was determined by their height and wrist circumference.(17) Wrist circumference was measured using a tape measure. Frame size was determined based on criteria outlined in Table 3 and Table 4. All the physiological measures were recorded on the participant screening data sheet by researchers.

**Table 3. Criteria for determining male frame size.**

| Male Height | Male Wrist | Male Frame Size |
|---|---|---|
| Taller than 5'5" | Smaller than 6.5" | Small |
| Taller than 5'5" | 6.5" to 7.5" | Medium |
| Taller than 5'5" | Larger than 7.5" | Large |

**Table 4. Criteria for determining female frame size.**

| Female Height | Female Wrist | Female Frame Size |
|---|---|---|
| Shorter than 5'2" | Smaller than 5.5" | Small |
| Shorter than 5'2" | 5.5" to 5.75" | Medium |
| Shorter than 5'2" | Larger than 5.75" | Large |
| 5'2" to 5'5" | Smaller than 6" | Small |
| 5'2" to 5'5" | 6" to 6.25" | Medium |
| 5'2" to 5'5" | Larger than 6.25" | Large |
| Taller than 5'5" | Smaller than 6.25" | Small |
| Taller than 5'5" | 6.25" to 6.5" | Medium |
| Taller than 5'5" | Larger than 6.5" | Large |

#### *3.6.2.2 Pre-study Questionnaires*

After participants met all study requirements and signed the ICF, they were given several pre-study questionnaires to complete. The set of pre-study questionnaires included the following: a demographic questionnaire, a driver stress inventory, a life stress inventory, the NEO Personal Inventory Five Factor Questionnaire, and the Dula Dangerous Driving Index. Participants were asked to complete these questionnaires and return them within a few days. Each of the pre-study questionnaires is described below:

**Demographic questionnaire:** An 18-item questionnaire that assesses demographic characteristics (e.g., age, gender, education) and driving history (e.g., experience, endorsements, prior violations, and crashes).

**Driver stress inventory:** A 53-item questionnaire that uses a 10-point Likert-type scale ("Not At All" to "Very Much") to assess driver emotions about driving, including fear, anger, and boredom. This experimentally-validated questionnaire is designed to assess an individual's vulnerability to stress in a driving context and to evaluate the coping methods typically employed in stressful driving situations. It is divided into two sections. The first section is comprised of 12 items designed to evaluate driving habits and history, including the number of years a driver has been licensed, the typical number of days driven in a week, the typical roads traveled, the number of miles driven annually, and the number and severity of accidents in the last 3 years (this section was not used in the current study); and the second section is comprised of 41 items designed to assess a driver on 5 dimensions of driver stress vulnerability: aggression, dislike of driving, hazard monitoring, thrill-seeking, and proneness to fatigue. Scores are scaled so that they may range from 0 to 100.[18]

**Holmes-Rahe Life Stress Inventory:** A validated questionnaire listing 42 stressful life events[19] that may have occurred within the past year, such as death of a spouse or parent, divorce, separation, personal injury or illness, and job change. Each stressful event is given a unique score. The more stressful the event, the higher the score. The scores are summed; higher scores indicate an increased susceptibility to stress-induced health breakdown.

**NEO Personal Inventory (Five Factor) Questionnaire:** An abbreviated version of the NEO Five-Factor Inventory was used to measure personality types. This 60-item (5-point scale) questionnaire classifies drivers on 5 scales: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. This test is used extensively in research, psychological assessment, and personnel selection.[20]

**Dula Dangerous Driving Index:** A 28-item validated questionnaire[21] that measures drivers' self-reported likelihood to drive dangerously. It is comprised of several scales, including Total, Aggressive Driving, Negative Emotion, Driving, and Risky Driving.

#### *3.6.2.3 Post-study Questionnaires*

When the 4-week data collection was completed, the participants were asked to complete several post-study questionnaires. The post-study questionnaires included health assessment questionnaire, shortened sleep hygiene questionnaire, safety belt use questionnaire, job descriptive index, and reactivity-to-being-observed questionnaire. Below are brief descriptions of the post-study questionnaires used in the study.

**Health assessment questionnaire:** A three-item questionnaire that assesses general medical conditions and medication usage.

**Shortened sleep hygiene questionnaire:** A 14-item questionnaire that assesses general sleep habits, substance use, and sleep disorders. This questionnaire is a shortened version of the Walter Reed Sleep Hygiene Questionnaire.(22)

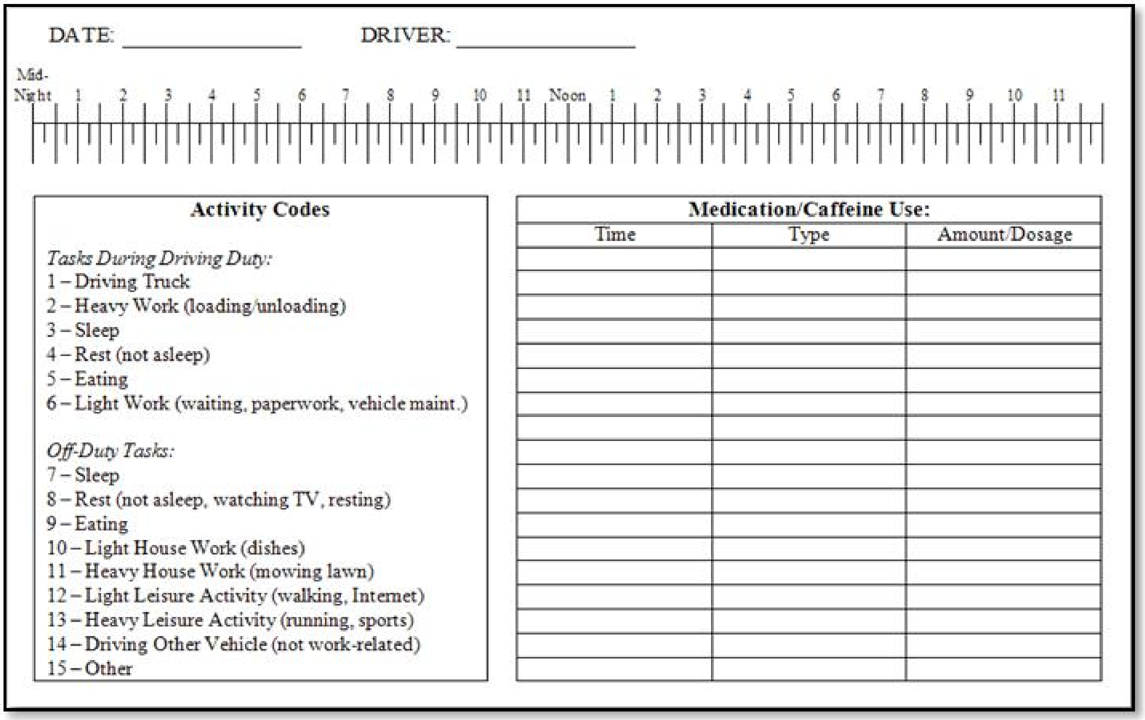
**Safety belt use questionnaire:** A seven-item questionnaire that assesses drivers' safety belt use, perceptions of safety belt use, reasons for lack of safety belt use, and ways to increase safety belt use.

**Job Descriptive Index:** Using a 90-item questionnaire designed to measure employees' satisfaction with their jobs, this tool assesses five important aspects or facets of job satisfaction, including Work on Present Job, Present Pay, Opportunities for Promotion, Supervision, and Coworkers. After 40 years of research and application, it remains one of the most widely used measures of job satisfaction.(23,24)

**Reactivity-to-being-observed questionnaire:** A three-item questionnaire that assesses participants' perceptions and reactivity to being observed while driving.

**Driver Sleep Duration:** The quantity-of-sleep/awake data were collected with the actigraphy device worn by the drivers during their participation.

**Daily Logs:** Participants recorded their on- and off-duty activities in driver activity registers created by researchers (see Figure 15). These activity registers were created in a style similar to activity registers with which most CMV drivers were previously familiar.



DATE: ______________ DRIVER: ______________

Mid-Night 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4 5 6 7 8 9 10 11

**Activity Codes**

*Tasks During Driving Duty:*
1 – Driving Truck
2 – Heavy Work (loading/unloading)
3 – Sleep
4 – Rest (not asleep)
5 – Eating
6 – Light Work (waiting, paperwork, vehicle maint.)

*Off-Duty Tasks:*
7 – Sleep
8 – Rest (not asleep, watching TV, resting)
9 – Eating
10 – Light House Work (dishes)
11 – Heavy House Work (mowing lawn)
12 – Light Leisure Activity (walking, Internet)
13 – Heavy Leisure Activity (running, sports)
14 – Driving Other Vehicle (not work-related)
15 – Other

**Medication/Caffeine Use:**

| Time | Type | Amount/Dosage |
| --- | --- | --- |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Figure 15. Form. Daily activity register used to record activities.**

The top part of the daily log was a timeline, which began at midnight and ended at 11:59 p.m., with 15-minute increments (see Figure 15). Participants were instructed to choose one of the 15 codes for their activity (left side of Figure 15) and write down the chosen code on the timeline. The on-duty activities included codes 1–6, while the off-duty activities were coded as 7–15. Participants were required to record their activities over a 24-hour period each day by using the timeline on the daily activity register. Figure 16 displays an example of a completed daily log. Table 5 explains the time and duration of the activities in Figure 16.

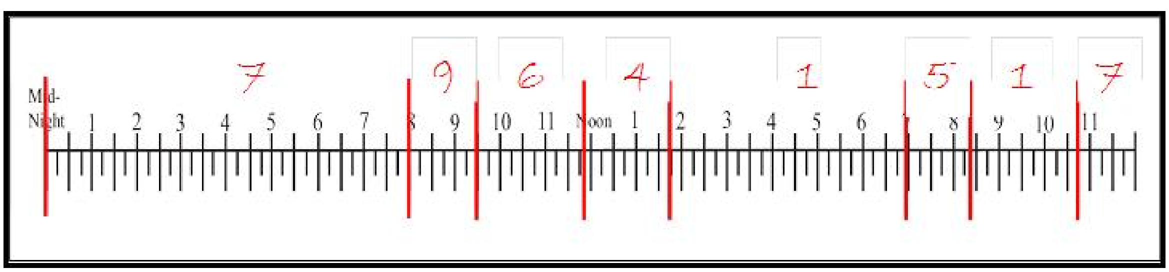



**Figure 16. Diagram. Timeline with activity codes.**

**Table 5. Explanation of time, duration, and activity in Figure 16.**

| Period | Activity Code (Task) |
|---|---|
| Midnight–8 a.m. | 7 (Sleep during off-duty) |
| 8–9:30 a.m. | 9 (Eating during off-duty) |
| 9:30–11:45 a.m. | 6 (Light work during on-duty) |
| 11:45 a.m.–1:45 p.m. | 4 (Rest during on-duty) |
| 1:45–7 p.m. | 1 (Driving truck during on-duty) |
| 7–8:15 p.m. | 5 (Eating during on-duty) |
| 8:15–10:45 p.m. | 1 (Driving truck during on-duty) |
| 10:45 p.m.~ | 7 (Sleep during off-duty) |

The participants were also instructed to write on each daily activity register the time, type, and amount/dosage of their over-the-counter or prescribed medication use as well as caffeine use (the right side of Figure 15). Data entry for the daily logs was conducted using subjective judgments of participants' recordings. It is important to emphasize that entering codes in the daily activity registers was subjective and should be considered an estimate of activities.

**Psychomotor vigilance:** Psychomotor vigilance and reaction time data were collected from participants by administering the PVT to participants up to five times during the length of their participation.

**Debriefing interview:** On the last day of data collection, participants were interviewed regarding their perceptions and opinions on the contributing factors or causes of truck crashes, and on how they thought these crashes could be prevented. Participants were free to respond as they wished; however, the following probes were used as a way to guide them:

- Things that can increase the risk of a crash while driving on the road:
  - Type of people.
  - Type of weather.
  - Type of location.
  - Time of day.
  - Type of cars.
  - Type of road.
  - Type of driving behavior.
  - Periods during the day.
  - How the driver feels (e.g., tired, happy, sad, etc.).
  - Difficulties with the truck (e.g., mechanical problems).
- Things the driver thinks can reduce the risk of crashes.
- A futuristic device to help the driver avoid a crash.

**Load history:** Participants' load histories were obtained from the official load shipment records from their respective truck fleet companies. The load histories included load information about the locations of origin and destination, departure and arrival times, weight of the load, and distance traveled.

# 4. DATA MANAGEMENT

## 4.1 DATA STORAGE AND ARCHIVAL

The data storage structure was developed to meet requirements for storage capacity, file transfer rates, and data protection. As described below, the authors designed a combination of hardware storage, software, and project-specific procedures to meet these requirements.

### 4.1.1 Calculation for Storage Capacity

Approximately 8 terabytes (TB) of storage was required to store all the on-road data collected in the NTDS. The storage had to be part of a complete storage system that could provide multiple streams of video and data files simultaneously to separate workstations for data reduction.

Total storage capacity requirements were determined by the data-recording rate, the number of drivers in the study, and the number of driving hours projected. Video data-recording rate was crucial since video data accounted for more than 90 percent of the on-road data collected, yet needed to be minimized for the storage capacity requirements while maintaining high quality. A compression quality setting of 10 was selected on an arbitrary scale of 1 to 30, where 1 represented the highest quality. This quality setting resulted in a variable video-recording rate ranging from 2 megabytes (MB)/minute when unchanging pictures were recorded (such as when a truck was parked in a garage with no driver inside) to 10 MB/minute when dynamic and high-contrast pictures were recorded (such as when the vehicle was in motion). An MPEG-4 video hardware-compression board was selected, because it changed the compression rate to optimally match the required video quality.

Total storage capacity was determined based on the following:

- An overall average data rate of 7 MB/minute for the combined binary data plus variable compression MPEG-4 video streams.
- 45 hours of driving files collected per week used as a conservative (high) estimate.
- 100 subject drivers with 4 weeks of data collection each.

Thus, the total data volume equaled 7.56 TB (or approximately 8 TB) using the following formula: (100 drivers × 4 weeks/driver × 45 hours/week × 60 minutes/hour × 7 MB/minute) / (106 MB/TB).

### 4.1.2 Storage Area Network

A storage area network (SAN) design was employed to store the estimated 8 TB of data and to play multiple driving and video files simultaneously at several PC workstations (see Figure 17).

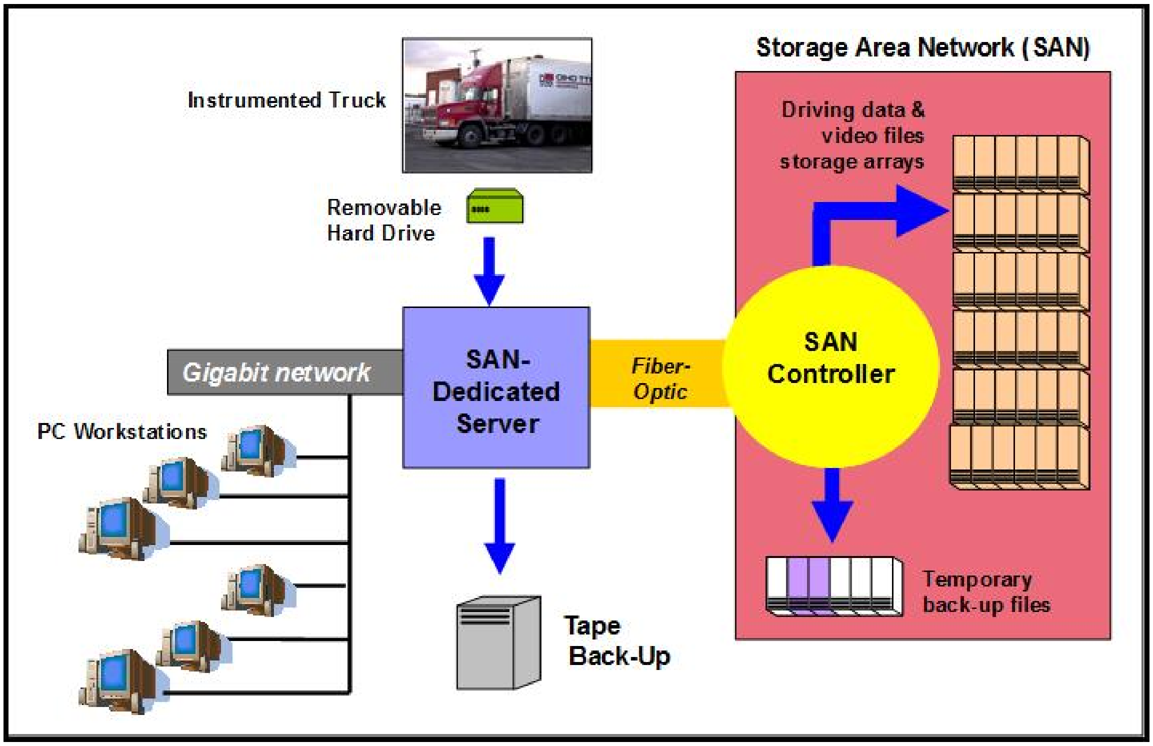



**Figure 17. Diagram. SAN design in the NTDS.**

The main features of the SAN design included the following:

- The SAN was connected to PC workstations via a SAN-dedicated server.
- The SAN-dedicated server handled file transfers and communications between the SAN and PC workstations. The server directed file transfers to and from the SAN via fiber-optic connections and then to and from the PC workstations over a gigabit-speed network.
- The SAN dedicated server used redundant practices to increase data protection and continue operation in the event of component failure(s). The redundant practices included dual-central processing units, power supplies, cooling fans, disk controllers, and mirrored hard drives. This data protection system is called “RAID 0.”
- The SAN file storage consisted of multiple arrays with up to 15 hard drives per array, one of which was designated as a hot-swap hard drive that automatically replaced a failed hard drive. Each array functioned as one large storage unit.
- Another type of data protection system called “RAID 5” was used across the SAN hard drive arrays, which enabled the data files on a failed hard drive to be recovered in the hot-swap drive and temporarily used the drive as a replacement of the failed drive. A RAID 5 scheme would rebuild the failed drive with data stored redundantly across the remaining hard drives in the array.
- The SAN controller managed file operations across the multiple arrays by use of proprietary hardware and software.

### 4.1.3 Data Transfer and Upload Procedure for On-road Data

The on-road data were transferred from a hard drive and stored as temporary "backup" copies, and then uploaded onto the assigned location in the SAN. Figure 18 illustrates the data transfer and upload procedure for on-road data.

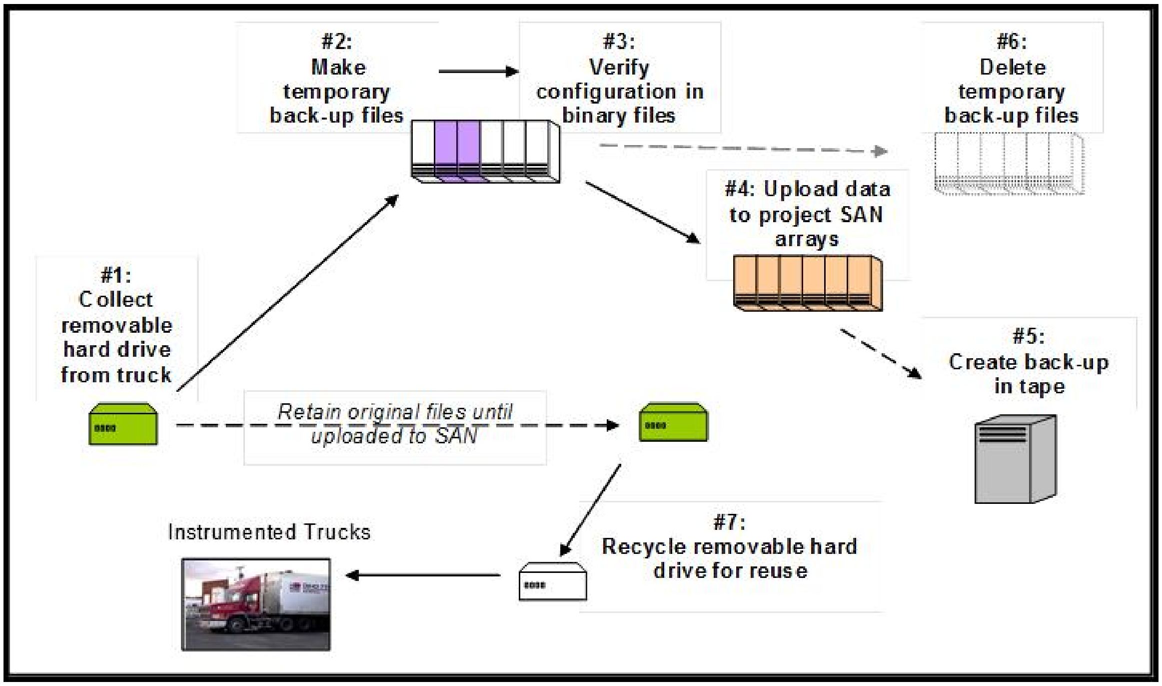



**Figure 18. Flowchart. Data transfer and upload procedure for on-road data files.**

Details of the seven steps for the data transfer and upload procedure are described below.

1. *Collect removable hard drive from truck*. A hard drive was collected from a DAS in an instrumented truck and placed in a bubble-wrap-padded envelope. The researcher recorded on the envelope label all the required information, such as the collection date, instrumented truck ID, driver ID, and any comments the researcher considered relevant to the data retrieval.
2. *Make temporary backup files*. All files in the hard drive were copied to a temporary location in a SAN drive array. The temporary backup files were created prior to their permanent installation onto the SAN and any other use of the hard drive.
3. *Verify configuration data in binary files*. The temporary binary data files were verified to make sure they had the accurate configuration information as a header. A text-based header contained the information, such as the driver identity, truck identity, file record start time and date, and data collection interval (which represented the number of times the instrumented truck used hard drives and it informed the upload software about the location and path to store the binary data and corresponding video files on the SAN array). The information in the header was verified with the label on the envelope. A header also contained the information to interpret the variables recorded as binary data, and was used to assign the variables to the correct location in the database so that the on-road data and corresponding video would be viewed with data-reviewing software.

4. *Upload on-road data files to SAN array.* After the header was verified, the temporary backup files were uploaded to the pre-specified SAN array. If problems occurred during the upload, a log file was generated detailing the errors. Once file upload was complete, the files were verified for their correct locations in the array. Each binary data file was synchronized in time to the corresponding video file. The paired files were then reviewed and labeled.
5. *Create backup files in tape*. All files uploaded to the specified SAN array or changed after a successful upload were copied to a digital tape as a backup on a daily basis. This meant that it would be necessary to copy the uploaded files within 24 hours in the event of data loss.
6. *Delete temporary backup files.* The temporary backup files were kept until a successful upload to the SAN array was confirmed and the files were copied onto a digital tape. Once the tape backup was completed, the temporary backup in the SAN array was deleted.
7. *Recycle hard drive.* After the files were correctly uploaded, the original hard drive was recycled by removing data files and updating the latest DAS system software for reuse in the instrumented truck. The hard drive was sealed in a bubble-wrap-padded envelope ready for re-installation in an instrumented truck.

#### *4.1.3.1 Data Archive*

All the binary data, video, and the associated files were stored on 100-gigabyte digital tape cartridges to be archived (copied). New archives were made monthly and stored in a fire safe. Final data archives are contained on 60–80 digital tape cartridges and stored at an offsite facility that has a limited access and is temperature- and humidity-controlled.

### 4.1.4 Quality Control/Analysis Process

#### *4.1.4.1 Quality Control*

The process of data quality control was undertaken once the data files were transferred to the SAN servers. The data were reviewed to verify correct driver and synchronization of video to sensor data. Then several files from the hard drive were selected for further review to fully assess the quality and integrity of all inputs. This high-level quality review was stored in a spreadsheet and reviewed by researchers to verify sensor video function and identify any impending trends that might be used to discover components with a high probability of failure, as well as to prevent degradation or loss of data.

#### *4.1.4.2 Quality Analysis*

During the quality analysis of the data files that were transferred to the SAN servers, two ratios were used to verify quantity and quality of collected data. The quantity was determined by the ratio of collected file length (in minutes) to the logged driving time, thereby yielding an indication of the overall DAS operation reliability. The quality of the video and sensor data were determined by the ratio of collected data to the data identified as having sufficient video and sensor input for valid analysis, thereby yielding an indication of the overall DAS operation validity.

For the DAS operation reliability, the length of each collected file in minutes was summed to obtain the total collected data time for each driver. This collected file time was compared to the driver's logged time to determine reliability of the DAS operation (i.e., whether or not the DAS booted up and operated each time the driver drove and whether the DAS continued to operate for the entire time logged by the driver). From this initial cumulative period, a researcher identified files with a non-participant driver and files in which a malfunction of one or more of the DAS components caused insufficient collection of the data. Non-participant driver files were removed from the pool of data files and corrupt or bad input files were retained for DAS operational validity.

### 4.1.5 Data Transfer and Upload Procedure for Participant Data

Like the on-road data, participant data were saved in the network server. An online database (i.e., NTDS database) organizes all the participant data. Some data (e.g., questionnaires, activity codes) were directly entered in the database when those data were delivered. Actigraphy and PVT data were first reviewed by researchers, and the outputs of preliminary analyses were saved in spreadsheets. Figure 19 illustrates the process of storing participant data.

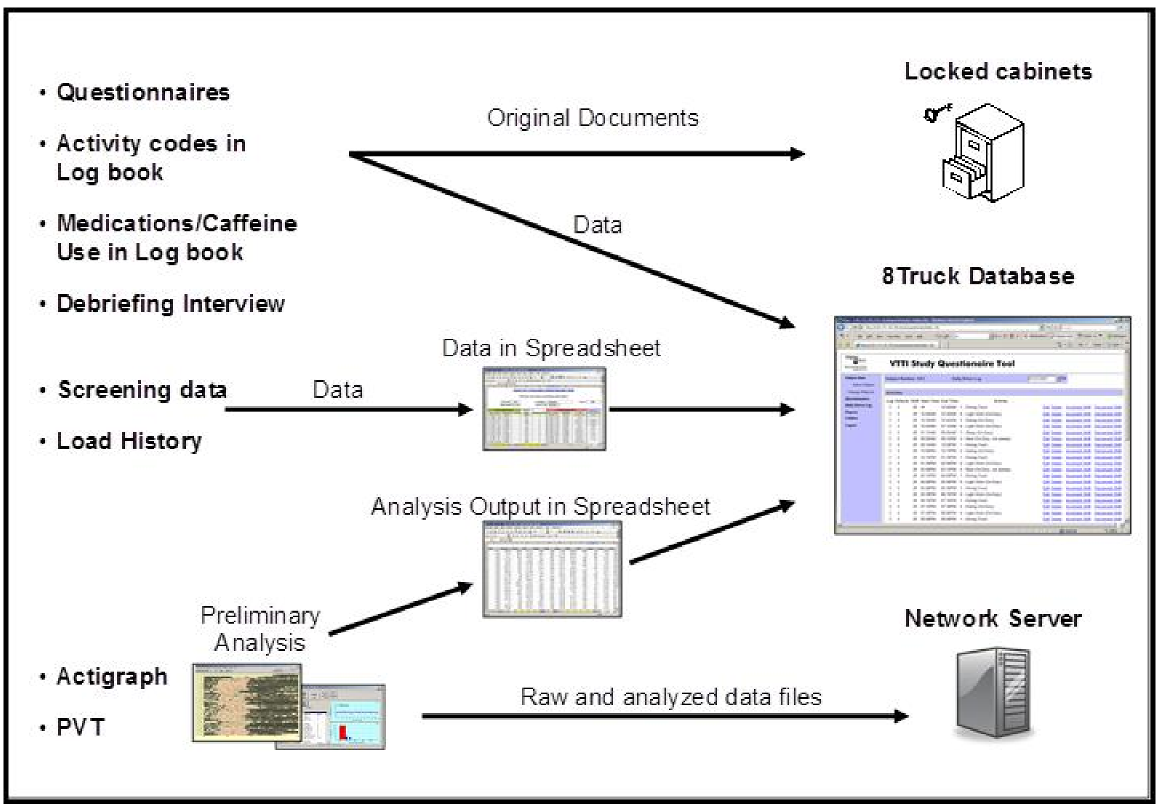



**Figure 19. Flowchart. Process of participant data storage.**

#### *4.1.5.1 Questionnaires*

Responses on the questionnaires were manually entered into the NTDS database after the participant completed the questionnaires and returned them. Any missing or unclear responses on a questionnaire were clarified by contacting the appropriate participant. The original questionnaires were filed by participant number and stored in a locked cabinet. The NTDS database has a function to display responses from all participants by questionnaire. Those responses can be shown in either a Web page or a spreadsheet format.

#### *4.1.5.2 Daily Activity Registers*

Participants were instructed to record their on- and off-duty activities in their daily activity registers by marking one of the activity codes listed in Figure 15. When the completed activity registers were returned, the following seven procedures were performed before the codes were entered into the NTDS database:

- Checking whether the daily activity register contained all the designated dates, including days off.
- Checking whether the driver made notes about when he or she drove a non-instrumented vehicle during his or her on-duty periods.
- Checking whether one code was entered in all the time periods. Marking the period as blank if no code is entered.
- Choosing one code if multiple codes were entered in one period.
- Determining the on- and off-duty shifts.
- Writing the shift number for the on-duty period, and "OFF" for the off-duty periods.
- Entering the driver number, date, daily activity register number, time of period, on- or off-duty shift, and activity code into the NTDS database.

The NTDS database has functions to search particular activities and/or participants and display the results by the participant number, activity code(s), time periods, and on/off shifts. For example, the database can search "Driving Truck" (Activity Code 1) from all the drivers and report the results of the activity and its duration by drivers.

*Medications/Caffeine Use.* Participants were instructed to record their daily medication(s) and drink/food intake for items containing caffeine. Medication and caffeine use were recorded on daily activity registers and those recordings were manually entered into the NTDS database. The database contained information about the medication and caffeine use, including time of use, name of product, and amount/dosage. Each instance of medication and/or caffeine use was labeled as one of the types listed in Table 6. When the product or medicine had two major components, it was entered in the database under the two separate types. For example, the medicine "Advair®" (for asthma treatment) has two main components, corticosteroid (250 milligrams [mgs]) and bronchodilator (50 mg); therefore, Advair® was entered into the database twice, one with corticosteroid as the medicine type and the other with bronchodilator as the medicine type.

**Table 6. Type of medications/caffeine use, in alphabetical order..**

| Types of Medications/Caffeine Use (A-D) | Types of Medications/Caffeine Use (E-V) |
|---|---|
| Attention-Deficit-Related | Expectorant |
| Analgesic | Finasteride |
| Anesthetic | Herbal/Natural |
| Antacid/Heartburn | Hormonal |
| Anti-Inflammatory | Immunosuppressive |
| Antibiotic | Laxative |
| Antidepressant | Narcotic |
| Antihistamine | Prostate-Related |
| Antihypertensive | Sedative |
| Antipsychotic | Steroid—Corticosteroid |
| Antitussive | Stimulant—Amphetamine |
| Barbiturate | Stimulant—Caffeine |
| Blood Pressure | Stimulant—Other |
| Bronchodilator | Thyroid |
| Cholesterol-Related | Vitamin |
| Cold Remedy | Vitamin—Cholesterol |
| Coronary-Related | |
| Decongestant | |
| Depressant—Alcohol | |
| Depressant—Other | |
| Diabetes-Related | |
| Diuretic | |

The NTDS database has functions to search participants' medications and caffeine use and report the results by participant number, type of medication(s), product name, and on-/off-duty shifts. For example, the database can search "coffee" intake from all the participants and report the results of coffee intake, date and time of usage, and the activity.

#### *4.1.5.3 Debriefing Interview*

Transcriptions of the debriefing interviews were entered into the NTDS database by researchers. All drivers who completed 4 weeks of data collection were interviewed after their data collection was completed.

#### *4.1.5.4 Screening Data and Load Histories*

The screening data (e.g., vision, hearing, height, weight, BMI, frame size) and load histories were entered into the NTDS database as they were collected.

#### *4.1.5.5 Actigraphy Data*

Actigraphy data were successfully collected from the majority of drivers (97 out of 100) who finished their 4-week data collection. More than 65,000 hours (100 files) of actigraphy data were collected. After a raw data file (.ami) was downloaded from a driver's actigraphy device, the raw file was uploaded to the "Incoming Data" folder on the server and then sorted into the individual driver's folder. The file downloaded on the last day of data collection was considered the final raw file. The final raw file from each driver was analyzed to calculate the duration of sleep or waking periods during his/her participation in the study. All these data were entered into a database, which can be queried for future analyses.

#### *4.1.5.6 Psychomotor Vigilance Test Data*

A raw PVT file was uploaded to the “Incoming” folder on the server. The authors used software to view the results of each trial. Figure 20 displays an example of a PVT output. The numerical outputs for each PVT trial were copied into the NTDS spreadsheet and stored on the network server.

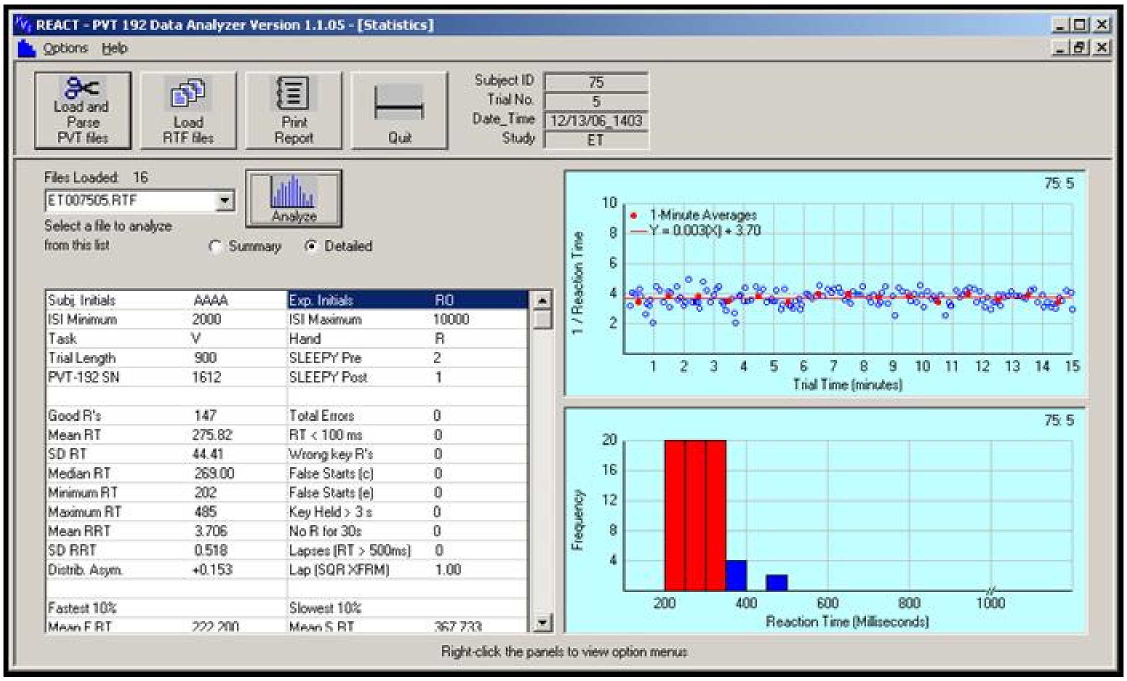



**Figure 20. Screenshot. Example of PVT result.**

### 4.1.6 Data Reduction and Analysis Software

The Data Analysis and Reduction Tool (DART) software was used to support analyses of the on-road data collected in the NTDS. The following sections provide details of this software, including screen shots of the user interface.

#### *4.1.6.1 Data Directory*

As in the analysis of motor vehicle crashes from PARs, the analysis of other safety-significant events begins with the development and adoption of a data directory listing all variables (e.g., weather) and specific data elements for each variable (e.g., clear, rain, snow, fog, etc.). All events were coded based on the data directory; once they were coded, comparisons were made on variables or data elements in the directory.

The data directory included classification variables relating to each overall event, to the subject vehicle (truck) and driver, and (to a limited extent) the other involved vehicle/driver or non-motorist. Specification of the data directory was critical since it defined and delimited the possible analyses from the data. The authors had discussions with FMCSA personnel regarding the format of the data directory and the elements to be included. The data directory presented in this report was the result of these discussions and of development during Phase I (i.e., the data directory was refined as new events and/or conditions arose in Phase I).[9] The data directory includes variables from the General Estimates System (GES), Fatality Analysis Reporting System (FARS), the Large Truck Crash Causation Study (LTCCS), and the 100-Car Naturalistic Driving Study.[25,26,27,28]

Three primary steps were involved in performing the data reduction and analysis of events captured in the NTDS:

1. Running the event trigger program.
2. Checking the validity of the triggered events.
3. Applying the data directory to the validated events.

These steps are described in detail below.

### 4.1.7 Running the Event Trigger Program

The first step in the data reduction process was to identify events of interest, including crashes, near-crashes, and crash-relevant conflicts. Each of these events might or might not have involved an interaction with another vehicle. DART was used to find events of interest by scanning the dataset for notable actions, including hard braking, quick steering maneuvers, short TTC, and lane deviations. To identify these actions, threshold values (triggers) were developed. Table 7 displays the seven triggers and their event signatures.

**Table 7. Triggers and trigger values used to identify critical incidents.**

| Trigger Type | Definition | Description |
|---|---|---|
| Longitudinal Acceleration (LA) | Hard braking or sudden acceleration | Acceleration or deceleration greater than or equal to $\lvert 0.20\ g \rvert$. Speed greater than or equal to 1 mi/h (1.6 km/h). |
| Time-to-Collision (TTC) | The amount of time (in seconds) that it would take for two vehicles to collide if one vehicle did not perform an evasive maneuver. | A forward TTC value less than or equal to 2 seconds, coupled with a range less than or equal to 250 ft, a target speed greater than or equal to 5 mi/h (8 km/h), a yaw rate less than or equal to $\lvert$6/second$\rvert$, and an azimuth less than or equal to $\lvert 0.12 \rvert$. |
| Swerve | A sudden "jerk" of the steering wheel to return the truck to its original position in the lane. | Swerve value greater than or equal to 2 rad/s$^2$. Speed greater than or equal to 5 mi/h (8.05 km/h). |
| Lane Deviation | Any occasion on which the truck aborts crossing the lane line and returns to the same lane without making a lane change. | Lane-tracker status = abort. Distance from center of lane to outside of lane line < 44 inches. |
| Critical Incident Button | A self-report by the driver of an incident. | Activated by the driver by pressing a button, located by the driver's visor, when an incident occurs that he/she deems critical. |
| Analyst-Identified | An event that is identified by the analyst but has not been identified by a trigger. | Event identified by a data analyst viewing video footage; no other trigger listed above identified the event (i.e., longitudinal acceleration, TTC, etc.). |

These event signatures, or trigger types, were selected based on data collected in the 100-Car Study.[28] They were refined to reflect heavy-vehicle kinematics during the DDWS FOT study and subsequently improved for the NTDS. The first five trigger types are parametric variables, while the last two (incident button and analyst-identified) are non-parametric (Yes or No).

#### *4.1.7.1 Checking the Validity of the Triggered Events*

The DART software scanned the dataset and flagged potential events of interest with a trigger for review. A 75-second epoch was created for each trigger (an epoch consisting of 1 minute prior to trigger and 15 seconds after trigger). The result of the automatic scan was an event dataset that included both valid and invalid events.

Valid events were those in which recorded dynamic-motion values actually occurred and were verifiable in the video and other sensor data from the event (also identified by critical incident button or by analyst). Invalid events were those in which sensor readings were spurious, caused by a transient spike or some other anomaly (false positive). The validity of all events was determined through video review. Events determined to be invalid were not analyzed further. Valid events continued to be analyzed and classified as conflicts or non-conflicts. Conflicts were valid events that also represented a traffic conflict (i.e., crash, near-crash, crash-relevant conflict). Non-conflicts were events that did not create safety-significant traffic events, even though their trigger values were valid ("true triggers"). To reiterate, in non-conflict events, the sensor reading was correct (that is, the recorded vehicle acceleration occurred), but no actual traffic conflict occurred. Examples of valid events that were non-conflicts include hard braking by a driver in the absence of a specific crash threat or a high swerve value from a lane change not resulting in any loss of control, lane departure, or proximity to other vehicles. While such situations sometimes reflected at-risk driving habits and styles, they did not result in a discernible crash-relevant conflict.

To determine the validity of the events, data analysts observed the recorded video and data plots of the various sensor measures associated with each 75-second epoch. The vehicle sensor measures, represented in pull-down menus in the software program, are shown in Figure 21.

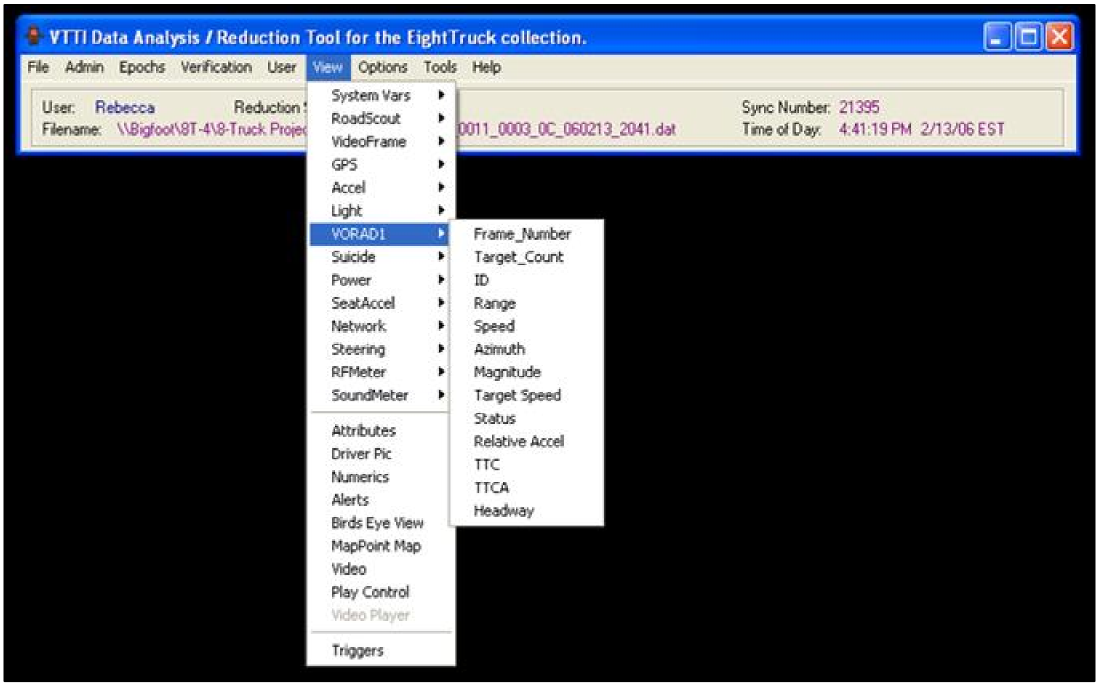



**Figure 21. Screenshot. Plots to aid in determining the validity of triggered events.**

Please note that the lower the trigger values were set, the more false-positive events, non-conflict events, and less-severe conflicts (i.e., crash-relevant conflicts) occurred. The trade-off for the increased number of false positives was that lower trigger values resulted in relatively few missed valid events. The goal of setting the lower, optimum trigger value was to identify all of the most severe events (crashes and near-crashes) without having an unmanageable number of false-positive events, non-conflict events, and low-severity conflict events.

Figure 22 shows an example of a valid trigger for longitudinal acceleration. In this example, the Trigger Chart shows the trigger at the same point that the Accel_X plot shows the value reaching -0.26 *g*, indicating a sharp deceleration of the vehicle. For this example, the longitudinal acceleration trigger was set at ± 0.20 *g*; therefore, any time the software detected a longitudinal acceleration of magnitude greater than ± 0.20 *g*, a trigger was created. Looking closely at the video in the top right quadrant in Figure 22, a vehicle can be seen in front (and to the right) of the subject vehicle. At this point, a Jeep has begun to change lanes, crossing a solid lane line, directly into the lane in front of the instrumented vehicle, and the driver of the instrumented truck brakes to avoid the Jeep.

**Figure 22. Screenshot. Example of a validated trigger for longitudinal acceleration.**

Figure 23 shows an example of a non-conflict that had a valid swerve (quick steering) trigger. During this event, the driver was pulling off onto the side of the road. The Trigger Chart shows that the trigger appeared when the swerve value reached 2.01 (the value for this trigger was set at ≥ 2.0). After reviewing the video, it was seen that there were no vehicles in front of or to the side of the instrumented vehicle, and that the driver was simply pulling off onto the side of the road.

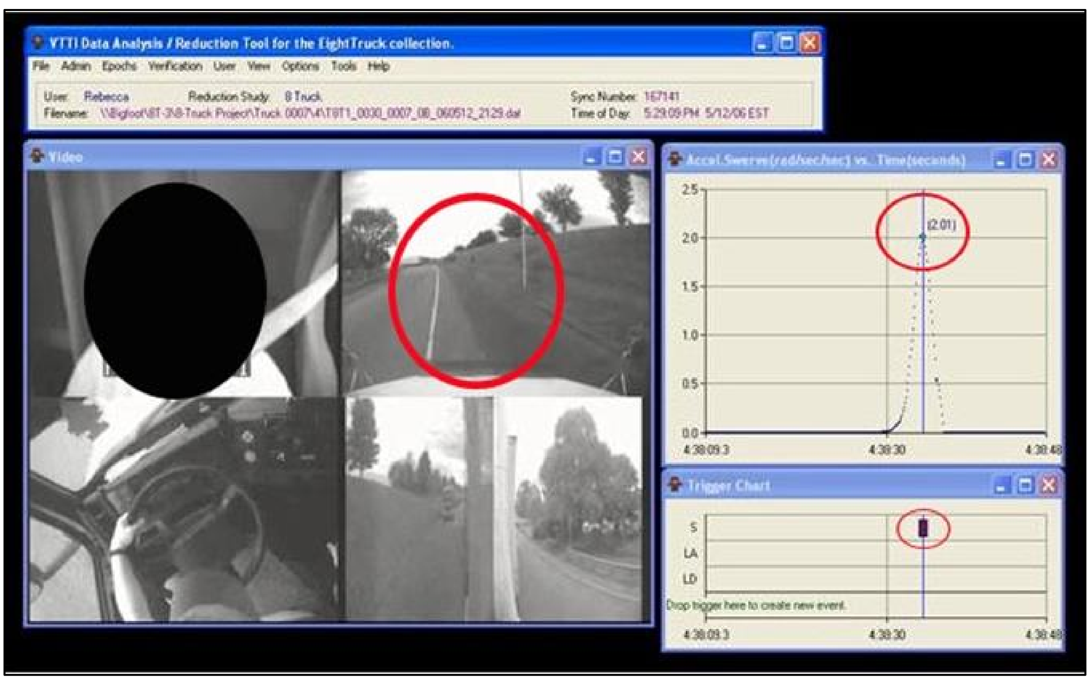


**Figure 23. Screenshot. Example of a non-conflict event (with a valid trigger) where the driver's swerve (quick steering) was 2.01 (trigger set to ≥ 2.0).**

#### *4.1.7.2 Applying the Data Directory to the Validated Events*

An event-coding data directory was used to reduce and analyze valid events. The software presented the data analyst with a series of variables consisting either of a blank space for entry of specific comments (e.g., event comments) or pull-down menus for the data analyst to select the most applicable code (i.e., number corresponding to a data element). Different variables had different coding rules. For most, only one code could be selected. For a few variables, however, the data analyst could select up to four applicable codes. For example, data analysts could select multiple potential distraction behaviors.

#### *4.1.7.3 Baseline Events*

A random sample of 456 baseline events, each 30 seconds in length, was selected for data reduction. Data reductionists used the data directory and coded a variety of variables from these 456 randomly selected baseline driving events or brief driving periods. Ordinarily, one random baseline event was selected for each driver-week of data collection. Baseline events were described using many of the same variables used to describe SCEs. In particular, their conditions of occurrence were recorded.

#### *4.1.7.4 Classifying a Validated Event to a Safety-critical Event Type*

All the validated events were classified as one of the six SCEs: crash, crash—tire strike, near-crash, crash-relevant conflict, unintentional lane deviation, and illegal maneuver. Descriptions for all event types are listed in Table 8.

**Table 8. Description of each event type.**

| Event Type | Description |
|---|---|
| Crash | Any contact with an object, either moving or fixed, at any speed. |
| Crash: Tire Strike | Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated where the contact occurs on the truck's tire only. No damage occurs during these events (e.g., a truck is making a right turn at an intersection and runs over the sidewalk/curb with a tire). |
| Near-crash | Any circumstance that requires a rapid, evasive maneuver (e.g., hard braking, steering) by the subject vehicle or any other vehicle, pedestrian, pedalcyclist, or animal, in order to avoid a crash. |
| Crash-relevant Conflict | Any circumstance that requires, on the part of the subject vehicle, any other vehicle, pedestrian, pedalcyclist, or animal, a crash-avoidance response that was less severe than a rapid evasive maneuver (as defined above), but greater in severity than a normal maneuver. A crash-avoidance response can include braking, steering, accelerating, or any combination of control inputs. |
| Unintentional Lane Deviation | Any circumstance in which the subject vehicle crosses over a solid lane line (e.g., onto the shoulder) where no hazard (guardrail, ditch, vehicle, etc.) is present. |
| Illegal Maneuver | Any circumstance in which either the subject vehicle or the other vehicle performs an illegal maneuver such as passing another vehicle across the double yellow line or on a shoulder. For many of these cases, neither driver performs an evasive action. |

#### *4.1.7.5 Ensuring Data Coding Accuracy and Reliability*

To support accurate and consistent coding, a quality control procedure was established for the data coding. One inter-rater reliability "test" was given to each of the data reductionists. The "test" consisted of 10 events that were used to assess coding accuracy and inter-rater reliability of the coding. These events included some combination of crashes (if available), near-crashes, crash-relevant conflicts, and unintentional lane deviations. Baseline events were not used as test events because their codes were a smaller and less problematic subset of the codes for other events. The 10 test events were selected to include a variety of scenarios (e.g., truck-only versus two-vehicle) and potential coding issues.

Each of the 10 test events was coded by an expert analyst (e.g., key project personnel) who verified the correct coding for each variable in the data directory. Next, each data analyst coded the 10 events, and their codes were compared to those of the expert analyst. The results helped to determine whether analysts were correctly coding the events, and identified data analysts who were making more frequent coding errors. Those data analysts received additional training, supervision, and quality control oversight. Analyst judgment always plays a role in the coding of some variables, but the goal is to make all coding guidelines and decision rules as explicit as possible.

In addition to the inter-rater reliability test, spot checking was conducted on all of the coded events. Each analyst was provided with data from a driver (which he/she did not previously code for) and checked 10 percent of the events coded. If the analyst found any discrepancies, he or she was asked to note these in a log file; a third person reviewed the notes and made any necessary changes. Analysts were informed of discrepancies and retrained as needed. All valid events were evaluated by experienced researchers as the final step before being accepted into the final dataset.

### 4.1.8 Technical Problems Encountered

#### *4.1.8.1 Technical Problems with Data Acquisition System*

The DAS performed exceptionally well in the areas of system reliability (e.g., the DAS booting up each time an ignition signal was received and capturing data during the driver's logged driving times) and validity (e.g., recording data and video files matching the participants' driving time recorded in the daily activity register and having the minimum established views or readings). At times, the DAS operation and collection capabilities were hampered by events routinely encountered in the naturalistic environment of commercial truck operations. These were events outside the authors' control. Some events contributing to minor loss of collected data included:

- Downtime for truck maintenance—both periodic and unscheduled, during which times the participant operated a non-instrumented truck.
- Disruption of orientation or alignment of sensors/cameras due to replacement of windshields or other surfaces on which components were mounted.
- Damage to cameras and sensors due to impacts, collisions, or accidents.
- Intentional driver interference and misalignment by non-participants operating the truck during equipment shortages or participant absence.
- Lack of access to be able to repair or replace system components, whether component failure was component-related or externally induced, due to extended truck operation by the participant when assigned to priority loads.

Despite these issues, overall DAS operational reliability (the system booting up each time an ignition signal was received) was 88.9 percent. The overall reliability of the DAS in collecting usable data during times of operation was 93.6 percent across all instrumented trucks. See Table 9 for the DAS operational reliability and usable data for each instrumented truck. Note that the DAS collected data only while it was operational; thus, the percentage of usable data in column 3 of Table 9 reflects the percentage of usable data while the DAS was operational.

**Table 9. Percentages of DAS operational reliability and usable data by instrumented truck.**

| Truck Number | % of DAS Operational Reliability | % of Usable Data Collected |
|---|---|---|
| 1 | 74.1% | 90.5% |
| 2 | 86.1% | 98.6% |
| 3 | 96.9% | 99.5% |
| 4 | 98.2% | 98.4% |
| 5 | 96.2% | 97.3% |
| 6 | 87.0% | 94.1% |
| 7 | 86.4% | 90.4% |
| 8 | 89.1% | 72.7% |
| 9 | 93.5% | 99.5% |
| **Overall %** | **88.9%** | **93.6%** |

#### 4.1.8.2 Technical Problems with Actigraphy Device

As noted, the NTDS used the actigraphy device to collect actigraphy data. Throughout 18 months of data collection, nine actigraphy devices had mechanical or data-quality problems. All nine of these "broken" devices were returned to AMI for technical repair, and nine new devices were delivered as replacements. Of the nine "broken" devices, problems were found in two during a pilot test with researchers, whereas problems with the remaining seven devices occurred while they were being worn by drivers. Table 10 lists the frequency of technical problems identified in the nine devices returned to AMI for repair.

**Table 10. Type of technical problems with the actigraphy devices.**

| Problems | Number of Devices |
|---|---|
| No data were collected after successful initialization; the status became "Not calibrated" on downloading data. | 4 |
| No data were collected after successful initialization; the interface does not recognize the watch on downloading data. | 1 |
| Partial data were not collected after successful initialization. | 1 |
| Unexpected data (e.g., a thick line with activity levels on the 20s instead of flat line with level=0 when driver removed the watch). | 2 |
| Downloaded data file cannot be opened. | 1 |
| **Total number of devices returned to AMI** | **9** |

The most common problem encountered was the lack of partial or entire data collected from an actigraphy device after being successful initialized. From the seven actigraphy devices that malfunctioned during the study (the other two malfunctions were during pilot testing), a total of 84 days of data were lost (3 percent). Approximately 2,700 days of data were collected.

To help prevent loss of actigraphy data, the authors implemented a variety of verification procedures to ensure that the actigraphy device initialization was successful. The verification process checked the following:

- The battery in the device.
- Successful initialization (i.e., it verified that the device was collecting data on the accompanying software).
- Device status (i.e., it verified that the device was "calibrated").
- The memory status (i.e., it verified that the status was "OK").

If any of these verification procedures was not met, the device was considered incapable of collecting data and was returned to AMI.

## 4.2 LESSONS LEARNED

The following section presents the lessons learned from the NTDS, as well as suggestions for future naturalistic studies with CMV drivers. These suggestions are classified by the following:

- Fleet logistics.
- Drivers.
- Activity registers.

### 4.2.1 Fleet Logistics

On occasion, truck drivers and companies expressed reservations and decided not to participate in the study, due to the possible impact on driver and company. Their concerns included the following:

- Lost revenue due to restricted operation for drivers' load and route, attributed to weekly or bi-weekly meetings with project personnel.
- Invasion of privacy of company operations.
- Additional workload by management, maintenance, and drivers to schedule drivers and accommodate interactions with project personnel.
- Additional logistics required for management to find, schedule, and reassign drivers, as well as limited availability of the instrumented truck for delivery due to dedication of the truck to the study.

The potential lost revenue may fall short of the compensation offered to study participants. This information could prove valuable in future recruitment efforts. It may also be beneficial to estimate the minimum study length to minimize the impact on driver and company workload for logistics.

### 4.2.2 Drivers

#### *4.2.2.1 Bonus Qualification*

The requirements used for the bonus payment were often missed by drivers by a slight margin. The most common violations were drivers not wearing their actigraphy device and/or drivers not completing daily activity registers appropriately. However, these violations were rather minor and no financial penalty was assessed (i.e., no loss of bonus). Drivers looked forward to the bonus, so minor problems were not considered. Because drivers communicated with each other, recruiting future participants might have been more difficult if payments were reduced for minor infractions such as wearing the actigraphy device 1 day less than the minimum and/or completing the daily activity register with a few entries less than the minimum required.

#### *4.2.2.2 Actigraphy Device*

Many drivers not accustomed to wearing wristwatches found the actigraphy device uncomfortable. In one case, the driver was not able to sleep with the actigraphy device on his wrist. However, after a few nights of wearing the device, the driver became more accustomed to it and wore it for the duration of the study. It is recommended that a smaller, less bulky device be used in future studies, if possible.

#### *4.2.2.3 Driver's Attachment to His or Her Truck*

Some drivers refused to participate because they were told that they would have to drive the instrumented trucks during the study rather than their own trucks. This presented a barrier to recruiting. It may be preferable to involve companies that do not assign drivers to trucks. In addition, if funds are available for a more involved instrumentation process, the study may instrument the drivers' trucks instead of a study-focused truck where drivers rotate as needed.

#### *4.2.2.4 Equipment Sabotage by Non-participant Drivers*

Equipment in the trucks was occasionally vandalized by drivers who drove the instrumented trucks but were not participants in the study (i.e., slip-seat or replacement driver situations). Although we are aware that no data were being collected from non-participant drivers, we believe that non-participant drivers caused the sabotage. For future studies, researchers may continue to make non-participant drivers aware that no data are being collected from them during their drives, and ask them to avoid touching the equipment.

#### *4.2.2.5 High-security Areas*

One driver's route took him into a high-security area where video recordings were not allowed. This presented problems with the data collection systems in the instrumented truck. For future studies, the possibility of entering high-security areas may be ascertained prior to participation so that the necessary arrangements can be made with the administrators of high-security areas.

#### *4.2.2.6 Driver Availability During Participation*

Some drivers ran out of pages in their daily activity registers, despite having 16 pages (i.e., 16 days) in each book. This occurred infrequently; when it did occur, it was caused by the inability of the researcher to arrange a timely meeting with the driver. To ensure that drivers have access to new daily activity registers or other necessary materials, it might be worthwhile to provide selected company representatives with access to these materials. For this study, it was not feasible because of budgetary constraints. Companies were not compensated for their participation and no terminal assistants were available in the scope of this study.

#### *4.2.2.7 Drivers Who Can Drive Only Automatic Transmissions*

All of the instrumented trucks had manual transmissions, but participants who had recently obtained their CDLs were capable of driving only automatic transmissions. The manual transmissions in the instrumented trucks reduced the number of drivers eligible to participate in the study. These types of drivers are not the majority, but they are certainly needed and might be represented in future studies. To avoid this issue, future studies might consider including trucks with automatic transmissions.

#### *4.2.2.8 Activity Registers*

**Quality of activity codes:** The majority of the drivers filled out the activity registers appropriately. However, some drivers completed their daily activity registers with few activity codes per day (e.g., Code 1, Driving Truck for 13 hours from 12:30 a.m. to 1:30 p.m.; Code 3, Sleep, for 11 hours from 1:30 p.m. to 12:30 a.m.). Those drivers were still qualified to receive a bonus because the total number of hours for “blank (no entry)” was low, even though one activity code persisted for many hours. Even though these drivers were trained and retrained when the problem was identified, in future studies, additional training, feedback, and detailed examples of acceptable and non-acceptable entries might increase the quality of daily activity register entries.

**Code for driving non-instrumented vehicle during on-duty shift:** Participants occasionally drove vehicles other than the assigned instrumented trucks to make deliveries during their on-duty periods. They correctly marked Code 1 for “Driving Truck,” which was the only code available for driving during their on-duty period. Some participants made notes in their daily activity registers about driving non-instrumented trucks, but they did not do so each time. Creating a new code for “Driving Non-Instrumented Truck” during on-duty shifts would identify the time periods when the participant was actually driving a non-instrumented vehicle during work hours.

**Code for shower:** Some drivers indicated that they would like to have an activity code for showering/bathing. Drivers indicated that they entered the code “Other” when they took showers. Future studies might add more activity codes for more routine activities, such as showering.

[This page intentionally left blank.]

# 5. RESEARCH QUESTIONS

The main objective of this research effort was to collect data and to identify and evaluate SCEs. Naturalistic data collection provides the opportunity to answer a myriad of research questions. As part of this study, all the data collected were analyzed in terms of SCEs. Based on those events, four main sets of questions were answered. This section presents the research questions that are part of this study.

In addition to the data reduction effort to obtain the SCEs, several other data analyses were performed in order to obtain the measurements needed to answer these four sets of questions. This section presents the research questions, as well as some details about the additional analyses needed.

## 5.1 RESEARCH QUESTIONS

In addition to the data collection, reduction, and analysis of SCEs (the main objective of this study), several research questions were investigated. The focus of these questions is on the SCEs; therefore, all the data were calculated or evaluated taking into consideration the SCEs or baseline events. The following are the research questions that were answered based on the current data analysis effort:

- Restart period and SCEs.
  - How much time do drivers take off during their off-duty restart periods before a SCE?
  - Is there a relationship between restart periods and SCEs?
  - Is time from restart related to the type of SCE?
- Sleep pattern and SCEs.
  - How many hours of sleep did the driver have 24 hours before the SCE?
  - How many hours of sleep did the driver have since restart, before the SCE happened?
  - What are the characteristics of the rest period preceding the SCEs (e.g., single sleep period, multiple sleep periods)?
  - Was the rest period before the SCE taken on-duty or off-duty?
- Vehicle interactions by type of maneuver.
  - Based on the SCEs obtained, and as a function of the incident type, which vehicle is "at fault" (i.e., either the instrumented truck [V1] or the other vehicle [V2])?
  - For V2, what type of vehicle is more frequently involved in SCEs (i.e., light vehicle or another heavy vehicle)?
- Functional countermeasures.
  - What are the functional countermeasures that might have ameliorated the critical incident?

The answers to these research questions are presented in Section 6.

## 5.2 OPERATIONAL DEFINITIONS AND DATA ANALYSES

### 5.2.1 Operational Definitions

Below are some additional measurements used to answer the research questions for this study. These measurements are used as a reference point for the beginning of a SCE or a baseline (B) event trigger. Figure 24 shows a graphical representation of all the measurements with respect to the SCE or B point. Please note that all these measures are retrospective; therefore, they are relative to the SCE or B point (right side of the figure) and look back in time.

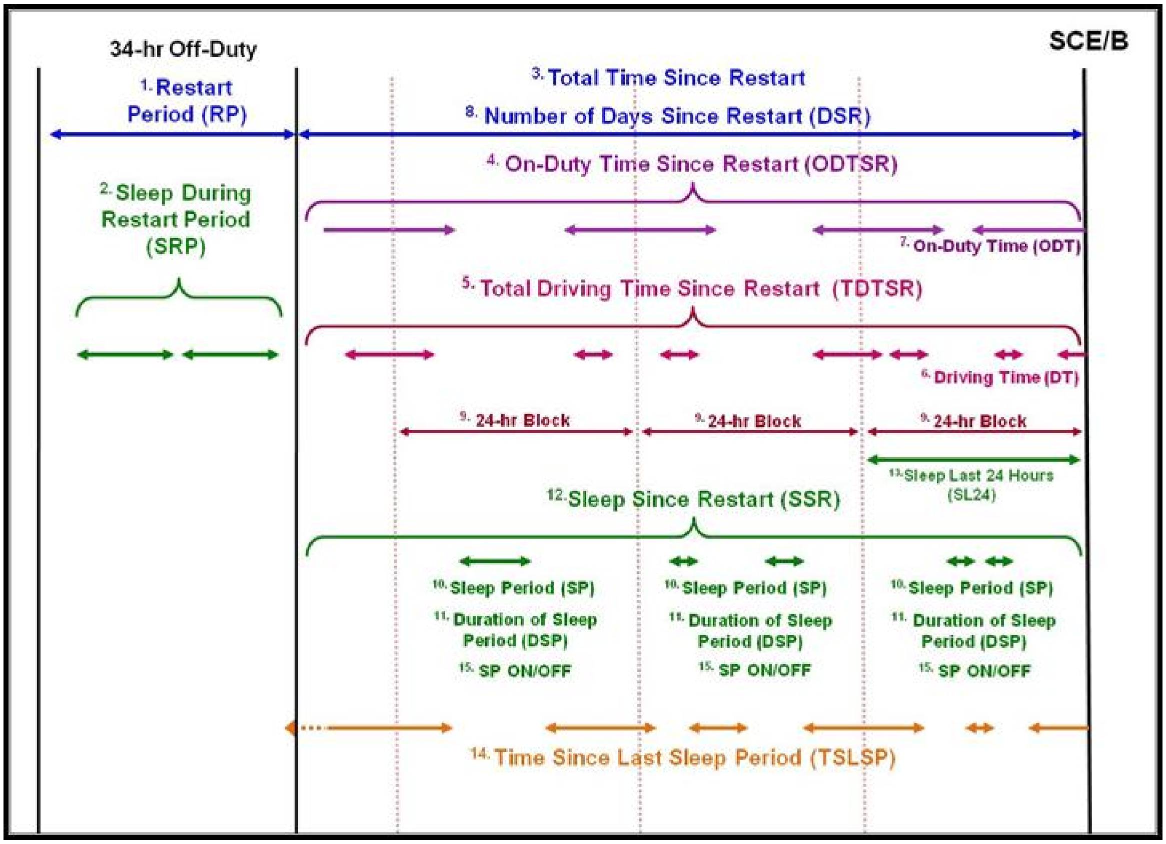



**Figure 24. Flowchart. Variable representation using the SCE or baseline event (right) as a reference point.**

#### *5.2.1.1 Duration of Restart Period*

***Operational definition***: Total time the driver was off-duty during the restart period that preceded the SCE/B of interest.

***Dataset***: Driving performance database to determine the time of the SCE/B of interest and activity register database to determine the restart period.

#### *5.2.1.2 Sleep During Restart Period*

***Operational definition***: Total sleep during restart period.

***Dataset***: Actigraphy database to determine sleep durations and activity register database to determine restart periods.

#### 5.2.1.3 Total Time Since Restart to Safety-critical Event/Baseline Event

***Operational definition***: Total time since restart (TTSR) from the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time). These included all on- and off-duty activities.

***Dataset***: Driving performance database for the beginning of the SCE/B and activity register database for the end of the restart period.

#### 5.2.1.4 On-duty Time Since Restart to Safety-critical Event/Baseline Event

***Operational definition***: Duration of all on-duty periods since restart (ODTSR) from the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time).

***Dataset***: Driving performance database for the beginning of the SCE/B and activity register database for the end of the restart period.

#### 5.2.1.5 Total Driving Time Since Restart to Safety-critical Event/Baseline Event

***Operational definition***: Total on-duty driving time since restart (TDTSR). These are all the codes “1-Driving Truck” marked under “Shift Number” after the restart period that precedes the SCE/B of interest. This variable is the sum of time marked as “1” in the activity register database.

***Dataset***: Driving performance database for the beginning of the SCE/B and activity register database for the end of the restart period.

#### 5.2.1.6 Driving Time to Safety-critical Event/Baseline Event

***Operational definition***: Total on-duty driving time in the current shift containing the SCE/B of interest. These are all the codes “1-Driving Truck” marked for the “Shift” that is part of the SCE/B of interest. This variable is the sum of time marked as “1” in the activity register database.

***Dataset***: Driving performance database for the beginning of the SCE/B and activity register database for the code “1” and shift information.

#### 5.2.1.7 On-duty Time to Safety-critical Event/Baseline Event

***Operational definition***: Total on-duty time (ODT) in the current shift containing the SCE/B of interest.

***Dataset***: Driving performance database for the beginning of the SCE/B and activity register database for the beginning of the shift.

#### 5.2.1.8 Number of Days Since Restart

***Operational definition***: Number of days since restart from the beginning of the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time).

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B and activity register database for the end of the restart period.

#### *5.2.1.9 24-hour Block*

***<u>Operational definition</u>***: A numerical count of each 24-hour block (24HB) from the beginning of the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time), where 24HB = 1 is the first block of 24 hours before the event of interest.

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B of interest and activity register database for the end of the restart period.

#### *5.2.1.10 Sleep Period*

***<u>Operational definition</u>***: A numerical count of each sleep period between the beginning of the SCE/B of interest and the end of the restart period that precedes the event of interest (i.e., looking back in time), where sleep period = 1 is the first sleep period before the event of interest.

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B, actigraphy database to determine sleep durations and activity register database to determine restart period.

#### *5.2.1.11 Duration of Sleep Period(s)*

***<u>Operational definition</u>***: Duration of each sleep period (DSP) from the beginning of the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time).

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B, actigraphy database to determine sleep durations and activity register database to determine restart period.

#### *5.2.1.12 Sleep Since Restart*

***<u>Operational definition</u>***: Total sleep since restart from the beginning of the SCE/B of interest to the end of the restart period that precedes the event of interest (i.e., looking back in time).

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B, actigraphy database to determine sleep durations and activity register database to determine restart period.

#### *5.2.1.13 Sleep Last 24 hours*

***<u>Operational definition</u>***: Total sleep 24 hours before the SCE/B of interest (i.e., 24HB = 1) or sum of all DSPs under 24HB = 1.

***<u>Dataset</u>***: Driving performance database for the beginning of the SCE/B and actigraphy database to determine sleep durations.

#### *5.2.1.14 Time Since Last Sleep Period*

***<u>Operational definition</u>***: Period of time from the end of the last sleep period (TSLSP) to the beginning of the next.

***Dataset***: Actigraphy database to determine sleep durations.

#### *5.2.1.15 Sleep Period On-/Off-duty*

***Operational definition***: Whether the sleep period was taken on-duty or off-duty (SP On/Off).

***Dataset***: Actigraphy database to determine sleep period begin and end times and activity register database to determine on-/off-duty.

Table 11 provides an example of some of the sleep measures taken during a 24-hour time period.

**Table 11. Short example of some sleep measures of interest in a 24HB.**

| Event ID | Driver ID | 24HB | Sleep Period | Duration of Sleep Period (minutes) | Time Since Last Sleep Period | Sleep Period On-/Off-Duty |
|---|---|---|---|---|---|---|
| 520 | 5 | 1 | 1 | 480 | 720 | On |
| 520 | 5 | 2 | 1 | 240 | 600 | Off |
| 520 | 5 | 2 | 2 | 120 | 180 | Off |

### 5.2.2 Activity Register Validation

As part of the development of the operational definitions, a validation of the actual driving time vs. the reported driving time in the study’s activity register was performed. The validation of the driving data was done by randomly selecting 10 drivers, and randomly sampling 2 driving episodes for each of the 10 drivers. An episode was a driving period or trip as marked by the driver in the activity register. These episodes varied in length, depending on the delivery route and\or type of operation. For each of these driving episodes, the video for that day and time was viewed in DART and examined to determine how long the driver was actually driving during that time period. This time was recorded, as was the corresponding activity register time, and the difference was calculated. Since the activity register allows for the time spent on any activity to be rounded to the nearest quarter of an hour, a difference of less than 30 minutes would be equivalent to no difference. A 95-percent confidence interval was constructed for the mean, and a hypothesis test was performed assuming normality. Figure 25 presents the output of this analysis.

**Log Book vs. Actual Drive Time: One Sample t-test for a Mean**

**Sample Statistics for Difference**

| N | Mean | Std. Dev. | Std. Error |
|---|---|---|---|
| 20 | 5.60 | 16.22 | 3.63 |

**Hypothesis Test**

| Null hypothesis | Alternative |
|---|---|
| Mean of Difference ≥ 30 | Mean of Difference < 30 |

| *t* Statistic | DF | Prob > *t* |
|---|---|---|
| -6.729 | 19 | <.0001 |

**95% Confidence Interval for the Mean**

| Lower Limit | Upper Limit |
|---|---|
| -1.99 | 13.19 |

**Figure 25. Diagram. Output for the activity register driving time using the activity register data.**

The results of this validation suggest that the mean of the difference between the activity register driving-time data and the actual driving-time data for the 20 instances that were used is 5.60 minutes (SE = 3.63 minutes). A 95-percent confidence limit was constructed; the lower confidence limit (LCL) is -1.99 and the upper confidence limit (UCL) is 13.19. Therefore, it was concluded that the difference between the activity register and the actual driving data is not statistically significant. A power analysis was also performed on these results using the following equation:

$$\text{Power} = \text{Probability}\,(t > t_{crit\text{-}U},\ \theta,\ NC) + \text{Probability}\,(t < t_{crit\text{-}L},\ \theta,\ NC)$$

Where $t$ is distributed as noncentral $t$ $(NC, \theta)$

$$t_{crit\text{-}U} = t_{(1\text{-}\alpha/2,\ \theta)} \textit{ is the } (1\text{-}\alpha/2) \textit{ quartile or upper quartile of the t distribution with } \theta \textit{ df}$$

$$t_{crit\text{-}L} = t_{(\alpha/2,\ \theta)} \textit{ is the } (\alpha/2) \textit{ quartile or lower quartile of the t distribution with } \theta \textit{ df}$$

$$\theta = n\text{-}1 \textit{ or the degrees of freedom}$$

$$NC = \delta\sqrt{n} \textit{ is the noncentrality parameter}$$

$$\delta = |s_\alpha - \mu_o|/s$$

$$s = \textit{standard deviation}$$

**Figure 26. Formula. Equation for determining statistical power.**

Using 16.22 minutes as an estimate for the standard deviation and a sample size of 20, the power of this is 0.999.

A process similar to the visual inspection that compared driving data to activity register driving time was performed for the full database. This process was automated by identifying the starting time at which the driver began driving the instrumented vehicle and the end of the drive (based on vehicle speed), and comparing those times to those in the activity register database. This process was applied to 17,353 files of driving data. The comparison with the activity register data suggested that there was a mean difference of 4.3 seconds (SE = 0.063 seconds) with a 95-percent confidence interval of 4.1–4.4 seconds. This suggests that the data in the activity register accurately reflect the driving data available.

By taking advantage of the activity register data and the actigraphy data, a more detailed validation procedure could be performed as part of future research in order to explore aspects such as perceived time slept vs. actual time slept.

### 5.2.3 Analysis of Actigraphy Data

Actigraphy data collected were used to measure sleep quantity for the participating drivers. As mentioned earlier, actigraphy data were successfully collected from the majority of drivers (97 out of 100) who completed data collection. More than 65,000 hours of actigraphy data were collected from 97 drivers. For each actigraphy file the following steps were taken to obtain the above-delineated sleep measures:

1. Identifying and marking any “bad data” episodes (e.g., driver takes actigraphy device off to shower).
2. Marking sleep and wake episodes.
3. Converting data into minute-by- minute files with “sleep,” “wake,” and “incorrect” already coded.
4. Importing all data into the actigraphy database.
5. Implementing the algorithm to identify sleep periods.

All the actigraphy data obtained as part of this study have been processed and marked according to the previous steps, and the operational definitions were used to develop the measures of interest for the different analyses related to sleep.

[This page intentionally left blank.]

# 6. RESULTS

This section presents the results, divided into two major sections:

- General descriptive analyses.
- Answers to research questions.

The first section describes the types of trucks instrumented, driver demographics, and a summary of the driving data obtained in this study. The second section goes over each of the four sets of research questions and the results obtained from the data analyses needed in order to answer each question.

## 6.1 GENERAL DESCRIPTIVE ANALYSES

### 6.1.1 Companies and Trucks

A total of nine trucks were instrumented in this study (though only eight trucks were in use at any one time). Table 12 shows the number of trucks per company location as well as the truck type. Those trucks represented three different manufacturers and five models. Two of the nine trucks were day cabs, whereas the remaining seven had sleeper berths.

**Table 12. Number of instrumented trucks per company location.**

| Company Name (Location) | Number of Instrumented Trucks | Truck Year, Make, and Model | Day Cab or Sleeper Berth |
|---|---|---|---|
| Carrier D (Charlotte/Henderson, NC) | 3 | 2005 Freightliner Century Class | Sleeper berth |
| Carrier D (Gordonsville, VA) | 2 | 2005 Freightliner Century Class | Sleeper berth |
| Carrier B (Kernersville, NC) | 1 | 2006 Freightliner Columbia | Day cab |
| Carrier A (Mount Crawford, VA) | 1 | 2004 Volvo 610 | Sleeper berth |
| Carrier A (Roanoke, VA) | 1 | 2004 Volvo VN 430 | Sleeper berth |
| Carrier C (Roanoke, VA) | 1 | 2003 Sterling AT9500 | Day cab |

### 6.1.2 Drivers

A total of 100 drivers participated in this study. Of these, 95 were male and 5 were female. Table 13 shows the number of participating drivers from each company location. The mean age of the drivers was 44.5 years (SD = 12.2 years), and ages ranged from 21 to 73 years old. Table 14 shows the age distribution.

**Table 13. Number of drivers from each company location.**

| Company Name | Location | Number of Drivers |
|---|---|---|
| Carrier D | Charlotte, NC | 36 |
| Carrier D | Henderson, NC | 2 |
| Carrier D | Gordonsville, VA | 24 |
| Carrier B | Kernersville, NC | 6 |
| Carrier A | Mount Crawford, VA | 8 |
| Carrier A | Roanoke, VA | 11 |
| Carrier C | Roanoke, VA | 13 |
| | **Total** | **100** |

**Table 14. Distribution of drivers' ages.**

| Age Group | Number of Drivers |
|---|---|
| 20–29 Years Old | 15 |
| 30–39 Years Old | 19 |
| 40–49 Years Old | 31 |
| 50–59 Years Old | 27 |
| 60–69 Years Old | 4 |
| 70+ Years Old | 4 |
| **Total** | **100** |

As shown in Table 15, the sample of truck drivers was similar to that in an American Trucking Associations study,(29) which reported that 19 percent of truck drivers were minorities.(28) In the current study, the majority of participants were Caucasian (81 percent).

**Table 15. Distribution of drivers' ethnicity.**

| Ethnicity | Percentage of Drivers |
|---|---|
| Caucasian | 81 |
| African American | 14 |
| Native American | 2 |
| Hispanic | 2 |
| Asian American | 1 |
| **Total** | **100** |

Table 16 displays the distribution of drivers by education. All participants reported their education levels. The majority of the drivers reported having high school (or higher) educations. Drivers also indicated their CMV driving experience (see Table 17). More than 50 percent of all drivers had 5 years or less CMV driving experience.

**Table 16. Distribution of drivers by education level.**

| Education Level | Percentage of Drivers |
|---|---|
| Did Not Complete High School | 10 |

| Education Level | Percentage of Drivers |
|---|---|
| High School Graduate | 43 |
| Some College | 32 |
| 2-year Degree | 5 |
| 4-year Degree | 9 |
| Professional Degree | 1 |
| **Total** | **100** |

**Table 17. Distribution of drivers by driving experience.**

| Experience Level | Percentage of Drivers |
|---|---|
| Less than 1 Year | 22 |
| 1–5 Years | 30 |
| 5.1–10 Years | 15 |
| 10.1–15 Years | 9 |
| 15.1–25 Years | 16 |
| 25.1–35 Years | 6 |
| 35.1–45 Years | 0 |
| 45.1–50 Years | 2 |
| **Total** | **100** |

### 6.1.3 Driving Data

More than 14,500 driving hours of valid data were collected during 2,200 driving shifts, with almost 26,000 on-duty hours of activity recorded by drivers in daily activity registers. The instrumented trucks covered nearly 735,000 miles during recorded driving hours, a distance equivalent to 265 transcontinental trips between New York and Los Angeles. Some other interesting statistics on the data collected are presented in Table 18. A shift was defined by the experimental logbook entries. This is different from previous studies, because this type of detail was not available in the past, and the shift was ended in the last driving period. For this study, light work and other on-duty tasks are part of the shift duration.

**Table 18. Driving duration and percentages, shift durations, and driving speed.**

| Category | Average | Standard Deviation | Median |
|---|---|---|---|
| Driving Duration Per Shift | 7.20 hours | 2.10 hours | 7.20 hours |
| Shift Duration (Excluding Sleep) | 11.71 hours | 3.24 hours | 11.31 hours |
| Shift Duration (Including Sleep) | 15.08 hours | 6.16 hours | 13.39 hours |
| Percentage of Time Driving an Instrumented Truck During Shift (Excluding Sleep) | 62.7 percent | 14.4 percent | 60.6 percent |
| Percentage of Time Driving an Instrumented Truck During Shift (Including Sleep) | 52.7 percent | 18.1 percent | 47.9 percent |
| Overall Driving Speed of the Instrumented Truck | 49.3 mi/h | 7.7 mi/h | 50.5 mi/h |

#### 6.1.3.1 *Data Reduction of Driving Data*

During data reduction, 320,011 triggers were visually inspected. From those triggers, 2,899 SCEs were identified by data analysts and analyzed in detail. These events are divided as follows:

- 13 crashes (8 were tire strikes).
- 61 near-crashes.
- 1,594 crash-relevant conflicts.
- 1,215 unintentional lane deviations.
- 16 illegal maneuvers.

### 6.1.4 In addition, 456 baseline events were evaluated for this study. Summary

The authors completed data collection for the NTDS in May 2007. The following list provides an overview of the data collected:

- **Fleets.**
  - Four fleet companies.
  - Seven different terminals represented.
- **Trucks.**
  - Nine trucks were instrumented.
  - Two day cabs.
  - Seven sleeper berths.
  - Three different manufacturers.
  - Five different vehicle models.
- **Number of drivers.**
  - 100 commercial drivers participated in the study.
  - 94 completed their 4-week data collection period.
  - Six left the study before finishing their 4-week data collection period.
  - Driver demographic information.
    - Gender: 95 males, 5 females.
    - Age: 44.5 years old on average (range: 21 to 73 years old).
    - More than 50 percent of all drivers had 5 years of experience or less as a CMV driver.
- **Amount of data collected.**
  - 6.2 TB of video and performance data.
  - More than 14,500 driving hours of valid data were collected.

- Approximately 2,200 driving shifts.
- 26,000 on-duty hours of daily activity register data.
- More than 735,000 miles (equivalent to approximately 265 transcontinental trips between New York and Los Angeles).
- More than 65,000 hours of actigraphy data were collected from 97 drivers.

## 6.2 ANSWERS TO RESEARCH QUESTIONS

As described in Section 1, the primary objective of this on-road study was to collect ND data and investigate crashes, near-crashes, and crash-relevant conflicts from the HV driver's perspective to help determine the most common functional countermeasures. In addition to the data collection effort, four research questions were analyzed. The results/answers to these questions are presented next. The focus of these questions is the SCEs; therefore, all the data were calculated or evaluated taking into consideration SCEs or baseline events, as appropriate (see Section 5 for operational definitions).

### 6.2.1 Research Question 1: Restart Period and Safety-critical Events

#### *6.2.1.1 How much time do drivers take off during their off-duty restart period before a safety-critical event?*

- In this data collection effort, several types of operations were represented. Some of the drivers had a regular weekly schedule where they did their delivery runs, came back home every day, and took the weekend off. However, other drivers were out on the road for several consecutive days, and on their return, took multiple days off. Therefore, the amount of time off during restart period will be shown as an overall measure, as well as being divided by miles driven. The U.S. Census Bureau usually classifies drivers into one of five categories.[30] The five Census categories are calculated based on the distance of the furthest locations from home base:
- Local: less than 50 miles.
- Short: 50–100 miles.
- Short Medium: 100–200 miles.
- Long Medium: 200–500 miles.
- Long: more than 500 miles.

For the purposes of this report, the drivers were grouped into three main categories (modified from the original U.S. Census categories), as follows:

- Short: less than 100 miles (local and short merged).
- Medium: 100–500 miles (short medium and long medium merged).
- Long: more than 500 miles.

The driver classification presented next was based on the average miles driven during each driver's participation in the study. These distances were calculated from the driver's home base (e.g., Roanoke, VA, for a Carrier C driver) to the furthest destination in each trip based on the load history. Table 19 presents the number of drivers in each classification.

**Table 19. Distribution of drivers by classification.**

| Driver Classification | Number of Drivers | Average Distance Driven from Home Base |
|---|---|---|
| Long–haul (LH) | 22 | 569 |
| Medium-haul | 57 | 252 |
| Short-haul (SH) | 11 | 59 |
| Unknown | 10 | N/A |

To evaluate the amount of time drivers took off-duty during restart periods before a SCE occurred, all the restart periods preceding an event were identified. A total of 251 restart periods are part of this analysis. Figure 27 shows the average length of a restart period, standard error, and a reference line for the minimum 34-hour off-duty restart required by FMCSA under the current hours-of-service (HOS) regulations.(31) On average, the duration of the restart period before a SCE was 53 hours every 5 days. LH drivers had a shorter restart (48 hours) than the SH (63 hours) drivers, but each of the 3 different types of operations took, on average, more than 34 hours. The LH drivers, on average, used the full length of the allowed number of driving days before taking a restart (see Figure 28). Under the current HOS regulations, FMCSA allows a maximum of 60/70 hours on-duty in 7/8 consecutive days. Based on these results, it is evident that the majority of drivers took a reasonable restart period before a SCE occurred.

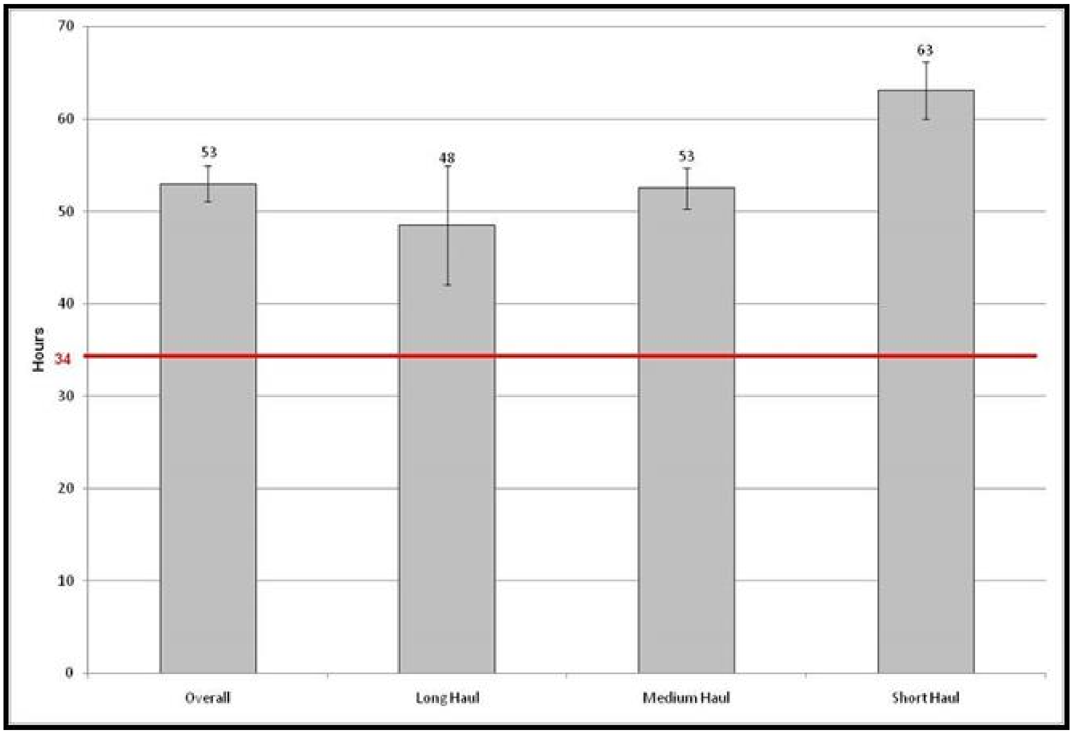



**Figure 27. Bar graph. Number of hours during restart periods preceding SCE by driver classification.**

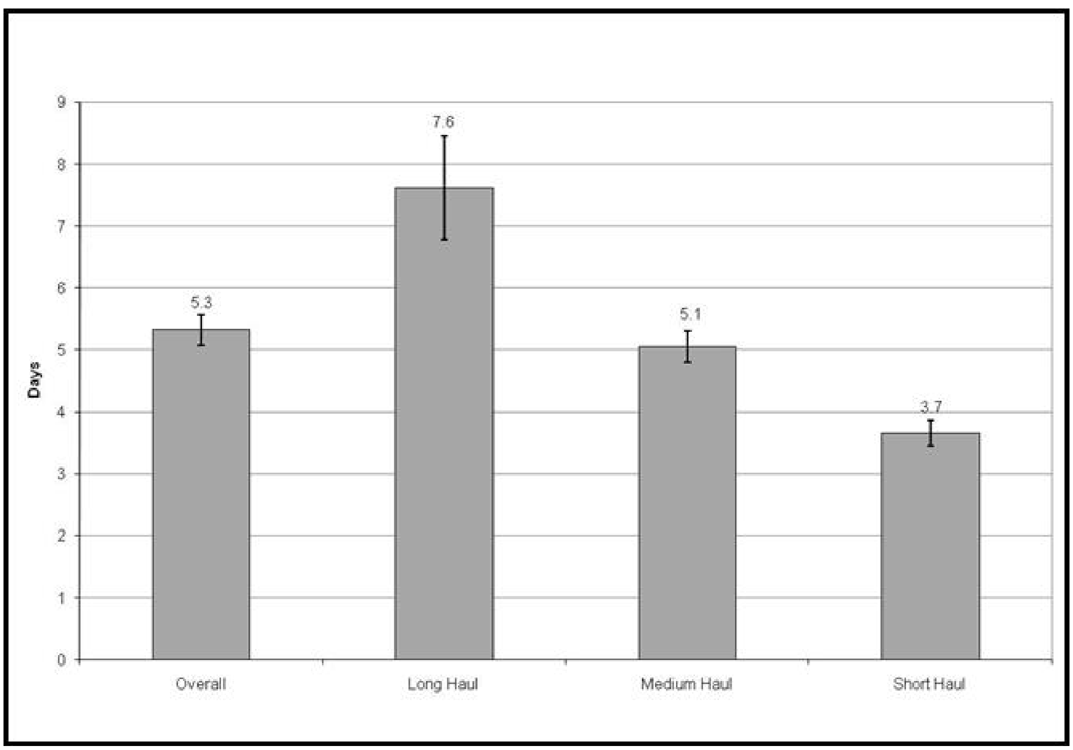



**Figure 28. Bar graph. Number of days (24 hours) between restart periods by driver classification.**

### *6.2.1.2 Is there a relationship between restart period and safety-critical event?*

In order to examine a potential relationship between the number of SCEs and the duration of the restart period prior to the events, a total of 251 restarts were taken into consideration. Figure 29 shows the average duration of the restart period taken prior to the SCE of interest. A regression analysis was performed to determine if there was a relationship between the restart period and the occurrence of a SCE. Since the analysis used the number of SCEs, a Poisson distribution was originally assumed, as well as independence between observations. An attempt to correct for the possible correlation that may exist between observations was made; however, the parameter estimates did not converge. This may be due to the extreme imbalance of the repeated measures. Table 20 contains the results from the Poisson regression analysis.

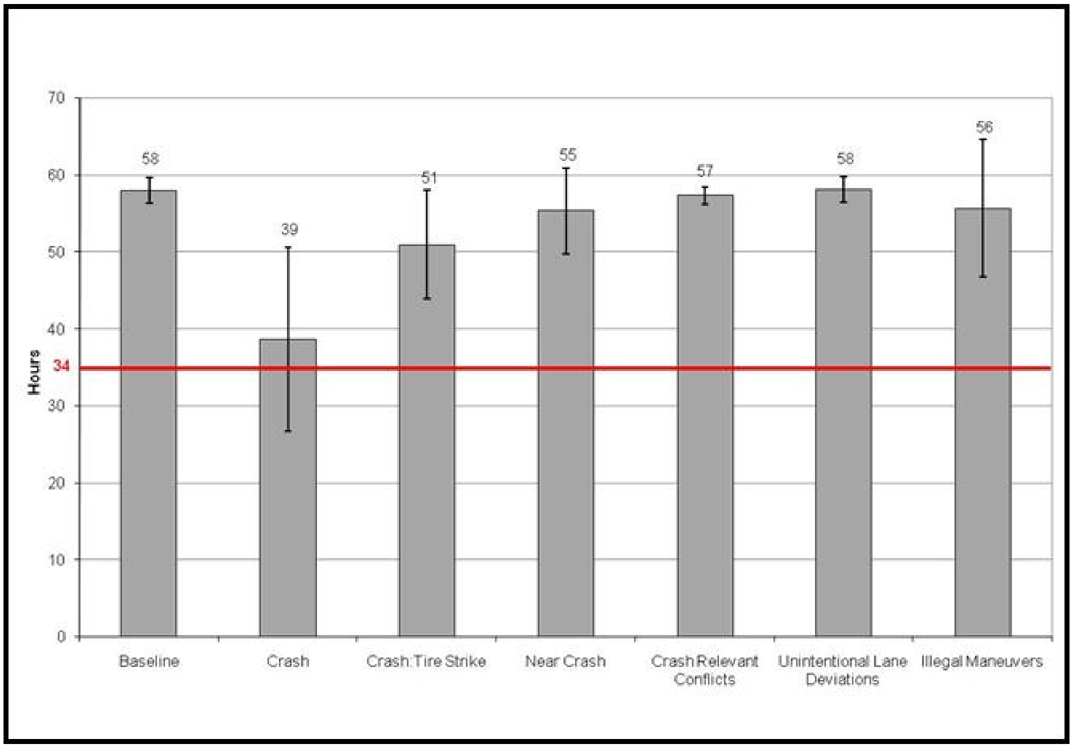



**Figure 29. Bar graph. Duration of restart period before a SCE or baseline event.**

**Table 20. Results of Poisson regression.**

| Parameter | DF | Estimate | Stand. Error | LCL | UCL | Chi-Squared | *p*-Value |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -2.6217 | 0.0409 | -2.7018 | -2.5417 | 4118.14 | *< 0.0001 |
| Restart Period Hour | 1 | 0.0009 | 0.0006 | -0.0003 | 0.0021 | 2.06 | 0.1512 |

**Note:** Criterion = Deviance, DF = 249, Value = 3528.2, Value/DF = 14.2, *p*-Value = < 0.0001

* Indicates lack of fit

When a Poisson distribution was assumed, there was a significant lack of fit in the model. The value of the deviance divided by the degrees of freedom was greater than one. Therefore, the lack of fit may have been caused by over-dispersion; when a Poisson distribution is used, the mean has to be the same value as the variance; if the variance is significantly larger than the mean, the model is said to be over-dispersed. In order to correct for the over-dispersion, the negative binomial distribution was assumed; this allows for the variance to be greater than the mean. Table 21 contains the results of the negative binomial regression analysis.

**Table 21. Results of negative binomial regression.**

| Parameter | DF | Estimate | Stand. Error | LCL | UCL | Chi-Squared | *p*-Value |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | -2.5641 | 0.1132 | -2.7859 | -2.3422 | 513.21 | < 0.0001 |
| Restart Period Hour | 1 | 0.0012 | 0.0017 | -0.0021 | 0.0044 | 0.51 | 0.4753 |

**Note**: Criterion = Deviance, DF = 249, Value = 268.9, Value/DF = 1.08, *p*-Value = < 0.1971

The results of the negative binomial analysis suggest a deviance of 269 with a *p*-value of 0.1907, which indicates there was no significant lack of fit, suggesting this is the appropriate distribution for this type of data. However, in this model the duration of the restart period was not significant ($p = 0.4753$). This suggests that there is no relationship between the duration of the restart period preceding a SCE and the event.

On average, the total time from the end of the restart period to the SCE was 3.6 days. The next section presents more details on this topic (as shown in Figure 30). It can be hypothesized that other factors closer in time to the SCE may be better predictors (e.g., traffic). More details about time since the restart period to the SCE are presented next. In addition, quantity of sleep before a SCE is presented as part of Research Question 2. However, evaluation of other non-sleep activities, medical conditions, medications taken, and other factors (i.e., other data collected during this study) that might increase the likelihood of a SCE, are outside the scope of the current research effort.

#### *6.2.1.3 Is time from restart related to the type of safety-critical event?*

For this analysis, several measurements were evaluated to look at potential relationships between the time from restart and SCEs. Overall, the number of SCEs is highest during the first day after restart (see Figure 30).This finding is consistent with results obtained by the study entitled, “Impact of Sleeper Berth Usage on Driver Fatigue” in a similar analysis with a different set of CMV drivers.(31)

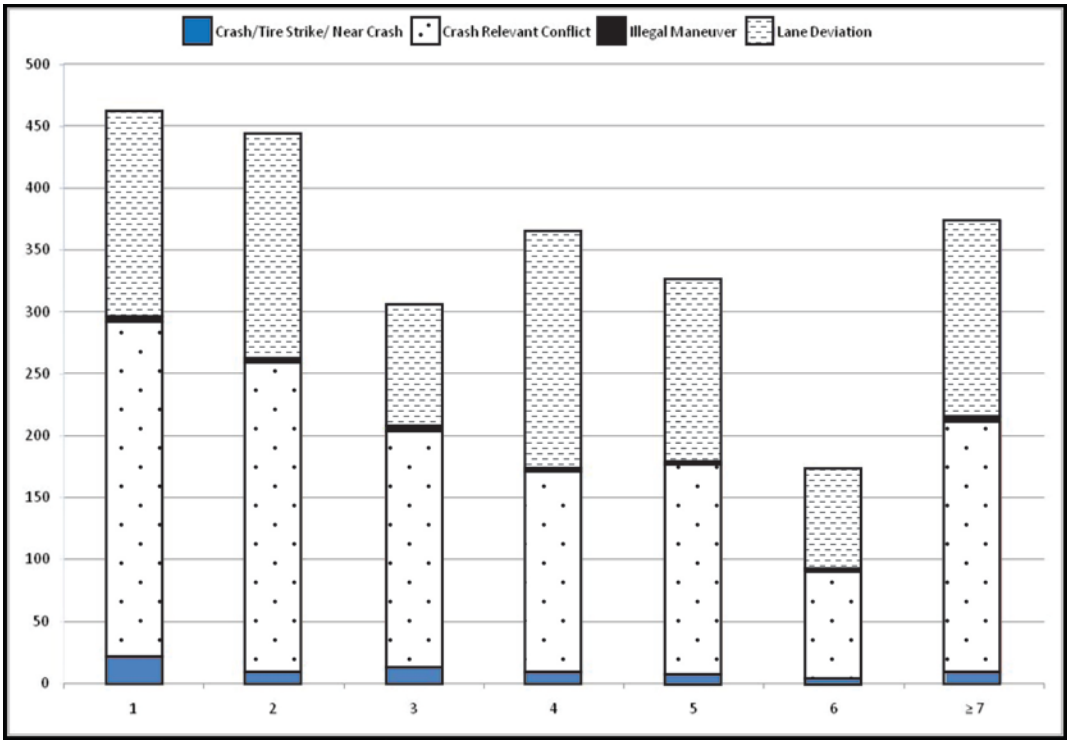



**Figure 30. Bar graph. Frequency of SCE as a function of days (24HB) since restart.**

To examine the possible relationship between the total time since restart and the type of SCE, a Spearman correlation and Kendall's Tau-b correlation were calculated. Both are non-parametric measures of association. For this analysis, the crashes and near-crashes were grouped together as the most severe type of events (see Table 22). A total of 2,452 SCEs from the 2,899 events obtained from the data reduction process were taken into consideration for this analysis. The remaining 447 events occurred close to the beginning of the data collection, and the restart periods preceding those events fell outside the activity register recording period (i.e., before participants started the study), making them inappropriate for this analysis.

On average, the crashes happened closer to the restart period than the other types of events (see Figure 31). However, both the Spearman correlation (*rho* = −0.0711) and the Kendall correlation (*tau-b* = −0.0614) suggest that time since restart is not associated with type of SCE. The time since restart for all of the least severe events is not statistically different from the time when the crashes happened (only different from the tire strikes). Similar results are found when the total on-duty time (see Figure 32) and the total driving time (see Figure 33) since restart are examined.

**Table 22. Types of SCEs as a function of total time since restart.**

| Days Since Restart | Baseline Event | Crash/Tire Strike/ Near-crash | Crash-relevant Conflict | Illegal Maneuver | Lane Deviation | Total SCEs |
|---|---|---|---|---|---|---|
| 1 | 90 | 20 | 273 | 2 | 167 | 462 |
| 2 | 70 | 9 | 249 | 1 | 185 | 444 |
| 3 | 67 | 12 | 191 | 4 | 100 | 307 |

| Days Since Restart | Baseline Event | Crash/Tire Strike/ Near-crash | Crash-relevant Conflict | Illegal Maneuver | Lane Deviation | Total SCEs |
|---|---|---|---|---|---|---|
| 4 | 45 | 8 | 163 | 2 | 193 | 366 |
| 5 | 35 | 6 | 171 | 1 | 148 | 326 |
| 6 | 13 | 3 | 87 | 1 | 82 | 173 |
| ≥ 7 | 57 | 8 | 203 | 3 | 160 | 374 |
| **Total** | **377** | **66** | **1,337** | **14** | **1,035** | **2,452** |

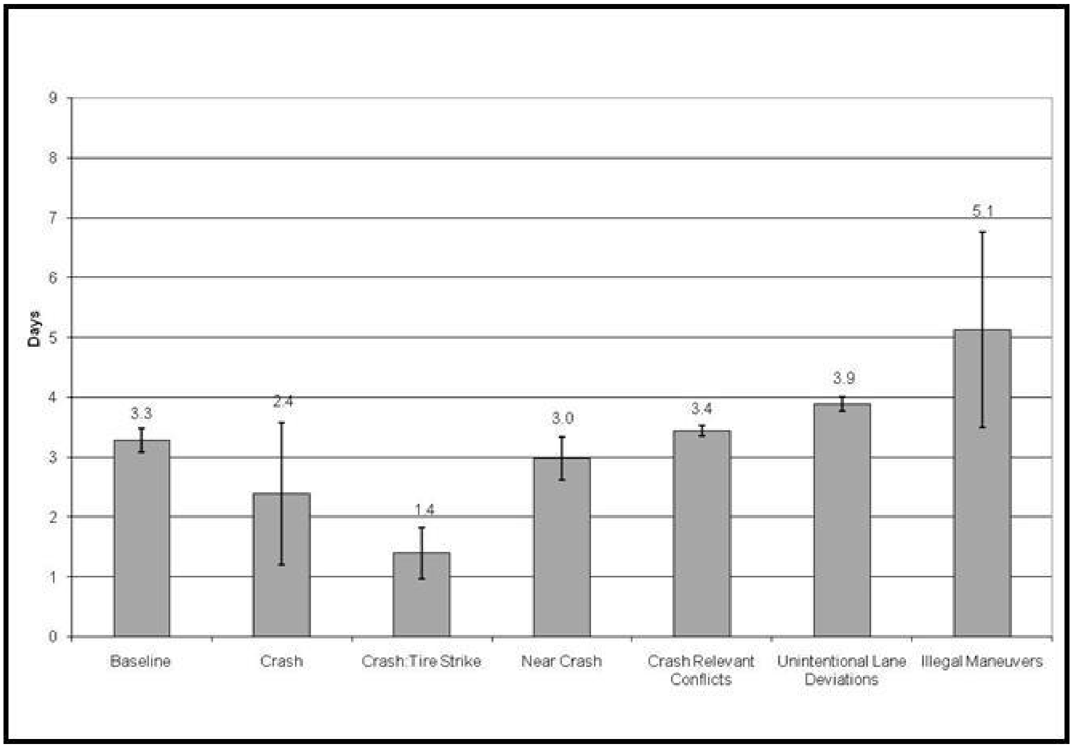



**Figure 31. Bar graph. Total time since restart to SCE or baseline event.**

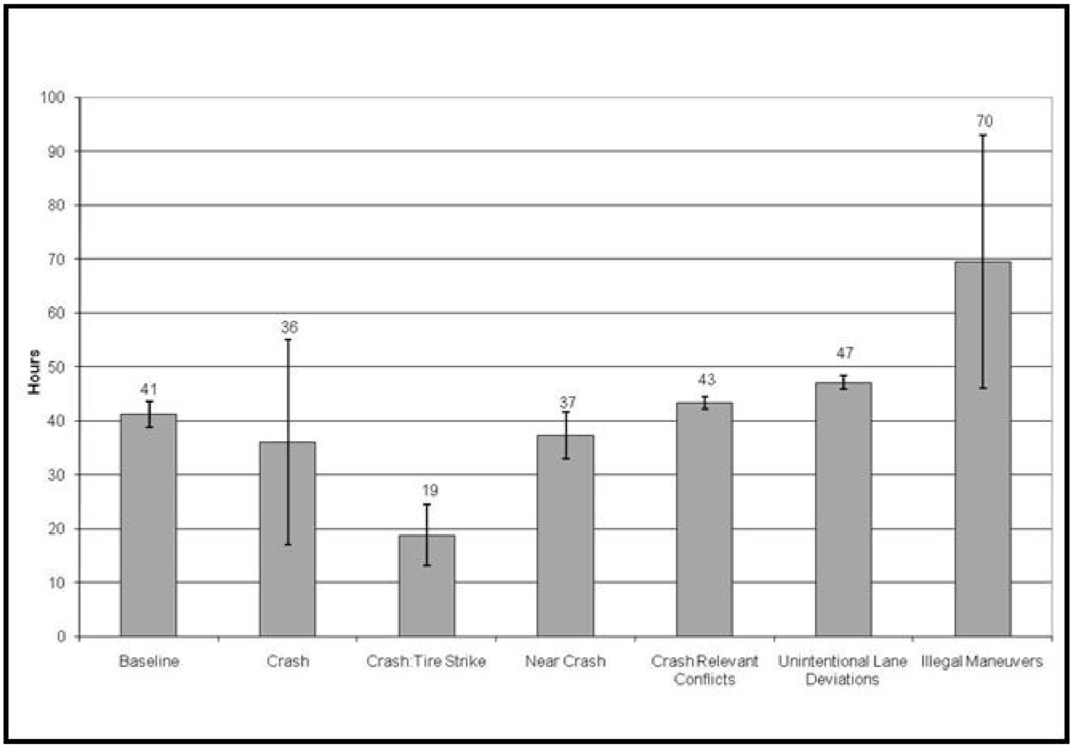



**Figure 32. Bar graph. On-duty time since restart to SCE or baseline event.**

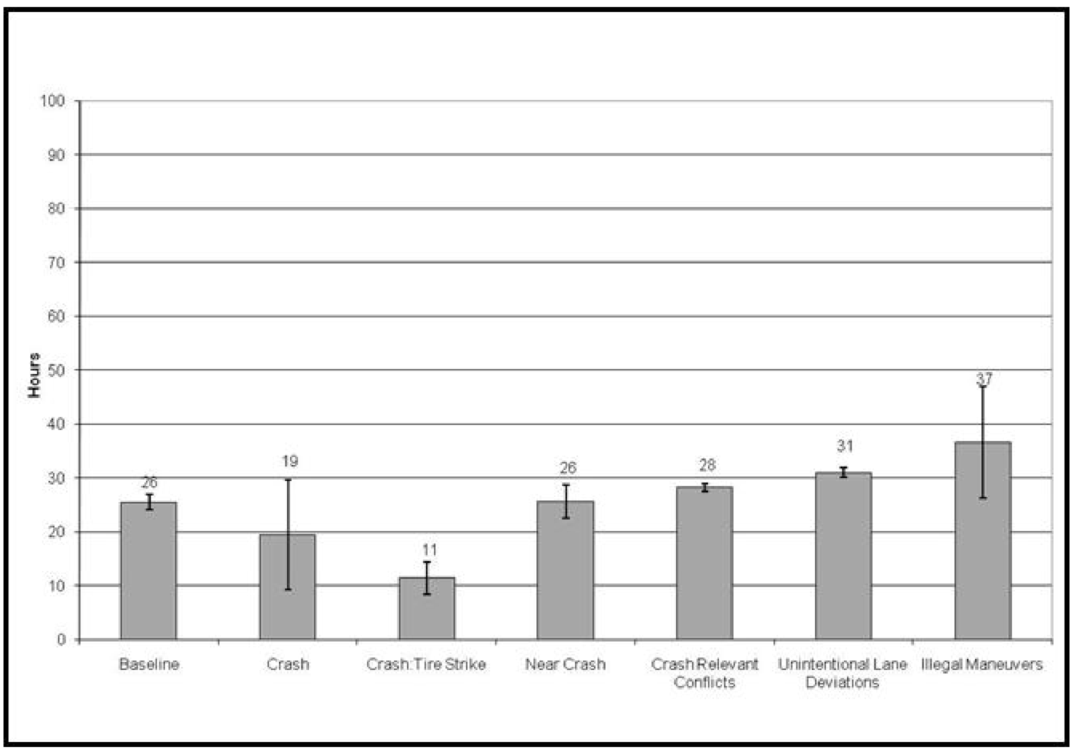



**Figure 33. Bar graph. Total driving time since restart to SCE or baseline event.**

In addition to restart, additional measures that this research question explored related to the shift when the SCE happened. Specifically, the driving time from the beginning of the shift to the event of interest (see Figure 34) and the amount of on-duty time (see Figure 35). However, these two analyses did not show statistically-significant differences between crashes and baseline conditions or crashes and other types of SCEs.

Using logistic regression analyses, other analyses could be performed, such as the following:

- Risk associated with shorter restart periods and SCEs.
- Risk associated with time since restart and SCEs.

This approach requires the calculation of exposure data, which is outside the scope of this project, but can be performed as a part of future research. Including the calculation of exposure data (data are available, but this analysis was not intended under this study) would allow for an approximation of the risk associated with taking shorter restart periods and with longer time between restarts.

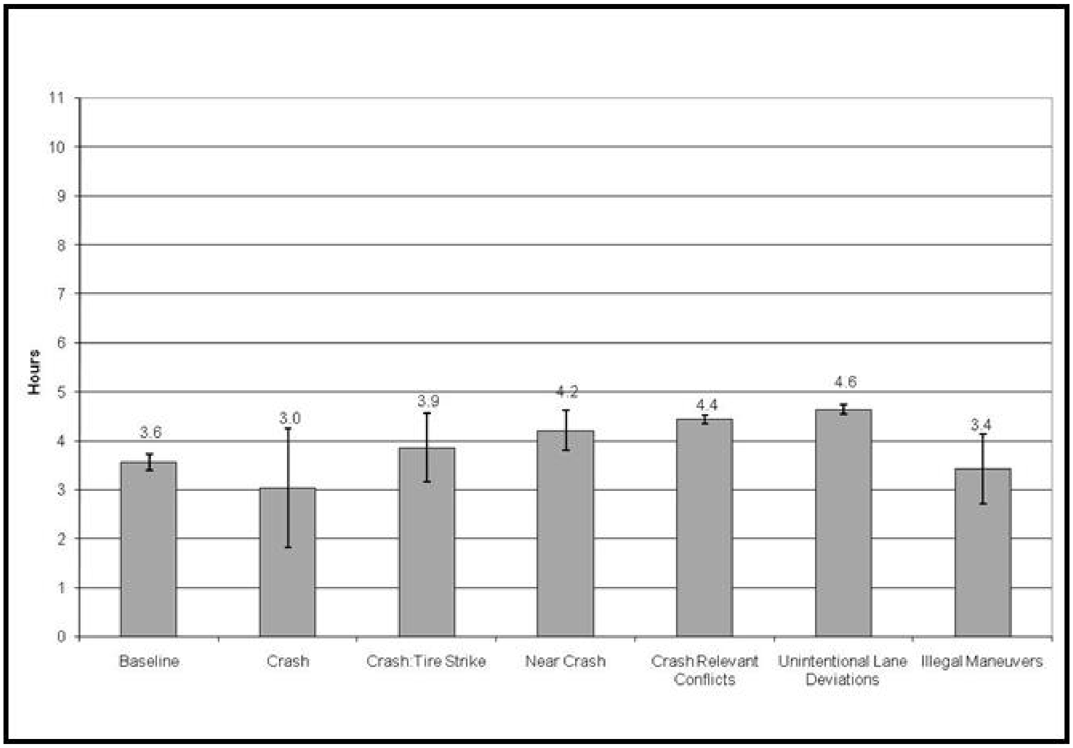



**Figure 34. Bar graph. Driving time from the beginning of the current shift to SCE or baseline event.**

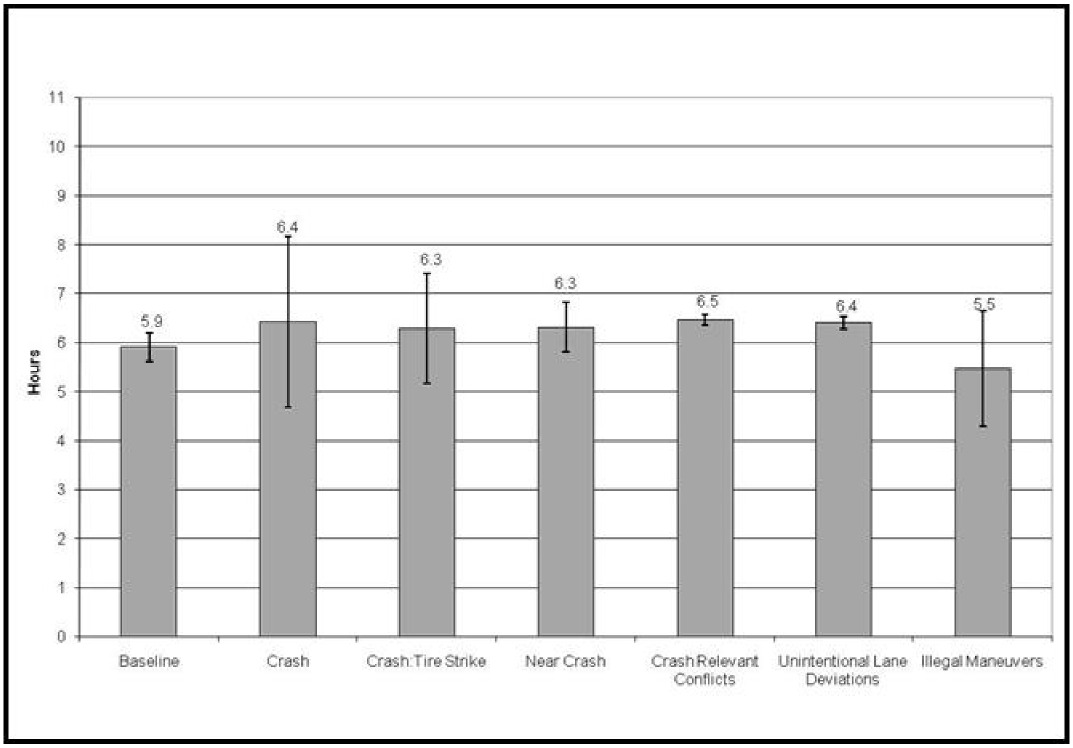



**Figure 35. Bar graph. On-duty time in the current shift to SCE or baseline event.**

### 6.2.2 Summary of Results for Research Question 1

All of the analyses performed for this research question are focused on the restart period preceding the SCEs. The three main analyses were as follows:

- Duration of the restart period.
- Relationship between SCEs and the restart period.
- Time from restart period to SCE.

On average, the duration of the restart period before a SCE was 53 hours every 5 days. For the baseline events taken as a comparison, the duration of the restart averaged 58 hours. LH drivers had a shorter restart (48 hours) than the SH (63 hours) drivers. The medium-haul drivers had an average restart of 53 hours. All three different types of operations took, on average, more than the 34-hour minimum of off-duty restart required by FMCSA under the current HOS regulations. Conversely, no relationship was found between the duration of the restart period and the SCEs. However, the results show that the number of SCEs is highest during the first day after restart. This is consistent with results obtained in previous associated studies.[32]

### 6.2.3 Research Question 2: Sleep Pattern and Safety-critical Events

The assessment of a participant's quality of sleep without invading privacy or making his/her sleep environment uncomfortable is an area of research that still needs to be refined. Traditionally, sleep quantity is measured by asking participants to take their principal sleep at a predetermined location in order to be able to do more laboratory-type procedures.[33] When using this type of method, polysomnographic scoring is performed by attaching electrodes to participants to obtain central and occipital electroencephalography, movement of both eyes, and electromyography of the chin. Other procedures performed to assist in the assessment of sleep include measuring the participant's respiratory airflow and pulse oximetry. The instruments required to obtain such measures, however, are intrusive and must be connected 60–90 minutes before the first period of sleep. Leads that are malfunctioning must also be replaced and respiratory sensors must be reapplied if disconnected. Although such measuring techniques can be very precise, researchers must monitor participants over the course of their sleep periods.

A well-accepted surrogate to the laboratory sleep measurement is devices that measure sleep according to level of activity.(34,35) Wrist actigraphy data are collected by participants wearing watch-like devices on their non-dominant hands. Sleep is assessed according to wrist motion, where low activity is indicative of sleep. It has been reported that the Cole-Kripke sleep estimation algorithm) detects sleep from actigraphy data approximately 88 percent of the time (as validated by a standard polysomnogram montage, two-channel electrooculogram and mentalis electromyogram). Actigraph sleep percentage and sleep latency estimates correlated 0.82 and 0.90, respectively, with corresponding parameters scored from the polysomnograms ($p < 0.0001$). With the use of the Cole-Kripke sleep estimation algorithm to identify periods of sleep, various statistics are computed to quantify a participant's overall amount of sleep.(34) In 2004, a team of researchers assessed sleep quantity by summing scored sleep periods over a 12-hour period.(36) Another research team associated with this study estimated quantity of sleep by summing the scored sleep periods from the actigraphy data over a 24-hour period.(37)

For this study, the less invasive actigraphy data collection approach was used. The results presented are for 97 drivers; they were obtained by identifying scored sleep minutes accrued while participants were resting. To do this, the elapsed time from the onset of sleep to the offset of sleep, or the O-O interval, was determined. The O-O interval can be estimated by analyzing participant sleep logs. However, the accuracy of the amount of sleep suggested by the activity registers has not been validated. Although the data are available for validation, this type of validation effort was outside the scope of this study. An alternative approach to validating sleep logs was developed using mathematical algorithms to identify O-O intervals. The algorithm functions by grouping scored sleep periods together when they are proximal in time.

#### *6.2.3.1 How many hours of sleep did the driver have 24 hours before a safety-critical event?*

For the sleep-related analyses, there were data available for 97 of the 100 drivers that participated in the study. The focus of this analysis, and all the analyses presented under this research question, was the amount of sleep obtained with respect to the SCEs. Baseline events (i.e., normal driving conditions) were used for comparison against the SCEs. There were 2,553 SCEs recorded in the study. An additional 397 baseline events were used to make comparisons. The amount of sleep in the 24 hours preceding the SCEs was compared to the baseline events. Given that not all drivers had actigraphy data (i.e., no data for three drivers, not all drivers wore the device 100 percent of the time), only a subset of events had sleep data available during the period of interest for this research question.

Based on the actigraphy data collected during the study, drivers in the baseline events had a mean of 6.6 hours (LCL: 6.4 hours, UCL: 6.8 hours) of sleep during the 24 hours before the baseline event. For SCEs, drivers had an average of 6.5 hours (LCL: 6.4 hours, UCL: 6.6 hours) of sleep during the 24 hours before the event. Figure 36 presents the average sleep duration and standard error for the baseline and SCEs. Drivers' sleep before a SCE ranged from 6.3 to 7 hours.

A *t*-test comparing the average sleep 24 hours before baseline events and SCEs occurred suggests that there is no statistical difference between them ($t = -0.35$, $p = 0.7251$). A Satterthwaite was used for the *t*-test (unequal variance). A more liberal test (i.e., regular pooled *t*-test) also suggests that there is no significant difference ($t = -0.36$, $p = 0.7215$).

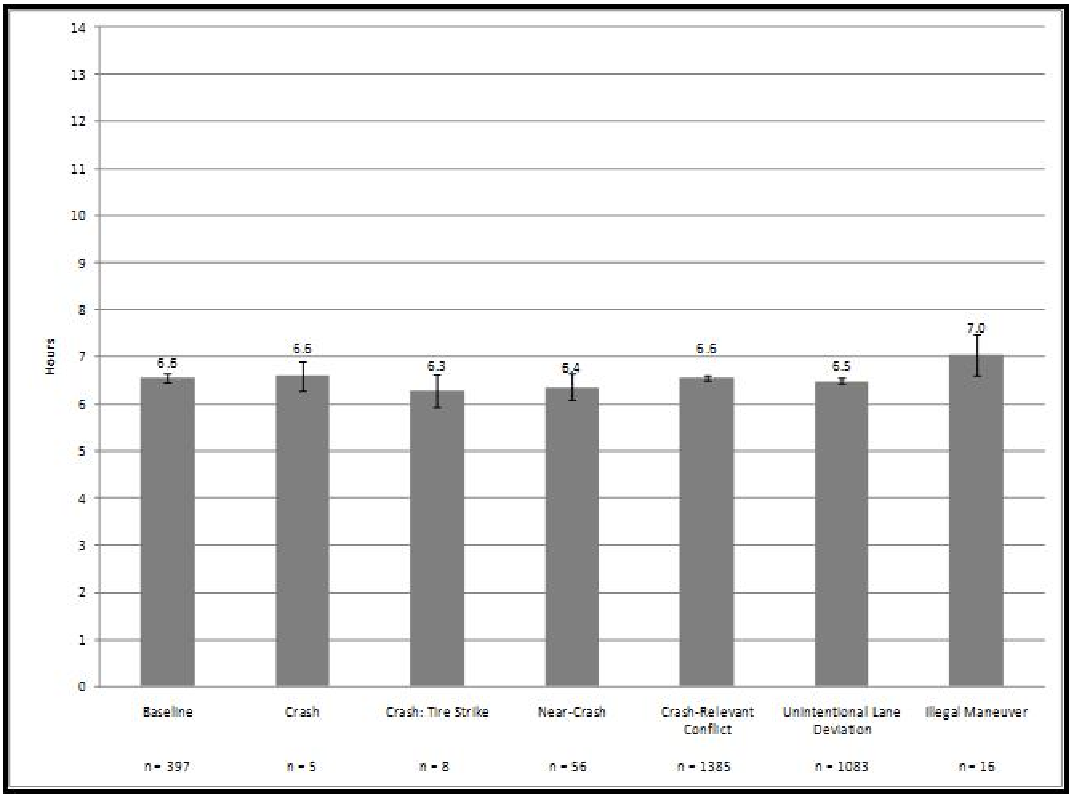



**Figure** 36**. Bar graph. Sleep 24 hours before event of interest.**

### *6.2.3.2 How many hours of sleep did the driver have since restart, before the safety-critical event occurred?*

Table 23 presents a comparison of the amount of sleep drivers had at three different points before the SCE:

- Sleep in 24-hour period during the restart period preceding the SCE.
- Sleep in 24-hour period since restart (excluding the actual restart period).
- Average sleep 24 hours before the SCE.

Figure 37 is a graphical representation of how these variables relate to the SCEs or baseline events. These results present a view of how much the driver slept as he/she approached the event of interest. As with the previous question, the sleep data for all drivers and all events were not available for this question. Therefore, only when all three measures of interest were available for a given SCE or baseline event were they included in the analysis. A total of 1,901 SCEs and 276 baseline events were used for this analysis.


**Figure 37. Timeline. Graphical representation of sleep variables of interest.**

**Table 23. Mean sleep values and confidence intervals.**

| Variable | Event | N | LCL | Mean | UCL |
|---|---|---|---|---|---|
| Sleep During Restart | SCE | 1,901 | 6.9 | 7.0 | 7.1 |
| Sleep During Restart | Baseline | 276 | 6.9 | 7.2 | 7.5 |
| Sleep During Restart | Difference | – | -0.5 | -0.2 | 0.1 |
| Sleep Since Restart | SCE | 1,901 | 5.9 | 5.9 | 6.0 |
| Sleep Since Restart | Baseline | 276 | 5.8 | 6.1 | 6.3 |
| Sleep Since Restart | Difference | – | -0.4 | -0.1 | 0.1 |
| Sleep Last 24 hours | SCE | 1,901 | 6.4 | 6.5 | 6.6 |
| Sleep Last 24 hours | Baseline | 276 | 6.4 | 6.6 | 6.9 |
| Sleep Last 24 hours | Difference | – | -0.3 | -0.1 | 0.1 |

The results in Table 23 suggest that overall, drivers sleep approximately 1.1 hours more during their restarts than on their regular workdays. The average sleep for CMV drivers since restart and 24 hours before a SCE is less than the average sleep they obtained during the restart period preceding the SCE. However, this difference represents only one-half hour less sleep during the 24 hours before a SCE. As with the previous question, the results included all SCEs (i.e., driver participating in the study, at-fault or not at-fault). Figure 38**Error! Reference source not found.** shows the average sleep for each of the three measures of interest as a function of the type of SCE.

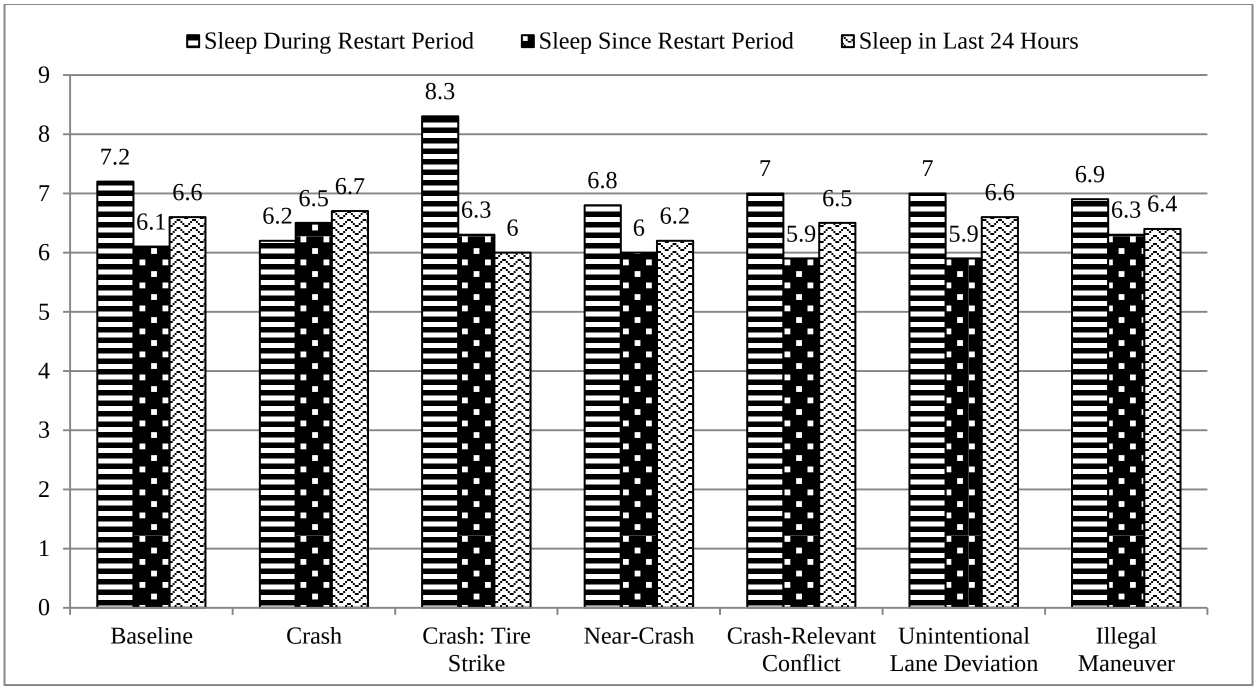



**Figure 38. Bar graph. Sleep during restart, after restart, and 24 hours before event.**

A *t*-test was performed to compare baseline events to the SCEs for each of the three variables of interest for this question. The results suggest that there is no statistical difference between the amount of sleep during the baseline and the SCEs for the following:

- Sleep during restart ($t = -1.14$, $p = 0.2546$).
- Sleep since restart ($t = -1.11$, $p = 0.2691$).
- Sleep in last 24 hours ($t = -0.81$, $p = 0.4207$).

As with the previous questions, a Satterthwaite was used for the *t*-test (unequal variance), but a more liberal test (i.e., regular pooled *t*-test) suggests that there is no significant difference either.

It is suggested that future research might look at the SCEs and the difference in the amount of sleep among different types of events based on the "at-fault" condition, as well as in terms of sleep efficiency (e.g., 5 hours in one full sleep period versus waking up several times during the sleep period), in addition to the amount of sleep that is normally reported. Lower sleep efficiency might increase the likelihood of overall involvement in SCEs as well as increasing the at-fault events.

#### *6.2.3.3 What are the characteristics of the rest period preceding the safety-critical events?*

The sleep periods 24 hours before SCEs and baseline events were further investigated. The amount of sleep reported in the previous two research questions related to consolidated sleep and reflected the sum of all the sleep periods within a 24-hour period (i.e., one total sleep per SCE or baseline event). However, an 8-hour sleep in the past 24 hours could be composed of two sleep periods. For this research question, this situation would be reported as two sleep periods prior to the event instead of one sleep period. For this reason, the total number of sleep periods (n) reported for the results in this section will be higher than the actual number of baseline events or SCEs previously reported.

The results presented in Figure 39 show the number of sleep periods that characterize the sleep received by the driver 24 hours before each of the safety-critical and baseline events. Most of the sleep 24 hours before SCEs and baseline events was in single sleep periods. However, some of the SCEs and baseline events involved up to four sleep periods, although this was relatively rare.

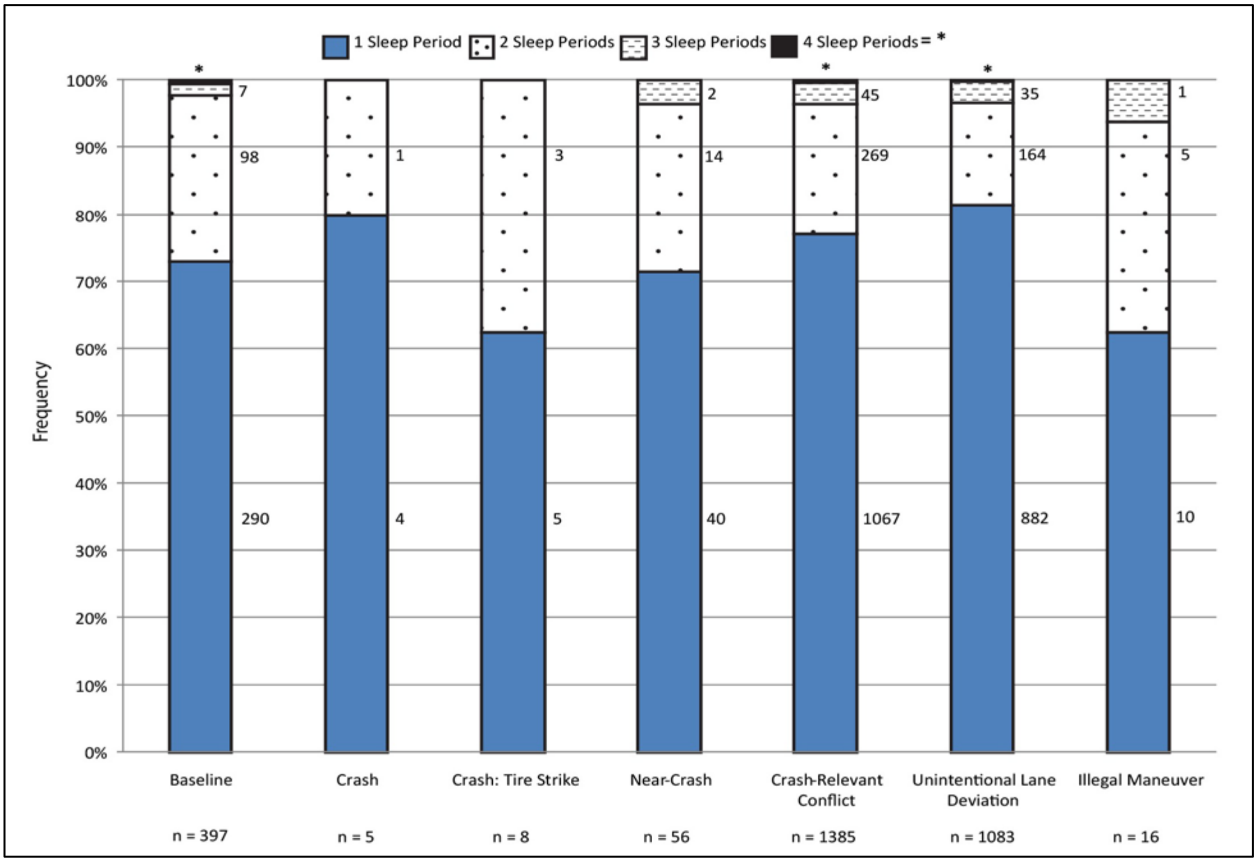



**Figure 39. Bar graph. Number of sleep periods present in the 24 hours before event.**

In addition to the number of sleep periods (see Figure 39), the following three measures were evaluated (as shown in Figure 40):

- Duration of sleep period (all sleep periods in the last 24 hours).
- Time since last sleep period preceding the event of interest (only first sleep period preceding an event).
- Time between sleep periods (only when multiple sleep periods exist within the last 24 hours).

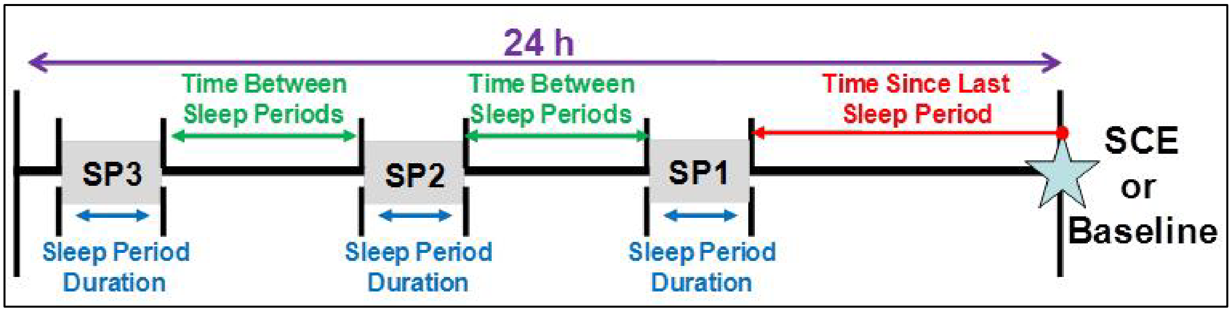



**Figure 40. Timeline. Graphical representation of sleep period variables of interest.**

Figure 41 presents the average and standard error for these three analyses for the baseline events and SCEs. The duration of a sleep period was on average 5.1 hours for the baseline events and 5.0 hours for the SCEs. On average, drivers had a sleep period 7.0 hours before the baseline event and 7.8 hours before a SCE. When CMV drivers had multiple sleep periods in the 24 hours before a baseline event or SCE, these sleep periods were taken 5.2 and 5.1 hours apart, respectively.

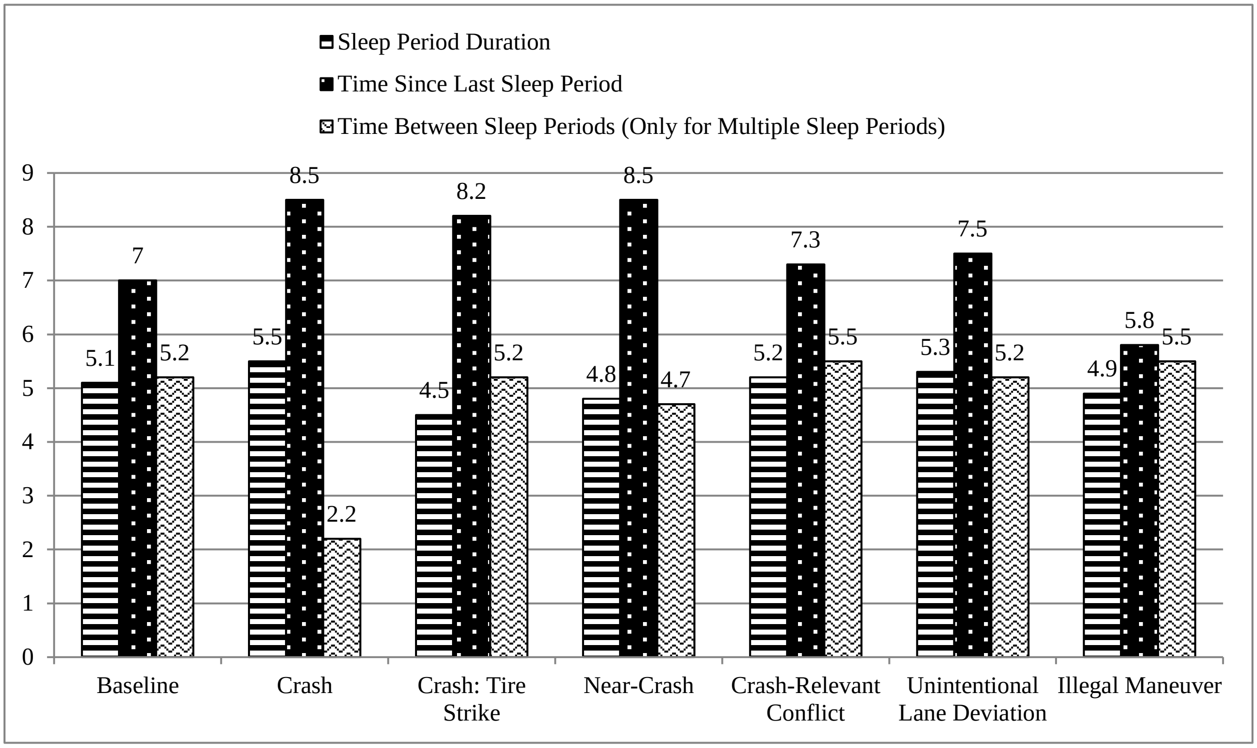



**Figure 41. Bar graph. Sleep period duration, time since last sleep period, and time between sleep periods 24 hours before event.**

### *6.2.3.4 Was the rest period before the safety-critical event taken on-duty or off-duty?*

For this research question, each of the individual sleep periods obtained for the analysis of the previous question was classified into on-duty or off-duty. An on-duty sleep period is the one taken in the sleeper berth or while on the road going to/from a delivery location. An off-duty sleep period is the one taken outside the work environment or at home. The data to answer this question were obtained by linking the sleep database to the activity register database. Figure 42 presents the number and proportion of on- and off-duty sleep periods for baseline events and SCEs. Based on these results, most of the sleep periods preceding the SCEs were taken off-duty.

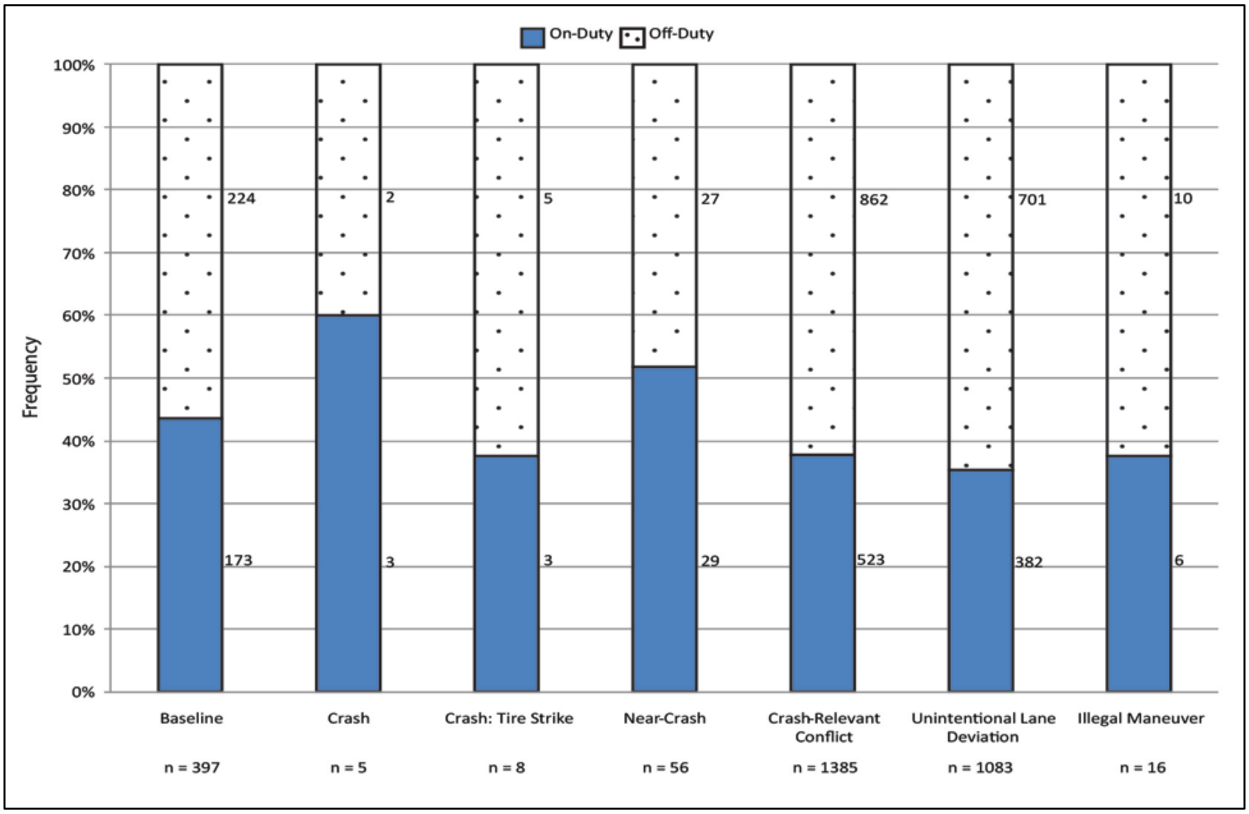



**Figure 42. Bar graph. Proportion of sleep periods taken on-duty vs. off-duty in the 24 hours before event.**

### 6.2.4 Summary of Results for Research Question 2

The results are based on all the SCEs for this study (i.e., at fault or not). Based on the actigraphy data collected during the study, CMV drivers in the baseline events slept, on average, 6.6 hours (6.4–6.8 hours at the 95-percent confidence interval) during the 24 hours before the baseline event. For SCEs, CMV drivers had an average of 6.5 hours (6.4–6.6 hours at the 95-percent confidence interval) of sleep during the 24 hours before the SCE. In addition to the amount of sleep in the 24 hours preceding a SCE, the sleep during the restart period and the sleep since the restart period were evaluated. On average, CMV drivers slept 1.1 hours more during their restart period than during their regular work days. The average sleep for CMV drivers since restart and 24 hours before a SCE is less than what they obtained during the restart period preceding the SCE. However, this difference represents only one-half hour less sleep during the 24 hours before a SCE. These results included all SCEs (i.e., at fault or not).

The amounts of sleep reported above reflected the sum of all the sleep periods within a 24-hour period (i.e., one total sleep per SCE or baseline event). However, an 8-hour sleep in the last 24 hours might not always be taken in a single sleep period. The total sleep could be composed of two sleep periods or even more, shorter sleep periods. The analysis performed for this study showed that most of the sleep received 24 hours before a SCE or baseline event involved a single sleep period, but some drivers divided their sleep into four different periods. However, having three or more sleep periods was not predominant. The duration of the sleep period (all sleep periods in the last 24 hours), the amount of time since the last sleep period preceding the event of interest (only the first sleep period preceding an event), and the amount of time between sleep periods (only when multiple sleep periods exist within the last 24 hours) were also evaluated. The average duration of a sleep period 24 hours before a baseline event or a SCE were 5.1 hours and 5 hours, respectively. On average, drivers had a sleep period 7 hours before the baseline event and 7.8 hours before a SCE. When CMV drivers had multiple sleep periods in the 24 hours before a baseline event or SCE, these sleep periods were taken 5.2 hours and 5.1 hours apart, respectively.

### 6.2.5 Research Question 3: Vehicle Interactions by Type of Maneuver

The most fundamental analyses in the current study were descriptions and comparisons of the six major types of safety-relevant events:

- Crashes (including tire strikes).
- Near-crashes.
- Crash-relevant conflicts.
- Illegal maneuvers.
- Unintentional lane deviations.
- Baseline events.

Since the number of crashes was very low (13, including tire strikes), statistical analyses focusing on crashes were limited. Descriptions of near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations provided information on the characteristics and conditions associated with these SCEs. Near-crashes were essentially extreme crash-relevant conflicts, so a comparison of these two event types could also reveal the factors and conditions associated with increased risk. This is analogous to the Heinrich, Petersen, and Roos hazard analysis technique based on the underlying premise that for every injury accident, many similar accidents occurred in which no injury was sustained (i.e., for every crash, there are so many near-crashes; for every near-crash there are so many crash-relevant conflicts; and so on down the severity scale).[38] Thus, through study of lower-severity events, such as near-crashes and crash-relevant conflicts, information can be learned about crash scenarios and the behaviors and contributing factors involved in their genesis. This will inform crash avoidance technologies, enforcement regulations, and safety management methods.

While the number of crashes and near-crashes was much less than the number of crash-relevant conflicts, these event types may be more indicative and predictive of true driver risk. In the 100-Car Study, the research team ran a discriminant analysis (comparing crashes, near-crashes, and incidents [i.e., crash-relevant conflicts] with the vehicles' kinematic signatures) and determined that the kinematic signatures of the crashes and near-crashes were very similar, but that incidents were too varied to be predicted by the vehicles' kinematic signatures.

Description of baseline events characterized “normal” driving for the participants, including the proportion of time spent driving under various conditions (e.g., wet versus dry, light versus dark, divided highways versus undivided highways) and the proportion of time that drivers performed various behaviors (e.g., eating/drinking, talking on Citizen’s Band (CB) radio or cell phone). Comparisons among baseline events, near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations permitted inferences to be drawn regarding the increased risk of driver error associated with various factors. The combined total of all SCEs (i.e., crashes, near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations) provided the most robust statistical basis for comparison with baseline events. Many of the statistical comparisons reported are made between this aggregated risk category and the baseline event (normal driving/non-risk) category.

While some SCEs involved only the instrumented HV, most involved interactions with other vehicles, and these vehicles were overwhelmingly LVs. However, in regard to the issue of LV-HV interactions, and particularly the issue of which vehicle/driver type is predominantly “at fault,” the current study was limited by the fact that the vehicle instrumentation included tractor-mounted sensors (e.g., forward radar), but no trailer instrumentation (e.g., rearward radar). In addition, dynamic sensor triggers used to capture events were based primarily on evasive maneuvers by the truck and would not flag events in which the only evasive maneuver was performed by the other vehicle. For example, events in which the subject vehicle (i.e., the instrumented truck) made evasive maneuvers following encroachment toward another vehicle (longitudinal or lateral) were likely to be flagged and captured, but the opposite scenarios, involving encroaching non-subject vehicles, were not likely to be captured. For this reason, the current study did not capture the universe of LV-HV interactions and the data do not accurately characterize the percentage of all safety-significant traffic events attributable to LVs versus HVs. Large numbers of both truck-driver-initiated and other-driver-initiated events were captured and analyzed, and are described in the current report, but their proportions do not reflect all LV-HV interactions and thus cannot be used to apportion “fault” for the universe of such events.

#### *6.2.5.1 Trigger Types*

The current NTDS dataset included a total of 2,899 SCEs and 456 baseline events. Of the 2,899 SCEs in the Phase I dataset, 13 were crashes (8 of these crashes were tire strikes), 61 were near-crashes, 1,594 were crash-relevant conflicts, 16 were illegal maneuvers, and 1,215 were unintentional lane deviations. Baseline events were 30-second time periods randomly selected from the recorded dataset. Baseline events were described using many of the same variables and data elements used to describe and classify crashes, near-crashes, and crash-relevant conflicts. As described above, SCEs were identified when dynamic sensor data surpassed a pre-determined criterion, when a driver pressed the critical incident button, or when identified by analyst. The operational definitions of the six trigger types can be found in Table 7. Error! Reference source not found. displays the distribution of trigger types in the NTDS dataset.

Table 24. Distribution of trigger types.

| Trigger Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Analyst-identified | 0 (0.0%) | 4 (50.0%) | 1 (1.6%) | 4 (0.3%) | 3 (18.8%) | 0 (0.0%) | 12 (0.4%) |
| Analyst-identified and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 3 (18.8%) | 0 (0.0%) | 5 (0.2%) |
| Critical Incident Button | 0 (0.0%) | 2 (25.0%) | 1 (1.6%) | 12 (0.8%) | 5 (31.3%) | 0 (0.0%) | 20 (0.7%) |
| Lane Deviation | 0 (0.0%) | 0 (0.0%) | 19 (31.1%) | 1,140 (71.5%) | 1 (6.3%) | 1,202 (98.9%) | 2,362 (81.5%) |
| Lane Deviation and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| Lane Deviation and Swerve | 0 (0.0%) | 0 (0.0%) | 7 (11.5%) | 25 (1.6%) | 0 (0.0%) | 12 (1.0%) | 44 (1.5%) |
| Lane Deviation, Swerve and Longitudinal Acceleration | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Lane Deviation, Swerve and TTC | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Longitudinal Acceleration | 3 (60.0%) | 2 (25.0%) | 9 (14.8%) | 156 (9.8%) | 2 (12.5%) | 0 (0.0%) | 172 (5.9%) |
| Longitudinal Acceleration and Critical Incident Button | 1 (20.0%) | 0 (0.0%) | 2 (3.3%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 23 (0.8%) |
| Longitudinal Acceleration and Lane Deviation | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| Longitudinal Acceleration and Lane Deviation and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Longitudinal Acceleration and Swerve | 1 (20.0%) | 0 (0.0%) | 3 (4.9%) | 16 (1.0%) | 0 (0.0%) | 0 (0.0%) | 20 (0.7%) |
| Longitudinal Acceleration, Swerve and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Longitudinal Acceleration and TTC | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 38 (2.4%) | 0 (0.0%) | 0 (0.0%) | 41 (1.4%) |
| Swerve | 0 (0.0%) | 0 (0.0%) | 9 (14.8%) | 54 (3.4%) | 1 (6.3%) | 1 (0.1%) | 65 (2.2%) |
| Swerve and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| TTC | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 72 (4.5%) | 0 (0.0%) | 0 (0.0%) | 72 (2.5%) |
| TTC and Critical Incident Button | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| TTC and Lane Deviation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| TTC and Swerve | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 22 (1.4%) | 1 (6.3%) | 0 (0.0%) | 23 (0.8%) |
| TTC, Swerve and Longitudinal Acceleration | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| **Total** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** |

### 6.2.5.2 *Number of Vehicles Involved*

Table 25 displays the frequency and percentage of vehicles involved in crashes, tire strikes, near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations in the NTDS dataset. Most of the SCEs were single-vehicle events (81.1 percent). A smaller percentage was classified as two-vehicle events (17.3 percent). Most crashes involved V1 only or V1 plus an animal (60 percent and 20 percent, respectively). All of the tire-strike events and unintentional lane deviations involved V1 only (both 100 percent). Most of the near-crashes involved two vehicles (68.9 percent), while most of the crash-relevant conflicts involved V1 only (69.3 percent).

**Table 25. Frequency and percentage of number of vehicles involved.**

| Vehicles Involved | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 1 Vehicle (Subject Vehicle Only) | 3 (60.0%) | 8 (100.0%) | 16 (26.2%) | 1,104 (69.3%) | 4 (25.0%) | 1,215 (100.0%) | 2,350 (81.1%) |
| 2 Vehicles | 1 (20.0%) | 0 (0.0%) | 42 (68.9%) | 448 (28.1%) | 11 (68.8%) | 0 (0.0%) | 502 (17.3%) |
| 3 Vehicles | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 31 (1.9%) | 1 (6.3%) | 0 (0.0%) | 35 (1.2%) |
| 4 Vehicles | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Subject Vehicle + Pedestrian | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Subject Vehicle + Animal | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

### 6.2.5.3 *Vehicle Type*

Table 26 shows the frequency and percentage for each "Vehicle Type" in the NTDS dataset. The "Vehicle Type" indicates the type of vehicle or non-vehicle involved in each SCE. For completeness, this can include non-vehicles such as animals and objects. Overall, most of the SCEs involved an object (26.5 percent) or automobile (8 percent).

**Table 26. Frequency and percentage of vehicle type.**

| Vehicle Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event—No Object) | 2 (40.0%) | 0 (0.0%) | 7 (11.5%) | 351 (22.0% ) | 4 (25.0%) | 1,215 (100.0%) | 1,579 (54.5%) |
| Automobile | 1 (20.0%) | 0 (0.0%) | 21 (34.4%) | 205 (12.9%) | 6 (37.5%) | 0 (0.0%) | 233 (8.0%) |

| Vehicle Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Van (Minivan or Standard Van) | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 40 (2.5%) | 0 (0.0%) | 0 (0.0%) | 43 (1.5%) |
| Pickup Truck | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 68 (4.3%) | 2 (12.5%) | 0 (0.0%) | 72 (2.5%) |
| SUV (Includes Jeep) | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 52 (3.3%) | 2 (12.5%) | 0 (0.0%) | 60 (2.1%) |
| School Bus | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Transit Bus | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Greyhound Bus | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Single-unit Straight Truck: Multi-stop/Step Van | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Single-unit Straight Truck: Box | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Single-unit Straight Truck: Dump | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Single-unit Straight Truck: Garbage/Recycling | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Single-unit Straight Truck: Flatbed | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Single-unit Straight Truck: Tow Truck | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Single-unit Straight Truck: Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Tractor-trailer: Cab Only | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Tractor-trailer: Cab + Trailer | 0 (0.0%) | 0 (0.0%) | 7 (11.5%) | 51 (3.2%) | 1 (6.3%) | 0 (0.0%) | 59 (2.0%) |
| Tractor-trailer: Flatbed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Tractor-trailer: Tank | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Tractor-trailer: Car Carrier | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Tractor-trailer: Lowboy Trailer | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Tractor-trailer: Dump | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Tractor-trailer: Multiple Trailers | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Tractor-trailer: Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Motorcycle or Moped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Vehicle Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Vehicle Pulling Trailer (Other Than Tractor Trailer) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 12 (0.8%) | 1 (6.3%) | 0 (0.0%) | 14 (0.5%) |
| Other Vehicle Type | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Pedestrian | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Deer | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| Other Animal | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Object | 1 (20.0%) | 8 (100.0%) | 8 (13.1%) | 752 (47.2%) | 0 (0.0%) | 0 (0.0%) | 769 (26.5%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.4 Relevant Object*

Table 27 shows the frequency and percentage for each "Relevant Object" in the NTDS dataset. The "Relevant Object" refers to the most relevant object that was struck in a crash or which constituted a crash threat during the near-crash, crash-relevant conflict, illegal maneuver, or unintentional lane deviation (excluding other moving vehicles, people, and animals). Not including all the "not applicable" Relevant Objects, the most frequent Relevant Objects in the SCEs were guardrails (23.2 percent) and concrete traffic barriers (1.4 percent).

**Table 27. Frequency and percentage of relevant object.**

| Relevant Object | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event—No Object) | 2 (40.0%) | 0 (0.0%) | 7 (11.5%) | 351 (22.0%) | 4 (25.0%) | 1,215 (100.0%) | 1,579 (54.5%) |
| Not Applicable (Multivehicle Event, Pedestrian, Animal, etc.) | 2 (40.0%) | 0 (0.0%) | 45 (73.8%) | 489 (30.7%) | 12 (75.0%) | 0 (0.0%) | 548 (18.9%) |
| Parked Motor Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| Fixed Object: Mailbox | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Fixed Object: Bridge Structure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |

| Relevant Object | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Fixed Object: Guardrail | 0 (0.0%) | 0) (0.0% | 6 (9.8%) | 667 (41.8%) | 0 (0.0%) | 0 (0.0%) | 673 (23.2%) |
| Fixed Object: Concrete Traffic Barrier | 0 (0.0%) | 0) (0.0% | 0 (0.0%) | 41 (2.6%) | 0 (0.0%) | 0 (0.0%) | 41 (1.4%) |
| Fixed Object: Post, Pole or Support | 0 (0.0%) | 0) (0.0% | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| Fixed Object: Curb | 0 (0.0%) | 8) (100.0% ) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| Fixed Object: Embankment | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Fixed Object: Fence | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Fixed Object: Shrubbery or Bush | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Non-fixed Object: Dead Animal in Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Non-fixed Object: Trash/Debris | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Non-fixed Object: Construction Barrel | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| Non-fixed Object: Construction Cone | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.5 Vehicle Position*

Figure 43 shows a diagram of V1 with the corresponding Vehicle Position codes. Percentages in this figure refer to total SCEs. Not including all the “not applicable” events, the most frequent Vehicle Positions for V2 during SCEs were the passenger-side front quarter panel of V1’s cab (coded “B,” 18 percent), passenger-side quarter panel of V1’s cab (coded “C,” 11 percent), and the front of V1 (coded “A,” 9.6 percent).

Table 28 displays the frequency and percentage for each Vehicle Position in multiple-vehicle crashes (single-vehicle crashes were coded as “not applicable”). The “Vehicle Position” refers to the position of V2 in relation to V1 (coded during the time in which the event first created the crash risk). Vehicles in the adjacent left lane to V1 were coded “J,” “I,” “H,” or “G,” depending on position. Vehicles in right lane adjacent to V1 were coded “B,” “C,” “D,” or “E,” depending on position.

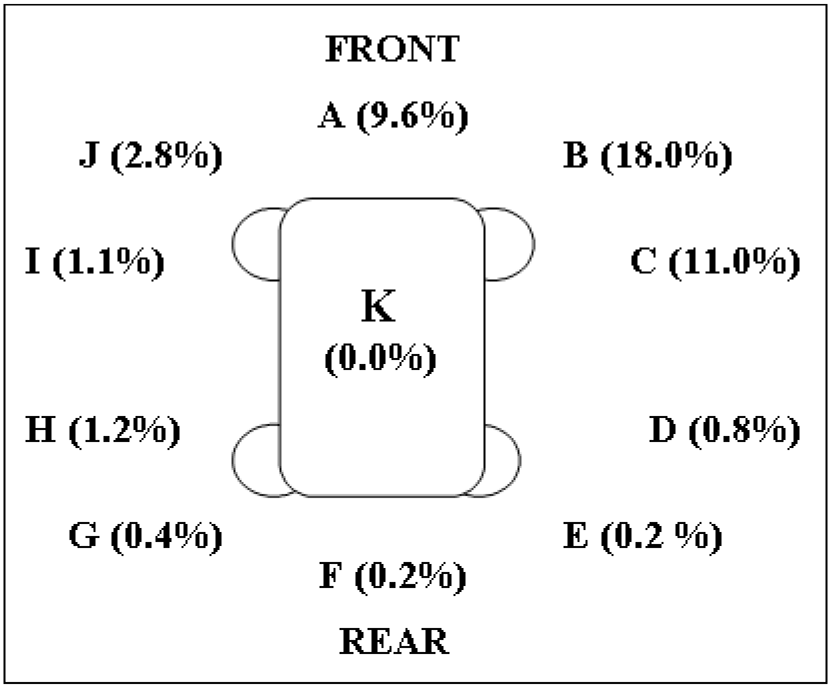



**Figure 43. Diagram. Diagram of V1 used to indicate the relative position of V2.**

**Table 28. Frequency and percentage of vehicle position.**

| Vehicle Position | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event) | 2 (40.0%) | 0 (0.0%) | 7 (11.5%) | 355 (22.3%) | 4 (25.0%) | 1,215 (100.0%) | 1,583 (54.6%) |
| A | 1 (20.0%) | 1 (12.5%) | 13 (21.3%) | 260 (16.3%) | 2 (12.5%) | 0 (0.0%) | 277 (9.6%) |
| B | 2 (40.0%) | 3 (37.5%) | 7 (11.5%) | 508 (31.9%) | 1 (6.3%) | 0 (0.0%) | 521 (18.0%) |
| C | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 312 (19.6%) | 0 (0.0%) | 0 (0.0%) | 320 (11.0%) |
| D | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 15 (0.9%) | 1 (6.3%) | 0 (0.0%) | 22 (0.8%) |
| E | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| F | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 3 (18.8%) | 0 (0.0%) | 6 (0.2%) |
| G | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 13 (0.4%) |
| H | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 27 (1.7%) | 1 (6.3%) | 0 (0.0%) | 36 (1.2%) |
| I | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 26 (1.6%) | 1 (6.3%) | 0 (0.0%) | 32 (1.1%) |

| Vehicle Position | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| J | 0 (0.0%) | 2 (25.0%) | 7 (11.5%) | 70 (4.4%) | 3 (18.8%) | 0 (0.0%) | 82 (2.8%) |
| K | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.6 Vehicle 1 Pre-event Movement*

Table 29 shows the frequency and percentage for each V1 Pre-event Movement. The "Pre-event Movement" describes the movement of the vehicle immediately prior to the event envelope and vehicle motions that place the vehicle(s) on a collision path.(39) The most frequent V1 Pre-event Movements for SCEs were *going straight* (81.2 percent), *negotiating a curve* (7.9 percent), and *decelerating in traffic lane* (5.1 percent).

**Table 29. Frequency and percentage of V1 Pre-event movement**

| Vehicle 1 Pre-event Movement | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Going Straight | 3 (60.0%) | 0 (0.0%) | 35 (57.4%) | 1,207 75.7% | 6 (37.5%) | 1,104 (90.9%) | 2,355 (81.2%) |
| Decelerating in Traffic Lane | 0 (0.0%) | 2 (25.0%) | 4 (6.6%) | 126 7.9% | 3 (18.8%) | 13 (1.1%) | 148 (5.1%) |
| Accelerating in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 58 3.6% | 4 (25.0%) | 8 (0.7%) | 74 (2.6%) |
| Stopped in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 0.1% | 1 (6.3%) | 0 (0.0%) | 3 (0.1%) |
| Passing or Overtaking Another Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 3 0.2% | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Entering a Parking Position, Backing | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 0.0% | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Turning Right | 0 (0.0%) | 3 (37.5%) | 2 (3.3%) | 17 1.1% | 0 (0.0%) | 0 (0.0%) | 22 (0.8%) |
| Turning Left | 0 (0.0%) | 3 (37.5%) | 1 (1.6%) | 12 0.8% | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| Making a U-turn | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 0.0% | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Negotiating a Curve | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 134 8.4% | 1 (6.3%) | 86 (7.1%) | 229 (7.9%) |
| Changing Lanes | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 13 0.8% | 0 (0.0%) | 3 (0.2%) | 16 (0.6%) |
| Merging | 0 | 0 | 5 | 18 | 1 | 1 | 25 |

| Vehicle 1 Pre-event Movement | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| | (0.0%) | (0.0%) | (8.2%) | 1.1% | (6.3%) | (0.1%) | (0.9%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 0.3% | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

### *6.2.5.7 Vehicle 2 Pre-event Movement*

Table 30 shows the frequency and percentage for each V2 Pre-event Movement. Not including the single-vehicle events, the most frequent V2 Pre-event Movements for SCEs were *going straight* (6.2 percent) and *decelerating in traffic lane* (3.7 percent).

**Table 30. Frequency and percentage of V2 pre-event movement.**

| Vehicle 2 Pre-event Movement | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event) | 4 (80.0%) | 8 (100.0%) | 16 (26.2%) | 1,114) (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,361 (81.4%) |
| Going Straight | 1 (20.0%) | 0 (0.0%) | 23 (37.7%) | 154 (9.7%) | 3 (18.8%) | 0 (0.0%) | 181 (6.2%) |
| Decelerating in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 105 (6.6%) | 1 (6.3%) | 0 (0.0%) | 107 (3.7%) |
| Accelerating in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 17 (1.1%) | 5 (31.3%) | 0 (0.0%) | 24 (0.8%) |
| Starting in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Stopped in Traffic Lane | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 28 (1.8%) | 0 (0.0%) | 0 (0.0%) | 29 (1.0%) |
| Passing or Overtaking Another Vehicle | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 12 (0.8%) | 1 (6.3%) | 0 (0.0%) | 16 (0.6%) |
| Disabled or Parked in Travel Lane | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| Leaving a Parking Position, Moving Forward | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Leaving a Parking Position, Backing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Turning Right | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 19 (1.2%) | 0 (0.0%) | 0 (0.0%) | 22 (0.8%) |
| Turning Left | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 17 (0.6%) |
| Making a U-turn | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Negotiating a Curve | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 28 (1.8%) | 1 (6.3%) | 0 (0.0%) | 31 (1.1%) |
| Changing Lanes | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 40 (2.5%) | 0 (0.0%) | 0 (0.0%) | 42 (1.4%) |

| Vehicle 2 Pre-event Movement | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Merging | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 39 (2.4%) | 1 (6.3%) | 0 (0.0%) | 46 (1.6%) |
| Successful Avoidance Maneuver in Response to a Previous Critical Event | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.8 Vehicle 1 Critical Pre-crash Event*

Table 31 shows the frequency and percentage for each V1 Critical Pre-crash Event. The "Critical Pre-crash Event" refers to the maneuver or incident which made the event imminent.(39) As can be seen in this table

Table 31, the predominant V1 Critical Pre-crash Events for SCEs were *toward or off the edge of the road on right side of travel* (78 percent) and *toward or over the lane line on left side of travel* (4.1 percent).

Table 31. Frequency and percentage of V1 critical pre-crash events.

| Category | Vehicle 1 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| This Vehicle (V1) Loss of Control Due To: | Poor Road Conditions | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| This Vehicle (V1) Traveling: | Toward or Over the Lane Line on Left Side of Travel | 0 (0.0%) | 0 (0.0%) | 14 (23.0%) | 104 (6.5%) | 2 (12.5%) | 0 (0.0%) | 120 (4.1%) |
| This Vehicle (V1) Traveling: | Toward or Over the Lane Line on Right Side of Travel | 1 (20.0%) | 0 (0.0%) | 7 (11.5%) | 34 (2.1%) | 0 (0.0%) | 0 (0.0%) | 42 (1.4%) |
| This Vehicle (V1) Traveling: | Toward or Off the Edge of the Road on the Left Side | 0 (0.0%) | 2 (25.0%) | 4 (6.6%) | 47 (2.9%) | 0 (0.0%) | 5 (0.4%) | 58 (2.0%) |
| This Vehicle (V1) Traveling: | Toward or Off the Edge of the Road on the Right Side | 0 (0.0%) | 2 (25.0%) | 9 (14.8%) | 1,038 (65.1%) | 2 (12.5%) | 1,210 (99.6%) | 2,261 (78.0%) |
| This Vehicle (V1) Traveling: | End Departure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| This Vehicle (V1) Traveling: | Turning Left at Intersection | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 5 (0.3%) | 1 (6.3%) | 0 (0.0%) | 7 (0.2%) |
| This Vehicle (V1) Traveling: | Turning Right at Intersection | 0 (0.0%) | 2 (25.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| This Vehicle (V1) Traveling: | Crossing Over (Passing Through) Intersection | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| This Vehicle (V1) Traveling: | This Vehicle Decelerating | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 70 (4.4%) | 2 (12.5%) | 0 (0.0%) | 75 (2.6%) |
| This Vehicle (V1) Traveling: | This Vehicle Accelerating | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 16 (1.0%) | 1 (6.3%) | 0 (0.0%) | 18 (0.6%) |
| This Vehicle (V1) Traveling: | Unknown Travel Direction | 2 (40.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |

| Category | Vehicle 1 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Other Motor Vehicle (V2) in Lane: | Other Vehicle Stopped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 14 (0.9%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) |
| Other Motor Vehicle (V2) in Lane: | Traveling in Same Direction With Lower Steady Speed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 24 (1.5%) | 1 (6.3%) | 0 (0.0%) | 26 (0.9%) |
| Other Motor Vehicle (V2) in Lane: | Traveling in Same Direction While Decelerating | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 67 (4.2%) | 0 (0.0%) | 0 (0.0%) | 70 (2.4%) |
| Other Motor Vehicle (V2) in Lane: | Traveling in Same Direction With Higher Speed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 5 (0.3%) | 6 (37.5%) | 0 (0.0%) | 12 (0.4%) |
| Other Motor Vehicle (V2) in Lane: | Traveling in Opposite Direction | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Other Motor Vehicle (V2) in Lane: | In Crossover | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other Motor Vehicle (V2) in Lane: | Backing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Adjacent Lane (Same Direction)—Toward or Over Left Lane Line | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 38 (2.4%) | 0 (0.0%) | 0 (0.0%) | 40 (1.4%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Adjacent Lane (Same Direction)—Toward or Over Right Lane Line | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 55 (3.5%) | 0 (0.0%) | 0 (0.0%) | 61 (2.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Opposite Direction—Toward or Over Left Lane Line | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 12 (0.4%) |

| Category | Vehicle 1 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Other Motor Vehicle (V2) Encroaching into Lane: | From Opposite Direction—Toward or Over Right Lane Line | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Parking Lane | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Crossing Street, Across Path | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Crossing Street, Turning into Opposite Direction | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Crossing Street, Intended Path Not Known | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Driveway, Turning into Same Direction | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Driveway, Turning into Opposite Direction | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | From Driveway, Intended Path Not Known | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Category | Vehicle 1 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Other Motor Vehicle (V2) Encroaching into Lane: | From Entrance to Limited-Access Highway | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 5 (0.3%) | 1 (6.3%) | 0 (0.0%) | 7 (0.2%) |
| Other Motor Vehicle (V2) Encroaching into Lane: | Encroachment by Other Vehicle—Details Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Pedestrian, Pedalcyclist, or Other Nonmotorist: | Pedestrian in Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Pedestrian, Pedalcyclist, or Other Nonmotorist: | Pedestrian Approaching Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Object or Animal: | Animal in Roadway | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| Object or Animal: | Object in Roadway | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Other: | Other Critical Pre-crash Event | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other: | Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| | **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.9 Vehicle 2 Critical Pre-crash Event*

Table 32 shows the frequency and percentage for each V2 Critical Pre-crash Event. As can be seen in this tableTable 32, the predominant V2 Critical Pre-crash Events for SCEs were more varied, including: *toward or over the lane line on left side of travel* (2.6 percent), *turning right at intersection* (2.4 percent), *traveling in same direction with higher speed* (2.4 percent), *from adjacent lane* (same direction), *toward or over right lane line* (1.8 percent), *this vehicle decelerating* (1.8 percent), and *toward or over the lane line on right side of travel* (1.7 percent).

Table 32. Frequency and percentage of V2 pre-crash events.

| Category | Vehicle 2 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| No Category | Not Applicable (Single-vehicle Event) | 4 (80.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,361 (81.4%) |
| This Vehicle (V2) Loss of Control Due To: | Non-disabling Vehicle Problem | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| This Vehicle (V2) Loss of Control Due To: | Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| This Vehicle (V2) Traveling: | Toward or Over the Lane Line on Left Side of Travel | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 68 (4.3%) | 3 (18.8%) | 0 (0.0%) | 76 (2.6%) |
| This Vehicle (V2) Traveling: | Toward or Over the Lane Line on Right Side of Travel | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 44 (2.8%) | 0 (0.0%) | 0 (0.0%) | 48 (1.7%) |
| This Vehicle (V2) Traveling: | Toward or Off the Edge of the Road on the Left Side | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| This Vehicle (V2) Traveling: | Toward or Off the Edge of the Road on the Right Side | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 1 (6.3%) | 0 (0.0%) | 12 (0.4%) |
| This Vehicle (V2) Traveling: | End Departure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| This Vehicle (V2) Traveling: | Turning Left at Intersection | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 28 (1.8%) | 0 (0.0%) | 0 (0.0%) | 29 (1.0%) |
| This Vehicle (V2) Traveling: | Turning Right at Intersection | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 67 (4.2%) | 0 (0.0%) | 0 (0.0%) | 69 (2.4%) |
| This Vehicle (V2) Traveling: | Crossing Over (Passing Through) Intersection | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| This Vehicle (V2) Traveling: | This Vehicle Decelerating | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 48 (3.0%) | 0 (0.0%) | 0 (0.0%) | 52 (1.8%) |

| Category | Vehicle 2 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| This Vehicle (V2) Traveling: | This Vehicle Accelerating | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 16 (1.0%) | 5 (31.3%) | 0 (0.0%) | 24 (0.8%) |
| This Vehicle (V2) Traveling: | Unknown Travel Direction | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| Other Motor Vehicle (V1) in Lane: | Traveling in Same Direction With Lower Steady Speed | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 3 (0.1%) |
| Other Motor Vehicle (V1) in Lane: | Traveling in Same Direction While Decelerating | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Other Motor Vehicle (V1) in Lane: | Traveling in Same Direction With Higher Speed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 66 (4.1%) | 2 (12.5%) | 0 (0.0%) | 69 (2.4%) |
| Other Motor Vehicle (V1) in Lane: | Traveling in Opposite Direction | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other Motor Vehicle (V1) Encroaching into Lane: | From Adjacent Lane (Same Direction)—Toward or Over Left Lane Line | 1 (20.0%) | 0 (0.0%) | 7 (11.5%) | 24 (1.5%) | 0 (0.0%) | 0 (0.0%) | 32 (1.1%) |
| Other Motor Vehicle (V1) Encroaching into Lane: | From Adjacent Lane (Same Direction)—Toward or Over Right Lane Line | 0 (0.0%) | 0 (0.0%) | 9 (14.8%) | 42 (2.6%) | 0 (0.0%) | 0 (0.0%) | 51 (1.8%) |
| Other Motor Vehicle (V1) Encroaching into Lane: | From Opposite Direction—Toward or Over Left Lane Line | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 35 (2.2%) | 0 (0.0%) | 0 (0.0%) | 35 (1.2%) |
| Other Motor Vehicle (V1) Encroaching into Lane: | From Opposite Direction—Toward or Over Right Lane Line | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Category | Vehicle 2 Critical Pre-crash Event | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Other Motor Vehicle (V1) Encroaching into Lane: | From Crossing Street, Turning into Opposite Direction | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other Motor Vehicle (V1) Encroaching into Lane: | From Entrance to Limited Access Highway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other: | Other Critical Pre-crash Event | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other: | Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| | **Total** | **5 (100%)** | **8 100%)** | **61 100%)** | **1,594 100%)** | **16 100%)** | **1,215 100%)** | **2,899 100%)** |

#### *6.2.5.10 Vehicle 1 Critical Reason (All Events)*

Table 33 shows the frequency and percentage for each V1 CR (all events). The “CR” is the primary reason for the event.[39] The table does not include the 219 SCEs for which the CR was not coded to V1 (7.6 percent). Only one CR was coded for each SCE (i.e., coded to either V1 or V2, but not both). Not including the SCEs where a CR was not coded to V1, the most frequent V1 CRs for SCEs were *internal distraction* (57.1 percent), *external distraction* (11.4 percent), and *drowsy, fatigue, or other reduced alertness* (8.9 percent). Almost half of the crashes had an environment-related (other) V1 CR, such as *animal in roadway* (20 percent) or *object in roadway* (20 percent).

Table 33. Frequency and percentage of V1 CRs.

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| No Category | CR Not Coded to This Vehicle | 0 (0.0%) | 0 (0.0%) | 16 (26.2%) | 193 (12.1%) | 10 (62.5%) | 0 (0.0%) | 219 (7.6%) |
| Driver-related Factor—Critical Non-performance Errors: | Sleep, That is, Actually Asleep | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 8 (0.7%) | 14 (0.5%) |
| Driver-related Factor—Critical Non-performance Errors: | Drowsiness, Fatigue, or Other Reduced Alertness | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 127 (8.0%) | 0 (0.0%) | 127 (10.5%) | 258 (8.9%) |
| Driver-related Factor—Recognition Errors: | Inattention (i.e., Daydreaming) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 22 (1.4%) | 0 (0.0%) | 20 (1.6%) | 43 (1.5%) |
| Driver-related Factor—Recognition Errors: | Internal Distraction | 0 (0.0%) | 0 (0.0%) | 9 (14.8%) | 764 (47.9%) | 0 (0.0%) | 882 (72.6%) | 1,655 (57.1%) |
| Driver-related Factor—Recognition Errors: | External Distraction | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 182 (11.4%) | 0 (0.0%) | 146 (12.0%) | 331 (11.4%) |
| Driver-related Factor—Recognition Errors: | Inadequate Surveillance (e.g., Failed to Look) | 1 (20.0%) | 0 (0.0%) | 13 (21.3%) | 21 (1.3%) | 0 (0.0%) | 0 (0.0%) | 35 (1.2%) |
| Driver-related Factor—Recognition Errors: | Other Recognition Error | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 1 (6.3%) | 1 (0.1%) | 9 (0.3%) |
| Driver-related Factor—Recognition Errors: | Unknown Recognition Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.5%) | 0 (0.0%) | 10 (0.8%) | 18 (0.6%) |
| Driver-related Factor—Decision Errors: | Too Fast for Conditions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Driver-related Factor—Decision Errors: | Misjudgment of Gap or Other's Speed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 30 (1.9%) | 0 (0.0%) | 0 (0.0%) | 31 (1.1%) |
| Driver-related Factor—Decision Errors: | Following Too Closely to Respond to Unexpected Actions | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 13 (0.4%) |
| Driver-related Factor—Decision Errors: | False Assumption of Other Road User's Actions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Driver-related Factor—Decision Errors: | Apparently Intentional Sign/Signal Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 2 (12.5%) | 0 (0.0%) | 3 (0.1%) |
| Driver-related Factor—Decision Errors: | Illegal U-turn | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Driver-related Factor—Decision Errors: | Other Illegal Maneuver | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 3 (18.8%) | 0 (0.0%) | 10 (0.3%) |
| Driver-related Factor—Decision Errors: | Inadequate Evasive Action (e.g., Braking Only, Not Braking and Steering) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 107 (6.7%) | 0 (0.0%) | 0 (0.0%) | 107 (3.7%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving: Intimidation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving: Wanton, Neglectful, or Reckless Behavior | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Driver-related Factor—Decision Errors: | Other Decision Error | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 5 (0.3%) | 0 (0.0%) | 1 (0.1%) | 7 (0.2%) |
| Driver-related Factor—Decision Errors: | Unknown Decision Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Driver-related Factor—Decision Errors: | DRIVER-RELATED: Apparent Recognition or Decision Error (Unknown Which) | 0 (0.0%) | 1 (12.5%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| Driver-related Factor—Performance Errors: | Overcompensation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 1 (0.1%) | 5 (0.2%) |
| Driver-related Factor—Performance Errors: | Poor Directional Control | 1 (20.0%) | 1 (12.5%) | 3 (4.9%) | 18 (1.1%) | 0 (0.0%) | 18 (1.5%) | 41 (1.4%) |
| Driver-related Factor—Performance Errors: | Other Performance Error | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Driver-related Factor—Performance Errors: | Unknown Performance Error | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 2 (0.1%) |

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Driver-related Factor—Performance Errors: | DRIVER-RELATED: Type of Driver Error Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Environment-related Factor—Highway-related: | Road Design—Roadway Geometry | 0 (0.0%) | 6 (75.0%) | 1 (1.6%) | 23 (1.4%) | 0 (0.0%) | 0 (0.0%) | 30 (1.0%) |
| Environment-related Factor—Highway-related: | Maintenance Problems | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Environment-related Factor—Highway-related: | Slick Roads | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Environment-related Factor—Other: | Animal in Roadway (No Driver Error) | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| Environment-related Factor—Other: | Pedestrian or Pedalcyclist in Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Environment-related Factor—Other: | Object in Roadway | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| | **Total** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** | **(100%)** |

#### *6.2.5.11 Vehicle 1 Critical Reason (Single-vehicle Events)*

Table 34 shows the frequency and percentage for each V1 CR for all single-vehicle events. The most frequent CRs for V1 single-vehicle events were *internal distraction* (69.2 percent), *external distraction* (13.6 percent), and *drowsy, fatigue, or other reduced alertness* (10.9 percent).

**Table 34. Frequency and percentage of V1 CRs (single-vehicle events).**

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Driver-related Factor—Critical Non-performance Errors: | Sleep, That is, Actually Asleep | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.5%) | 0 (0.0%) | 8 (0.7%) | 14 (0.6%) |
| Driver-related Factor—Critical Non-performance Errors: | Drowsiness, Fatigue, or Other Reduced Alertness | 0 (0.0%) | 0 (0.0%) | 4 (25.0%) | 126 (11.4%) | 0 (0.0%) | 127 (10.5%) | 257 (10.9%) |
| Driver-related Factor—Recognition Errors: | Inattention (i.e., Daydreaming) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (1.8%) | 0 (0.0%) | 20 (1.6%) | 40 (1.7%) |
| Driver-related Factor—Recognition Errors: | Internal Distraction | 0 (0.0%) | 0 (0.0%) | 5 (31.3%) | 740 (67.0%) | 0 (0.0%) | 882 (72.6%) | 1,627 (69.2%) |
| Driver-related Factor—Recognition Errors: | External Distraction | 0 (0.0%) | 0 (0.0%) | 2 (12.5%) | 171 (15.5%) | 0 (0.0%) | 146 (12.0%) | 319 (13.6%) |
| Driver-related Factor—Recognition Errors: | Other Recognition Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 1 (25.0%) | 1 (0.1%) | 4 (0.2%) |
| Driver-related Factor—Recognition Errors: | Unknown Recognition Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.5%) | 0 (0.0%) | 10 (0.8%) | 16 (0.7%) |
| Driver-related Factor—Decision Errors: | Too Fast for Conditions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Driver-related Factor—Decision Errors: | Apparently Intentional Sign/Signal Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (50.0%) | 0 (0.0%) | 2 (0.1%) |
| Driver-related Factor—Decision Errors: | Illegal U-turn | 1 (33.3%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Driver-related Factor—Decision Errors: | Other Illegal Maneuver | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 1 (25.0%) | 0 (0.0%) | 2 (0.1%) |
| Driver-related Factor—Decision Errors: | Other Decision Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 0 (0.0%) | 1 (0.1%) | 3 (0.1%) |

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Driver-related Factor—Decision Errors: | DRIVER-RELATED: Apparent Recognition or Decision Error (Unknown Which) | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 2 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Driver-related Factor—Performance Errors: | Overcompensation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 0 (0.0%) | 1 (0.1%) | 3 (0.1%) |
| Driver-related Factor—Performance Errors: | Poor Directional Control | 1 (33.3%) | 1 (12.5%) | 3 (18.8%) | 11 (1.0%) | 0 (0.0%) | 18 (1.5%) | 34 (1.4%) |
| Driver-related Factor—Performance Errors: | DRIVER-RELATED: Type of Driver Error Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Environment-related Factor—Highway-related: | Road Design—Roadway Geometry | 0 (0.0%) | 6 (75.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 7 (0.3%) |
| Environment-related Factor—Highway-related: | Maintenance Problems | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Environment-related Factor—Highway-related: | Slick Roads | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Environment-related Factor—Other: | Animal in Roadway (No Driver Error) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 5 (0.5%) | 0 (0.0%) | 0 (0.0%) | 6 (0.3%) |
| Environment-related Factor—Other: | Object in Roadway | 1 (33.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.4%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| | **Total** | **3 (100%)** | **8 (100%)** | **16 (100%)** | **1,105 (100%)** | **4 (100%)** | **1,215 (100%)** | **2,351 (100%)** |

#### *6.2.5.12 Vehicle 1 Critical Reason (Multivehicle Events)*

Table 35 shows the frequency and percentage for V1 CRs for all multivehicle events. Not including the SCEs where a CR was not coded to V1, the most frequent CRs for V1 multivehicle events were *inadequate evasive action* (19.5 percent), *inadequate surveillance* (6.2 percent), *misjudgment of gap or other's speed* (5.7 percent), *internal distraction* (5.1 percent), and *road design—roadway geometry* (4.2 percent).

**Table 35. Frequency and percentage of V1 CRs (multi-vehicle events).**

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| No Category | CR Not Coded to This Vehicle | 0 (0.0%) | 0 (0.0%) | 16 (35.6%) | 193 (39.5%) | 10 (83.3%) | 0 (0.0%) | 219 (40.0%) |
| Driver-related Factor—Critical Non-performance Errors: | Drowsiness, Fatigue, or Other Reduced Alertness | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Recognition Errors: | Inattention (i.e., Daydreaming) | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 2 (0.4%) | 0 (0.0%) | 0 (0.0%) | 3 (0.5%) |
| Driver-related Factor—Recognition Errors: | Internal Distraction | 0 (0.0%) | 0 (0.0%) | 4 (8.9%) | 24 (4.9%) | 0 (0.0%) | 0 (0.0%) | 28 (5.1%) |
| Driver-related Factor—Recognition Errors: | External Distraction | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 11 (2.2%) | 0 (0.0%) | 0 (0.0%) | 12 (2.2%) |
| Driver-related Factor—Recognition Errors: | Inadequate Surveillance (e.g., Failed to Look) | 1 (50.0%) | 0 (0.0%) | 13 (28.9%) | 20 (4.1%) | 0 (0.0%) | 0 (0.0%) | 34 (6.2%) |
| Driver-related Factor—Recognition Errors: | Other Recognition Error | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 5 (0.9%) |
| Driver-related Factor—Recognition Errors: | Unknown Recognition Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| Driver-related Factor—Decision Errors: | Too Fast for Conditions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 4 (0.7%) |
| Driver-related Factor—Decision Errors: | Misjudgment of Gap or Other's Speed | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 30 (6.1%) | 0 (0.0%) | 0 (0.0%) | 31 (5.7%) |
| Driver-related Factor—Decision Errors: | Following Too Closely to Respond to Unexpected Actions | 0 (0.0%) | 0 (0.0%) | 2 (4.4%) | 11 (2.2%) | 0 (0.0%) | 0 (0.0%) | 13 (2.4%) |
| Driver-related Factor—Decision Errors: | False Assumption of Other Road User's Actions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (1.6%) | 0 (0.0%) | 0 (0.0%) | 8 (1.5%) |
| Driver-related Factor—Decision Errors: | Apparently Intentional Sign/Signal Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Driver-related Factor—Decision Errors: | Other Illegal Maneuver | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (1.2%) | 2 (16.7%) | 0 (0.0%) | 8 (1.5%) |
| Driver-related Factor—Decision Errors: | Inadequate Evasive Action (e.g., Braking Only, Not Braking and Steering) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 107 (21.9%) | 0 (0.0%) | 0 (0.0%) | 107 (19.5%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving: Intimidation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving: Wanton, Neglectful, or Reckless Behavior | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 7 (1.4%) | 0 (0.0%) | 0 (0.0%) | 8 (1.5%) |
| Driver-related Factor—Decision Errors: | Other Decision Error | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 3 (0.6%) | 0 (0.0%) | 0 (0.0%) | 4 (0.7%) |
| Driver-related Factor—Decision Errors: | Unknown Decision Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| Driver-related Factor—Decision Errors: | DRIVER-RELATED: Apparent Recognition or Decision Error (Unknown Which) | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 7 (1.4%) | 0 (0.0%) | 0 (0.0%) | 8 (1.5%) |
| Driver-related Factor—Performance Errors: | Overcompensation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| Driver-related Factor—Decision Errors: | Poor Directional Control | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (1.4%) | 0 (0.0%) | 0 (0.0%) | 7 (1.3%) |
| Driver-related Factor—Decision Errors: | Other Performance Error | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 3 (0.6%) | 0 (0.0%) | 0 (0.0%) | 4 (0.7%) |
| Driver-related Factor—Decision Errors: | Unknown Performance Error | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Environment-related Factor—Highway-related: | Road Design—Roadway Geometry | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 22 (4.5%) | 0 (0.0%) | 0 (0.0%) | 23 (4.2%) |
| Environment-related Factor—Other: | Animal in Roadway (No Driver Error) | 1 (50.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 5 (0.9%) |

| Category | Vehicle 1 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| Environment-related Factor—Other: | Pedestrian or Pedalcyclist in Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 4 (0.7%) |
| Environment-related Factor—Other: | Object in Roadway | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.6%) | 0 (0.0%) | 0 (0.0%) | 3 (0.5%) |
| | **Total** | **2 (100%)** | **0 (0%)** | **45 (100%)** | **489 (100%)** | **12 (100%)** | **0 (100%)** | **548 (100%)** |

#### *6.2.5.13 Vehicle 2 Critical Reason*

Table 36 shows the frequency and percentage for each V2 CR. Since V2 was not instrumented, it was difficult to ascertain the V2 CR. Thus, the word “apparent” was added to some CRs to reflect the data reductionists’ subjective interpretation based on limited objective data for the V2 driver. For completeness, the table includes the 323 (11.1 percent) SCEs for which the CR was not coded to V2 and the 2,361 (81.4 percent) single-vehicle events which involved only V1. Not including the SCEs in which a CR was not coded to V2 or a single-vehicle event, the most frequent V2 CRs for SCEs were *other decision error* (1.4 percent), *aggressive driving: wanton, neglectful, or reckless behavior* (1 percent); *other illegal maneuver* (0.8 percent); *apparent recognition error* (0.7 percent); and *too slow for traffic stream* (0.7 percent).

Table 36. Frequency and percentage of V2 CRs.

| Category | Vehicle 2 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| **No Category** | Not Applicable (Single-vehicle Event) | 4 (80.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,361 (81.4%) |
| **No Category** | CR Not Coded to This Vehicle | 1 (20.0%) | 0 (0.0%) | 30 (49.2%) | 290 (18.2%) | 2 (12.5%) | 0 (0.0%) | 323 (11.1%) |
| **Driver-related Factor:** | DRIVER-RELATED FACTOR—Apparent Critical Non-Performance | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Driver-related Factor:** | DRIVER-RELATED FACTOR—Apparent Recognition Error | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 21 (0.7%) |
| **Driver-related Factor—Decision Errors:** | Too Slow for Traffic Stream | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 21 (0.7%) |
| **Driver-related Factor—Decision Errors:** | Following Too Closely to Respond to Unexpected Actions | 0 (0.0%) | 0v (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Driver-related Factor—Decision Errors:** | False Assumption of Other Road User's Actions | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| **Driver-related Factor—Decision Errors:** | Illegal U-turn | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Driver-related Factor—Decision Errors:** | Other Illegal Maneuver | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 11 (0.7%) | 10 (62.5%) | 0 (0.0%) | 24 (0.8%) |

| Category | Vehicle 2 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| **Driver-related Factor—Decision Errors:** | Inadequate Evasive Action (e.g., Braking Only, Not Braking and Steering) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| **Driver-related Factor—Decision Errors:** | Aggressive Driving: Wanton, Neglectful, or Reckless Behavior | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 28 (1.8%) | 0 (0.0%) | 0 (0.0%) | 28 (1.0%) |
| **Driver-related Factor—Decision Errors:** | Other Decision Error | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 39 (2.4%) | 0 (0.0%) | 0 (0.0%) | 41 (1.4%) |
| **Driver-related Factor—Decision Errors:** | Unknown Decision Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 15 (0.5%) |
| **Driver-related Factor—Decision Errors:** | DRIVER-RELATED: Apparent Recognition or Decision Error (Unknown Which) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Driver-related Factor—Decision Errors:** | DRIVER-RELATED FACTOR — Apparent Performance Error | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 15 (0.5%) |
| **Driver-related Factor—Decision Errors:** | DRIVER-RELATED: Type of Driver Error Unknown | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) |
| **Vehicle-related Factor:** | Apparent Other Vehicle Failure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| **Environment-related Factor—Highway-related:** | Signs/Signals Missing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Category | Vehicle 2 CR | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|---|
| **Environment-related Factor—Highway-related:** | Road Design—Roadway Geometry | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| **Environment-related Factor—Highway-related:** | Maintenance Problems | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Environment-related Factor—Highway-related:** | Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| **Environment-related Factor—Other:** | Unknown Reason for Critical Event | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| | **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.14 Critical Reasons for Light-vehicle/Heavy-vehicle Interactions*

Table 37 displays the frequency and percentage for each CR for all LV-HV interaction events. There were a total of 407 SCEs in which V1 interacted with an LV (i.e., V2). As indicated above, V2 was not instrumented, making it difficult to ascertain the V2 CR. Thus, the word "apparent" was added to some CRs to reflect the data reductionists' subjective interpretation based on limited objective data for the V2 driver. Of the 235 LV-HV interactions in which the HV driver (i.e., V1 driver) was coded as being "at fault," the most frequent CRs were *inadequate evasive action (e.g. braking only, not braking and steering; releasing accelerator only instead of braking)* (35.9 percent); *misjudgment of gap or other's speed* (12.2 percent); *internal distraction* (11.4 percent); and *inadequate surveillance (e.g. failed to look; looked but did not see)* (11 percent). Of the 146 LV-HV interactions in which the LV driver (i.e., V2 driver) was coded "at fault," the most frequent CRs were *other decision error* (23.6 percent), *aggressive driving behavior: wanton, neglectful or reckless behavior* (18.8 percent), *other illegal maneuver* (13.9 percent), and *too slow for traffic stream* (10.4 percent). Of the 26 LV-HV interactions in which neither the HV nor the LV driver was coded "at fault," the most frequent CR was *road design—roadway geometry (e.g., ramp curvature)* (76.9 percent). This usually involved the HV driver having difficulty making a right or left turn on an urban street with a tight turning radius.

**Table 37. Frequency and percentage of CRs for LV-HV interactions.**

| Category | CR | HV at Fault (%) | LV at Fault (%) | No Fault (%) | Total SCEs (%) |
|---|---|---|---|---|---|
| No Category: | CR Not Coded to This Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (7.7%) | 2 (0.5%) |
| Apparent Factor: | DRIVER-RELATED FACTOR—Apparent Critical Non-Performance | 0 (0.0%) | 1 (0.7%) | 0 (0.0%) | 1 (0.2%) |
| Apparent Factor: | DRIVER-RELATED FACTOR—Apparent Recognition Error | 0 (0.0%) | 9 (6.3%) | 0 (0.0%) | 9 (2.2%) |
| Apparent Factor: | DRIVER-RELATED FACTOR—Apparent Performance Error | 0 (0.0%) | 5 (3.5%) | 0 (0.0%) | 5 (1.2%) |
| Apparent Factor: | Apparent Vehicle Failure | 0 (0.0%) | 2 (1.4%) | 0 (0.0%) | 2 (0.5%) |
| Driver-related Factor—Critical Non-performance Errors: | Drowsiness, Fatigue, or Other Reduced Alertness (Not Asleep) | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Recognition Errors: | Inattention (i.e. Daydreaming) | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Recognition Errors: | Internal Distraction | 27 (11.4%) | 0 0.0%) | 0 (0.0%) | 27 (6.6%) |
| Driver-related Factor—Recognition Errors: | External Distraction | 10 (4.2%) | 0 (0.0%) | 0 (0.0%) | 10 (2.5%) |
| Driver-related Factor—Recognition Errors: | Inadequate Surveillance (e.g., Failed to Look, Looked But Did Not See) | 26 (11.0%) | 0 (0.0%) | 0 (0.0%) | 26 (6.4%) |
| Driver-related Factor—Recognition Errors: | Other Recognition Error | 3 (1.3%) | 0 (0.0%) | 0 (0.0%) | 3 (0.7%) |
| Driver-related Factor—Recognition Errors: | Unknown Recognition Error | 2 (0.8%) | 0 (0.0%) | 0 (0.0%) | 2 (0.5%) |
| Driver-related Factor—Decision Errors: | Too Fast for Conditions (e.g., For Safe Vehicle Control or to be Able to Respond to Unexpected Actions of Other Road Users) | 4 (1.7%) | 0 (0.0%) | 0 (0.0%) | 4 (1.0%) |
| Driver-related Factor—Decision Errors: | Too Slow for Traffic Stream | 0 (0.0%) | 15 (10.4%) | 0 (0.0%) | 15 (3.7%) |

| Category | CR | HV at Fault (%) | LV at Fault (%) | No Fault (%) | Total SCEs (%) |
|---|---|---|---|---|---|
| Driver-related Factor—Decision Errors: | Misjudgment of Gap or Other's Speed | 29 (12.2%) | 0 (0.0%) | 0 (0.0%) | 29 (7.1%) |
| Driver-related Factor—Decision Errors: | Following Too Closely to Respond to Unexpected Actions (Close Proximity for 2 or More Seconds) | 10 (4.2%) | 1 (0.7%) | 0 (0.0%) | 11 (2.7%) |
| Driver-related Factor—Decision Errors: | False Assumption of Other Road User's Actions | 6 (2.5%) | 5 (3.5%) | 0 (0.0%) | 11 (2.7%) |
| Driver-related Factor—Decision Errors: | Apparently Intentional Sign/Signal Violation | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Decision Errors: | Illegal U-turn | 0 (0.0%) | 1 (0.7%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Decision Errors: | Other Illegal Maneuver | 4 (1.7%) | 20 (13.9%) | 0 (0.0%) | 24 (5.9%) |
| Driver-related Factor—Decision Errors: | Inadequate Evasive Action (e.g., Braking Only Not Braking and Steering; Release Accelerator Only Instead of Braking) | 85 (35.9%) | 9 (6.3%) | 0 (0.0%) | 94 (23.1%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving Behavior: Intimidation | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Decision Errors: | Aggressive Driving Behavior: Wanton, Neglectful, or Reckless Behavior | 4 (1.7%) | 27 (18.8%) | 0 (0.0%) | 31 (7.6%) |
| Driver-related Factor—Decision Errors: | Other Decision Error | 2 (0.8%) | 34 (23.6%) | 0 (0.0%) | 36 (8.8%) |
| Driver-related Factor—Decision Errors: | Unknown Decision Error | 1 (0.4%) | 12 (8.3%) | 0 (0.0%) | 13 (3.2%) |
| Driver-related Factor—Decision Errors: | Apparent Recognition or Decision Error (Unknown Which) | 6 (2.5%) | 0 (0.0%) | 0 (0.0%) | 6 (1.5%) |
| Driver-related Factor—Performance Errors: | Overcompensation | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Performance Errors: | Poor Directional Control (e.g., Failing to Control Vehicle With Skill Ordinarily Expected) | 6 (2.5%) | 0 (0.0%) | 0 (0.0%) | 6 (1.5%) |
| Driver-related Factor—Performance Errors: | Other Performance Error | 4 (1.7%) | 0 (0.0%) | 0 (0.0%) | 4 (1.0%) |

| Category | CR | HV at Fault (%) | LV at Fault (%) | No Fault (%) | Total SCEs (%) |
|---|---|---|---|---|---|
| Driver-related Factor—Performance Errors: | Unknown Performance Error | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Driver-related Factor—Performance Errors: | Type of Driver Error Unknown | 0 (0.0%) | 4 (2.8%) | 0 (0.0%) | 4 (1.0%) |
| Environment-related Factors—Highway-related: | Signs/Signals Missing | 0 (0.0%) | 0 (0.0%) | 1 (3.8%) | 1 (0.2%) |
| Environment-related Factors—Highway-related: | Road Design—Roadway Geometry (e.g., Ramp Curvature) | 0 (0.0%) | 0 (0.0%) | 20 (76.9%) | 20 (4.9%) |
| Environment-related Factors—Other: | Object in Roadway | 0 (0.0%) | 0 (0.0%) | 3 (11.5%) | 3 (0.7%) |
| Environment-related Factors—Other: | Unknown Reason for Critical Event | 0 (0.0%) | 1 (0.7%) | 0 (0.0%) | 1 (0.2%) |
| | **Total** | **235 (100%)** | **146 (100%)** | **26 (100%)** | **407 (100%)** |

#### 6.2.5.15 *Driver at Fault*

Table 38 displays the distribution of "Driver at Fault" for all events, while Figure 39 displays the distribution of Driver at Fault for all events in which two or more vehicles were involved. Although fault has a legal connotation, it is used here to indicate the vehicle/driver that was assigned the CR. In other words, the critical error precipitating the event was associated with this vehicle and/or driver. Only multivehicle events are presented in Table 39. All single-vehicle events were excluded. There were a few events in which it was difficult to assign fault to either V1 or V2, and in these cases, the events were coded "unknown." Further, there were some events in which neither V1 or V2 was judged at fault; in these, "no fault" was coded. As discussed earlier in this report, the vehicle-based sensor suite employed in the study is better suited for detecting V1-initiated actions than V2-initiated actions, and as a result, there was a preponderance of V1 "at fault" events in this dataset. This was especially true for low-severity events.

As shown in Table 38, V1 was judged to be at fault in 90.4 percent of the SCEs, while V2 was judged at fault in 7.8 percent of the SCEs (0.1 and 1.7 percent were unknown or no fault was assigned, respectively). The overwhelming distribution of fault assigned to V1 is skewed because the majority of SCEs were single-vehicle events. When considering SCEs in which two or more vehicles were involved (as in Table 39), the distribution of assigned fault is split more evenly between V1 and V2.

**Table 38. Distribution of driver at fault (all events).**

| At Fault | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Vehicle 1 | 3 (60.0)% | 2 (25.0%) | 42 (68.9%) | 1,354 (84.9%) | 6 (37.5%) | 1,215 (100.0%) | 2,622 (90.4%) |
| Vehicle 2 | 1 (20.0%) | 0 (0.0%) | 15 (24.6%) | 199 (12.5%) | 10 (62.5%) | 0 (0.0%) | 225 (7.8%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| No Fault | 1 (20.0%) | 6 (75.0%) | 3 (4.9%) | 40 (2.5%) | 0 (0.0%) | 0 (0.0%) | 50 (1.7%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

**Table 39. Distribution of driver at fault (two or more vehicles involved).**

| At Fault | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Vehicle 1 | 1 (50.0%) | 0 (0.0%) | 28 (65.1%) | 262 (53.5%) | 2 (16.7%) | 0 (0.0%) | 293 (53.5%) |
| Vehicle 2 | 1 (50.0%) | 0 (0.0%) | 14 (32.6%) | 193 (39.4%) | 10 (83.3%) | 0 (0.0%) | 218 (39.8%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 1 (2.3%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| No Fault | 0 (0.0%) | 1 (100.0%) | 0 (0.0%) | 34 (6.9%) | 0 (0.0%) | 0 (0.0%) | 35 (6.4%) |
| **Total** | **2 (100%)** | **1 (100%)** | **43 (100%)** | **490 (100%)** | **12 (100%)** | **0 (0%)** | **548 (100%)** |

### *6.2.5.16 Driver at Fault (Light-vehicle/Heavy-vehicle Interactions)*

Table 40 displays the distribution of Driver at Fault for all LV-HV interaction events. There were 407 SCEs in which V1 interacted with an LV. Of these 407 SCEs, V1 (or the HV) was judged to be at fault in 57.7 percent of the events, while the LV was judged at fault in 35.9 percent of the events (“no fault” was coded in 6.4 percent of the events).

**Table 40. Frequency and percentage of driver at fault (LV-HV interactions).**

| At Fault | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| HV at Fault | 1 (100.0%) | 0 (0.0%) | 22 (68.8%) | 211 (58.0%) | 1 (10.0%) | 0 (0.0%) | 235 (57.7%) |
| LV at Fault | 0 (0.0%) | 0 (0.0%) | 9 (28.1%) | 128 (35.2%) | 9 (90.0%) | 0 (0.0%) | 146 (35.9%) |
| No Fault | 0 (0.0%) | 0 (0.0%) | 1 (3.1%) | 25 (6.9%) | 0 (0.0%) | 0 (0.0%) | 26 (6.4%) |
| **Total** | **1 (100%)** | **0 (0%)** | **32 (100%)** | **364 (100%)** | **10 (100%)** | **0 (0%)** | **407 (100%)** |

### *6.2.5.17 Vehicle 1 Attempted Avoidance Maneuver*

Table 41 displays the frequency and percentage for each V1 “Avoidance Maneuver.” Obviously, the V1 Attempted Avoidance Maneuvers in crashes and tire strikes were unsuccessful or not present, while the V1 Attempted Avoidance Maneuver was successful or not present in near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations. Almost 80 percent of the V1 Attempted Avoidance Maneuvers for SCEs involved steering to the left. Steering responses to the right or left were the predominant attempted avoidance maneuvers across the events of different levels of severity. A large percentage of crashes and tire strikes involved no V1 avoidance maneuver. Interestingly, 18 percent of the V1 Attempted Avoidance Maneuvers for near-crashes involved the V1 driver braking and steering to the right. This avoidance maneuver—braking and steering—implies that the driver believed that braking alone was insufficient to avoid the other vehicle/object. Of course, the detection of events, in general, depends largely on evasive maneuvers, which create detectable dynamic triggers. This is especially true of non-crashes in which there was no impact.

**Table 41. Frequency and percentage of V1 attempted avoidance maneuvers.**

| Vehicle 1 Attempted Avoidance Maneuver | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| No Avoidance Maneuver | 1 (20.0%) | 4 (50.0%) | 2 (3.3%) | 17 (1.1%) | 10 (62.5%) | 2 (0.2%) | 36 (1.2%) |
| Braking (No Lockup or Lockup Unknown) | 2 (40.0%) | 0 (0.0%) | 0 (0.0%) | 212 (13.3%) | 0 (0.0%) | 0 (0.0%) | 214 (7.4%) |
| Braking (Lockup) | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Releasing Brakes | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Steered to Left | 0 (0.0%) | 2 (25.0%) | 16 (26.2%) | 1,101 (69.1%) | 0 (0.0%) | 1,191 (98.0%) | 2,310 (79.7%) |
| Steered to Right | 0 (0.0%) | 1 (12.5%) | 15 (24.6%) | 99 (6.2%) | 1 (6.3%) | 4 (0.3%) | 120 (4.1%) |
| Braked and Steered to Left (No Lockup or Lockup Unknown) | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 48 (3.0%) | 0 (0.0%) | 2 (0.2%) | 56 (1.9%) |
| Braked and Steered to Right (No Lockup or Lockup Unknown) | 1 (20.0%) | 0 (0.0%) | 11 (18.0%) | 35 (2.2%) | 2 (12.5%) | 0 (0.0%) | 49 (1.7%) |
| Accelerated | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Accelerated and Steered to Left | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 21 (1.3%) | 1 (6.3%) | 7 (0.6%) | 29 (1.0%) |
| Accelerated and Steered to Right | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 1 (6.3%) | 0 (0.0%) | 12 (0.4%) |
| Released Gas Pedal Without Braking | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 1 (6.3%) | 0 (0.0%) | 17 (0.6%) |
| Released Gas Pedal Without Braking and Steered to Left | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 9 (0.7%) | 25 (0.9%) |
| Released Gas Pedal Without Braking and Steered to Right | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 14 (0.9%) | 0 (0.0%) | 0 (0.0%) | 15 (0.5%) |
| Unknown if Driver Attempted Any Corrective Action | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Vehicle 1 Attempted Avoidance Maneuver | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.18 Vehicle 2 Attempted Avoidance Maneuver*

Table 42 shows the frequency and percentage for each V2 Attempted Avoidance Maneuver. As the analysis of the NTDS dataset was based largely on the occurrence of V1 triggers, many possible V2 avoidance maneuvers were not seen. Not surprisingly, of the V2 Attempted Avoidance Maneuvers, 7.7 percent were coded as *no avoidance maneuver* and 2 percent were coded as *unknown if driver attempted any corrective action*.

**Table 42. Frequency and percentage of V2 attempted avoidance maneuvers.**

| Vehicle 2 Attempted Avoidance Maneuver | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event) | 4 (80.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,361 (81.4%) |
| No Avoidance Maneuver | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 209 (13.1%) | 5 (31.3%) | 0 (0.0%) | 222 (7.7%) |
| Braking (No Lockup or Lockup Unknown) | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 28 (1.8%) | 0 (0.0%) | 0 (0.0%) | 32 (1.1%) |
| Braking (Lockup) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Releasing Brakes | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| Steered to Left | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 35 (2.2%) | 1 (6.3%) | 0 (0.0%) | 41 (1.4%) |
| Steered to Right | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 59 (3.7%) | 0 (0.0%) | 0 (0.0%) | 63 (2.2%) |
| Braked and Steered to Left (No Lockup or Lockup Unknown) | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| Braked and Steered to Right (No Lockup or Lockup Unknown) | 1 (20.0%) | 0 (0.0%) | 6 (9.8%) | 16 (1.0%) | 0 (0.0%) | 0 (0.0%) | 23 (0.8%) |
| Braked and Steered to Right (Lockup) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Accelerated | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 23 (1.4%) | 1 (6.3%) | 0 (0.0%) | 24 (0.8%) |
| Accelerated and Steered to Left | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 23 (1.4%) | 2 (12.5%) | 0 (0.0%) | 30 (1.0%) |
| Accelerated and Steered to Right | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 13 (0.8%) | 3 (18.8%) | 0 (0.0%) | 18 (0.6%) |

| Vehicle 2 Attempted Avoidance Maneuver | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Other Actions | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| Unknown if Driver Attempted Any Corrective Action | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 53 (3.3%) | 0 (0.0%) | 0 (0.0%) | 57 (2.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.19 Vehicle 1 Accident Type*

Table 43 displays the frequency and percentage for each V1 Accident Type. The “Accident Type” categorizes the collisions of drivers involved in crashes. However, since most of the events in the NTDS dataset were not crashes, but rather near-crashes or other traffic conflicts, data reductionists were instructed to code the Accident Type variable as if a crash actually occurred in the scenario. This required a judgmental extrapolation of the event. Data reductionists were instructed to ask themselves the question, “If a crash had occurred, what type of crash would it have been?” Events in which V1 had an interaction with another vehicle, object, or animal while off the road were coded as single-vehicle collisions in accordance with the LTCCS and other USDOT crash databases. A visual representation of each Accident Type can be seen in Figure 44.[39]

The most frequent V1 Accident Types for SCEs were *right-roadside (or lane) departure* (V1 Accident Types 1-5, 78 percent), *rear-end, striking, lead vehicle (V2) decelerating* (V1 Accident Type 28, 4.8 percent), and *same direction sideswipe, non-encroaching vehicle* (V1 Accident Type 45, 4.2 percent). A large proportion of V1 Accident Types for near-crashes were *same direction sideswipe, encroaching vehicle* (V1 Accident Types 46-47, 29.5 percent).

**Table 43. Frequency and percentage of V1 accident types.**

| Vehicle 1 Accident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 01–05: Right Roadside (or Lane) Departure | 0 (0.0%) | 2 (25.0%) | 9 (14.8%) | 1,039 (65.2%) | 1 (6.3%) | 1,210 (99.6%) | 2,261 (78.0%) |
| 06–10: Left Roadside (or Lane) Departure | 0 (0.0%) | 3 (37.5%) | 5 (8.2%) | 47 (2.9%) | 1 (6.3%) | 5 (0.4%) | 61 (2.1%) |
| 12: Stationary Object | 1 (20.0%) | 3 (37.5%) | 1 (1.6%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 17 (0.6%) |
| 13: Pedestrian/Animal | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 15 (0.5%) |
| 11, 14–16: Other Forward Impact (Not With Vehicle in Transport) | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |

| Vehicle 1 Accident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 20: Rear-End, Striking, Lead Vehicle (V2) Stopped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 13 (0.4%) |
| 21–23: Rear-End, Struck, V1 Stopped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 24: Rear-End, Striking, Lead Vehicle (V2) Slower | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 60 (3.8%) | 1 (6.3%) | 0 (0.0%) | 63 (2.2%) |
| 25-27: Rear-End, Struck, V1 Slower | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 28: Rear-End, Striking, Lead Vehicle (V2) Decelerating | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 134 (8.4%) | 1 (6.3%) | 0 (0.0%) | 139 (4.8%) |
| 29–31: Rear-End, Struck, V1 Decelerating | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 32: Rear-End, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 34, 36, 38, 40: Forward Impact (With Same Direction Vehicle), Striking, Control Loss or Avoiding Collision | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 35, 37, 39, 41–43: Other Forward Impact (With Same Direction Vehicle) Type or Role (e.g., Struck Vehicle) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 45: Same Direction Sideswipe, Non-Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 8 (13.1%) | 107 (6.7%) | 8 (50.0%) | 0 (0.0%) | 123 (4.2%) |
| 46–47: Same Direction Sideswipe, Encroaching Vehicle | 1 (20.0%) | 0 (0.0%) | 18 (29.5%) | 58 (3.6%) | 1 (6.3%) | 0 (0.0%) | 78 (2.7%) |
| 44, 48–49: Same Direction Sideswipe, Other | 0 (0.0%) | 0 (0.0%) | 5 v8.2%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 18 (0.6%) |
| 50, 64: Head-On or Opposite Direction Sideswipe, Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 0 (0.0%) | 0 (0.0%) | 26 (0.9%) |
| 51, 65: Head-On or Opposite Direction Sideswipe, Non-Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 54, 56, 58, 60: Forward Impact (With Opposite Direction Vehicle), Striking, Control Loss or Avoiding Collision | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |

| Vehicle 1 Accident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 55, 57, 59, 61–63: Other Forward Impact (With Opposite Direction Vehicle) Type or Role (e.g., Struck Vehicle) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 66: Head-On or Opposite Direction Sideswipe, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 68, 70, 72: Turn Across Path, Turning Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 69, 71, 73: Turn Across Path, Vehicle Going Straight | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 76, 78, 80, 82: Turn Into Path, Turning Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) |
| 77, 79, 81, 83: Turn Into Path, Vehicle Going Straight | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| 74, 75, 84, 85: Other Turning Event/Role, Specifics Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 86, 88: Straight Crossing Paths, Striking Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 87, 89: Straight Crossing Paths, Struck Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 90–91: Straight Crossing Paths, Specifics Unknown or Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 1 (0.0%) |
| 92: Backing Vehicle | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 93: Struck Vehicle, Other Vehicle Backing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 98–99: Other or Unknown Accident Type | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (12.5%) | 0 (0.0%) | 2 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

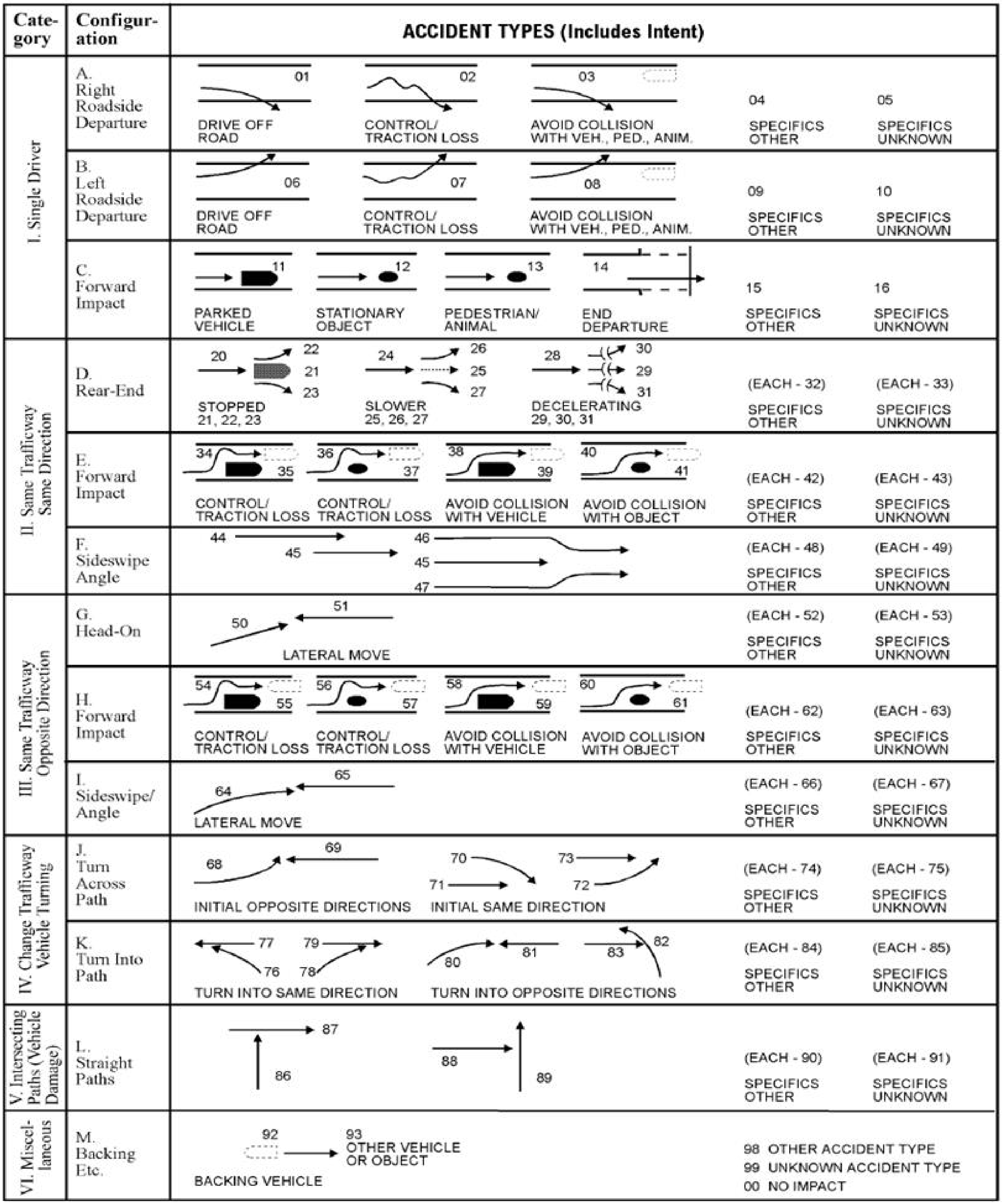



**Figure 44. Diagram. Description of the LTCCS accident types.**

### 6.2.5.20 *Vehicle 2 Accident Type*

Table 44 shows the frequency and percentage for each V2 Accident Type. Not including the single-vehicle events (in which case there was no V2), the majority of the V2 Accident Types for SCEs were *rear-end, struck, V1 decelerating* (V2 Accident Type 29-31, 4.8 percent), *same direction sideswipe, encroaching vehicle* (V2 Accident Types 46-47, 4 percent), and *same direction sideswipe, non-encroaching vehicle* (V2 Accident Type 45, 3.2 percent).

**Table 44. Frequency and percentage of V2 accident types.**

| Vehicle 2 Accident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 0: Not Applicable (Single-vehicle Event) | 3 (60.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,360 (81.4%) |
| 01–05: Right Roadside (or Lane) Departure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 06–10: Left Roadside (or Lane) Departure | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 12: Stationary Object | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 13: Pedestrian/Animal | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 11, 14–16: Other Forward Impact (Not With Vehicle in Transport) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 20: Rear-End, Striking, Lead Vehicle (V2) Stopped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 21–23: Rear-End, Struck, V1 Stopped | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 13 (0.4%) |
| 24: Rear-End, Striking, Lead Vehicle (V2) Slower | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 25–27: Rear-End, Struck, V1 Slower | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 60 (3.8%) | 1 (6.3%) | 0 (0.0%) | 63 (2.2%) |
| 28: Rear-End, Striking, Lead Vehicle (V2) Decelerating | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 29–31: Rear-End, Struck, V1 Decelerating | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 134 (8.4%) | 1 (6.3%) | 0 (0.0%) | 139 (4.8%) |
| 32: Rear-End, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 34, 36, 38, 40: Forward Impact (With Same Direction Vehicle), Striking, Control Loss or Avoiding Collision | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 35, 37, 39, 41–43: Other Forward Impact (With Same Direction Vehicle) Type or Role (e.g., Struck Vehicle) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 45: Same Direction Sideswipe, Non-Encroaching Vehicle | 1 (20.0%) | 0 (0.0%) | 22 (36.1%) | 69 (4.3%) | 1 (6.3%) | 0 (0.0%) | 93 (3.2%) |

| Vehicle 2 Accident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 46–47: Same Direction Sideswipe, Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 9 (14.8%) | 101 (6.3%) | 7 (43.8%) | 0 (0.0%) | 117 (4.0%) |
| 44, 48–49: Same Direction Sideswipe, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.5%) | 1 (6.3%) | 0 (0.0%) | 9 (0.3%) |
| 50, 64: Head-On or Opposite Direction Sideswipe, Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 51, 65: Head-On or Opposite Direction Sideswipe, Non-Encroaching Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 0 (0.0%) | 0 (0.0%) | 26 (0.9%) |
| 54, 56, 58, 60: Forward Impact (With Opposite Direction Vehicle), Striking, Control Loss or Avoiding Collision | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 55, 57, 59, 61–63: Other Forward Impact (With Opposite Direction Vehicle) Type or Role (e.g., Struck Vehicle) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 66: Head-On or Opposite Direction Sideswipe, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 68, 70, 72: Turn Across Path, Turning Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 69, 71, 73: Turn Across Path, Vehicle Going Straight | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 76, 78, 80, 82: Turn Into Path, Turning Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| 77, 79, 81, 83: Turn Into Path, Vehicle Going Straight | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) |
| 74, 75, 84, 85: Other Turning Event/Role, Specifics Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 86, 88: Straight Crossing Paths, Striking Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 87, 89: Straight Crossing Paths, Struck Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 90–91: Straight Crossing Paths, Specifics Unknown or Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 92: Backing Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 93: Struck Vehicle, Other Vehicle Backing | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 98–99: Other or Unknown Accident Type | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 0.0%) | 1 (0.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.21 Coding and Description of V1 and V2 Incident Types*

**1–2—Aborted Lane Change:** A driver tries to make a lane change into a lane where there is already a vehicle (driver does not see vehicle). The driver has to brake and move back into the original lane.

**5–6–7–8—Backing in Roadway:** A driver backs the vehicle while on a roadway in order to maneuver around an obstacle ahead on the roadway.

**9–10—Clear Path for Emergency Vehicle:** A driver is traveling ahead of an emergency vehicle (e.g., ambulance, fire truck) and has to move to the side of the road to let the emergency vehicle pass.

**11–12—Conflict Between Merging and/or Exiting Traffic:** Drivers entering and/or exiting a roadway, causing a conflict.

**13–14—Conflict with Oncoming Traffic:** A driver is approaching oncoming traffic (e.g., through an intersection) and has to maneuver back into the correct lane to avoid an oncoming vehicle.

**15–16—Exit Then Re-entrance onto Roadway:** A driver exits a roadway then crosses a solid white line to re-enter.

**17–18—Following Too Closely:** A driver does not allow adequate spacing between their vehicle and the lead vehicle (e.g., tailgating).

**19–20—Improper Lane Change:** A driver makes an improper lane change with regard to another vehicle (e.g., does not use blinker, changes lanes behind another vehicle then does not let vehicle change lanes, changes lanes across multiple lanes, etc.)

**21–22–23—Improper Passing:** A driver passes another vehicle when it is illegal or unsafe (e.g., passing across a double yellow line or without clearance from oncoming traffic).

**24–25—Improper U-turn:** A driver makes a U-turn in the middle of the road (over the double yellow line) and blocks traffic in the opposite direction.

**26–27—Lane Change without Sufficient Gap:** A driver enters an adjacent lane without allowing adequate space between the driver's vehicle and the vehicle ahead/behind it.

**28–29—Lane Drift:** A driver drifts into an adjacent lane without intention to make a lane change.

**30–31—Late Braking (and/or Steering) for Stopped/Stopping Traffic:** A driver fails to slow in advance for stopped or stopping traffic and must brake and/or steer abruptly.

**32–33—Lateral Deviation of Through Vehicle:** A driver has substantial lateral deviation of a through vehicle. Vehicle may or may not deviate from the lane.

**34–35—Left Turn without Clearance:** A driver turns left without adequate clearance from either oncoming through traffic or cross traffic from the left. The driver crosses another driver's path while entering an intersecting roadway.

**36–37—Merge Out of Turn (Before Lead Vehicle):** A driver merges onto a roadway before the lead vehicle. The lead vehicle must wait for the merged vehicle to pass before it is safe to enter the main highway.

**38–39–40—Merge without Sufficient Gap:** A driver merges into traffic without a sufficient gap to either the front or back of one or more vehicles.

**41–42—Obstruction in Roadway:** A stationary object blocks through traffic, such as traffic that is backed up or an animal in the roadway.

**43–44—Proceeding through Red Traffic Signal:** A driver fails to respond to a red traffic signal, conflicting with a vehicle proceeding through the intersection legally.

**45–46—Roadway Entrance without Clearance:** A driver turns onto a roadway without adequate clearance from through traffic.

**47–48—Slow Speed:** A driver is traveling at a much slower speed than the rest of the traffic, causing following traffic to pass the slow vehicle to avoid a conflict.

**49–50—Slow Upon Passing:** A driver moves in front of another vehicle then slows, causing the second (passed) vehicle to slow as well, or to go around the first vehicle.

**51–52–53—Sudden Braking in Roadway:** A driver is traveling ahead of another vehicle and brakes suddenly and improperly in the roadway for traffic, a traffic light, etc., causing the following vehicle to come close to their vehicle or to also brake suddenly.

**54–55—Through Traffic Does Not Allow Lane Change:** A driver is trying to make a lane change (with their turn signal on) but traffic in the adjacent lane will not allow the lane change to be completed.

**56–57–58—Through Traffic Does Not Allow Merge:** Through traffic obstructs (either intentionally or unintentionally) a driver from entering the roadway or from performing any type of merging behavior.

**59–60—Turn without Sufficient Warning:** A driver slows and turns without using a turn signal or without using a turn signal in advance.

**61–62—Turn/Exit from Incorrect Lane:** A driver turns onto a side road from the incorrect lane (e.g., a driver makes a right turn from the left lane instead of the right lane).

**63–64—Wide Turn into Adjacent Lane:** A vehicle partially enters an adjacent lane when turning. Traffic in the adjacent lane may be moving in the same or opposite direction.

**65—Conflict with Animal/Pedestrian/Pedalcyclist/Object in Roadway:** A vehicle approaches an animal/ pedestrian/pedalcyclist/object in the roadway and either makes contact with it, or performs an evasive maneuver in order to avoid it.

**66—Conflict with Animal/Pedestrian/Pedalcyclist/Object on Side of Roadway:** A vehicle approaches an animal/pedestrian/pedalcyclist/object on the side of the road and either makes contact with it, or performs an evasive maneuver in order to avoid it.

**67—Other Single-vehicle Event:** A vehicle is involved in a single-vehicle event. For example, runs off the side of the road without a threat of hitting a fixed object.

6**8–69—Close Proximity to Turning Vehicle:** The lead vehicle is making a right/left turn or changing lanes to the right/left, and the following vehicle comes close to the rear of the lead vehicle as they pass.

**70–71—Vehicle Passes through Intersection without Clearance:** A vehicle passes through an intersection (signal or non-signal) without adequate clearance from through traffic.

**72–73—Conflict with through Traffic:** A vehicle starts to turn (right or left) at an intersection, but has to brake to avoid a conflict with traffic passing through the intersection.

**99—Unable to Determine:** It is not possible to determine which vehicle is at fault, therefore, it is not possible to assign an incident type to the event.

#### *6.2.5.22 Vehicle 1 Incident Type*

Table 45 shows the frequency and percentage for each V1 Incident Type. Table 45 shows an illustrated table that contains the SCE percentages for V1 and V2 (far right column) and each Incident Type code. The “Incident Types” are similar to Accident Types in that they refer to the vehicles’ actions during each SCE. However, rather than being designed to describe the collision between two vehicles or a pedestrian/object (as described by the Accident Type), the Incident Types were developed to describe SCEs such as near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations.(4) The most frequent V1 Incident Types for SCEs were *other single-vehicle event* (V1 Incident Type 67, 54.2 percent) and *conflict with animal/pedestrian/pedalcyclist/object on side of roadway* (V1 Incident Type 66, 26.3 percent). For the more severe SCEs, including crashes and tire strikes, the most frequent V1 Incident Type included *conflict with animal/pedestrian/pedalcyclist/object in or on side of roadway* (V1 Incident Types 65–66).

**Table 45. Frequency and percentage of V1 incident types.**

| Vehicle 1 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 0 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 1 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 2 | 1 (20.0%) | 0 (0.0%) | 11 (18.0%) | 19 (1.2%) | 0 (0.0%) | 0 (0.0%) | 31 (1.1%) |

| Vehicle 1 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 5 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 6 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 7 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 8 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 9 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 10 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 11 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| 12 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 13 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 14 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 15 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 1 (6.3%) | 0 (0.0%) | 5 (0.2%) |
| 16 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 17 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 18 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| 19 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 20 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| 21 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 22 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 6 (37.5%) | 0 (0.0%) | 9 (0.3%) |
| 23 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.5%) | 1 (6.3%) | 0 (0.0%) | 9 (0.3%) |
| 24 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 25 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 26 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 43 (2.7%) | 0 (0.0%) | 0 (0.0%) | 43 (1.5%) |
| 27 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| 28 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 23 (0.8%) |
| 29 | 0 (0.0%) | 0 (0.0%) | 7 (11.5%) | 35 (2.2%) | 0 (0.0%) | 0 (0.0%) | 42 (1.4%) |
| 30 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| 31 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 30 (1.9%) | 1 (6.3%) | 0 (0.0%) | 31 (1.1%) |
| 32 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 19 (1.2%) | 0 (0.0%) | 0 (0.0%) | 20 (0.7%) |
| 33 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 34 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 35 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 12 (0.4%) |
| 36 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (18.8%) | 0 (0.0%) | 3 (0.1%) |
| 37 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 38 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 39 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 40 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 21 (0.7%) |
| 41 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 42 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| 43 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 1 (0.0%) |
| 44 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 45 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 46 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 47 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 48 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 17 (0.6%) |
| 49 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Vehicle 1 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 50 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 51 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 52 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 53 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| 54 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 55 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 56 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 57 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 58 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 14 (0.9%) | 0 (0.0%) | 0 (0.0%) | 15 (0.5%) |
| 59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 60 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 61 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 62 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 63 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 64 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 22 (0.8%) |
| 65 | 2 (40.0%) | 2 (25.0%) | 1 (1.6%) | 23 (1.4%) | 0 (0.0%) | 0 (0.0%) | 28 (1.0%) |
| 66 | 1 (20.0%) | 6 (75.0%) | 9 (14.8%) | 746 (46.8%) | 0 (0.0%) | 0 (0.0%) | 762 (26.3%) |
| 67 | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 346 (21.7%) | 3 (18.8%) | 1,215 (100.0%) | 1,570 (54.2%) |
| 68 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 69 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 76 (4.8%) | 0 (0.0%) | 0 (0.0%) | 76 (2.6%) |
| 70 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 71 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 72 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 73 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 99 | 1 (20.0%) | 0 (0.0%) | 2 (3.3%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.23 Vehicle 2 Incident Type*

Table 46 shows the frequency and percentage for each V2 Incident Type. Not including the single-vehicle events, the most frequent V2 Incident Types for SCEs were *close proximity to turning vehicle* (V2 Incident Type 68, 2.4 percent), *lane change without sufficient gap* (V2 Incident Type 27, 1.5 percent), *lane drift* (V2 Incident Type 28, 1.4 percent), *late braking (and/or steering) for stopped/stopping traffic* (V2 Incident Type 30, 1.1 percent), and *aborted lane change* (V2 Incident Type 1, 1.1 percent).

**Table 46. Frequency and percentage of V2 incident types.**

| Vehicle 2 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 0 | 3 (60.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,360 (81.4%) |
| 1 | 1 (20.0%) | 0 (0.0%) | 11 (18.0%) | 19 (1.2%) | 0 (0.0%) | 0 (0.0%) | 31 (1.1%) |
| 2 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 5 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Vehicle 2 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 6 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 7 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 8 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 9 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 10 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 11 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 12 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| 13 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 14 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 15 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 16 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 1 (6.3%) | 0 (0.0%) | 5 (0.2%) |
| 17 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| 18 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 19 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| 20 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 21 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 22 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 1 (6.3%) | 0 (0.0%) | 8 (0.3%) |
| 23 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 6 (37.5%) | 0 (0.0%) | 11 (0.4%) |
| 24 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 25 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 26 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| 27 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 43 (2.7%) | 0 (0.0%) | 0 (0.0%) | 43 (1.5%) |
| 28 | 0 (0.0%) | 0 (0.0%) | 7 (11.5%) | 35 (2.2%) | 0 (0.0%) | 0 (0.0%) | 42 (1.4%) |
| 29 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 21 (1.3%) | 0 (0.0%) | 0 (0.0%) | 24 (0.8%) |
| 30 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 30 (1.9%) | 1 (6.3%) | 0 (0.0%) | 31 (1.1%) |
| 31 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| 32 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 33 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 19 (1.2%) | 0 (0.0%) | 0 (0.0%) | 20 (0.7%) |
| 34 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 12 (0.8%) | 0 (0.0%) | 0 (0.0%) | 12 (0.4%) |
| 35 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 36 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 37 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (18.8%) | 0 (0.0%) | 3 (0.1%) |
| 38 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 39 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 21 (0.7%) |
| 40 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 41 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| 42 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 43 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 44 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 45 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 46 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 47 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 18 (1.1%) | 0 (0.0%) | 0 (0.0%) | 18 (0.6%) |
| 48 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 49 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 50 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Vehicle 2 Incident Type | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 51 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 52 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) |
| 53 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 54 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 55 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 56 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 57 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) |
| 58 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 60 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 61 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 62 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 63 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 20 (1.3%) | 0 (0.0%) | 0 (0.0%) | 22 (0.8%) |
| 64 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 65 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 66 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 67 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 68 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 75 (4.7%) | 0 (0.0%) | 0 (0.0%) | 75 (2.6%) |
| 69 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0) |
| 70 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 71 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.0%) |
| 72 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.0%) |
| 73 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 98 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 99 | 1 (20.0%) | 0 (0.0%) | 2 (3.3%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.24 Driver Wearing Safety Belt*

Table 47 displays the frequency and percentage of V1 driver safety-belt use for crashes, tire strikes, near-crashes, crash-relevant conflicts, illegal maneuvers, unintentional lane deviations, SCEs, and baseline events. This is one of a number of variables in the dataset for which data were collected for a random sample of baseline events as well as for SCEs. The percentage of V1 drivers who were wearing their safety belts during SCEs (83.6 percent) was similar to the number in baseline events (84.6 percent). The percentages were relatively the same across the different event severities.

**Table 47. Frequency and percentage of safety belt use for V1 drivers.**

| Seat Belt Worn? | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Yes | 4 (80.0%) | 8 (100.0%) | 47 (77.0%) | 1,316 (82.6%) | 13 (81.3%) | 1,037 (85.3%) | 2,425 (83.6%) | 386 (84.6%) |
| No | 1 (20.0%) | 0 (0.0%) | 14 (23.0%) | 273 (17.1%) | 3 (18.8%) | 175 (14.4%) | 466 (16.1%) | 66 (14.5%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 3 (0.2%) | 8 (0.3%) | 4 (0.9%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Odds ratios were calculated for comparisons between SCEs and baseline events. The odds ratio is a way of comparing the odds of some outcome (e.g., a SCE) occurring given the presence of some predictor factor, condition, or classification (e.g., safety belt). It is usually a comparison of the presence of a condition to its absence (e.g., SCE and baseline event). Odds ratios of "1" indicate the outcome is equally likely to occur or not occur, given the condition. An odds ratio greater than "1" indicates the outcome is more likely to occur than not, given the condition, while an odds ratio of less than "1" indicates the outcome is less likely to occur than not.[40] Of course, the comparison could also be between two mutually exclusive conditions or other classifications, such as blond hair versus brown hair. Some of the variables were also coded for baseline events; thus, a comparison between these baseline events and SCEs will assess whether certain variables are more likely to occur during a risky traffic event than under normal driving conditions.

A Chi-Square test assesses whether the odds ratio differs significantly from "1" (i.e., there is a significant difference between the case and control). Odds ratios that do not include "1" in the 95-percent confidence interval are considered significantly different than "1." In other words, if the derived odds ratio is so different from "1" that the probability of its being "1" is 0.05 or less, then one can conclude that the presence or absence of the predictor is indeed associated with occurrence of the outcome. For example, if the 95-percent confidence interval calculated using the Chi-Square test was 3.4 to 7.4, there is a 95-percent certainty that the true odds ratio is between 3.4 and 7.4, which does not include "1." Conversely, if the 95-percent confidence interval were much wider, say, 0.9 to 9.9, the odds ratio would be rejected as non-significant because the true odds ratio might actually be "1." All odds ratios derived for principal predictor factors in the study will include a determination of whether they are significantly different from "1" statistically.[41] All odds ratios presented compared total SCEs and baseline events.

Not surprisingly, the odds ratio for safety belt use was not significant (odds ratio = 0.89). The LCL was 0.673 and the UCL was 1.176; thus, the 95-percent confidence limit contained "1" and was not significant. Therefore, drivers were just as likely to be wearing a safety belt during a total SCE as during a baseline event.

#### 6.2.5.25 *Vision Obscured By (V1 Only)*

Table 48 shows the frequency and percentage for each "Vision Obscured By" code, a variable that was coded for V1 only. The "Vision Obscured By" variable indicates whether the driver's vision was obscured by something. The majority of SCEs did not involve a visual obstruction (97.9 percent). When a visual obstruction was present, it typically involved rain, snow, fog, smoke, sand, dust, or glare.

**Table 48. Frequency and percentage of vision obscured (V1 only).**

| Vision Obscured By: | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| No Obstruction | 4 (80.0%) | 8 (100.0%) | 57 (93.4%) | 1,551 (97.3%) | 15 (93.8% | 1,202 (98.9%) | 2,837 (97.9%) |
| Rain, Snow, Fog, Smoke, Sand, Dust | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 11 (0.7%) | 0 (0.0%) | 4 (0.3%) | 17 (0.6%) |
| Reflected Glare, sunlight, Headlights | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (0.6%) | 0 (0.0%) | 6 (0.5%) | 16 (0.6%) |
| Curve or Hill | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Building, Billboard, or Other Design Features (Includes Signs, Embankment) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Trees, Crops, Vegetation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Moving Vehicle (Including Load) | 0 (0.0%) | 0 (0.0%) | 0 0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Parked Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Splash or Spray of Passing Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Inadequate Defrost or Defog System | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Inadequate Lighting system (Includes Vehicle/Object in Dark Area) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Obstruction Interior to Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Mirrors | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Head Restraints | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Broken or Improperly Cleaned Windshield | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 3 (0.2%) | 9 (0.3%) |
| Fog | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Other Vehicle or Object in Blind Spot | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |

| Vision Obscured By: | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Vision Obscured—No Details | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Unknown Whether Vision Was Obstructed | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 1 (0.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.26 V1 Potential Distracters*

Table 49 shows the frequency and percentage for each V1 Potential Distraction. Data reductionists were instructed to code up to four "Potential Distractions" observed during 10 seconds prior to the maximum/minimum trigger value or during the final 10 seconds of the baseline event. Potential Distractions were coded regardless of their apparent relevance to the event. If there were more than four Potential Distractions, data reductionists were instructed to select the ones that occurred closest in time to the trigger. As more than one Potential Distraction could be selected and percentages were based on the number of events, the column totals exceed 100 percent.

The most frequent Potential Distractions exhibited by V1 drivers for SCEs were *look at left-side mirror/out left-side window* (31.8 percent), *look down (at lap, floor, etc.)* (22.7 percent), and *look at/for object in vehicle* (18.4 percent). These were surprisingly similar to the baseline events. Given the similarity of Potential Distractions between SCEs and baseline events, one might conclude that engaging in a distraction does not increase a driver's risk of being involved in a SCE. However, perhaps a more appropriate explanation for the results concerns how data reductionists were instructed to code Potential Distractions. They were instructed to code all Potential Distractions regardless of their relevance to the event. In the NTDS dataset, it appeared that drivers engaged in many potentially distracting events, but the occurrence of these events did not necessarily predict event involvement. This is a possible area for follow-up research to identify the types of potentially distracting behaviors associated with event occurrence, the critical times of their occurrence in relation to the event, the length of time engaging in each Potential Distraction (e.g., time away from forward roadway), and how best to capture these to quantify risk associated with various potentially distracting behaviors.

**Table 49. Frequency and percentage of V1 potential distractions.**

| Potential Distractions | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| None Observed | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 110 (6.9%) | 4 (25.0%) | 41 (3.4%) | 159 (5.5%) |
| Looked But Did Not See | 0 (0.0%) | 0 (0.0%) | 7 (11.5%) | 31 (1.9%) | 0 (0.0%) | 3 (0.2%) | 41 (1.4%) |
| Interact With or Look at Other Occupant(s) | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 8 (0.5%) | 0 (0.0%) | 4 (0.3%) | 14 (0.5%) |
| Look At/For Object in Vehicle | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 255 (16.0%) | 2 (12.5%) | 272 (22.4%) | 532 (18.4%) |
| Reach for Object in Vehicle | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 205 (12.9%) | 2 (12.5%) | 161 (13.3%) | 373 (12.9%) |
| Talk/Listen to Hand-Held Phone | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 93 (5.8%) | 0 (0.0%) | 64 (5.3%) | 160 (5.5%) |
| Talk/Listen to Hands-Free Phone | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 36 (2.3%) | 0 (0.0%) | 27 (2.2%) | 65 (2.2%) |
| Talk/Listen to CB or Other Device | 0 (0.0%) | 1 (12.5%) | 1 (1.6%) | 13 (0.8%) | 0 (0.0%) | 12 (1.0%) | 27 (0.9%) |
| Dial Hand-Held Phone | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 26 (1.6%) | 0 (0.0%) | 26 (2.1%) | 52 (1.8%) |
| Dial Hands-Free Phone | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 6 (0.5%) | 7 (0.2%) |
| Using Cell Phone—Text Messaging | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 34 (2.1%) | 0 (0.0%) | 41 (3.4%) | 76 (2.6%) |
| Operate PDA (Inputting or Reading) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 1 (0.1%) | 6 (0.2%) |
| Adjust Instrument Panel (Includes Climate Control, Radio, CD) | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 131 (8.2%) | 2 (12.5%) | 94 (7.7%) | 229 (7.9%) |
| Look at Left-Side Mirror/Out Left-Side Window | 2 (40.0%) | 6 (75.0%) | 26 (42.6%) | 531 (33.3%) | 7 (43.8%) | 351 (28.9%) | 923 (31.8%) |
| Look at Right-Side Mirror/Out Right-Side window | 2 (40.0%) | 5 (62.5%) | 16 (26.2%) | 248 (15.6%) | 3 (18.8%) | 114 (9.4%) | 388 (13.4%) |
| Look in Sleeper Berth | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 11 (0.7%) | 0 (0.0%) | 10 (0.8%) | 22 (0.8%) |
| Shift Gears | 0 (0.0%) | 2 (25.0%) | 6 (9.8%) | 99 (6.2%) | 1 (6.3%) | 12 (1.0%) | 120 (4.1%) |
| Look Down (at Lap, Floor, etc.) | 0 (0.0%) | 1 (12.5%) | 9 (14.8%) | 354 (22.2%) | 3 (18.8%) | 291 (24.0%) | 658 (22.7%) |
| Use Calculator | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 8 (0.7%) | 12 (0.4%) |
| Use or Reach for Other Devices | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 96 (6.0%) | 0 (0.0%) | 114 (9.4%) | 212 (7.3%) |
| Appears Drowsy, Sleepy, Asleep, Fatigued | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 87 (5.5%) | 0 (0.0%) | 65 (5.3%) | 155 (5.3%) |
| Look at Previous Crash or Highway Incident | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |

| Potential Distractions | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Look at Outside Animal, Object, Store, etc. | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (0.6%) | 0 (0.0%) | 2 (0.2%) | 12 (0.4%) |
| Look at Outside Person | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 4 (0.3%) | 9 (0.3%) |
| Look at Undetermined Outside Event, Person, or Object | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 12 (0.8%) | 0 (0.0%) | 10 (0.8%) | 22 (0.8%) |
| Eat with Utensil | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 1 (6.3%) | 4 (0.3%) | 7 (0.2%) |
| Eat without Utensil (Includes Chewing, Other Than Gum; e.g., Toothpick) | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 71 (4.5%) | 0 (0.0%) | 72 (5.9%) | 147 (5.1%) |
| Drink from Covered Container (e.g., With Straw) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 9 (0.7%) | 14 (0.5%) |
| Drink from Open Container | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 19 (1.2%) | 0 (0.0%) | 13 (1.1%) | 33 (1.1%) |
| Chewing Gum | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 32 (2.0%) | 0 (0.0%) | 24 (2.0%) | 56 (1.9%) |
| Smoking-Related Behavior—Reaching, Lighting, Extinguishing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 22 (1.4%) | 0 (0.0%) | 10 (0.8%) | 32 (1.1%) |
| Smoking-Related Behavior—Other (e.g., Cigarette in Hand/Mouth) | 1 (20.0%) | 2 (25.0%) | 5 (8.2%) | 92 (5.8%) | 1 (6.3%) | 60 (4.9%) | 161 (5.6%) |
| Using Chewing Tobacco (e.g., Putting in Mouth, Holding in Mouth, Spitting, etc.) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 6 (0.5%) | 13 (0.4%) |
| Read/Look at Map | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 17 (1.1%) | 0 (0.0%) | 35 (2.9%) | 53 (1.8%) |
| Read Book, Newspaper, etc. | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 31 (1.9%) | 0 (0.0%) | 49 (4.0%) | 80 (2.8%) |
| Writing Pad, Notebook, etc. | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 15 (0.9%) | 0 (0.0%) | 14 (1.2%) | 29 (1.0%) |
| Talk/Sing/Dance with No Indication of Passenger | 0 (0.0%) | 1 (12.5%) | 4 (6.6%) | 90 (5.6%) | 0 (0.0%) | 69 (5.7%) | 164 (5.7%) |
| Handle/Interact with Dispatching, Electronic Recording, or Navigational Device | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 61 (3.8%) | 0 (0.0%) | 80 (6.6%) | 141 (4.9%) |
| Read/Look at Dispatching, Electronic Recording, or Navigational Device | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 21 (1.3%) | 0 (0.0%) | 43 (3.5%) | 64 (2.2%) |
| Comb/Brush/Fix Hair | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (0.6%) | 0 (0.0%) | 5 (0.4%) | 15 (0.5%) |
| Bite Nails/Cuticles | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 4 (0.3%) | 8 (0.3%) |
| Remove/Adjust Jewelry | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 4 (0.3%) | 7 (0.2%) |

| Potential Distractions | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Other Personal Hygiene | 0 (0.0%) | 2 (25.0%) | 5 (8.2%) | 196 (12.3%) | 0 (0.0%) | 153 (12.6%) | 356 (12.3%) |
| Put on/Remove/Adjust Sunglasses | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 18 (1.1%) | 0 (0.0%) | 18 (1.5%) | 36 (1.2%) |
| Put on/Remove/Adjust Hat | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 4 (0.3%) | 5 (0.2%) |
| Put on/Remove/Adjust Seatbelt | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 3 (0.2%) | 10 (0.3%) |
| Look at/Handle DAS | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other Potentially Distracting Behavior | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 104 (6.5%) | 1 (6.3%) | 89 (7.3%) | 196 (6.8%) |
| **Total** | **7 (140%)** | **21 (263%)** | **100 (164%)** | **3,087 (194%)** | **23 (144%)** | **2,453 (202%)** | **5,691 (196%)** |
| **Event Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

Table 50 displays the odds ratios, LCLs, and UCLs for a select number of V1 Potential Distractions. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be *looking at/for an object in vehicle* (odds ratio = 1.97), *reaching for an object in vehicle* (odds ratio = 2.18), *using or reaching for other devices* (odds ratio = 6.17), *reading/looking at a map* (odds ratio= 3.76), *reading book, newspaper, etc.* (odds ratio = 11.41), *handling/interacting with dispatching, electronic recording, or navigational device* (odds ratio = 10.16), or *reading/looking at dispatching, electronic recording, or navigational device* (odds ratio = 4.55) during total SCEs compared to baseline events. Some behaviors had a protective effect as drivers were less likely to be *looking at the left-side mirror/out left-side window* (odds ratio = 0.62) or *looking at the right-side mirror/out right-side window* (odds ratio = 0.52) during total SCEs compared to baseline events.

**Table 50. Odds ratios, LCLs, and UCLs for potential distractions (V1 only).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Look at/for Object in Vehicle | 1.97* | 1.41 | 2.74 |
| Reach for Object in Vehicle | 2.18* | 1.44 | 3.29 |
| Talk/Listen to Handheld Phone | 1.19 | 0.74 | 1.93 |
| Talk/Listen to Hands-free Phone | 0.76 | 0.41 | 1.41 |
| Talk/Listen to CB or Other Device | 0.76 | 0.29 | 1.98 |
| Dial Handheld Phone | 2.45 | 0.76 | 7.88 |
| Using Cell Phone—Text Messaging | N/A | N/A | N/A |
| Adjust Instrument Panel (Includes Climate Control, Radio, CD) | 1.36 | 0.88 | 2.08 |
| Look at Left-Side Mirror/out Left-Side Window | 0.62* | 0.52 | 0.74 |
| Look at Right-Side Mirror/out Right-Side Window | 0.52* | 0.41 | 0.66 |

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Look down (at Lap, Floor, etc.) | 0.91 | 0.72 | 1.13 |
| Use or Reach for Other Devices | 6.17* | 2.53 | 15.03 |
| Appears Drowsy, Sleepy, Asleep, Fatigued | 1.70 | 0.96 | 3 |
| Eat without Utensil (Includes Chewing, Other Than Gum; e.g., Toothpick) | 1.74 | 0.96 | 3.16 |
| Drink from Open Container | 0.51 | 0.24 | 1.08 |
| Read/Look at Map | 3.76* | 0.91 | 15.45 |
| Read Book, Newspaper, etc. | 11.42 | 1.59 | 82.17 |
| Writing on Pad, Notebook, etc. | N/A | N/A | N/A |
| Talk/Sing/Dance with No Indication of Passenger | 1.00 | 0.64 | 1.56 |
| Handle/Interact with Dispatching, Electronic Recording, or Navigational Device | 10.16* | 2.21 | 41.12 |
| Read/Look at Dispatching, Electronic Recording, or Navigational Device | 4.55* | 1.11 | 18.62 |
| Other Personal Hygiene | 0.80 | 0.6 | 1.05 |
| Other Potentially Distracting Behavior | 1.06 | 0.71 | 1.61 |

*Indicates significant odds ratio

#### *6.2.5.27 V1 Driver Actions/Factors/Behaviors*

Table 51 displays the frequency and percentage for each V1 Driver Behavior. Data reductionists coded up to four V1 items believed to be relevant to the occurrence of the SCEs (similar to a contributing factor). If there were more than four, data reductionists were instructed to select the four most important in relation to the event. As more than one item could be selected, the column totals exceed 100 percent (the denominator was the number of events).

The most frequent V1 Driver Behaviors for SCEs were *inattentive or distracted* (73.2 percent), *drowsy, sleepy, asleep, fatigued, other reduced alertness* (9.1 percent), *driving without lights or insufficient lights* (8.9 percent), and *inadequate evasive action* (5.5 percent). Not surprisingly, almost all (75 percent) of the tire strikes involved some type of improper turn. Almost one-quarter of the near-crashes (24.6 percent) involved the V1 driver not seeing the other vehicle during a lane change or merge.

**Table 51. Frequency and percentage of V1 driver behaviors.**

| Vehicle 1 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| None Observed | 1 (20.0%) | 1 (12.5%) | 12 (19.7%) | 152 (9.5%) | 8 (50.0%) | 17 (1.4%) | 191 (6.6%) |
| Apparent Excessive Speed for Conditions or Location (Does Not Include Tailgating, Unless Above Speed Limit) | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 22 (1.4%) | 0 (0.0%) | 4 (0.3%) | 29 (1.0%) |
| Drowsy, Sleepy, Asleep, Fatigued, Other Reduced Alertness | 0 (0.0%) | 1 (12.5%) | 9 (14.8%) | 9 (0.6%) | 0 (0.0%) | 246 (20.2%) | 265 (9.1%) |

| Vehicle 1 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Angry | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| Other Emotional State | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 22 (1.4%) | 2 (12.5%) | 2 (0.2%) | 28 (1.0%) |
| Inattentive or Distracted | 1 (20.0%) | 0 (0.0%) | 21 (34.4%) | 1,034 (64.9%) | 0 (0.0%) | 1,066 (87.7%) | 2,122 (73.2%) |
| Driving Slowly; Below Speed Limit or in Relation to Other Traffic | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 10 (0.6%) | 1 (6.3%) | 1 (0.1%) | 13 (0.4%) |
| Illegal Passing (i.e., Across Double Line) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 14 (0.9%) | 1 (6.3%) | 0 (0.0%) | 15 (0.5%) |
| Passing on Right | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 1 (6.3%) | 0 (0.0%) | 8 (0.3%) |
| Other Improper or Unsafe Passing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 33 (2.1%) | 2 (12.5%) | 0 0.0%) | 35 (1.2%) |
| Cutting in, Too Close in Front of Other Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 18 (1.1%) | 0 (0.0%) | 0 (0.0%) | 18 (0.6%) |
| Cutting in, Too Close Behind Other Vehicle | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Making Turn from Wrong Lane (e.g., Across Lanes) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Did Not See Other Vehicle During Lane Change or Merge | 1 (20.0%) | 0 (0.0%) | 15 (24.6%) | 23 (1.4%) | 0 (0.0%) | 0 (0.0%) | 39 (1.3%) |
| Aggressive Driving, Specific, Directed Menacing Actions | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| Aggressive Driving, Other | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 10 (0.6%) | 1 (6.3%) | 0 (0.0%) | 13 (0.4%) |
| Wrong Side of Road, Not Overtaking (Includes Partial or Full Drift into Oncoming Lane) | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 1 (6.3%) | 0 (0.0%) | 27 (0.9%) |
| Following Too Close | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 38 (2.4%) | 0 (0.0%) | 2 (0.2%) | 42 (1.4%) |
| Inadequate Evasive Action | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 155 (9.7%) | 0 (0.0%) | 0 (0.0%) | 159 (5.5%) |
| Failed to Signal, or Improper Signal | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 13 (0.8%) | 1 (6.3%) | 0 (0.0%) | 16 (0.6%) |
| Improper Turn: Wide Right Turn | 0 (0.0%) | 2 (25.0%) | 1 (1.6%) | 16 (1.0%) | 0 (0.0%) | 0 (0.0%) | 19 (0.7%) |
| Improper Turn: Cut Corner on Left Turn | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Other Improper Turning | 1 (20.0%) | 3 (37.5%) | 2 (3.3%) | 5 (0.3%) | 1 (6.3%) | 0 (0.0%) | 12 (0.4%) |

| Vehicle 1 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Improper Backing, Other | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Signal Violation, Apparently Did Not See Signal | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Signal Violation, Intentionally Ran Red Light | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 1 (0.0%) |
| Signal Violation, Tried to Beat Signal Change | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Stop Sign Violation, Rolling Stop | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 1 (0.0%) |
| Other Sign (e.g., Yield) Violation, Apparently Did Not See Sign | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Right-of-Way Error in Relation to Other Vehicle or Person, Apparent Recognition Failure | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 16 (0.6%) |
| Right-of-Way Error in Relation to Other Vehicle or Person, Apparent Decision Failure | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| Right-of-Way Error in Relation to Other Vehicle or Person, Other or Unknown Cause | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Sudden or Improper Stopping on Roadway | 1 (20.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Driving without Lights or with Insufficient Lights | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 259 (16.2%) | 0 (0.0%) | 0 (0.0%) | 259 (8.9%) |
| Avoiding Pedestrian | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Avoiding Other Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 19 (0.7%) |
| Avoiding Animal | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| Avoiding Object | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 17 (1.1%) | 0 (0.0%) | 2 (0.2%) | 20 (0.7%) |
| Apparent Unfamiliarity with Roadway | 1 (20.0%) | 1 (12.5%) | 2 (3.3%) | 10 (0.6%) | 1 (6.3%) | 0 (0.0%) | 15 (0.5%) |

| Vehicle 1 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| Use of Cruise Control Contributed to Late Braking (Does Not Imply Malfunction of Cruise Control System) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Loss of Control on Slippery Road Surface | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Loss of Control on Dry (or Unknown) Surface | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Driving in Other Vehicle's Blind Spot | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 12 (0.8%) | 0 (0.0%) | 7 (0.6%) | 19 (0.7%) |
| **Total** | **8 (160%)** | **9 (113%)** | **93 (152%)** | **1,982 (124%)** | **22 (138%)** | **1,347 (111%)** | **3,461 (119%)** |
| **Event Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.28 V2 Driver Actions/Factors/Behaviors*

Table 52 shows the frequency and percentage for each V2 Driver Behavior. As V2 was not instrumented, it was difficult to observe many of the driving behaviors. Again, as more than one choice could have been coded for each event, the column totals may exceed 100 percent. Not including single-vehicle events or events where no V2 Driver Behavior was observed, the most frequent V2 Driver Behaviors for SCEs were *cutting in, too close in front of other vehicle* (2.9 percent), *right-of-way error in relation to other vehicle or person* (2 percent), *driving slowly; below speed limit or in relation to other traffic* (1.8 percent), *failed to signal, or improper signal* (1.8 percent) and *aggressive driving, other* (1.6 percent).

**Table 52. Frequency and percentage of V2 driver behaviors**

| Vehicle 2 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total Safety-critical events (%) |
|---|---|---|---|---|---|---|---|
| Not Applicable (Single-vehicle Event) | 4 (80.0%) | 8 (100.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,361 (81.4%) |
| None Observed | 0 (0.0%) | 0 (0.0%) | 19 (31.1%) | 227 (14.2%) | 1 (6.3%) | 0 (0.0%) | 247 (8.5%) |
| Vehicle "Drift" or "Slow Weave" Consistent with Possible Drowsy/Distracted Driving | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 18 (1.1%) | 0 (0.0%) | 0 (0.0%) | 20 (0.7%) |

| Vehicle 2 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total Safety-critical events (%) |
|---|---|---|---|---|---|---|---|
| Driving Slowly; Below Speed Limit or in Relation to Other Traffic | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 48 (3.0%) | 1 (6.3%) | 0 (0.0%) | 53 (1.8%) |
| Illegal Passing (i.e., Across Double Line) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 9 (56.3%) | 0 (0.0%) | 13 (0.4%) |
| Passing on Right | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 11 (0.7%) | 2 (12.5%) | 0 (0.0%) | 14 (0.5%) |
| Other Improper or Unsafe Passing | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 10 (0.6%) | 1 (6.3%) | 0 (0.0%) | 12 (0.4%) |
| Cutting in, Too Close in Front of Other Vehicle | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 78 (4.9%) | 1 (6.3%) | 0 (0.0%) | 83 (2.9%) |
| Cutting in at Safe Distance but Then Decelerating, Causing Conflict | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| Cutting in, Too Close Behind Other Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 11 (0.7%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| Making Turn From Wrong Lane (e.g., Across Lanes) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Did Not See Other Vehicle During Lane Change or Merge | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| Driving in Other Vehicle's Blind Zone | 1 (20.0%) | 0 (0.0%) | 4 (6.6%) | 9 (0.6%) | 1 (6.3%) | 0 (0.0%) | 15 (0.5%) |
| Aggressive Driving, Specific, Directed Menacing Actions | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 6 (0.4%) | 4 (25.0%) | 0 (0.0%) | 12 (0.4%) |
| Aggressive Driving, Other | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 37 (2.3%) | 8 (50.0%) | 0 (0.0%) | 46 (1.6%) |
| Wrong Side of Road, Not Overtaking (Includes Partial or Full Drift Into Oncoming Lane) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| Following Too Close | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Inadequate Evasive Action | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 21 (1.3%) | 0 (0.0%) | 0 (0.0%) | 23 (0.8%) |
| Failed to Signal, or Improper Signal | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 49 (3.1%) | 0 (0.0%) | 0 (0.0%) | 51 (1.8%) |
| Improper Turn: Wide Right Turn | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Improper Turn: Cut Corner on Left Turn | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Other Improper Turning | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 0 (0.0%) | 0 (0.0%) | 26 (0.9%) |

| Vehicle 2 Behaviors | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total Safety-critical events (%) |
|---|---|---|---|---|---|---|---|
| Improper Backing, Apparently Did Not See | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| Improper Backing, Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Stop Sign Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other Sign (e.g., Yield) Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other Sign Violation | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| Right-of-Way Error in Relation to Other Vehicle or Person | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 51 (3.2%) | 1 (6.3%) | 0 (0.0%) | 58 (2.0%) |
| Sudden or Improper Stopping on Roadway | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 15 (0.9%) | 0 (0.0%) | 0 (0.0%) | 17 (0.6%) |
| Avoiding Pedestrian | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Avoiding Other Vehicle | 0 (0.0%) | 0 (0.0%) | 3 4.9%) | 10 (0.6%) | 0 (0.0%) | 0 (0.0%) | 13 (0.4%) |
| Excessive Braking/Deceleration Creating Potential Hazard | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 18 (0.6%) |
| Loss of Control on Slippery Road Surface | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Apparent Vehicle Failure (e.g., Brakes) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| **Total** | **1 (20%)** | **0 (0%)** | **63 (103%)** | **686 (43%)** | **29 (181%)** | **0 (0%)** | **779 (27%)** |
| **Event Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.5.29 Light Condition*

Table 53 displays the frequency and percentage for each Light Condition. Most of the SCEs occurred during the *daylight* or *dark* (80.4 and 15.3 percent, respectively). While this was also true for baseline events, the distribution was somewhat different (66.7 and 22.4 percent occurred during the *daylight* and *dark*, respectively).

**Table 53. Frequency and percentage of light conditions.**

| Light Condition | Crashes (%) | Crashes Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Daylight | 3 (60.0%) | 7 (87.5%) | 46 (75.4%) | 1,267 (79.5%) | 10 (62.5%) | 997 (82.1%) | 2,330 (80.4%) | 304 (66.7%) |
| Dark | 2 (40.0%) | 0 (0.0%) | 9 (14.8%) | 248 (15.6%) | 3 (18.8%) | 181 (14.9%) | 443 (15.3%) | 102 (22.4%) |
| Dark but Lighted | 0 (0.0%) | 1 (12.5%) | 4 (6.6%) | 37 (2.3%) | 2 (12.5%) | 12 (1.0%) | 56 (1.9%) | 29 (6.4%) |
| Dawn | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 18 (1.1%) | 0 (0.0%) | 12 (1.0%) | 30 (1.0%) | 12 (2.6%) |
| Dusk | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 1 (6.3%) | 13 (1.1%) | 40 (1.4%) | 9 (2.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 54 displays the odds ratios, LCLs, and UCLs for each Light Condition. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, during the *daylight* (odds ratio = 2.05). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, during the *dark*, *dark but lighted*, and *dawn* (odds ratios = 0.63, 0.29, 0.39, respectively).

**Table 54. Odds ratios, LCLs, and UCLs for light conditions.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Daylight | 2.05* | 1.65 | 2.54 |
| Dark | 0.63* | 0.49 | 0.80 |
| Dark But Lighted | 0.29* | 0.18 | 0.46 |
| Dawn | 0.39* | 0.20 | 0.76 |
| Dusk | 0.69 | 0.33 | 1.44 |

* Indicates significant odds ratio

### *6.2.5.30 Weather Condition*

Table 55 shows the frequency and percentage for each Weather Condition. Almost all the SCEs (94 percent) occurred when there were no adverse weather conditions. An almost identical percentage of baseline events (92.3 percent) occurred during no adverse weather conditions. Rain was the most frequently coded weather condition during SCEs (4.9 percent) and baseline events (6.8 percent).

**Table 55. Frequency and percentage of weather conditions.**

| Weather Conditions | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| No Adverse Conditions | 5 (100.0%) | 8 (100.0%) | 56 (91.8%) | 1,497 (93.9%) | 15 (93.8%) | 1,143 (94.1%) | 2,724 (94.0%) | 421 (92.3%) |
| Rain | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 81 (5.1%) | 1 (6.3%) | 55 (4.5%) | 142 (4.9%) | 31 (6.8%) |
| Sleet | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 2 (0.1%) | 0 (0.0%) |
| Snow | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 8 (0.7%) | 15 (0.5%) | 2 (0.4%) |
| Fog | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 7 (0.6%) | 14 (0.5%) | 0 (0.0%) |
| Rain and Fog | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 0 (0.0%) |
| Sleet and Fog | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 2 (0.4%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 56 displays the odds ratios, LCLs, and UCLs for each Weather Condition. Odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." As shown in Table 56, no odds ratios were significant.

**Table 56. Odds ratios, LCLs, and UCLs for each weather condition.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| No Adverse Conditions | 1.29 | 0.89 | 1.89 |
| Rain | 0.71 | 0.47 | 1.06 |
| Sleet | N/A | N/A | N/A |
| Snow | 1.18 | 0.27 | 5.18 |
| Fog | N/A | N/A | N/A |
| Rain and Fog | N/A | N/A | N/A |
| Sleet and Fog | N/A | N/A | N/A |
| Other | N/A | N/A | N/A |

### *6.2.5.31 Roadway Surface Condition*

Table 57 shows the frequency and percentage for each Roadway Surface Condition. Almost all the SCEs (94 percent) and baseline events (91.7 percent) occurred when the roadway was dry. *Wet* was the second most frequently coded roadway surface during SCEs (5.8 percent) and baseline events (7.5 percent).

**Table 57. Frequency and percentage of roadway surface conditions.**

| Roadway Surface Conditions | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Dry | 5 (100.0%) | 7 (87.5%) | 56 (91.8%) | 1,487 (93.3%) | 15 (93.8%) | 1,142 (94.0%) | 2,712 (93.5%) | 418 (91.7%) |
| Wet | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 98 (6.1%) | 1 (6.3%) | 63 (5.2%) | 167 (5.8%) | 34 (7.5%) |
| Snow or Slush | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 7 (0.6%) | 15 (0.5%) | 2 (0.4%) |
| Ice | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Sand, Oil, Dirt | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 1 (0.0%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 2 (0.2%) | 4 (0.1%) | 2 (0.4%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 58 displays the odds ratios, LCLs, and UCLs for each Roadway Surface Condition. Odds ratios that could not be calculated due to small sample sizes are noted with an “N/A.” As shown in Table 58, no odds ratios were significant.

**Table 58. Odds ratios, LCLs, and UCLs for each roadway surface condition.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Dry | 1.32 | 0.92 | 1.9 |
| Wet | 0.76 | 0.52 | 1.11 |
| Snow or Slush | 1.18 | 0.27 | 5.18 |
| Ice | N/A | N/A | N/A |
| Sand, Oil, Dirt | N/A | N/A | N/A |
| Unknown | 0.31 | 0.06 | 1.72 |
| Other | N/A | N/A | N/A |

### *6.2.5.32 Relation to Junction*

Table 59 shows the frequency and percentage for each “Relation to Junction” code. Most of the SCEs (90.1 percent) and baseline events (86.4 percent) occurred on a non-junction road. All of the tire strikes occurred on an intersection or intersection-related junction. Near-crashes and illegal maneuvers were more varied; 19.7 percent and 25 percent, respectively, occurred on entrance or exit ramps.

**Table 59. Frequency and percentage of relation to junction.**

| Relation to Junction | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Non-junction | 4 (80.0%) | 0 (0.0%) | 42 (68.9%) | 1,347 (84.5%) | 9 (56.3%) | 1,209 (99.5%) | 2,611 (90.1%) | 394 (86.4%) |
| Intersection | 0 (0.0%) | 7 (87.5%) | 3 (4.9%) | 25 (1.6%) | 1 (6.3%) | 0 (0.0%) | 36 (1.2%) | 5 (1.1%) |
| Intersection-related | 0 (0.0%) | 1 (12.5%) | 3 (4.9%) | 109 (6.8%) | 2 (12.5%) | 2 (0.2%) | 117 (4.0%) | 11 (2.4%) |
| Driveway, Alley Access, etc. | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) | 5 (1.1%) |
| Parking Lot | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 9 (0.3%) | 19 (4.2%) |
| Entrance/Exit Ramp | 0 (0.0%) | 0 (0.0%) | 12 (19.7%) | 74 (4.6%) | 4 (25.0%) | 4 (0.3%) | 94 (3.2%) | 18 (3.9%) |
| Rail Grade Crossing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 1 (0.2%) |
| On a Bridge | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 25 (1.6%) | 0 (0.0%) | 0 (0.0%) | 25 (0.9%) | 0 (0.0%) |
| Crossover-related | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) |
| Other | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 2 (0.4%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 60 displays the odds ratios, LCLs, and UCLs for each Relation to Junction. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a total SCE, compared to a baseline event, on a non-junction road (odds ratio = 1.43). Drivers were significantly less likely to be involved in a total SCE, compared to a baseline event, on a *driveway, alley access, etc.*, or in a *parking lot* (odds ratios = 0.09 and 0.07, respectively).

**Table 60. Odds ratios, LCLs, and UCLs for each relation to junction.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Non-junction | 1.43* | 1.06 | 1.91 |
| Intersection | 1.13 | 0.44 | 2.91 |
| Intersection-related | 1.70 | 0.09 | 3.18 |
| Driveway, Alley Access, etc. | 0.09* | 0.02 | 0.39 |
| Parking Lot | 0.07* | 0.03 | 0.16 |
| Entrance/Exit Ramp | 0.82 | 0.49 | 1.36 |
| Rail Grade Crossing | 0.16 | 0.01 | 2.51 |
| On a Bridge | N/A | N/A | N/A |

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Crossover-related | N/A | N/A | N/A |

* Indicates significant odds ratio

#### *6.2.5.33 Trafficway Flow*

Table 61 displays the frequency and percentage for each "Trafficway Flow" code. Most of the SCEs occurred on a divided trafficway (88.4 percent), while 11 percent occurred on a road that was not physically divided. A smaller percentage (compared to SCEs) of baseline epochs occurred on a divided trafficway (79.2 percent), while a greater percentage occurred on a road that was not physically divided (17.8 percent).

**Table 61. Frequency and percentage of trafficway flow.**

| Trafficway Flow | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Not Physically Divided (Center 2-Way Turn Lane) | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 35 (2.2%) | 0 (0.0%) | 3 (0.2%) | 40 (1.4%) | 13 (2.9%) |
| Not Physically Divided (2-Way Trafficway) | 3 (60.0%) | 7 (87.5%) | 13 (21.3%) | 223 (14.0%) | 10 (62.5%) | 23 (1.9%) | 279 (9.6%) | 68 (14.9%) |
| Divided | 2 (40.0%) | 0 (0.0%) | 44 (72.1%) | 1,325 (83.1%) | 5 (31.3%) | 1187 (97.7%) | 2,563 (88.4%) | 361 (79.2%) |
| One-way Trafficway | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 9 (0.6%) | 1 (6.3%) | 2 (0.2%) | 15 (0.5%) | 8 (1.8%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 6 (1.3%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 62 displays the odds ratios, LCLs, and UCLs for each Trafficway Flow. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a total SCE, compared to a baseline event, on a *divided* road (odds ratio = 2.01). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on an *undivided road with a center two-way turn lane*, a *not physically divided road with a two-way trafficway*, or a *one-way trafficway* (odds ratios = 0.48, 0.61, and 0.29, respectively).

**Table 62. Odds ratios, LCLs, and UCLs for each trafficway flow.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Not Physically Divided (Center Two-way Turn Lane) | 0.48* | 0.25 | 0.9 |
| Not Physically Divided (Two-way Trafficway) | 0.61* | 0.46 | 0.81 |
| Divided | 2.01* | 1.56 | 2.59 |
| One-way Trafficway | 0.29* | 0.12 | 0.69 |

*Indicates significant odds ratio

### *6.2.5.34 Number of Travel Lanes*

Table 63 shows the frequency and percentage for each Number of Travel Lanes. Most of the SCEs occurred on roadways with two or three travel lanes (76.3 and 17.1 percent, respectively). Similarly, most of the baseline events occurred on roadways with two or three travel lanes (68.4 and 17.8 percent, respectively).

**Table 63. Frequency and percentage of number of travel lanes.**

| Travel Lanes | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 20 (1.3%) | 3 (18.8%) | 2 (0.2%) | 28 (1.0%) | 16 (3.5%) |
| 2 | 5 (100%) | 4 (50.0%) | 30 (49.2%) | 1,171 (73.5%) | 8 (50.0%) | 995 (81.9%) | 2,213 (76.3%) | 312 (68.4%) |
| 3 | 0 (0.0%) | 2 (25.0%) | 13 (21.3%) | 277 (17.4%) | 2 (12.5%) | 202 (16.6%) | 496 (17.1%) | 81 (17.8%) |
| 4 | 0 (0.0%) | 1 (12.5%) | 11 (18.0%) | 83 (5.2%) | 3 (18.8%) | 13 (1.1%) | 111 (3.8%) | 26 (5.7%) |
| 5 | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 37 (2.3%) | 0 (0.0%) | 3 (0.2%) | 44 (1.5%) | 11 (2.4%) |
| 6 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 1 (0.2%) |
| 7+ | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) | 9 (2.0%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 64 displays the odds ratios, LCLs, and UCLs for each Number of Traffic Lanes. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on roads with two travel lanes (odds ratio = 1.49). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on a road with one travel lane (odds ratio = 0.27).

**Table 64. Odds ratios, LCLs, and UCLs for each number of traffic lanes.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 1 | 0.27* | 0.14 | 0.5 |
| 2 | 1.49* | 1.2 | 1.85 |
| 3 | 0.95 | 0.74 | 1.24 |
| 4 | 0.66 | 0.42 | 1.02 |
| 5 | 0.62 | 0.32 | 1.22 |
| 6 | 0.31 | 0.03 | 3.47 |
| 7+ | N/A | N/A | N/A |

*Indicates significant odds ratio

### *6.2.5.35 Number of Travel Lanes (Undivided Highway)*

Table 65 shows the frequency and percentage for each Number of Travel Lanes on undivided highways. Most of the SCEs occurred on undivided highways with two or three travel lanes (68.8 and 12.1 percent, respectively). Similarly, most of the baseline events occurred on undivided highways with two or three travel lanes (63.2 and 11.5 percent, respectively).

**Table 65. Frequency and percentage of number of travel lanes (undivided highways).**

| Travel Lanes | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCE (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 (0.0%) | 0 (0.0%) | 1 (6.7%) | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 2 (0.6%) | 3 (3.4%) |
| 2 | 3 (100%) | 4 (57.1%) | 10 (66.7%) | 178 (68.5%) | 7 (70.0%) | 19 (73.1%) | 221 (68.8%) | 55 (63.2%) |
| 3 | 0 (0.0%) | 2 (28.6%) | 1 (6.7%) | 32 (12.3%) | 1 (10.0%) | 3 (11.5%) | 39 (12.1%) | 10 (11.5%) |
| 4 | 0 (0.0%) | 1 (14.3%) | 0 (0.0%) | 19 (7.3%) | 2 (20.0%) | 2 (7.7%) | 24 (7.5%) | 5 (5.7%) |
| 5 | 0 (0.0%) | 0 (0.0%) | 3 (20.0%) | 26 (10.0%) | 0 (0.0%) | 2 (7.7%) | 31 (9.7%) | 6 (6.9%) |
| 6 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.3%) | 0 (0.0%) |
| 7+ | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.4%) | 0 (0.0%) | 0 (0.0%) | 1 (0.3%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.8%) | 0 (0.0%) | 0 (0.0%) | 2 (0.6%) | 8 (9.2%) |
| **Total** | **3 (100%)** | **7 (100%)** | **15 (100%)** | **260 (100%)** | **10 (100%)** | **26 (100%)** | **321 (100%)** | **87 (100%)** |

Table 66 displays the odds ratios, LCLs, and UCLs for each Number of Traffic Lanes. Odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." As can be seen in this table, there were no significant odds ratios.

**Table 66. Odds ratios, LCLs, and UCLs for each number of traffic lanes (undivided highways)**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 1 | 0.18 | 0.03 | 1.07 |
| 2 | 1.29 | 0.78 | 2.11 |
| 3 | 1.06 | 0.51 | 2.23 |
| 4 | 1.32 | 0.49 | 3.59 |
| 5 | 1.44 | 0.58 | 3.58 |
| 6 | N/A | N/A | N/A |
| 7+ | N/A | N/A | N/A |

### *6.2.5.36 Number of Travel Lanes (Divided Highway and One-way Traffic)*

Table 67 shows the frequency and percentage for each Number of Travel Lanes on divided highways and one-way traffic roads. Most of the SCEs occurred on divided highways and one-way roadways with two or three travel lanes (77.3 and 17.7 percent, respectively). Similarly, most of the baseline events occurred on divided highways and one-way roadways with two or three travel lanes (68.4 and 18.9 percent, respectively).

**Table 67. Frequency and percentage of number of travel lanes (divided highway and one-way traffic).**

| Travel Lanes | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 (0.0%) | 1 (100.0%) | 1 (2.2%) | 19 (1.4%) | 3 (50.0%) | 2 (0.2%) | 26 (1.0%) | 13 (3.5%) |
| 2 | 2 (100.0%) | 0 (0.0%) | 20 (43.5%) | 993 (74.4%) | 1 (16.7%) | 976 (82.1%) | 1,992 (77.3%) | 257 (68.4%) |
| 3 | 0 (0.0%) | 0 (0.0%) | 12 (26.1%) | 245 (18.4%) | 1 (16.7%) | 199 (16.7%) | 457 (17.7%) | 71 (18.9%) |
| 4 | 0 (0.0%) | 0 (0.0%) | 11 (23.9%) | 64 (4.8%) | 1 (16.7%) | 11 (0.9%) | 87 (3.4%) | 21 (5.6%) |
| 5 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 11 (0.8%) | 0 (0.0%) | 1 (0.1%) | 13 (0.5%) | 5 (1.3%) |
| 6 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 1 (0.3%) |
| 7+ | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 8 (2.1%) |
| **Total** | **2 (100%)** | **1 (100%)** | **46 (100%)** | **1,334 (100%)** | **6 (100%)** | **1,189 (100%)** | **2,578 (100%)** | **376 (100%)** |

Table 68 displays the odds ratios and LCLs and UCLs for each Number of Travel Lanes (Divided and One-way Traffic). Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on roads with two travel lanes (odds ratio = 1.57). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on roads with one or four travel lanes (odds ratios = 0.25 and 0.59, respectively).

**Table 68. Odds ratios, LCLs, and UCLs for each number of traffic lanes (divided and one-way traffic).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 1 | 0.25* | 0.13 | 0.5 |
| 2 | 1.57* | 1.24 | 1.99 |
| 3 | 1.15 | 0.88 | 1.52 |
| 4 | 0.59* | 0.36 | 0.96 |
| 5 | 0.37 | 0.13 | 1.06 |
| 6 | 0.15 | 0.01 | 2.33 |
| 7+ | N/A | N/A | N/A |

*Indicates significant odds ratio

#### *6.2.5.37 Roadway Alignment*

Table 69 shows the frequency and percentage of each Roadway Alignment. Most of the SCEs (88.7 percent) and baseline events (88.6 percent) occurred on a straight roadway.

**Table 69. Frequency and percentage of roadway alignment.**

| Roadway Alignment | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Straight | 5 (100.0%) | 7 (87.5%) | 51 (83.6%) | 1,379 (86.5%) | 12 (75.0%) | 1,117 (91.9%) | 2,571 (88.7%) | 404 (88.6%) |
| Curve Right | 0 (0.0%) | 1 (12.5%) | 6 (9.8%) | 110 (6.9%) | 3 (18.8%) | 56 (4.6%) | 176 (6.1%) | 30 (6.6%) |
| Curve Left | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 103 (6.5%) | 1 (6.3%) | 42 (3.5%) | 150 (5.2%) | 16 (3.5%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 6 (1.3%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 70 displays the odds ratios, LCLs, and UCLs for each Roadway Alignment. As can be seen in this table, there were no significant odds ratios.

**Table 70. Odds ratios, LCLs, and UCLs for each roadway alignment.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Straight | 1.01 | 0.74 | 1.38 |
| Curve Right | 0.92 | 0.62 | 1.37 |
| Curve Left | 1.5 | 0.89 | 2.54 |

### 6.2.5.38 *Roadway Profile*

Table 71 displays the frequency and percentage of each Roadway Profile. Most of the SCEs (93.9 percent) and baseline events (95.4 percent) occurred on a level roadway.

**Table 71. Frequency and percentage of roadway profile.**

| Road-way Profile | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Level | 5 (100.0%) | 8 (100.0%) | 58 (95.1%) | 1,490 (93.5%) | 15 (93.8%) | 1,145 (94.2%) | 2,721 (93.9%) | 435 (95.4%) |
| Grade Up | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 91 (5.7%) | 1 (6.3%) | 70 (5.8%) | 164 (5.7%) | 16 (3.5%) |
| Grade Down | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 13 (0.8%) | 0 (0.0%) | 0 (0.0%) | 14 (0.5%) | 2 (0.4%) |
| Hillcrest | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Sag | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 72 displays the odds ratios, LCLs, and UCLs for each Roadway Profile. Odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." As can be seen in this table, there were no significant odds ratios.

**Table 72. Odds ratios, LCLs, and UCLs for each roadway profile.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Level | 0.74 | 0.46 | 1.17 |
| Grade Up | 1.65 | 0.98 | 2.78 |
| Grade Down | 1.1 | 0.25 | 4.86 |
| Hillcrest | N/A | N/A | N/A |
| Sag | N/A | N/A | N/A |

### 6.2.5.39 *Traffic Density*

Table 73 shows the frequency and percentage for each "Traffic Density." The Traffic Density is listed in increasing order from level-of-service (LOS) A to LOS F. LOS A is the best, described as conditions in which traffic flows at or above the posted speed limit and all motorists have complete mobility between lanes. LOS B is slightly more congested, with some inhibition of maneuverability; two motorists might be forced to drive side-by-side, limiting lane changes. LOS C involves more congestion than B—congestion in which the ability to pass or change lanes is not always assured. In LOS D, speeds are somewhat reduced, and motorists are hemmed in by other cars and trucks. LOS E is a marginal service state; flow becomes irregular and speed varies rapidly, but rarely reaches the posted limit. LOS F is the lowest level of efficiency for a road's performance. Flow is forced; every vehicle moves in lockstep with the vehicle in front of it, with frequent drops in speed to nearly zero mi/h.[42] Most of the SCEs occurred in LOS A or LOS B traffic densities (64.8 and 26.1 percent, respectively). Almost all of the baseline events (95.8 percent) occurred in LOS A or LOS B traffic densities.

**Table 73. Frequency and percentage of traffic density.**

| Traffic Density | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| LOS A | 3 (60.0%) | 4 (50.0%) | 23 (37.7%) | 939 (58.9%) | 7 (43.8%) | 903 (74.3%) | 1,879 (64.8%) | 343 (75.2%) |
| LOS B | 2 (40.0%) | 3 (37.5%) | 22 (36.1%) | 465 (29.2%) | 5 (31.3%) | 261 (21.5%) | 758 (26.1%) | 94 (20.6%) |
| LOS C | 0 (0.0%) | 0 (0.0%) | 13 (21.3%) | 135 (8.5%) | 1 (6.3%) | 48 (4.0%) | 197 (6.8%) | 16 (3.5%) |
| LOS D | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 31 (1.9%) | 0 (0.0%) | 1 (0.1%) | 33 (1.1%) | 0 (0.0%) |
| LOS E | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 19 (1.2%) | 1 (6.3%) | 2 (0.2%) | 25 (0.9%) | 2 (0.4%) |
| LOS F | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 2 (12.5%) | 0 (0.0%) | 6 (0.2%) | 0 (0.0%) |
| Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) | 1 (0.2%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 74 displays the odds ratios, LCLs, and UCLs for each Traffic Density. Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on roads with LOS B and LOS C (odds ratios = 1.36 and 2.01, respectively). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on roads with LOS A (odds ratio = 0.61).

**Table 74. Odds ratios, LCLs, and UCLs for each traffic density.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| LOS A | 0.61* | 0.48 | 0.76 |
| LOS B | 1.36* | 1.07 | 1.74 |
| LOS C | 2.01* | 1.19 | 3.37 |
| LOS D | N/A | N/A | N/A |
| LOS E | 1.97 | 0.47 | 8.37 |
| LOS F | N/A | N/A | N/A |

*Indicates significant odds ratio

#### *6.2.5.40 Construction Zone*

Table 75 shows the frequency and percentage of all events by Construction Zone. Almost all of the SCEs (98.8 percent) and baseline events (98.5 percent) occurred in non-construction zones.

**Table 75. Frequency and percentage by construction zone.**

| Construction Zone-related | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Not Construction Zone-related (or Unknown) | 5 (100.0%) | 7 (87.5%) | 60 (98.4%) | 1,562 (98.0%) | 16 (100.0%) | 1,214 (99.9%) | 2,864 (98.8%) | 449 (98.5%) |
| Construction Zone (Occurred in Zone) | 0 (0.0%) | 1 (12.5%) | 1 (1.6%) | 26 (1.6%) | 0 (0.0%) | 0 (0.0%) | 28 (1.0%) | 6 (1.3%) |
| Construction-Zone-related (Occurred in Approach or Otherwise Related to Zone) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 1 (0.1%) | 7 (0.2%) | 1 (0.2%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 76 displays the odds ratios, LCLs, and UCLs for each Construction Zone. As can be seen in Table 76this table, there were no significant odds ratios.

**Table 76. Odds Ratios, LCLs, and UCLs for each construction zone.**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Not Construction Zone-related | 1.28 | 0.56 | 2.89 |
| Construction Zone | 0.73 | 0.30 | 1.78 |
| Construction Zone-related | 1.10 | 0.14 | 8.97 |

#### *6.2.5.41 Day of Week (All Events)*

Table 77 displays the frequency and percentage for each “Day of Week” (all events). With the exception of one day (Friday), the SCEs were evenly distributed among most of the days of the week. Friday had the highest proportion of SCEs (21 percent). While the baseline events were evenly distributed among most of the days of the week, relatively few baseline events occurred on Sunday (3.3 percent).

**Table 77. Frequency and percentage by day of week (all events).**

| Day of Week | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Sunday | 0 (0.0)% ) | 0 (0.0%) | 8 (13.1%) | 156 (9.8%) | 2 (12.5%) | 156 (12.8%) | 322 (11.1%) | 15 (3.3%) |
| Monday | 1 (20.0%) | 2 (25.0%) | 10 (16.4%) | 154 (9.7%) | 3 (18.8%) | 99 (8.1%) | 269 (9.3%) | 45 (9.9%) |
| Tuesday | 1 (20.0%) | 2 (25.0%) | 9 (14.8%) | 222 (13.9%) | 1 (6.3%) | 137 (11.3%) | 372 (12.8%) | 100 (21.9%) |
| Wednesday | 0 (0.0%) | 2 (25.0%) | 9 (14.8%) | 282 (17.7%) | 2 (12.5%) | 178 (14.7%) | 473 (16.3%) | 81 (17.8%) |
| Thursday | 0 (0.0%) | 2 (25.0%) | 9 (14.8%) | 263 (16.5%) | 4 (25.0%) | 206 (17.0%) | 484 (16.7%) | 101 (22.1%) |
| Friday | 3 (60.0%) | 0 (0.0%) | 10 (16.4%) | 312 (19.6%) | 1 (6.3%) | 283 (23.3%) | 609 (21.0%) | 75 (16.4%) |
| Saturday | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 205 (12.9%) | 3 (18.8%) | 156 (12.8%) | 370 (12.8%) | 39 (8.6%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 78 displays the odds ratios, LCLs, and UCLs for each Day of Week (all events). Significant odds ratios have an asterisk. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on a Sunday, Friday, or Saturday (odds ratios = 3.67, 1.36, and 1.56, respectively) than on other days of the week. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on a Tuesday (odds ratio = 0.52) than on other days of the week.

**Table 78. Odds ratios, LCLs, and UCLs for each day of week (all events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Sunday | 3.67* | 2.17 | 6.23 |
| Monday | 0.93 | 0.67 | 1.30 |
| Tuesday | 0.52* | 0.41 | 0.67 |
| Wednesday | 0.90 | 0.70 | 1.17 |
| Thursday | 0.70* | 0.56 | 0.90 |
| Friday | 1.36* | 1.04 | 1.76 |
| Saturday | 1.56* | 1.11 | 2.21 |

*Indicates significant odds ratio

### *6.2.5.42 Day of Week (Single-vehicle Events)*

Table 79 shows the frequency and percentage for each Day of Week (single-vehicle events). The same baseline data as shown in Table 77 are provided for comparison. With the exception of one day, the SCEs were evenly distributed among all the days of the week; however, few of the SCEs occurred on a Monday (8.4 percent).

**Table 79. Frequency and percentage by day of week (single-vehicle events).**

| Day of Week | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Sunday | 0 (0.0%) | 0 (0.0%) | 3 (18.8%) | 123 (11.1%) | 2 (50.0%) | 156 (12.8%) | 284 (12.1%) | 15 (3.3%) |
| Monday | 0 (0.0%) | 2 (25.0%) | 1 (6.3%) | 95 (8.6%) | 1 (25.0%) | 99 (8.1%) | 198 (8.4%) | 45 (9.9%) |
| Tuesday | 1 (33.3%) | 2 (25.0%) | 2 (12.5%) | 161 (14.6%) | 0 (0.0%) | 137 (11.3%) | 303 (12.9%) | 100 (21.9%) |
| Wednesday | 0 (0.0%) | 2 (25.0%) | 3 (18.8%) | 196 (17.7%) | 0 (0.0%) | 178 (14.7%) | 379 (16.1%) | 81 (17.8%) |
| Thursday | 0 (0.0%) | 2 (25.0%) | 5 (31.3%) | 157 (14.2%) | 1 (25.0%) | 206 (17.0%) | 371 (15.8%) | 101 (22.1%) |
| Friday | 2 (66.7%) | 0 (0.0%) | 2 (12.5%) | 223 (20.2%) | 0 (0.0%) | 283 (23.3%) | 510 (21.7%) | 75 (16.4%) |
| Saturday | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 150 (13.6%) | 0 (0.0%) | 156 (12.8%) | 306 (13.0%) | 39 (8.6%) |
| **Total** | **3 (100%)** | **8 (100%)** | **16 (100%)** | **1,105 (100%)** | **4 (100%)** | **1,215 (100%)** | **2,351 (100%)** | **456 (100%)** |

Table 80 displays the odds ratios, LCLs, and UCLs for each Day of Week (single-vehicle events). Significant odds ratios have an asterisk. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on a Sunday, Friday, or Saturday (odds ratios = 4.04, 1.41, and 1.6, respectively) than on other days of the week. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on a Tuesday or Thursday (odds ratios = 0.53 and 0.66, respectively) than on other days of the week.

**Table 80. Odds ratios, LCLs, and UCLs for each day of week (single-vehicle events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Sunday | 4.04* | 2.38 | 6.86 |
| Monday | 0.84 | 0.60 | 1.18 |
| Tuesday | 0.53* | 0.41 | 0.68 |
| Wednesday | 0.89 | 0.68 | 1.16 |
| Thursday | 0.66* | 0.51 | 0.84 |
| Friday | 1.41* | 1.08 | 1.84 |
| Saturday | 1.60* | 1.13 | 2.27 |

*Indicates significant odds ratio

### *6.2.5.43 Day of Week (Multivehicle Events)*

Table 81 shows the frequency and percentage for each Day of Week (multivehicle events). With the exception of one day, the SCEs were evenly distributed among all the days of the week; however, few of the SCEs occurred on a Sunday (6.9 percent).

**Table 81. Frequency and percentage by day of week (multivehicle events).**

| Day of Week | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| Sunday | 0 (0.0%) | 0 (0.0%) | 5 (11.1%) | 33 (6.7%) | 0 (0.0%) | 0 (0.0%) | 38 (6.9%) | 15 (3.3%) |
| Monday | 1 (50.0%) | 0 (0.0%) | 9 (20.0%) | 59 (12.1%) | 2 (16.7%) | 0 (0.0%) | 71 (13.0%) | 45 (9.9%) |
| Tuesday | 0 (0.0%) | 0 (0.0%) | 7 (15.6%) | 61 (12.5%) | 1 (8.3%) | 0 (0.0%) | 69 (12.6%) | 100 (21.9%) |
| Wednesday | 0 (0.0%) | 0 (0.0%) | 6 (13.3%) | 86 (17.6%) | 2 (16.7%) | 0 (0.0%) | 94 (17.2%) | 81 (17.8%) |
| Thursday | 0 (0.0%) | 0 (0.0%) | 4 (8.9%) | 106 (21.7%) | 3 (25.0%) | 0 (0.0%) | 113 (20.6%) | 101 (22.1%) |
| Friday | 1 (50.0%) | 0 (0.0%) | 8 (17.8%) | 89 (18.2%) | 1 (8.3%) | 0 (0.0%) | 99 (18.1%) | 75 (16.4%) |
| Saturday | 0 (0.0%) | 0 (0.0%) | 6 (13.3%) | 55 (11.2%) | 3 (25.0%) | 0 (0.0%) | 64 (11.7%) | 39 (8.6%) |
| **Total** | **2 (100%)** | **0 (0%)** | **45 (100%)** | **489 (100%)** | **12 (100%)** | **0 (0%)** | **548 (100%)** | **456 (100%)** |

Table 82 displays the odds ratios, LCLs, and UCLs for each Day of Week (multivehicle events). Significant odds ratios have an asterisk. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, on a Sunday (odds ratio = 2.19) than on other days. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, on a Tuesday (odds ratio = 0.51) than on other days.

**Table 82. Odds ratios, LCLs, and UCLs for each day of week (multivehicle events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| Sunday | 2.19* | 1.19 | 4.04 |
| Monday | 1.36 | 0.91 | 2.02 |
| Tuesday | 0.51* | 0.37 | 0.72 |
| Wednesday | 0.96 | 0.69 | 1.33 |
| Thursday | 0.91 | 0.67 | 1.24 |
| Friday | 1.12 | 0.81 | 1.56 |
| Saturday | 1.41 | 0.93 | 2.15 |

*Indicates significant odds ratio

#### *6.2.5.44 Time-of-day (All Events)*

Table 83 shows the frequency and percentage for each “Time of Day” (all events). Few of the SCEs occurred before 11:00, while most of the SCEs occurred between 11:00 and 22:59. The highest frequency of SCEs occurred between 13:00 and 22:59. The baseline events were much more evenly distributed among the 1-hour time blocks than were the SCEs.

**Table 83. Frequency and percentage by time of day (all events).**

| Time-of-day | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 0:00–0:59 | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 36 (2.3%) | 1 (6.3%) | 36 (3.0%) | 77 (2.7%) | 21 (4.6%) |
| 1:00–1:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 31 (1.9%) | 1 (6.3%) | 33 (2.7%) | 65 (2.2%) | 8 (1.8%) |
| 2:00–2:59 | 1 (20.0%) | 1 (12.5%) | 1 (1.6%) | 36 (2.3%) | 0 (0.0%) | 23 (1.9%) | 62 (2.1%) | 11 (2.4%) |
| 3:00–3:59 | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 31 (1.9%) | 0 (0.0%) | 10 (0.8%) | 43 (1.5%) | 9 (2.0%) |
| 4:00–4:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 31 (1.9%) | 0 (0.0%) | 14 (1.2%) | 46 (1.6%) | 11 (2.4%) |
| 5:00–5:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 22 (1.4%) | 0 (0.0%) | 7 (0.6%) | 30 (1.0%) | 14 (3.1%) |
| 6:00–6:59 | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 24 (1.5%) | 0 (0.0%) | 13 (1.1%) | 39 (1.3%) | 19 (4.2%) |
| 7:00–7:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 11 (0.7%) | 0 (0.0%) | 9 (0.7%) | 21 (0.7%) | 10 (2.2%) |
| 8:00–8:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 21 (1.3%) | 0 (0.0%) | 17 (1.4%) | 39 (1.3%) | 10 (2.2%) |
| 9:00–9:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 15 (0.9%) | 0 (0.0%) | 17 (1.4%) | 33 (1.1%) | 18 (3.9%) |
| 10:00–10:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 24 (1.5%) | 1 (6.3%) | 28 (2.3%) | 54 (1.9%) | 14 (3.1%) |
| 11:00–11:59 | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 47 (2.9%) | 2 (12.5%) | 38 (3.1%) | 88 (3.0%) | 12 (2.6%) |
| 12:00–12:59 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 93 (5.8%) | 0 (0.0%) | 45 (3.7%) | 141 (4.9%) | 21 (4.6%) |
| 13:00–13:59 | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 80 (5.0%) | 0 (0.0%) | 68 (5.6%) | 152 (5.2%) | 20 (4.4%) |
| 14:00–14:59 | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 103 (6.5%) | 0 (0.0%) | 85 (7.0%) | 191 (6.6%) | 39 (8.6%) |
| 15:00–15:59 | 0 (0.0%) | 2 (25.0%) | 3 (4.9%) | 105 (6.6%) | 1 (6.3%) | 74 (6.1%) | 185 (6.4%) | 33 (7.2%) |
| 16:00–16:59 | 0 (0.0%) | 1 (12.5%) | 1 (1.6%) | 103 (6.5%) | 1 (6.3%) | 107 (8.8%) | 213 (7.3%) | 26 (5.7%) |
| 17:00–17:59 | 0 (0.0%) | 0 (0.0%) | 5 (8.2%) | 140 (8.8%) | 2 (12.5%) | 130 (10.7%) | 277 (9.6%) | 24 (5.3%) |
| 18:00–18:59 | 0 (0.0%) | 1 (12.5%) | 2 (3.3%) | 135 (8.5%) | 2 (12.5%) | 114 (9.4%) | 254 (8.8%) | 26 (5.7%) |
| 19:00–19:59 | 2 (40.0%) | 1 (12.5%) | 2 (3.3%) | 119 (7.5%) | 1 (6.3%) | 89 (7.3%) | 214 (7.4%) | 31 (6.8%) |
| 20:00–20:59 | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 130 (8.2%) | 1 (6.3%) | 97 (8.0%) | 231 (8.0%) | 24 (5.3%) |
| 21:00–21:59 | 0 (0.0%) | 1 (12.5%) | 11 (18.0%) | 113 (7.1%) | 0 (0.0%) | 75 (6.2%) | 200 (6.9%) | 17 (3.7%) |
| 22:00–22:59 | 0 (0.0%) | 0 (0.0%) | 6 (9.8%) | 89 (5.6%) | 1 (6.3%) | 57 (4.7%) | 153 (5.3%) | 20 (4.4%) |
| 23:00–23:59 | 1 (20.0%) | 0 (0.0%) | 4 (6.6%) | 55 (3.5%) | 2 (12.5%) | 29 (2.4%) | 91 (3.1%) | 18 (3.9%) |
| **Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** | **456 (100%)** |

Table 84 displays the odds ratios, LCLs, and UCLs for each Time of Day (all events). Significant odds ratios have an asterisk. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, from 17:00 to 17:59, 18:00 to 18:59, 20:00 to 20:59, and 21:00 to 21:59 (odds ratios = 1.9, 1.59, 1.56, and 1.91, respectively). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, from 0:00 to 0:59, 5:00 to 5:59, 6:00 to 6:59, 7:00 to 7:59, and 9:00 to 9:59 (odds ratios = 0.57, 0.33, 0.31, 0.33, and 0.28, respectively).

**Table 84. Odds ratios, LCLs, and UCLs for each time of day (all events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 0:00–0:59 | 0.57* | 0.35 | 0.93 |
| 1:00–1:59 | 1.28 | 0.61 | 2.70 |
| 2:00–2:59 | 0.88 | 0.46 | 1.70 |
| 3:00–3:59 | 0.75 | 0.36 | 1.54 |
| 4:00–4:59 | 0.65 | 0.34 | 1.27 |
| 5:00–5:59 | 0.33* | 0.17 | 0.63 |
| 6:00–6:59 | 0.31* | 0.18 | 0.55 |
| 7:00–7:59 | 0.33* | 0.15 | 0.70 |
| 8:00–8:59 | 0.61 | 0.30 | 1.23 |
| 9:00–9:59 | 0.28* | 0.16 | 0.50 |
| 10:00–10:59 | 0.60 | 0.33 | 1.09 |
| 11:00–11:59 | 1.16 | 0.63 | 2.13 |
| 12:00–12:59 | 1.06 | 0.66 | 1.69 |
| 13:00–13:59 | 1.21 | 0.75 | 1.94 |
| 14:00–14:59 | 0.75 | 0.53 | 1.08 |
| 15:00–15:59 | 0.87 | 0.6 | 1.28 |
| 16:00–16:59 | 1.31 | 0.86 | 2.00 |
| 17:00–17:59 | 1.90* | 1.24 | 2.92 |
| 18:00–18:59 | 1.59* | 1.05 | 2.41 |
| 19:00–19:59 | 1.09 | 0.74 | 1.61 |
| 20:00–20:59 | 1.56* | 1.01 | 2.40 |
| 21:00–21:59 | 1.91* | 1.15 | 3.17 |
| 22:00–22:59 | 1.21 | 0.75 | 1.96 |
| 23:00–23:59 | 0.79 | 0.47 | 1.32 |

*Indicates significant odds ratio

### *6.2.5.45 Time-of-day (Single-vehicle Events)*

Table 85 shows the frequency and percentage for each Time of Day (single-vehicle events). The same baseline data as shown in Table 83 are provided for comparison. The single-vehicle SCEs were distributed less evenly across the 1-hour time blocks than were all the events taken as a whole. The highest frequency of SCEs occurred between 14:00 and 20:59.

Table 85. Frequency and percentage by time of day (single-vehicle events).

| Time-of-day | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 0:00–0:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 21 (1.9%) | 0 (0.0%) | 36 (3.0%) | 58 (2.5%) | 21 (4.6%) |
| 1:00–1:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 24 (2.2%) | 1 (25.0%) | 33 (2.7%) | 58 2.5%) | 8 (1.8%) |
| 2:00–2:59 | 1 (33.3%) | 1 (12.5%) | 0 (0.0%) | 30 (2.7%) | 0 (0.0%) | 23 (1.9%) | 55 (2.3%) | 11 (2.4%) |
| 3:00–3:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 27 (2.4%) | 0 (0.0%) | 10 (0.8%) | 38 (1.6%) | 9 (2.0%) |
| 4:00–4:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 26 (2.4%) | 0 (0.0%) | 14 (1.2%) | 41 (1.7%) | 11 (2.4%) |
| 5:00–5:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 19 (1.7%) | 0 (0.0%) | 7 (0.6%) | 27 (1.1%) | 14 (3.1%) |
| 6:00–6:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 20 (1.8%) | 0 (0.0%) | 13 (1.1%) | 34 (1.4%) | 19 (4.2%) |
| 7:00–7:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 11 (1.0%) | 0 (0.0%) | 9 (0.7%) | 21 (0.9%) | 10 (2.2%) |
| 8:00–8:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (1.8%) | 0 (0.0%) | 17 (1.4%) | 37 (1.6%) | 10 (2.2%) |
| 9:00–9:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 14 (1.3%) | 0 (0.0%) | 17 (1.4%) | 32 (1.4%) | 18 (3.9%) |
| 10:00–10:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 21 (1.9%) | 0 (0.0%) | 28 (2.3%) | 49 (2.1%) | 14 (3.1%) |
| 11:00–11:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 35 (3.2%) | 0 (0.0%) | 38 (3.1%) | 73 (3.1%) | 12 (2.6%) |
| 12:00–12:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 66 (6.0%) | 0 (0.0%) | 45 (3.7%) | 112 (4.8%) | 21 (4.6%) |
| 13:00–13:59 | 0 (0.0%) | 0 (0.0%) | 1 (6.3%) | 58 (5.2%) | 0 (0.0%) | 68 (5.6%) | 127 (5.4%) | 20 (4.4%) |
| 14:00–14:59 | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 72 (6.5%) | 0 (0.0%) | 85 (7.0%) | 158 (6.7%) | 39 (8.6%) |
| 15:00–15:59 | 0 (0.0%) | 2 (25.0%) | 1 (6.3%) | 75 (6.8%) | 0 (0.0%) | 74 (6.1%) | 152 (6.5%) | 33 (7.2%) |
| 16:00–16:59 | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 65 (5.9%) | 1 (25.0%) | 107 (8.8%) | 174 (7.4%) | 26 (5.7%) |
| 17:00–17:59 | 0 (0.0%) | 0 0.0%) | 1 6.3%) | 104 (9.4%) | 1 (25.0%) | 130 (10.7%) | 236 (10.0%) | 24 (5.3%) |
| 18:00–18:59 | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 83 (7.5%) | 1 (25.0%) | 114 (9.4%) | 199 (8.5%) | 26 (5.7%) |
| 19:00–19:59 | 2 (66.7%) | 1 (12.5%) | 1 (6.3%) | 78 (7.1%) | 0 (0.0%) | 89 (7.3%) | 171 (7.3%) | 31 (6.8%) |
| 20:00–20:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 79 (7.1%) | 0 (0.0%) | 97 (8.0%) | 176 (7.5%) | 24 (5.3%) |
| 21:00–21:59 | 0 (0.0%) | 1 (12.5%) | 2 (12.5%) | 65 (5.9%) | 0 (0.0%) | 75 (6.2%) | 143 (6.1%) | 17 (3.7%) |
| 22:00–22:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 54 (4.9%) | 0 (0.0%) | 57 (4.7%) | 111 (4.7%) | 20 (4.4%) |
| 23:00–23:59 | 0 (0.0%) | 0 (0.0%) | 2 (12.5%) | 38 (3.4%) | 0 (0.0%) | 29 (2.4%) | 69 (2.9%) | 18 (3.9%) |
| **Total** | **3 (100%)** | **8 (100%)** | **16 (100%)** | **1,105 (100%)** | **4 (100%)** | **1,215 (100%)** | **2,351 (100%)** | **456 (100%)** |

Table 86 displays the odds ratios and LCLs and UCLs for each Time of Day (single-vehicle events). Significant odds ratios have an asterisk. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, from 17:00 to 17:59 and 18:00 to 18:59 (odds ratios = 2.01 and 1.53, respectively). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, from 0:00 to 0:59, 5:00 to 5:59, 6:00 to 6:59, 7:00 to 7:59, and 9:00 to 9:59 (odds ratios = 0.52, 0.37, 0.34, 0.40, and 0.34, respectively).

**Table 86. Odds ratios, LCLs, and UCLs for each time of day (single-vehicle events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 0:00–0:59 | 0.52* | 0.31 | 0.87 |
| 1:00–1:59 | 1.42 | 0.67 | 2.99 |
| 2:00–2:59 | 0.97 | 0.50 | 1.87 |
| 3:00–3:59 | 0.82 | 0.39 | 1.70 |
| 4:00–4:59 | 0.72 | 0.37 | 1.41 |
| 5:00–5:59 | 0.37* | 0.19 | 0.71 |
| 6:00–6:59 | 0.34* | 0.19 | 0.60 |
| 7:00–7:59 | 0.40* | 0.19 | 0.86 |
| 8:00–8:59 | 0.71 | 0.35 | 1.44 |
| 9:00–9:59 | 0.34* | 0.19 | 0.60 |
| 10:00–10:59 | 0.67 | 0.38 | 1.23 |
| 11:00–11:59 | 1.19 | 0.64 | 2.20 |
| 12:00–12:59 | 1.04 | 0.64 | 1.67 |
| 13:00–13:59 | 1.25 | 0.77 | 2.02 |
| 14:00–14:59 | 0.77 | 0.53 | 1.11 |
| 15:00–15:59 | 0.89 | 0.6 | 1.31 |
| 16:00–16:59 | 1.32 | 0.86 | 2.02 |
| 17:00–17:59 | 2.01* | 1.30 | 3.10 |
| 18:00–18:59 | 1.53* | 1.00 | 2.33 |
| 19:00–19:59 | 1.08 | 0.72 | 1.60 |
| 20:00–20:59 | 1.46 | 0.94 | 2.26 |
| 21:00–21:59 | 1.67 | 1.00 | 2.79 |
| 22:00–22:59 | 1.08 | 0.66 | 1.76 |
| 23:00–23:59 | 0.74 | 0.43 | 1.25 |

*Indicates significant odds ratio

### *6.2.5.46 Time-of-day (Multivehicle Events)*

Table 87 shows the frequency and percentage for each Time of Day (multivehicle events). Few of the multiple-vehicle SCEs occurred before 10:00. Most occurred between 12:00 and 22:59, with the highest frequency between 18:00 and 22:59. The multiple-vehicle SCE distribution contrasts sharply with the baseline event distribution.

Table 87. Frequency and percentage by time of day (multivehicle events).

| Time-of-day | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) | Baseline Events (%) |
|---|---|---|---|---|---|---|---|---|
| 0:00–0:59 | 0 (0.0%) | 0 (0.0%) | 3 (6.7%) | 15 (3.1%) | 1 (8.3%) | 0 (0.0%) | 19 (3.5%) | 21 (4.6%) |
| 1:00–1:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (1.4%) | 0 (0.0%) | 0 (0.0%) | 7 (1.3%) | 8 (1.8%) |
| 2:00–2:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 6 (1.2%) | 0 (0.0%) | 0 (0.0%) | 7 (1.3%) | 11 (2.4%) |
| 3:00–3:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 5 (0.9%) | 9 (2.0%) |
| 4:00–4:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (1.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.9%) | 11 (2.4%) |
| 5:00–5:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.6%) | 0 (0.0%) | 0 (0.0%) | 3 (0.5%) | 14 (3.1%) |
| 6:00–6:59 | 1 (50.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.8%) | 0 (0.0%) | 0 (0.0%) | 5 (0.9%) | 19 (4.2%) |
| 7:00–7:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 10 (2.2%) |
| 8:00–8:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) | 10 (2.2%) |
| 9:00–9:59 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) | 18 (3.9%) |
| 10:00–10:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 3 (0.6%) | 1 (8.3%) | 0 (0.0%) | 5 (0.9%) | 14 (3.1%) |
| 11:00–11:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 12 (2.5%) | 2 (16.7%) | 0 (0.0%) | 15 (2.7%) | 12 (2.6%) |
| 12:00 –12:59 | 0 (0.0%) | 0 (0.0%) | 2 (4.4%) | 27 (5.5%) | 0 (0.0%) | 0 (0.0%) | 29 (5.3%) | 21 (4.6%) |
| 13:00–13:59 | 0 (0.0%) | 0 (0.0%) | 3 (6.7%) | 22 (4.5%) | 0 (0.0%) | 0 (0.0%) | 25 (4.6%) | 20 (4.4%) |
| 14:00–14:59 | 0 (0.0%) | 0 (0.0%) | 2 (4.4%) | 31 (6.3%) | 0 (0.0%) | 0 (0.0%) | 33 (6.0%) | 39 (8.6%) |
| 15:00–15:59 | 0 (0.0%) | 0 (0.0%) | 2 (4.4%) | 30 (6.1%) | 1 (8.3%) | 0 (0.0%) | 33 (6.0%) | 33 (7.2%) |
| 16:00–16:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 38 (7.8%) | 0 (0.0%) | 0 (0.0%) | 39 (7.1%) | 26 (5.7%) |
| 17:00–17:59 | 0 (0.0%) | 0 (0.0%) | 4 (8.9%) | 36 (7.4%) | 1 (8.3%) | 0 (0.0%) | 41 (7.5%) | 24 (5.3%) |
| 18:00–18:59 | 0 (0.0%) | 0 (0.0%) | 2 (4.4%) | 52 (10.6%) | 1 (8.3%) | 0 (0.0%) | 55 (10.0%) | 26 (5.7%) |
| 19:00–9:59 | 0 (0.0%) | 0 (0.0%) | 1 (2.2%) | 41 (8.4%) | 1 (8.3%) | 0 (0.0%) | 43 (7.8%) | 31 (6.8%) |
| 20:00–20:59 | 0 (0.0%) | 0 (0.0%) | 3 (6.7%) | 51 (10.4%) | 1 (8.3%) | 0 (0.0%) | 55 (10.0%) | 24 (5.3%) |
| 21:00–21:59 | 0 (0.0%) | 0 (0.0%) | 9 (20.0%) | 48 (9.8%) | 0 (0.0%) | 0 (0.0%) | 57 (10.4%) | 17 (3.7%) |
| 22:00–22:59 | 0 (0.0%) | 0 (0.0%) | 6 (13.3%) | 35 (7.2%) | 1 (8.3%) | 0 (0.0%) | 42 (7.7%) | 20 (4.4%) |
| 23:00–23:59 | 1 (50.0%) | 0 (0.0%) | 2 (4.4%) | 17 (3.5%) | 2 (16.7%) | 0 (0.0%) | 22 (4.0%) | 18 (3.9%) |
| **Total** | **2 (100%)** | **0 (0%)** | **45 (100%)** | **489 (100%)** | **12 (100%)** | **0 (0%)** | **548 (100%)** | **456 (100%)** |

Table 88 displays the odds ratios, LCLs, and UCLs for each Time of Day (multivehicle events). Significant odds ratios have an asterisk, and odds ratios that could not be calculated due to small sample sizes are noted with an "N/A." Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, from 18:00 to 18:59, 20:00 to 20:59, 21:00 to 21:59, and 22:00 to 22:59 (odds ratios = 1.85, 2.01, 3.00, and 1.81, respectively). Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, from 5:00 to 5:59, 6:00 to 6:59, 9:00 to 9:59, and 10:00 to 10:59 (odds ratios = 0.17, 0.21, 0.16, 0.04, and 0.29, respectively).

**Table 88. Odds ratios, LCLs, and UCLs for each time-of-day (multivehicle events).**

| Comparison | Odds Ratio | LCL | UCL |
|---|---|---|---|
| 0:00–0:59 | 0.74 | 0.4 | 1.4 |
| 1:00–1:59 | 0.72 | 0.26 | 2.01 |
| 2:00–2:59 | 0.52 | 0.2 | 1.36 |
| 3:00–3:59 | 0.46 | 0.15 | 1.37 |
| 4:00–4:59 | 0.37 | 0.13 | 1.08 |
| 5:00–5:59 | 0.17* | 0.05 | 0.61 |
| 6:00–6:59 | 0.21* | 0.08 | 0.57 |
| 7:00–7:59 | N/A | N/A | N/A |
| 8:00–8:59 | 0.16* | 0.04 | 0.75 |
| 9:00–9:59 | 0.04* | 0.01 | 0.33 |
| 10:00–10:59 | 0.29* | 0.10 | 0.81 |
| 11:00–11:59 | 1.04 | 0.48 | 2.25 |
| 12:00–12:59 | 1.16 | 0.65 | 2.06 |
| 13:00–13:59 | 1.04 | 0.57 | 1.9 |
| 14:00–14:59 | 0.69 | 0.42 | 1.11 |
| 15:00–15:59 | 0.82 | 0.5 | 1.35 |
| 16:00–16:59 | 1.27 | 0.76 | 2.12 |
| 17:00–17:59 | 1.46 | 0.87 | 2.45 |
| 18:00–18:59 | 1.85* | 1.14 | 2.99 |
| 19:00–19:59 | 1.17 | 0.72 | 1.89 |
| 20:00–20:59 | 2.01* | 1.22 | 3.3 |
| 21:00–21:59 | 3.00* | 1.72 | 5.23 |
| 22:00–22:59 | 1.81* | 1.05 | 3.13 |
| 23:00–23:59 | 1.02 | 0.54 | 1.92 |

*Indicates significant odds ratio

### *6.2.5.47 Summary of Results for Research Question 3*

The following paragraphs provide a summary of the results from 100 drivers who drove more than 735,000 miles, resulting in a dataset of 2,899 SCEs and 456 baseline events. Results from the four research questions yielded many important findings. This summary is not meant to be inclusive of all NTDS results, but discusses some of the more important study findings.

Of the 548 SCEs that involved two or more vehicles, V1 drivers were judged to be at fault in 53.5 percent of the SCEs, while V2 drivers were judged to be at fault in 39.8 percent of the SCEs (0.4 percent were unknown and 6.4 percent were judged no-fault). This distribution is somewhat lower than the results found in the preliminary analysis of the DDWS FOT.[9] Of the 625 SCEs that involved two or more vehicles the preliminary analysis of the DDWS FOT, V1 drivers were judged to be at fault in 71 percent of the SCEs, while V2 drivers were judged to be at fault in 27.8 percent of the SCEs (0.3 percent were unknown and 0.8 percent were judged no- fault).

The most frequent V1 CRs for SCEs involved internal distractions (57.1 percent), external distractions (11.4 percent), and drowsiness (8.9 percent). While it is not surprising that these types of factors would be prevalent CRs, the frequencies were much higher than anticipated. The preliminary analysis of the DDWS FOT found the following frequencies using a similar data collection approach: internal distractions (10.8 percent), external distractions (6.2 percent), and drowsiness (1.2 percent). The most obvious explanation for these discrepancies was the addition of an additional sensor in the NTDS to detect lane deviations. As lane deviations have been found to be predictive of driver inattention and fatigue, these frequencies are not entirely surprising.[43] The overwhelming majority of lane-deviation SCEs were single-vehicle events. Thus, by considering only multiple-vehicle SCEs, the NTDS V1 CRs are parallel with those found in the preliminary analysis of the DDWS FOT. For example, the V1 CRs for multiple-vehicle SCEs in the NTDS for internal distraction, external distraction, and drowsiness were 5.1, 2.2, and 0.2 percent, respectively.

Because V2 was not instrumented, it was difficult to determine the exact V2 CRs. However, the V2 CRs in the NTDS and in the preliminary analysis of the DDWS FOT were very similar. The current NTDS found the most frequent V2 CRs for SCEs were *other decision error* (1.4 percent), *aggressive driving: wanton, neglectful, or reckless behavior* (1 percent), *other illegal maneuver* (0.8 percent), *apparent recognition error* (0.7 percent), and *too slow for traffic stream* (0.7 percent). In the preliminary analysis of the DDWS FOT, the most frequent V2 CRs for SCEs were *apparent recognition or decision error* (13.4 percent), *apparent recognition failure* (2.6 percent), *other decision error* (2.4 percent), and *aggressive driving: wanton, neglectful, or reckless behavior* (2.1 percent). While the most frequent CRs were similar in the two studies, the percentages were lower in the NTDS, given the preponderance of single-vehicle events detected by the lane-deviation sensor.

One of the important research questions addressed the safety concerns during LV-HV interactions. A total of 407 LV-HV interactions were in the NTDS. Of these, the HV driver (or V1) was judged to be at fault in 235 safety-critical incidents, while the LV driver (or V2) was judged to be at fault in 146 SCEs (6.4 percent were no-fault). These data are similar to another naturalistic truck study assessing the effectiveness of a DDWS. In a preliminary analysis of the DDWS FOT, researchers found that V1 drivers were judged to be at fault in 71 percent of the SCEs, while V2 drivers were judged to be at fault in 27.8 percent of the SCEs. These results are not consistent with prior studies that suggest LV drivers are primarily responsible for LV-HV interactions. In an analysis of the University of Michigan Transportation Research Institute’s report entitled “Trucks Involved in Fatal Accidents” it was found that truck drivers were cited with a driver-related factor in 26.5 percent of the fatal crashes, while passenger-vehicle drivers were cited in more than 80 percent of the fatal crashes.[44] In a review of the USDOT’s Fatality Analysis Reporting System, similar results were found; truck-driver-related factors were cited in

29 percent of fatal truck crashes involving a passenger vehicle, while 67 percent of these same interactions were cited as passenger-vehicle-related.[45] In another study completed in 1999, it was found that LVs were the initiators in LV-HV fatal crashes by a ratio of approximately 3:1.[3] Moreover, an analysis of all LV-HV interaction in the 100-Car Study found that HV drivers were at fault in 32 percent of the incidents, while LV drivers were at fault in 56 percent of the incidents (12 percent were unknown).[46] The most likely explanation for these discrepancies is that the vehicle-based sensor suite employed in the NTDS was better suited for detecting V1-initiated actions than V2-initiated actions, and thus there was a predominance of V1 at-fault events in this dataset. Further, the lack of a camera able to detect events directly behind V1 limited the type of possible interactions (i.e., events in which V2 was directly behind V1 were not detected unless V2 struck V1).

The most frequent HV-driver CRs during LV-HV interactions were *inadequate evasive action* (35.9 percent), *misjudgment of gap or other's speed* (12.2 percent), *internal distraction* (11.4 percent), and *inadequate surveillance* (11 percent). It is hard to make direct comparisons between the NTDS and other naturalistic studies regarding LV-HV interactions because the 100-Car, Sleeper Berth (SB), and Local/Short-haul (L/SH) studies used a different classification system, although the 100-Car Study did code CRs—but only for the LV driver.[46]

For example, using a data collection approach similar to that used in the NTDS (in which the HV was instrumented), the SB study found that the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (16.2 percent), *aggressive driving* (7.4 percent), and *vehicle kinematics/physics* (4.4 percent). Similarly, the L/SH Study found that the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (5.6 percent), *roadway alignment*, (4.9 percent), and *aggressive driving* (2.1 percent). In the 100-Car Study, where the LV was instrumented, the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (16.2 percent) and *distractions* (3.7 percent).[46]

Of the 146 LV-HV interactions in the NTDS in which the LV driver (or V2) was judged to be at fault, the most frequent CRs were *other decision error* (23.6 percent), *aggressive driving behavior* (18.8 percent), *other illegal maneuver* (13.9 percent), and *too slow for traffic stream* (10.4 percent). While the 100-Car Study did not report HV-driver CRs for LV-HV interactions, it did report these for the LV driver. Thus, direct comparisons can be made. The most frequent LV-driver CRs during LV-HV interactions in the 100-Car Study were *aggressive driving behavior* (24.6 percent), *too fast for conditions* (15.2 percent), and *internal distraction* (13.8 percent).[10] The SB Study found that the most frequent LV-driver contributing factors during LV-HV interactions were *driving techniques* (31.7 percent) and *aggressive driving* (27.9 percent), while the L/SH Study reported that the most frequent LV-driver contributing factors were *aggressive driving* (35.2 percent) and *driving techniques* (18.3 percent). There is not much overlap between these studies and the NTDS regarding the HV- or LV-driver at-fault LV-HV interaction events. The different classification systems and instrumentation approaches probably explain some of the variability. However, the SB and L/SH studies involved specific driver populations driving specific routes; this is also likely to explain some of the discrepancies found between these studies. These data are consistent in that they show that aggressive driving by the LV driver is a frequent issue during LV-HV interactions.

Not surprisingly, drivers who engaged in Potential Distractions while driving were more likely to be involved in a SCE compared to a baseline event. Several of these Potential Distractions were especially dangerous, as they had odds ratios above 5.0; for example: *using or reaching for devices*, *reading while driving*, and *handling dispatching, electronic recording, or navigational devices*. Other Potential Distractions with significant odds ratios included *looking for objects in the vehicle*, *reaching for objects in the vehicles*, *reading or looking at maps*, and *reading or looking at dispatching, electronic recording, or navigational devices*. These results are analogous to the Potential Distractions found among passenger car drivers during crashes and near-crashes in the 100-Car Study. In the 100-Car Study, researchers found significant odds ratios for several secondary tasks performed while driving, such as *reaching for a moving object* (8.25), *reading* (3.18), *dialing handheld device* (2.58), *applying makeup* (2.9), *looking for external object* (3.46), and *eating* (1.47).(47)

In contrast to the literature, a driver being coded as drowsy, sleepy, or fatigued did not yield a significant odds ratio. Driver impairment due to drowsiness is a known Contributing Factor in many crashes involving CMV drivers.(48) The LTCCS found that 13 percent of truck drivers involved in crashes were coded as being fatigued at the time of the crash.(26) However, in the NTDS, data reductionists used subjective judgment when coding this Potential Distraction. More objective criteria, such as percentage of eye closure and observer rating of drowsiness would provide a valid assessment of driver fatigue.(49,50)

Two potential distractions showed a protective effect. Looking at the right- or left-side mirror/window was less likely to occur during a SCE compared to baseline event. This makes intuitive sense, as drivers who are looking out their mirrors or windows are surveying traffic and driving safely. Note that Potential Distractions were coded regardless of their apparent relevance to the event; thus, the odds ratios presented do not necessarily imply that they contributed to the occurrence of the event.

Several variables coded by data reductionists reflected the light level, weather, road conditions, road type, and traffic volume. Drivers were significantly more likely to be involved in a SCE, compared to a baseline event, during daylight hours. This makes sense as most traffic occurs during daylight hours, thereby increasing the probability of a vehicle-to- vehicle interaction.(51) A 2007 analysis of the DDWS FOT supports this contention.(52) Researchers who completed this analysis found a strong positive linear relationship between daily weekday traffic across all hours of the day and the relative frequency of SCEs across all hours of the day ($r = 0.83$, $R2 = 0.69$). Festin's traffic-density plot showed a sharp onset (around 6 a.m.) and slow decline after what presumably would be the evening rush period.(51) Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, while driving during the *dark*, *dark but lighted*, or *dusk*. Weather and roadway surface conditions did not have a significant impact on SCE occurrence.

Drivers in the NTDS were significantly more likely to be involved in a SCE, compared to a baseline event, while driving on a non-junction road. Drivers were less likely to be involved in a SCE, compared to a baseline event, while driving on a parking lot or driveway, alley access, etc. Regarding the trafficway flow, drivers were significantly more likely to be involved in a SCE, compared to a baseline event, while driving on a divided road. Divided roads typically have higher posted travel speeds than non-divided roads, and that might explain these results. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, while driving on a not-physically-divided road or a one-way trafficway.

The number of travel lanes revealed some interesting findings. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, while driving on a road with one travel lane. This is not entirely surprising, as one-lane roads limit sideswipe interactions. The only other significant results found that drivers were significantly more likely to be involved in a SCE, compared to a baseline event, while traveling on a road with two travel lanes. Intuitively, one might expect the level of risk to increase as the number of travel lanes increases (as the number of possible vehicle interactions increases). However, this was not found. Roadway alignment and roadway profile did not have a significant impact on SCE occurrence.

Drivers in the NTDS were significantly more likely to be involved in a SCE, compared to a baseline event, while driving during LOS B or LOS C. Drivers were less likely to be involved in a SCE, compared to a baseline event, while driving during LOS A. These results are somewhat expected; as traffic density increases, so does the probability of being involved in a SCE. The results show an increasing trend in the odds ratio as the LOS increases; however, this disappeared after LOS C due to the small number of events observed in LOS D, E, and F. It appears that SCEs were most likely to occur while drivers were driving during the daylight on a two-lane, non-junction, divided road during LOS B or LOS C. While this is beyond the scope of the current study, logistic regression techniques could be used to determine the appropriate model, given the interactions among these terms.

As indicated above, fatigue affects mental alertness, thereby decreasing an individual's ability to operate a vehicle safely. Many factors may affect driver alertness and fatigue, including time of day, hours of previous sleep, hours awake, health and wellness, caffeine intake, over-the-counter and prescription drug use, individual differences, and time-on-task.(53) It has been suggested that crash risk increases as the number of consecutive driving shifts increases (i.e., the cumulative effect of fatigue increases over consecutive shifts). In a study completed in 1991, researchers used retrospective crash reports and drive histories and found a consistent trend in crash risk over four successive driving shifts.(54) On average, crash risk was 6 percent higher on the second shift, 17 percent higher on the third shift, and 36 percent higher on the fourth shift (compared to the first shift). However, these effects were found only in drivers who drove during the night; there was no significant effect for drivers who drove during the day, suggesting time of day was more likely an explanation of the findings. The Driver Fatigue and Alertness Study found that the cumulative number of trips was not a strong or consistent predictor of fatigue.(55) Similarly, three different naturalistic driving studies with CMV drivers did not find an increase in critical incident occurrence as the cumulative number of shifts increased.(31,56,57) These studies suggest that cumulative shifts within the driver's work week have little effect on crash risk.

Across all events, the drivers were significantly more likely to be involved in a SCE, compared to a baseline event, while driving on a Friday, Saturday, or Sunday. Drivers were less likely to be involved in a SCE, compared to a baseline event, while driving on a Tuesday or Thursday. These same results were found when assessing only single-vehicle events; however, only Sunday and Tuesday reached significance when assessing only multivehicle events. These results could suggest the cumulative effects of fatigue, given that the odds ratios increase toward the end of the week. However, reviewing the day-of-week data can be misleading. These top-level data do not indicate when a driver started or stopped a shift; thus, there is no way of knowing whether these effects were cumulative. A more detailed analysis assessing driver shifts is needed to assess this research question.

Circadian effects have also been suggested as elevating crash risk. “Circadian rhythm” refers to the human body’s natural tendency to be alert or drowsy at different definite points within the 24-hour cycle. Circadian low periods are from 2:00 to 4:59 and 14:00 to 16:59; circadian high periods are from 9:00 to 11:00 and 20:00 to 20:59.[58]

The Commercial Motor Vehicle Driver Fatigue and Alertness Study was an on-road study with 80 drivers in the U.S. and Canada. Trucks were instrumented with video cameras and several driving measures were collected (e.g., driving task performance, driving speed and distance, physiological measures, and self-report questionnaires) over a period of 16 weeks. The strongest and most consistent factor influencing driver fatigue was time of day.[55] Across all events, drivers in the NTDS were significantly more likely to be involved in a SCE, compared to a baseline event, while driving during the periods 17:00 to 18:59 and 20:00 to 21:59. Drivers were significantly less likely to be involved in a SCE, compared to a baseline event, while driving during the periods 0:00 to 0:59, 5:00 to 7:59, and 9:00 to 9:59. These results were consistent when assessing only single-vehicle events and only multivehicle events. These data do not support a circadian effect. Similarly, researchers did not find support for a circadian effect in the 2007 analysis of the DDWS FOT dataset.[52]

### 6.2.6 Research Question 4: Applicable Functional Countermeasures

Functional countermeasures were found by reviewing the SCEs in the NTDS dataset, and interviewing the commercial drivers who participated in the data collection. As conducted in the Phase I analyses, the authors reviewed the SCEs and coded countermeasures likely to be applicable to those events. Countermeasures were defined functionally to the events; that is, countermeasures are functional interventions that would have prevented the genesis of the unsafe situation, or improved the driver response to the unsafe situation. For crashes, an applicable functional countermeasure will be one that probably would have prevented the crash. Near-crashes, crash-relevant conflicts, illegal maneuvers, and unintentional lane deviations were analyzed “as if” those events would have resulted in crashes. The frequency and percentage of countermeasures were calculated based on the SCEs in the NTDS dataset. More than one countermeasure concept could be applied to a particular SCE.

A major addition in the NTDS was the face-to-face interviews with drivers at the end of their data collection periods. The interview consisted of both generic questions (e.g., “What are some things you think will reduce the risk of crashes?”) and topic-specific questions (e.g., “What do you think about the type of driving behaviors that would increase the risk of a crash?”). The drivers were also asked about futuristic devices to avoid a crash. The inputs from the drivers expanded the list of possible functional countermeasures because of their great experience in driving commercial vehicles and being exposed to risky situations on the road. However, there were event scenarios in which none of the listed countermeasures was applicable. In these situations, the countermeasure “not applicable” was coded. In a few situations, only limited information was available to make a determination on a functional countermeasure. In these situations, the countermeasure “unknown” was coded.

#### 6.2.6.1 *Vehicle 1 Countermeasures*

Table 89 shows the frequency and percentage for each V1 Countermeasure. Because more than one V1 Countermeasure could be selected for each SCE, the column totals exceed 100 percent. Not including the SCEs where no V1 Countermeasure was coded, the most frequent V1 Countermeasures for SCEs were:

- Prevent “drift” lane departures (V1 Countermeasure 2, 79 percent).
- Increase driver attention to forward visual scene (V1 Countermeasure 7, 73.7 percent).
- Improve general driver situation awareness and/or proactive/defensive driving (V1 Countermeasure 9, 56.1 percent).
- Increase driver alertness (reduce drowsiness) (V1 Countermeasure 1, 14.4 percent).

The most frequent V1 Countermeasures for the five actual crashes were:

- Improve general driver situation awareness and/or proactive/defensive driving (V1 Countermeasure 9, 60 percent).
- Increase/improve driver use of mirrors or provide better information from mirrors (V1 Countermeasure 8, 40 percent).

**Table 89. Frequency and percentage of V1 countermeasures.**

| Vehicle 1 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| No Countermeasure Applicable | 0 (0.0%) | 0 (0.0%) | 11 (18.0%) | 154 (9.7%) | 8 (50.0%) | 0 (0.0%) | 173 (6.0%) |
| 1—Increase Driver Alertness (Reduce Drowsiness) | 0 (0.0%) | 1 (12.5%) | 7 (11.5%) | 206 (12.9%) | 0 (0.0%) | 203 (16.7%) | 417 (14.4%) |
| 2—Prevent “Drift” Lane Departures | 0 (0.0%) | 0 (0.0%) | 18 (29.5%) | 1,096 (68.8%) | 1 (6.3%) | 1,176 (96.8%) | 2,291 (79.0%) |
| 3—Improve Vehicle Control/Stability on Curves | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 2 (0.2%) | 4 (0.1%) |
| 4—Improve Vehicle Control/Stability on Slippery Road Surfaces | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 6—Improve Vehicle Control/Stability During Evasive Steering | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.2%) | 2 (0.1%) |
| 7—Increase Driver Attention to Forward Visual Scene | 0 (0.0%) | 0 (0.0%) | 16 (26.2%) | 1,024 (64.2%) | 0 (0.0%) | 1,097 (90.3%) | 2,137 (73.7%) |
| 8—Increase/Improve Driver Use of Mirrors or Provide Better Information from Mirrors | 2 (40.0%) | 0 (0.0%) | 11 (18.0%) | 18 (1.1%) | 0 (0.0%) | 0 (0.0%) | 31 (1.1%) |

| Vehicle 1 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 9—Improve General Driver Situation Awareness and/or Proactive/Defensive Driving | 3 (60.0%) | 2 (25.0%) | 23 (37.7%) | 884 (55.5%) | 7 (43.8%) | 707 (58.2%) | 1,626 (56.1%) |
| 10—Reduce Road/Highway Travel Speed | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 16 (1.0%) | 0 (0.0%) | 3 (0.2%) | 21 (0.7%) |
| 11—Reduce Speed on Down Grades | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 12—Reduce Speed on Curves or Turns | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 15—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Stopped Vehicle(s) in Lane Ahead | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 6 (0.4%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| 16—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Moving/Decelerating Vehicle(s) in Lane Ahead | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 113 (7.1%) | 1 (6.3%) | 0 (0.0%) | 117 (4.0%) |
| 17—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane | 0 (0.0%) | 0 (0.0%) | 9 (14.8%) | 28 (1.8%) | 0 (0.0%) | 0 (0.0%) | 37 (1.3%) |
| 18—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane | ` | 0 (0.0%) | 6 (9.8%) | 17 (1.1%) | 0 (0.0%) | 0 (0.0%) | 24 (0.8%) |
| 19—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane During Merging | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 10 (0.3%) |
| 20—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane During Merging | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 21—Increase Driver Recognition or Gap Judgment, i.e., Crossing or Oncoming Traffic at Intersections | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |

| Vehicle 1 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 22—Improve Driver Response Execution of Crossing or Turning Maneuver at Intersections | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 23— Improve Driver Recognition/Gap Judgment/Response Execution at Intersection | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 24—Improve Driver Compliance with Intersection Traffic Signal Controls (e.g., Red Light) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 25—Improve Driver Compliance with Intersection Traffic Signal Controls (e.g., Stop or Yield Sign) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (12.5%) | 0 (0.0%) | 2 (0.1%) |
| 26—Increase Forward Headway During Vehicle Following | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 24 (1.5%) | 0 (0.0%) | 1 (0.1%) | 27 (0.9%) |
| 28—Provide Warning to Prevent Rear Encroachment or Tailgating by Other Vehicle | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 32—Improve Driver Recognition/Gap Judgment Relating to Oncoming Vehicle During Passing Maneuver | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 5 (0.3%) | 0 (0.0%) | 0 (0.0%) | 5 (0.2%) |
| 33—Prevent Animals from Crossing Roadway | 1 (20.0%) | 0 (0.0%) | 1 (1.6%) | 10 (0.6%) | 0 (0.0%) | 0 (0.0%) | 12 (0.4%) |
| 34—Navigation System/Routing Aid | 1 (20.0%) | 1 (12.5%) | 1 (1.6%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 12 (0.4%) |
| 36—Prevent or Reduce Trailer Off-Tracking Outside Travel Lane or Path | 0 (0.0%) | 2 (25.0%) | 0 (0.0%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| 97—Improve Roadway Geometry | 0 (0.0%) | 5 (62.5%) | 1 (1.6%) | 24 (1.5%) | 0 (0.0%) | 0 (0.0%) | 30 (1.0%) |
| 98—Driver Error and/or Vehicle Failure Apparent but Unknown Countermeasure | 0 (0.0%) | 1 (12.5%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 99—Unknown | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 4 (0.3%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| **Total** | **8 (160%)** | **13 (163%)** | **119 (195%)** | **3,681 (231%)** | **19 (119%)** | **3,191 (263%)** | **7,031 (243%)** |
| **Event Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.6.2 Vehicle 2 Countermeasures*

Table 90 displays the frequency and percentage for each V2 Countermeasure. As more than one V2 Countermeasure could be selected for each SCE, the column totals may exceed 100 percent. Not including the single-vehicle SCEs or the SCEs in which no V2 Countermeasure was coded, the most frequent V2 Countermeasures for SCEs were:

- Improve general driver situation awareness and/or proactive/defensive driving (V2 Countermeasure 9, 4.9 percent).
- Improve driver night vision in the forward field (V2 Countermeasure 27, 4.3 percent).
- Increase driver recognition/appreciation of specific highway crash threats: vehicle in right adjacent lane (V2 Countermeasure 18, 1.1 percent).
- Increase driver recognition/appreciation of specific highway crash threats: vehicle in left adjacent lane (V2 Countermeasure 17, 1 percent).

The most frequent V2 Countermeasures for the five actual crashes were:

- Not applicable (single-vehicle event) (80 percent).
- No countermeasure applicable (20 percent).

**Table 90. Frequency and percentage of V2 countermeasures.**

| Vehicle 2 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| No Countermeasure Applicable | 1 (20.0%) | 0 (0.0%) | 23 (37.7%) | 181 (11.4%) | 1 (6.3%) | 0 (0.0%) | 206 (7.1%) |
| Not Applicable (Single-vehicle Event) | 4 (80.0%) | 0 (0.0%) | 16 (26.2%) | 1,114 (69.9%) | 4 (25.0%) | 1,215 (100.0%) | 2,353 (81.2%) |
| 1—Increase Driver Alertness (Reduce Drowsiness) | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 2—Prevent "Drift" Lane Departures | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 9 (0.6%) | 0 (0.0%) | 0 (0.0%) | 11 (0.4%) |
| 5—Improve Vehicle Control/Stability During Braking | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 7—Increase Driver Attention to Forward Visual Scene | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 8—Increase/Improve Driver Use of Mirrors or Provide Better Information from Mirrors | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 6 (0.2%) |
| 9—Improve General Driver Situation Awareness and/or Proactive/Defensive Driving | 0 (0.0%) | 0 (0.0%) | 10 (16.4%) | 124 (7.8%) | 9 (56.3%) | 0 (0.0%) | 143 (4.9%) |
| 10—Reduce Road/Highway Travel Speed | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 5 (0.3%) | 2 (12.5%) | 0 (0.0%) | 8 (0.3%) |

| Vehicle 2 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 16—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Moving/Accelerating Vehicle(s) in Lane Ahead | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 17—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane | 0 (0.0%) | 0 (0.0%) | 3 (4.9%) | 26 (1.6%) | 0 (0.0%) | 0 (0.0%) | 29 (1.0%) |
| 18—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 27 (1.7%) | 3 (18.8%) | 0 (0.0%) | 31 (1.1%) |
| 19—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane During Merging | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 25 (1.6%) | 0 (0.0%) | 0 (0.0%) | 27 (0.9%) |
| 20—Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane During Merging | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 7 (0.4%) | 1 (6.3%) | 0 (0.0%) | 9 (0.3%) |
| 21—Increase Driver Recognition or Gap Judgment, i.e., Crossing or Oncoming Traffic at Intersections | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 7 (0.4%) | 0 (0.0%) | 0 (0.0%) | 7 (0.2%) |
| 22—Improve Driver Response Execution of Crossing or Turning Maneuver at Intersections | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 4 (0.1%) |
| 23—Improve Driver Recognition/Gap Judgment/Response Execution at Intersection | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 8 (0.5%) | 0 (0.0%) | 0 (0.0%) | 8 (0.3%) |
| 24—Improve Driver Compliance With Intersection Traffic Signal Controls (e.g., Red Light) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 25—Improve Driver Compliance With Intersection Traffic Signal Controls (e.g., Stop or Yield Sign) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 26—Increase Forward Headway During Vehicle Following | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 1 (0.0%) |
| 27—Improve Driver Night Vision in the Forward Field | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 126 (7.9%) | 0 (0.0%) | 0 (0.0%) | 126 (4.3%) |
| 28—Provide Warning to Prevent Rear Encroachment or Tailgating by Other Vehicle | 0 (0.0%) | 0 (0.0%) | 2 (3.3%) | 0 (0.0%) | 1 (6.3%) | 0 (0.0%) | 3 (0.1%) |
| 30—Prevent Vehicle Mechanical Failure (e.g., Brakes, Steering, Tire) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |

| Vehicle 2 Countermeasures | Crashes (%) | Crash: Tire Strikes (%) | Near-crashes (%) | Crash-relevant Conflicts (%) | Illegal Maneuvers (%) | Unintentional Lane Deviations (%) | Total SCEs (%) |
|---|---|---|---|---|---|---|---|
| 32—Improve Driver Recognition/Gap Judgment Relating to Oncoming Vehicle During Passing Maneuver | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| 97—Improve Roadway Geometry | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| 98—Driver Error and/or Vehicle Failure Apparent but Unknown Countermeasure | 0 (0.0%) | 0 (0.0%) | 4 (6.6%) | 28 (1.8%) | 2 (12.5%) | 0 (0.0%) | 34 (1.2%) |
| 99—Unknown | 0 (0.0%) | 0 (0.0%) | 1 (1.6%) | 1 (0.1%) | 0 (0.0%) | 0 (0.0%) | 2 (0.1%) |
| **Total** | **5 (100%)** | **0 (0.0%)** | **71 (116%)** | **1,720 (108%)** | **23 (144%)** | **1,215 (100%)** | **3,034 (105%)** |
| **Event Total** | **5 (100%)** | **8 (100%)** | **61 (100%)** | **1,594 (100%)** | **16 (100%)** | **1,215 (100%)** | **2,899 (100%)** |

#### *6.2.6.3 Summary of Results for Research Question 4*

This study collected detailed information on a large number of SCEs. The non-crash events were operationally defined for this study as having elements identical to a crash scenario, with the exception that a successful evasive maneuver was also present. These types of events have two important features that crash data do not. First, they occur much more frequently. Second, near-crash events are cases in which a driver successfully performed an evasive maneuver. Understanding these cases may give additional insight into the factors that allow drivers to be effective defensive drivers, as well as potential countermeasures to aid these drivers. This research effort assessed applicable functional countermeasures that can be used to inform the development of crash avoidance technologies, enforcement regulations, and safety management methods by researchers to prevent the genesis of the unsafe situation and/or improve the driver's response to the unsafe situation. The most frequent CMV functional countermeasures were: prevent "drift" lane departures (79 percent), increase driver attention to forward visual scene (73.7 percent), improve general driver situation awareness and/or proactive/defensive driving (56.1 percent), and increase driver alertness (14.4 percent). Please note that more than one countermeasure could be selected for each SCE; therefore, the total is more than 100 percent. These countermeasures were different from the CMV countermeasures reported in the preliminary analysis of the DDWS FOT.[9] In that analysis, the most frequent CMV countermeasures were: increase driver recognition of specific highway crash threats—moving/decelerating vehicle(s) in lane ahead, traveling in same direction (18.8 percent); increase driver attention to forward scene (18.5 percent); and improve general driver situation awareness and/or defensive driving (13 percent).

The countermeasures for other vehicles obtained from this study and the ones from the DDWS FOT differed from each other. The most frequent countermeasures for other vehicles in the NTDS were improve general driver situation awareness and/or proactive/defensive driving (4.9 percent); improve driver night vision in the forward field (4.3 percent); increase driver recognition/appreciation of specific highway crash threats: vehicle in right adjacent lane (1.1

percent); and increase driver recognition/appreciation of specific highway crash threats: vehicle in left adjacent lane (1 percent). Frequent countermeasures for other vehicles in the DDWS FOT were to provide warning to prevent rear encroachment or tailgating by other vehicle (24.6 percent); increase driver recognition of specific highway crash threats: vehicle in left adjacent lane on highway (5.7 percent); and increase driver recognition of specific highway crash threats: vehicle in left adjacent lane during merging maneuver (4.8 percent). Comparisons between the countermeasures obtained from the NTDS and the DDWS FOT for CMV and other vehicles did not yield many similarities. There are several possible explanations for these discrepancies. First, different fleet types were used in the two studies. Differences in safety management techniques, goods delivered, routes traveled, etc., may explain some of these discrepancies. Second, certain drivers were overly involved in certain types of SCEs. These “outliers” may explain the divergent results. Finally, it is possible that the different vehicle-based sensor suite employed in the NTDS (with lane deviation tracking capabilities) explains some of the differences found. Future research might compile all these factors to assess whether they explain the variability in results.

# 7. CONCLUSIONS

The main objective of this on-road study was to collect ND data that could be used to investigate issues related to CMV crash risk. More specifically, three primary focus areas were evaluated under this report and will be evaluated in future research efforts:

- Work/rest parameters relating to driver fatigue and incident involvement.
- Event causation and LV-HV interactions.
- Applicable functional countermeasures.

The researchers completed data collection for the NTDS in May 2007. The list below provides an overview of the data collected:

**Amount of data collected:**

- More than 14,500 driving hours of valid data.
- Approximately 2,200 driving shifts.
- 26,000 on-duty hours of daily activity register data.
- More than 735,000 miles (equivalent to approximately 265 transcontinental trips between New York and Los Angeles).
- More than 65,000 hours of actigraphy data from 97 drivers.

**Results of data reduction:**

- 2,899 SCEs.
  - 13 crashes (8 were tire strikes).
  - 61 near-crashes.
  - 1,594 crash-relevant conflicts.
  - 1,215 unintentional lane deviations.
  - 16 illegal maneuvers.
- 456 baseline events.

The naturalistic data provide the opportunity to answer a myriad of research questions. Therefore, in addition to the data reduction effort undertaken to obtain the SCEs, several other data analyses were performed. The four main areas evaluated were:

- Restart Period and SCEs.
- Sleep Pattern and SCEs.
- Vehicle Interactions by Type of Maneuver.

- Functional Countermeasures.

The findings in each of the main areas are summarized below.

## 7.1 RESTART PERIOD AND SAFETY-CRITICAL EVENTS

All of the analyses performed for this research question were focused on the restart period preceding the SCEs. The three main analyses were: 1) duration of the restart period, 2) relationship between SCEs and the restart period, and 3) time from restart period to SCEs. On average, the duration of the restart period before a SCE was 53 hours every 5 days. For the baseline events taken as a comparison, the duration of the restart averaged 58 hours. LH drivers had a shorter restart (48 hours) than SH drivers (63 hours). The medium-haul drivers had an average restart of 53 hours. All three different types of operations took, on average, more than the 34-hour minimum of off-duty restart required by FMCSA under the current HOS regulations.(31) Conversely, no relationship was found between the duration of the restart period and the SCEs. However, the results show that the number of SCEs is highest during the first day after restart. This is consistent with results presented in a 2002 study on the impact of sleeper berth usage on driver fatigue.(32)

## 7.2 SLEEP PATTERN AND SAFETY-CRITICAL EVENTS

The findings presented in this report were based on all the SCEs for this study (i.e., at fault or not). Based on the actigraphy data collected during the study, CMV drivers in the baseline events slept, on average, 6.6 hours (6.4–6.8 hours at the 95-percent confidence interval) during the 24 hours before the baseline event. For SCEs, CMV drivers had an average of 6.5 hours (6.4–6.6 hours at the 95 percent confidence interval) of sleep during the 24 hours before the SCE. A previous study completed in 2007 with CMV drivers involved in SCEs (in which the CMV driver was judged to have been at fault) found that this subset of CMV drivers slept an average of 6.7 hours.(37) However, their sleep before an at-fault SCE was significantly less than their average sleep (i.e., 5.3 hours). The overall sleep quantity presented in this 2007 study falls inside the confidence interval suggested for the mean sleep of baseline events in the current study. However, there is a major difference (1.2 hours) between the mean sleep before a SCE presented in the current analysis (6.5 hours) and the one reported in the 2007 study. The 1.2-hour difference is attributed to a difference in the focus of these two analyses. In the current analysis, the results presented comprised all the SCEs in the dataset, while researchers from the 2007 study evaluated only "at-fault" SCEs. One possible explanation is that perhaps only when the event is the CMV driver's fault is there a significant difference in his/her average sleep before a SCE, but that might not be the case overall (i.e., if the fault is assigned to the other vehicle's driver). That is, looking at all SCEs together, one might not expect to find differences in sleep.

In addition to the amount of sleep in the 24 hours preceding a SCE, the sleep during the restart period and the sleep since the restart were evaluated. On average, CMV drivers slept 1.1 hours more during their restart than during their regular workdays. The average sleep for CMV drivers since restart and 24 hours before a SCE is less than what they obtained during the restart period preceding the SCE. However, this difference only represents one-half hour less sleep during the 24 hours before a SCE. These results included all SCEs (i.e., at fault or not).

The amounts of sleep reported above reflected the sum of all the sleep periods inside a 24-hour period (i.e., one total sleep per SCE or baseline event). However, an 8-hour sleep period in the last 24 hours might not always be taken in a single sleep period. The total sleep could be composed of two or more sleep periods. The analysis performed for this study showed that most of the sleep received 24 hours before a SCE or baseline event involved a single sleep period, but some drivers had their sleep divided into as many as four sleep periods. However, having three or more sleep periods was not predominant. The duration of the sleep period (all sleep periods in the last 24 hours), the amount of time since the last sleep period preceding the event of interest (only first sleep period preceding an event), and the amount of time between sleep periods (only when multiple sleep periods exist within the last 24 hours) were also evaluated. The average durations of a sleep period 24 hours before a baseline event and a SCE was 5.1 hours and 5 hours, respectively. On average, drivers had a sleep period 7 hours before a baseline event and 7.8 hours before a SCE. When CMV drivers had multiple sleep periods in the 24 hours before a baseline event or SCE, these sleep periods were taken 5.2 hours and 5.1 hours apart, respectively.

## 7.3 VEHICLE INTERACTIONS

As part of this study, the interactions of other vehicles with the CMV that participated in the study were assessed. The following paragraphs summarize the results obtained from the different parts of the vehicle interaction assessment. Of the 548 SCEs that involved two or more vehicles, CMV drivers were judged to be at fault 53.5 percent of the time, while other drivers were judged to be at fault 39.8 percent of the time (0.4 percent were unknown and 6.4 percent were judged no-fault). This distribution is somewhat lower than the results found in the preliminary analysis of the DDWS FOT.[9] Of the 625 SCEs that involved two or more vehicles in the preliminary analysis of the DDWS FOT, CMV drivers were judged to be at fault 71 percent of the time, while other drivers were judged to be at fault 27.8 percent of the time (0.3 percent were unknown and 0.8 percent were judged no-fault).

The most frequent CRs assigned to CMV drivers for SCEs involved *internal distractions* (57.1 percent), *external distractions* (11.4 percent), and *drowsiness* (8.9 percent). While it is not surprising that these types of factors would be prevalent CRs, the frequencies were much higher than anticipated. The preliminary analysis of the DDWS FOT found the following frequencies using a similar data collection approach: *internal distractions* (10.8 percent), *external distractions* (6.2 percent), and *drowsiness* (1.2 percent).[9] The most obvious explanation for these discrepancies was the presence of an additional sensor in the current study to detect lane deviations. As lane deviations have been found to be predictive of driver inattention and fatigue, these frequencies are not entirely surprising.[43] The overwhelming majority of lane-deviation SCEs were single-vehicle events. Thus, if we consider only multivehicle SCEs, the CRs for CMV drivers found in this analysis were parallel to those found in the preliminary analysis of the DDWS FOT. For example, the CRs for CMV drivers in a multivehicle SCE are *internal distraction*, *external distraction*, and *drowsiness* (5.1, 2.2, and 0.2 percent, respectively).

Because the other vehicle with which the CMV interacted was not instrumented, it was difficult to determine precise CRs for the other driver. However, the CRs for other drivers in this study and in the preliminary analysis of the DDWS FOT were very similar. The current study found that the most frequent CRs for other drivers involved in SCEs were *other decision error* (1.4 percent), *aggressive driving: wanton, neglectful, or reckless behavior* (1 percent), *other illegal maneuver* (0.8 percent), *apparent recognition error* (0.7 percent), and *too slow for traffic stream* (0.7 percent). In the preliminary analysis of the DDWS FOT, the most frequent CRs in these cases were *apparent recognition or decision error* (13.4 percent), *apparent recognition failure* (2.6 percent), *other decision error* (2.4 percent), and *aggressive driving: wanton, neglectful, or reckless behavior* (2.1 percent). While the most frequent CRs were similar for the vehicles that interacted with the CMV, the percentages were lower in the current study, given the preponderance of single-vehicle events detected by the lane-deviation sensor.

A total of 407 LV-HV interactions were involved in this study. Of these, the HV driver was judged to be at fault in 235 safety-critical incidents; while the LV driver was judged to be at fault in 146 SCEs (6.4 percent were no-fault). These data are similar to the preliminary analysis performed on the DDWS FOT data, where researchers found that HV drivers were at fault in 71 percent of the SCEs, while other drivers were judged to be at fault in 27.8 percent of the SCEs. These results are not consistent with prior studies that suggest LV drivers are primarily responsible for LV-HV interactions. In an analysis of the University of Michigan Transportation Research Institute's report entitled "Trucks Involved in Fatal Accidents," it was found that truck drivers were cited with a driver-related factor in 26.5 percent of the fatal crashes, while passenger-vehicle drivers were cited in more than 80 percent of the fatal crashes.(44) In a 1999 review of the data contained in FARS, it was found that truck driver-related factors were cited in 29 percent of fatal truck crashes involving a passenger vehicle, while 67 percent of these same interactions were cited as passenger-vehicle-related.(45) In another study completed in 1999, researchers found that LVs were the initiators in LV-HV fatal crashes by a ratio of approximately 3:1.(3) Moreover, an analysis of all LV-HV interactions in the 100-Car Study found that HV drivers were at fault in 32 percent of the incidents, while LV drivers were at fault in 56 percent of the incidents (12 percent were unknown).(46) The most likely explanation for these discrepancies is that the vehicle-based sensor suite employed in the current study was better suited for detecting HV-initiated actions than actions initiated by other vehicles, resulting in a predominance of HV at-fault events in this dataset. Further, the lack of a camera able to detect events directly behind the HV limited the type of possible interactions (i.e., events in which another vehicle was directly behind the HV were not detected unless the HV struck the other vehicle).

The most frequent HV-driver CRs during LV-HV interactions were *inadequate evasive action* (35.9 percent), *misjudgment of gap or other's speed* (12.2 percent), *internal distraction* (11.4 percent), and *inadequate surveillance* (11 percent). It is hard to make direct comparisons between the current study and other naturalistic studies regarding LV-HV interactions because the 100-Car, SB, and L/SH studies used a different classification system—although the 100-Car Study did code CRs, but only for the LV driver.(46)

For example, using a data collection approach similar to that used in this study (in which the HV was instrumented), the SB study found that the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (16.2 percent), *aggressive driving* (7.4

percent), and *vehicle kinematics/physics* (4.4 percent). Similarly, the L/SH study found that the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (5.6 percent), *roadway alignment*, (4.9 percent), and *aggressive driving* (2.1 percent). In the 100-Car Study, where the LV was instrumented, the most frequent HV-driver contributing factors during LV-HV interactions were *driving techniques* (16.2 percent) and *distractions* (3.7 percent).(46)

Of the 146 LV-HV interactions in the current study in which the LV driver was judged to be at fault, the most frequent CRs were *other decision error* (23.6 percent), *aggressive driving behavior* (18.8 percent), *other illegal maneuver* (13.9 percent), and *too slow for traffic stream* (10.4 percent). While the 100-Car Study did not report HV-driver CRs for LV-HV interactions, it did report these for the LV driver. Thus, direct comparisons can be made. The most frequent CRs for the LV-driver CRs during LV-HV interactions in the 100-Car Study were *aggressive driving behavior* (24.6 percent), *too fast for conditions* (15.2 percent), and *internal distraction* (13.8 percent).(46) The SB Study found that the most frequent LV-driver contributing factors during LV-HV interactions were *driving techniques* (31.7 percent) and *aggressive driving* (27.9 percent), while the L/SH Study reported that the most frequent LV-driver contributing factors were *aggressive driving* (35.2 percent) and *driving techniques* (18.3 percent). There is not much overlap between these previous studies and the current NTDS regarding the HV- or LV-driver at-fault LV-HV interaction events. The different classification systems and instrumentation approaches probably explain some of the variability. However, the SB and L/SH studies were focused on a portion of the CMV driver population. Therefore, the recruitment for these two studies was focused towards specific operations (LH and SH, respectively) and the current study represents a mixture of all types of operations. That is likely to explain some of the discrepancies found between these studies. These data are consistent in that they show that aggressive driving by the LV driver is a frequent issue in LV-HV interactions.

This naturalistic approach allows researchers to evaluate vehicle interactions as they evolve and to fill a void in our existing driving safety research. PARs and crash investigations rely on eyewitness accounts. Such data are very helpful, but can suggest possible CRs for a crash that in fact may not have been the real cause of the SCE. For example, in the case of rear-end events, following too closely might seem to be the most adequate CR during an investigation, but in most instances, naturalistic research reveals that distraction tends to be the main CR for these types of events. For instance, the LTCCS found that 13 percent of truck drivers involved in crashes were coded as being fatigued at the time of the crash,(59) while the present study found that 8.9 percent of CMV drivers were drowsy or fatigued during a SCE. Complementing the detailed pre-crash information obtained from naturalistic studies with the rich forensic dataset available in the LTCCS would create a more accurate picture of large-truck vehicle interactions and crash scenarios as they evolved, and of the footprint they leave. Further, such an undertaking would broaden our understanding of large-truck vehicle interactions and crash scenarios and would allow researchers to gain insight and understanding into a wide array of driving behavior issues, thus potentially serving as a basis for decision-making and program development.

## 7.4 FUNCTIONAL COUNTERMEASURES

This study collected detailed information on a large number of SCEs. These events were operationally defined for this study as characterized by the presence of elements identical to a crash scenario, with the difference that they were also characterized by successful evasive maneuvers. These types of events have two important features that crash data do not. First, they occur much more frequently. Second, near-crash events are cases in which a driver successfully performed an evasive maneuver. Understanding these cases may give additional insight into the factors that allow drivers to be effective defensive drivers, as well as into potential countermeasures to aid these drivers. This research effort assessed applicable functional countermeasures that can be used to inform the development of crash avoidance technologies, enforcement regulations, and safety management methods by researchers to prevent the genesis of the unsafe situation or improve the driver response to the unsafe situation. The most frequent CMV functional countermeasures were: prevent "drift" lane departures (79 percent), increase driver attention to forward visual scene (73.7 percent), improve general driver situation awareness and/or proactive/defensive driving (56.1 percent), and increase driver alertness (14.4 percent). Note that more than one countermeasure could be selected for each SCE; therefore, the total is more than 100 percent. These countermeasures were different from the CMV countermeasures reported in the preliminary analysis of the DDWS FOT. In that analysis, the most frequent CMV countermeasures were: increase driver recognition of specific highway crash threats—moving/decelerating vehicle(s) in lane ahead, traveling in same direction (18.8 percent), increase driver attention to forward scene (18.5 percent), and improve general driver situation awareness and/or defensive driving (13 percent).

The countermeasures for other vehicles obtained from this study and those obtained from the DDWS FOT differed from each other. The most frequent countermeasures for other vehicles in the NTDS were: improve general driver situation awareness and/or proactive/defensive driving (4.9 percent); improve driver night vision in the forward field (4.3 percent); increase driver recognition/appreciation of specific highway crash threats: vehicle in right adjacent lane (1.1 percent); and increase driver recognition/appreciation of specific highway crash threats: vehicle in left adjacent lane (1 percent). Frequent countermeasures for other vehicles in the DDWS FOT were: provide warning to prevent rear encroachment or tailgating by other vehicle (24.6 percent); increase driver recognition of specific highway crash threats: vehicle in left adjacent lane on highway (5.7 percent); and increase driver recognition of specific highway crash threats: vehicle in left adjacent lane during merging maneuver (4.8 percent). Comparisons between the countermeasures obtained from the NTDS and the DDWS FOT for CMV and other vehicles did not yield many similarities. There are several possible explanations for these discrepancies. First, different fleet types were used in the two studies. Differences in safety management techniques, goods delivered, routes traveled, etc., may explain some of these discrepancies. Second, certain drivers were overly involved in certain types of SCEs. These "outliers" may explain the divergent results. Finally, it is possible that the different vehicle-based sensor suite employed in the NTDS (e.g., lane deviation) explains some of the differences found. Future research might compile all these factors to assess whether they explain the variability in results.

## 7.5 FUTURE RESEARCH

This section describes the proposed analyses of the data obtained during Phases I and II of the LV-HV Interaction Data Collection and Countermeasure Research Project (the DDWS FOT and the NTDS, respectively).

Follow-on studies could include additional data analysis of the two existing datasets collected during the DDWS FOT and the NTDS. They could investigate and answer the research questions presented in the report entitled “Heavy Vehicle-Light Vehicle Interaction Data Collection and Countermeasure Research Project: Research Questions.”[(60)] A total of 13 research questions could be answered using the DDWS FOT and NTDS datasets, as well as an additional dataset created by combining these datasets into a larger amalgamated dataset. The DDWS FOT dataset includes approximately 48,000 driving-data hours covering 2.4 million vehicle miles traveled. The NTDS dataset is estimated to include approximately 14,500 driving-data hours, covering more than 735,000 miles traveled. Therefore, the combined dataset will involve more than 62,000 driving-data hours and more than 3 million vehicle miles traveled.

The analyses proposed next are broken into three groups. The first group of research questions will analyze factors associated with the relationship between work/rest parameters, drowsiness, and SCEs. These research questions include the following three topics:

- How does the number of self-reported “on-duty” driving minutes affect the occurrence of SCEs?
- How much total sleep do drivers receive during the 60-/70-hour on-duty limit?
- What is the relationship between the type of sleep patterns and the involvement in SCEs?

The first question will determine the relationship between the number of on-duty driving minutes and the involvement in SCEs. The potential data source will include the daily log from the NTDS. The intent of the second question is to determine whether certain sleep patterns are more prone to an increased involvement in SCEs. The potential data sources for this question include the DDWS FOT actigraphy device data, NTDS daily log data, and the NTDS actigraphy device data. The third question will provide an average total sleep period (in minutes) that each driver received during the 60-/70-hour on-duty limit. The potential data sources for this question include the DDWS FOT actigraphy device data, DDWS FOT video data, NTDS daily log data, NTDS actigraphy device data, and the NTDS video data.

The second group of research questions will investigate the impact of both non-driving activities and circadian cycle effects on involvement in SCEs (i.e., crashes, near-crashes, and crash-relevant conflicts). These research questions include the following five topics:

- What is the relationship between SCEs and an increase in non-driving, “on-duty” work activities (e.g., light, heavy) in the last 24 hours prior to the events?
- What are the most common types of non-driving “on-duty” activities (e.g., eating, heavy, or light work) as a function of time in the 24-hour period prior to involvement in a SCE?

- What is the relationship between SCEs and an increase of non-driving, “off-duty” work activities (e.g., light, heavy) in the last 24 hours prior to the events?
- What are the most common types of non-driving “off-duty” activities (e.g., eating, heavy, or light work) as a function of time in the 24-hour period prior to involvement in a SCE?
- How does the magnitude of shift pattern deviation affect the degree of crash risk?

The first question will compare the mean number of non-driving “on-duty” work activities (e.g., light, heavy) for those time periods that involved a SCE against those time periods that involved a baseline event. The second question will sum all non-driving “on-duty” work activities (e.g., light, heavy) for those epochs that involved a SCE. The third question will compare the mean number of non-driving “off-duty” work activities (e.g., light, heavy) for those epochs that involved a SCE against epochs that were a baseline event. The fourth question will sum all non-driving “off-duty” work activities for those epochs that involved a SCE. The fifth question will provide insight into the impact of varying shift patterns for commercial drivers on the frequency of safety-critical incidents. Drivers in the NTDS can be classified into two shift-pattern groups based on their self-reported shift times. Drivers that report an average shift pattern with less than 2 hours of deviation will be grouped into a Consistent Shift Pattern group, while drivers that report shift patterns with more than 4 hours of deviation will be grouped into an Inconsistent Shift Pattern group. The potential data source for all of these questions includes the NTDS daily log data.

The third group of research questions will assess the characteristics of the LV-HV interaction SCEs recorded in the Phase II study. This final group of research questions includes the following five topics:

- What CRs/errors did drivers make when HV drivers were at fault? The potential data sources for this question include the DDWS FOT vehicle performance data, DDWS FOT video data, NTDS vehicle performance data, and the NTDS video data.
- How do the driver error profiles compare between DDWS FOT and the NTDS? The potential data sources for this question include the DDWS FOT vehicle performance data, DDWS FOT video data, NTDS vehicle performance data, and the NTDS video data.
- What types of recognition, decision, or performance errors did drivers make in the DDWS FOT and the NTDS? The potential data sources for this question include the DDWS FOT vehicle performance data, DDWS FOT video data, NTDS vehicle performance data, and the NTDS video data.
- What is the association between pre-event speed and the occurrences of SCEs in the NTDS? The potential data sources for this question include the NTDS vehicle performance data and the NTDS video data.
- What types of roadway structures (e.g., number of lanes, roadway profile) or traffic factors (e.g., flow, density) are related to the occurrences of SCEs for the NTDS? The potential data sources for this question include the NTDS vehicle performance data and the NTDS video data.

The analyses presented above will use a comprehensive data directory of variables for coding SCEs (crashes, near-crashes, crash-relevant conflicts) and baseline events.[9] Most of the variables in the data directory are the same as or similar to those used in major national crash databases such as GES, FARS, and the LTCCS. The data directory will help classify the different SCEs into one of the accident categories in these major crash databases.

[This page intentionally left blank.]

# REFERENCES


1. U.S. Department of Transportation (USDOT). Federal Motor Carrier Safety Administration. August 2012. Large Truck and Bus Crash Facts 2010. Report No. RRA-12-023. U.S. Department of Transportation: Washington, DC.

2. Bureau of Transportation Statistics. (2005). National Transportation Statistics 2006. Retrieved on May 23, 2007 from *www.bts.gov/publications/national_transportation_statistics/2005*.

3. Wang, J.S., Knipling, R.R., Blincoe, L.J. (1999). The Dimensions of Motor Vehicle Crash Risk. *Journal of Transportation and Statistics*, 2(1):19–43.

4. Hanowski, R.J., Keisler, A.S., Wierwille, W.W. (2004). Light-Vehicle/Heavy-Vehicle Interactions: A Preliminary Assessment Using Critical Incident Analysis. Report No. FMCSA-RT-04-004. Washington, DC: Federal Motor Carrier Safety Administration.

5. Craft, R., Blower, D. (2004). The Large Truck Crash Causation Study. Paper presented and distributed at the FMCSA Research & Technology Stakeholder Forum, Arlington, VA.

6. Mississippi State University Extension Service. (2001). Economic Effects of Low-Weight Hauling Ordinances on Forest Landowner Income in Mississippi: The Webster County Example. Retrieved on May 23, 2007 from *http://msucares.com/forestry/economics/webster.html*

7. Scopatz, R.A. (2002). Large-Truck Crash Report Audits: Improving Data on Large Truck Safety. Proceedings of the International Truck and Bus Safety Research and Policy Symposium, 275–92.

8. Knipling, R.R., Hickman, J.S., Hanowski, R.J., Blanco, M. (2005). Heavy-Vehicle/Light-Vehicle Interaction Data Collection and Countermeasure Research Project Phase 1: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test: Task 4, Phase II Research Plan. Blacksburg, VA: Virginia Tech Transportation Institute.

9. Hickman, J.S., Knipling, R.R., Olson, R.L., Fumero, M.C., Blanco, M., Hanowski, R.J. (2005). Phase I: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test. Task 5: Preliminary analysis of drowsy driver warning system field operational tests data. Contract No. DTNH22-00-C-07007 (Task Order No. 21). Blacksburg, VA: Virginia Tech Transportation Institute.

10. Hanowski, R.J., Blanco, M., Nakata, A., Hickman, J.S., Schaudt, W.A., Fumero, M.C., et al. (2005a). The Drowsy Driver Warning System Field Operational Test, Data Collection Final Report. (Contract No. DTNH22-00-C-07007, Task Order 14). Blacksburg, VA: Virginia Tech Transportation Institute.

11. Society of Automotive Engineers, Inc. (2002). SAE J1587–Electronic Data Interchange between Microcomputer Systems in Heavy-Duty Vehicle Applications. Warrendale, PA: SAE, Inc.

12. Society of Automotive Engineers, Inc. (2001). SAE HS-1939- Truck and Bus Control and Communications Network Standards Manual. Warrendale, PA: SAE, Inc.

13. Society of Automotive Engineers, Inc. (1993). SAE J1708- Serial Data Communications between Microcomputer Systems in Heavy-Duty Vehicle Applications. Warrendale, PA: SAE, Inc.

14. Dinges, D.F., Powell, J.W. (1985). Microcomputer Analyses of Performance on a Portable, Simple Visual RT Task during Sustained Operations. *Behavioral Research Methods, Instruments, and Computers*, 17, 652–5.

15. Van Dongen, H.P.A., Maslin, G., Mullington, J.M., Dinges, D.F. (2003). The Cumulative Cost of Additional Wakefulness: Dose-Response Effects on Neurobehavioral Functions and Sleep Physiology from Chronic Sleep Restriction and Total Sleep Deprivation. *Sleep*, 26(2):117–26.

16. Garrow, J.S., Webster, J. (1985). Quetelet's Index (W/H2) as a Measure of Fatness. *International Journal of Obesity*, 9, 147–53.

17. U.S. National Library of Medicine. (2007). Calculating Body Frame Size. Retrieved on May 23, 2007 from *www.nlm.nih.gov/medlineplus/ency/imagepages/17182.htm*

18. Matthews, G., Desmond, P.A., Joyner, L.A., Carcary, B. (1997). A Comprehensive Questionnaire Measure of Driver Stress and Affect. In E. Carbonell-Vaya & J. A. Rothengatter (Eds.), *Traffic and Transport Psychology: Theory and Application* (pp. 317–26). Amsterdam: Pergamon Press.

19. Holmes, T., Rahe, R. (1967). The Social Readjustment Rating Scale. *Journal of Psychosomatic Research*, 11, 213–8.

20. McCrae, R.R., Costa Jr., P.T. (1987). Validation of a Five-Factor Model of Personality across Instruments and Observers. *Journal of Personality and Social Psychology*, 52, 81–90.

21. Dula, C., Ballard, M.E. (2003). Development and Evaluation of a Measure of Dangerous, Aggressive, Negative Emotional, and Risky Driving. *Journal of Applied Social Psychology*, 33(2), 263–282.

22. Harsh, J., Easley, A., LeBourgeois, M. (2002). A Measure of Sleep Hygiene. *Sleep*, 25, A316.

23. DeMeuse, K.P. (1985). A Compendium of Frequently Used Measures in Industrial/Organizational Psychology. *The Industrial-Organizational Psychologist*, 23, 53–59.

24. Zedeck, S. (1987). Satisfaction in Union Members and Their Spouses. Paper presented at the Job Satisfaction: Advances in Research and Practice Conference, Bowling Green, Ohio.

25. U.S. Department of Transportation (USDOT), National Highway Transportation Safety Administration. (2005a). General Estimates System Coding and Editing Manual. Washington, DC: U.S. Department of Transportation.

26. Tessmer, J.M. (2007). FARS Analytic Reference Guide 1975 to 2006. Washington, DC: National Highway Traffic Safety Administration.

27. U.S. Department of Transportation (USDOT), Federal Motor Carrier Safety Administration. (2006b). Report to Congress on the Large Truck Crash Causation Study. U.S. Report MC-R/MC-RRA. Washington, DC: Department of Transportation, Federal Motor Carrier Safety Administration.

28. Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., et al. (2006). The 100-Car Naturalistic Driving Study: Phase II—Results of the 100-Car Field Experiment. Contract No. DTNH22-00-C-07007. Washington, DC: National Highway Traffic Safety Administration.

29. American Trucking Associations. (2001). *Trucking Trends 2000.* Alexandria, VA.

30. U.S. Census Bureau. (2004). United States 2002 Economic Census: Vehicle Inventory and Use Survey. Washington, DC.

31. U.S. Department of Transportation (USDOT), Federal Motor Carrier Safety Administration. (2006c). Revised Hours-of-Service Regulations—2005. Retrieved January 25, 2008 from *http://www.fmcsa.dot.gov/rules-regulations/truck/driver/hos/brochure2005.htm*

32. Dingus, T., Neale, V., Garness, S., Hanowski, R., Keisler, A., Lee, S., et al. (2002). Impact of Sleeper Berth Usage on Driver Fatigue: Final Project Report. Contract No. DTFH61-96-C-00068. Washington, DC: Federal Motor Carrier Safety Administration, USDOT.

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

34. Cole, R.J., Kripke, D.F., Gruen, W., Mullaney, D.J., Gillin, J.C. (1992). Automatic Sleep/Wake Identification from Wrist Activity. *Sleep*, 15(5), 461–9.

35. Jean-Louis, G., Kripke, D.F., Mason, W.J., Elliott, J.A., Youngstedt, S.D. (2001). Sleep Estimation from Wrist Movement Quantified by Different Actigraphic Modalities. *Journal of Neuroscience Methods*, 105(2), 185–191.

36. Greco, K.E., Deaton, C., Kutner, M., Schnelle, J.F., Ouslander, J.G. (2004). Psychoactive Medications and Actigraphically Scored Sleep Quality in Frail Nursing Home Patients. Journal of the American Medical Directors Association, 5(4), 223–7.

37. Hanowski, R.J., Hickman, J., Fumero, M.C., Olson, R.L., Dingus, T.A. (2007b). The Sleep of Commercial Vehicle Drivers under the 2003 Hours-of-Service Regulations. *Accident Analysis and Prevention*, 39(6), 1140–1145.

38. Heinrich, H.W., Petersen, D., Roos, N. (1980). *Industrial Accident Prevention*. New York: McGraw-Hill Book Company.

39. Thieriez, K., Radja, G., Toth, G. (2002). Large Truck Crash Causation Study Interim Report (NHTSA Interim Technical Report #DOT HS 809 527). Springfield, VA: National Center for Statistics and Analysis.

40. Pedhazur, E.J. (1997). *Multiple Regression in Behavioral Research: Explanation and Prediction,* 3rd Edition. New York: Holt, Rinehart & Winston.

41. Schlesselman, J.J. (1982). *Case-Control Studies: Design, Conduct, Analysis*. New York: Oxford University Press.

42. Mannering, F.L., Kilareski, W.P., Washburn, S.S. (2004). *Principles of Highway Engineering and Traffic Analysis* (3rd ed.). John Wiley & Sons, 170–219.

43. Wierwille, W.W., Wreggit, S.S., Kirn, C.L., Ellsworth, L.A., Fairbanks, R.J. (1994). Research on Vehicle-Based Driver Status/Performance Monitoring. (Report #94-04). Blacksburg, VA: Virginia Polytechnic Institute and State University.

44. Blower, D. (1998). *The Relative Contribution of Truck Drivers and Passenger Vehicle Drivers to Truck-Passenger Vehicle Traffic Crashes*. Publication No. UMTRI-98-25. Ann Arbor, MI: University of Michigan Transportation Research Institute.

45. Stuster, J. (1999). The Unsafe Driving Acts of Motorists in the Vicinity of Large Trucks. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

46. Hanowski, R.J., Olson, R.L., Hickman, J.S., Dingus, T.A. (2005b). The 100-Car Naturalistic Driving Study: Analysis of Light-Vehicle/Heavy-Vehicle Interactions from the Light Vehicle Driver's Perspective. Contract No. DTNH22-00-C-07007. Blacksburg, VA: Virginia Tech Transportation Institute.

47. Klauer ,S.G., Dingus, T.A., Neal, V.L., Sudweeks, J.D., Ramsey, D.J. (2006). The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. Report No. DOT HS 810-594. Washington, DC: National Highway Traffic Safety Administration.

48. Maycock, G. (1997). Sleepiness and Driving: The Experience of UK Car Drivers. *Accident Analysis and Prevention*, 29,453–62.

49. Wierwille, W.W. (1999). Historical Perspective on Slow Eyelid Closure: Whence PERCLOS? Washington, DC: Federal Highway Administration, Report No. FHWA-MC-990136, Ocular Measures of Driver Alertness, pp. 31–52.

50. Wierwille, W.W., Ellsworth, L.A. (1994). Evaluation of Driver Drowsiness by Trained Observers. *Accident Analysis and Prevention*, 26(5): 571–81.

51. Festin, S.M. (1996). Summary of National and Regional Travel Trends: 1970–1995. U.S. Department of Transportation, Washington, DC.

52. Hanowski, R.J., Olson, R.L., Bocanegra, J., Hickman, J.S. (2007a). Analysis of Risk as a Function of Driving Hour: Assessment of Driving Hours 1 through 11. Contract Number DTMC75-D-00006, Task Order #3. Blacksburg, VA: Virginia Tech Transportation Institute.

53. Orris, P., Buchanan, S., Smiley, A., Davis, D., Dinges, D., Bergoffen, G. (2005). Literature Review on Health and Fatigue Issues Associated with Commercial Motor Vehicle Driver Hours of Work. *Commercial Truck and Bus Safety Synthesis Program, Synthesis 9.* Washington, DC: Transportation Research Board.

54. Jovanis, P.P., Kaneko, T., Lin, T-D. (1991). Exploratory Analysis of Motor Carrier Accident Risk and Daily Driving Patterns. *Transportation Research Record*, 1322, 34–43.

55. Wylie, C.D., Schultz, T., Miller, C.C., Mitler, M.M., Mackie, RR. (1996). Commercial Motor Vehicle Driver Fatigue and Alertness Study: Technical Summary. MC-97-001. Washington, DC: U.S. Department of Transportation.

56. Hanowski, R.J., Wierwille, W.W., Garness, S.A., Dingus, T.A. (2000). Impact of Local/Short-hHaul Operations on Driver Fatigue, Final Report. Report No. DOT-MC-00-203. Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration.

57. Olson, R.L. (2006). Assessment of Drowsy-Related Critical Incidents and the 2004 Revised Hours-of-Service Regulations [unpublished master's thesis]. Virginia Polytechnic Institute and State University, Blacksburg, VA.

58. Missoula Technology and Development Center (n.d.). Fatigue Awareness: USDA Forest Service. Retrieved on December 11, 2007 from *www.fs.fed.us/fire/training/fatigue/fatigue.ppt*

59. U.S. Department of Transportation (USDOT), Federal Motor Carrier Safety Administration. (2006a). Large Truck Crash Causation Study: Analytical User's Manual. Washington, DC. Department of Transportation.

60. Bowman, D., Blanco, M., Hanowski, R.J., Nakata, A. (2006). Heavy-Vehicle, Light-Vehicle Interaction Data Collection and Countermeasure Research Project. Task 4, Phase II: Research Questions. Blacksburg, VA: Virginia Tech Transportation Institute.

[This page intentionally left blank.]

# OTHER RESOURCES


U.S. Department of Transportation (USDOT), National Highway Transportation Safety Administration. (2005b). Traffic Safety Facts 2003. Washington, DC: U.S. Department of Transportation.

U.S. Department of Transportation (USDOT), National Highway Transportation Safety Administration. (2006d). Traffic Safety Facts 2005. Retrieved on May 23, 2007 from *www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2005.pdf*

Zaloshnja, E., Miller, T.R. (2004). Costs of large-truck-involved crashes in the United States. *Accident Analysis and Prevention*, 36:801–8.

[This page intentionally left blank.]

# LIST OF APPENDICES AVAILABLE UPON REQUEST

The appendices listed below may be obtained upon request to Martin Walker, PhD, Research Division Chief. His contact information:

Martin Walker
Office of Analysis, Research, and Technology,
Federal Motor Carrier Safety Administration,
U.S. Department of Transportation
1200 New Jersey Ave, SE
Washington, DC 20590

Email: martin.walker@dot.gov

Telephone: (202) 366-7928

- Appendix A. Institutional Review Board Approval Letter.
- Appendix B. Informed Consent Form.
- Appendix C. Initial Contract Form.
- Appendix D. Pre-study Questionnaires.
- Appendix E. Protocol for Visual Acuity and Hearing Level Tests.
- Appendix F. User Guide for Actigraphy Device.
- Appendix G. Protocol for PVT-192 Test.
- Appendix H. Post-study Questionnaires.
- Appendix I. Debriefing Interview Protocol.
- Appendix J. Bonus Requirements.
- Appendix K. Certificate of Confidentiality.
- Appendix L. Onsite DAS Operation Verification.
- Appendix M. Protocols for Height, Weight, Frame Size Measurements.
- Appendix N. On-road Data Quality Control Spreadsheet.
- Appendix O. Example Output of the Responses on NEO Five-Factor Inventory.
- Appendix P. Procedure of Activity Code Entry to Naturalistic Truck Driving Database.
- Appendix Q. Procedure for Selecting an Activity Code.
- Appendix R. Results of “Driving Truck” Activity Code and Durations for Subject 0072.
- Appendix S. Results of Coffee Intake for Subjects 0024 and 0025.
- Appendix T. Data Coding Directory.

- Appendix U. List of Technical Problems Encountered with Actigraphy Device.
- Appendix V. Operational Definitions for Research Questions.
- Appendix W. Actigraphy Data Reduction.
- Appendix X. Participants' Driving Data Summary (n = 100).
- Appendix Y. Event Distribution by Participants.
- Appendix Z. SCE descriptions.
- Appendix AA: Acknowledgements.