Light Vehicle-Heavy Vehicle Interaction Data Collection and Countermeasure Research Project

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

November 2016

FOREWORD

The Light Vehicle-Heavy Vehicle (LV-HV) Interaction Data Collection and Countermeasure Research Project leveraged data from the Drowsy Driver Warning System Field Operational Test (DDWS FOT) to investigate a set of research issues relating to driver performance and crash causation, but not directly related to the safety benefits of the DDWS. The four priority issues and study topics selected for exploratory investigation and analysis included:

- Analysis of heavy-vehicle safety events, including LV-HV interactions.
- Assessment of crashes and near-crashes, and identification of countermeasures.
- Identification of driving patterns and work/rest schedules.
- Calculation of driver risk.

The data collected in the DDWS FOT encompassed approximately 50,000 hours of naturalistic driving (ND) completed by 95 volunteer commercial driver participants. The collection of additional data from other commercial motor vehicle (CMV) drivers in different operational settings (employing a more extensive set of event analysis variables) is planned for the future.

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16. Abstract

The Light Vehicle-Heavy Vehicle Interaction (LV-HV) Data Collection and Countermeasure Research Project leveraged data from the Drowsy Driver Warning System Field Operational Test (DDWS FOT) to investigate a set of research issues relating to driver performance and crash causation, and not directly related to the safety benefits of the DDWS. The four priority issues and study topics selected for exploratory investigation and analysis included:

- **Analysis of HV safety events, including LV-HV vehicle interactions.**
- **Assessment of crashes and near-crashes, and identification of countermeasures.**
- **Identification of driving patterns and work/rest schedules.**
- **Calculation of driver risk.**

The data collected in the DDWS FOT between May 2004 and May 2005 encompassed approximately 50,000 hours of naturalistic driving (ND) completed by 95 volunteer commercial driver participants. The collection of additional data from other commercial motor vehicle (CMV) drivers in different operational settings (employing a more extensive set of event analysis variables) is planned for the future.

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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 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.)

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ANOVA	analysis of variance
baseline epoch	the principal control or exposure measure
BMI	body mass index
CB	Citizen’s Band
CMV	commercial motor vehicle
DAS	data acquisition system
DDWS	drowsy driver warning system
DFM	driver fatigue monitor
EMS	emergency medical services
FARS	Fatality Analysis Reporting System
FMCSA	Federal Motor Carrier Safety Administration
FOT	field operational test
GES	General Estimates System
HOS	hours-of-service
HV	heavy vehicle
Hz	Hertz
km/h	kilometers per hour
L/SH	local/short haul
LA	longitudinal acceleration
LOS	level of service
LTCCS	Large Truck Crash Causation Study
LV	light vehicle
MHz	Megahertz
mi/h	miles per hour
NHTSA	National Highway Traffic Safety Administration
ORD	observer rating of drowsiness
PAR	police accident report
PDA	personal digital assistant
PERCLOS	percentage of eye closure
SCE	safety-critical event
SD	standard deviation
SUV	sport utility vehicle
TB	terabyte
TTC	time-to-collision
USDOT	U.S. Department of Transportation

V1	the instrumented vehicle (large truck) participating in the study
V2	the other vehicle involved in the safety-critical event
Volpe Center	John A. Volpe National Transportation Systems Center
VTTI	Virginia Technical Transportation Institute

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EXECUTIVE SUMMARY

Under the sponsorship of the Federal Motor Carrier Safety Administration (FMCSA), the Commercial Motor Vehicle (CMV) Data Collection and Countermeasure Assessment project used instrumented vehicles to collect naturalistic driving (ND) data in conjunction with the National Highway Traffic Safety Administration (NHTSA)-sponsored Drowsy Driver Warning System Field Operational Test (DDWS FOT) to gain a greater understanding of the origins of large-truck traffic crashes. The DDWS is a driver monitor that estimates percentage of eye closure (PERCLOS), a previously validated measure of alertness. 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, including heavy-vehicle (HV) safety events, light vehicle-heavy vehicle (LV-HV) interactions, traffic conflict assessment, driving conditions associated with increased risk, countermeasure identification, driving patterns and work/rest schedules, and correlates of driver risk. The current report describes data collected in the DDWS FOT between May 2004 and May 2005. These data were collected from 95 volunteer commercial driver participants and encompassed approximately 50,000 hours of driving data. The collection of additional data from other CMV drivers in different operational settings (employing a more extensive set of event analysis variables) is planned for the future.

Four priority issues and study topics were selected for exploratory investigation and analysis. They were:

- Analysis of HV safety events, including LV-HV interactions.
- Assessment of crashes and near-crashes, and identification of countermeasures.
- Identification of driving patterns and work/rest schedules.
- Calculation of driver risk.

To investigate these issues and lay the foundation for broader and more in-depth analyses, a database of classification variables was used to compare four basic types of driving events: crashes (including tire strikes as a separate subcategory), near-crashes, crash-relevant conflicts (also termed incidents), and baseline epochs (the principal control or exposure measure). The frequencies of these events in the current dataset were as follows:

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

The NHTSA-sponsored 100-Car Naturalistic Driving Study[1] investigated crashes, near-crashes, and crash-relevant conflicts (incidents) from the LV driver's perspective. Definitions of a crash, near-crash, and crash-relevant conflict (as described in the 100-Car Naturalistic Driving Study) are as follows:

- Crash: Any contact with an object, either moving or fixed, at any speed in which kinetic energy was measurably transferred or dissipated. Objects include: other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, cyclists, or animals.
- Near-crash: Any circumstance requiring a rapid evasive maneuver by the subject vehicle, any other vehicle, pedestrian, cyclist, or animal, to avoid a crash. A rapid evasive maneuver was defined as steering, braking, accelerating, or any combination of control inputs that approached the limits of the vehicle capabilities.
- Crash-relevant conflict (incident): Any circumstance that required a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or animal that was less severe than a rapid evasive maneuver (as defined above), but greater in severity than a normal maneuver to avoid a crash. A crash avoidance response included braking, steering, accelerating, or any combination of control inputs. During the analysis, the criteria were made more stringent to eliminate false alarms and non-conflict events.

In addition to these three event types, the current data reduction included a random sample of short driving time periods (called baseline epochs) that functioned much as a control group:

- Baseline epoch: A 60-second time period randomly selected from the recorded dataset. Baseline epochs were described using many of the same variables and data elements used to describe and classify crashes, near-crashes, and incidents. Examples of such variables included ambient weather, roadway type, and driver distractions. The creation of a baseline dataset enabled the study to:
  - Describe and characterize "normal" driving for the study sample.
  - Infer the increased or decreased risk associated with various conditions and driver behaviors and comparisons between the control (baseline) dataset and the incident dataset.

METHODS

The data collection occurred in a ND environment in which data were collected from commercial trucks during normal operations. The participant sample included two different long-haul operations types (e.g., truckload and less-than-truckload) and was intended to be generally representative of the long-haul CMV driver population. Participants in the DDWS FOT were assigned to either an experimental or a control group; however, for the purposes of this study, data from these two groups were generally aggregated.

Forty-six truck tractors 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 on and in motion. The DAS consisted of an encased unit housing a computer and external hard drive, dynamic sensors, 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 [DFM]) and recorded data from it.

Three types of data were collected continuously by the vehicle instrumentation: video, dynamic sensor, and audio. The four video cameras were oriented as follows:

- Facing forward to the road in front of the tractor.
- Facing backward from the windshield (inside the tractor, viewing the driver).
- Facing rearward from the left side of the tractor.
- Facing 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. No cameras or other sensors were mounted on trailers. Therefore, there was no recorded view directly behind the instrumented truck and trailer, although following vehicles could usually be partially seen in the rearward side view cameras. The limited number of cameras, all tractor-mounted, limited the analysis to primarily those events occurring in front and at the sides of the instrumented vehicle.

Recorded dynamic data included basic vehicle motion parameters, such as speed, longitudinal acceleration (e.g., indicative of braking levels), and lateral acceleration. Vehicles were also equipped with global positioning system sensors, lane trackers, and forward-looking radar units. The audio data were from an "incident box" with a pushbutton and microphone for drivers to make verbal comments about traffic incidents. This feature was rarely used by drivers.

There were three primary steps in detecting and classifying SCEs:

1. Identifying potential events, mostly using an event trigger program.
2. Checking the validity of these triggered events.
3. Applying a data directory to verified crash-relevant conflicts.

To identify events, a software program scanned the dynamic dataset to identify notable actions, including hard braking, quick steering maneuvers, and short times-to-collision (TTC), i.e., close proximity with consideration of both range and range rate. Threshold values of these parameters (or "triggers") were established to flag events for further review. Events could also be flagged by the driver via the incident button mentioned above. Finally, analysts reviewing the data could identify SCEs not associated with the above triggers during their general review of the data, but this process was not comprehensive due to the huge size of the dataset. Events were then reviewed to ensure they represented actual safety-critical scenarios. Many events meeting the minimum dynamic trigger criteria were not actual crash threat situations. These were termed "non-conflicts." Events judged to be true conflicts, and thus to have safety significance, were classified using a detailed data directory. A detailed and comprehensive data directory of 54 variables and data elements was developed for analyzing events in the DDWS FOT.

The configuration of the instrumentation and the event detection routines limited the number of other vehicle encroachments toward V1 that could be captured. For example, V2 rapidly closing toward the rear of V1's trailer could create a near-crash or other traffic conflict, but this dynamic event would not ordinarily be detected by the V1 sensors or the subsequent data analysis. The study methodology (i.e., instrumentation suite and associated data analysis procedures) differentially detected V1 encroachments toward V2 as opposed to V2 encroachments toward V1. This differential detection meant the apportionment of events in the current dataset was either:

- V1 driver-initiated (truck at fault).
- V2 driver-initiated (truck not at fault).

This apportionment did not represent the universe of such events that occurred in actual driving. However, all events that were detected could be analyzed based on instant replays of video data and associated dynamic data recordings of the events. This analysis captured both the observable causal sequences leading to events as well as the conditions and correlates of event occurrence.

SUMMARY OF FINDINGS

The CMV 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. At the time it was completed, this data collection was the largest commercial transportation ND study ever undertaken, and it was among the first to perform systematic analyses of SCEs and exposure-risk analyses to quantify risks associated with various conditions and behaviors. The study addressed four priority commercial driving safety issues through an analysis of 915 SCEs. As a comparison group for exposure-risk analyses, 1,072 randomly selected baseline epochs were analyzed.

A significant advantage of naturalistic data collection over post-hoc (i.e., after-the-fact) crash investigation is that it permits direct viewing of SCEs, 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. Driver recognition errors were common in the study, as were decision and performance errors. A range of driver errors was observed for both V1 and V2 drivers. However, the current methodology better documents truck driver errors because the event triggers mainly captured those events with evasive maneuvers by the instrumented truck, and only the truck driver was directly observed. Thus, the proportion of V1-initiated and V2-initiated conflicts in the current dataset does not represent the universe of such conflicts, and the specificity of error identification is greater for the instrumented truck drivers than for other drivers.

The data coding variables in the current study were based primarily upon major crash datasets such as the General Estimates System (GES), the Fatality Analysis Reporting System (FARS), and the Large Truck Crash Causation Study (LTCCS). In particular, the LTCCS provided a framework for characterizing event sequences and causal events. The LTCCS critical reason (CR) variable is perhaps the most illuminating since it attempts to capture the principal reason that caused the event. Like past studies of crash causation, this study observed many driver recognition and decision errors, as well as performance errors and critical non-performance errors (e.g., high-drowsiness). However, the mere occurrence of distracted driver behaviors or the presence of high-drowsiness did not necessarily mean these factors were the CRs for the event. Indeed, in the majority of events, high fatigue or potentially distracting behaviors were observed prior to the event.

Relating to the potential to reduce large truck crashes through the application of countermeasures, it appears that the most promising functional countermeasures to the events observed in the study are those that would intervene to make drivers aware of crash threats. In most cases, these threats were in the forward view of the driver, and thus interventions to increase driver recognition of specific forward field events and/or to increase driver general situation awareness appear to have the greatest promise to reduce the types of SCEs observed, and the crashes potentially associated with them.

Project findings relating to differential driver risk strongly support and reinforce the notion that driver risk varies dramatically and a relatively small percentage of drivers are associated with the preponderance of aggregate risk in most groups of drivers. Consistent with past studies and expectations, there was sharp differential risk for both at-fault events and high-drowsiness events. In addition, the rate of driver involvement in not-at-fault events was found to vary greatly and was correlated with driver factors such as age and experience. This finding points to the importance of defensive driving skills among CMV drivers and the notion that driving safely not only involves obeying rules and staying alert, but also driving in a manner in which the mistakes of other drivers can be anticipated and avoided.

Driver risk as measured by all three metrics (at-fault, not-at-fault, and high-drowsiness rate) was found to be correlated with certain driver factors such as age, CMV driving experience, driver-stated likelihood of dozing, and work hours per shift. Other correlations were observed but were not statistically significant and need to be tested more extensively in future studies. Reducing driver risk either through prediction (e.g., selection) or direct amelioration (e.g., management practices focusing on at-risk behaviors) represents a promising approach to reducing overall fleet and industry risk.

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1. INTRODUCTION

Crashes involving large trucks constitute a significant risk to the driving public and occupational risk to truck drivers. Truck crashes represent a significant problem on our Nation's highways. In 2008, approximately 380,000 large trucks (gross weight greater than 10,000 pounds) were involved in vehicle crashes. Of these, 4,066 were fatal crashes (in which 4,229 people died); an additional 90,000 were injury-only crashes. Large trucks accounted for only 4 percent of all registered vehicles in 2007, yet represented 8 percent of all vehicles involved in fatal crashes.(2) Large truck crashes and their associated injuries and fatalities cost an estimated $24.4 billion in direct and indirect costs in 2000.(3)

Statistics like these can be misleading because:

- Commercial motor vehicle (CMV) drivers exhibit lower rates of most types of incidents and lower rates of crash involvement per mile than light vehicle (LV) drivers.(4)
- LV drivers have been found to initiate a significant proportion of CMV crashes.(5,6) 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 large truck occupants) largely because of the significant difference in weight between a large truck and a passenger vehicle.(7)

Thus, increasing the safe driving practices of CMV drivers will help to make the roadways safer for all drivers.

The data used to generate the crash statistics listed above came from police accident reports (PARs). Typically, after a crash occurs and is reported to authorities, police are dispatched to the crash scene and complete an accident report. The PAR data are entered into a crash database that can be analyzed to produce crash statistics. These data allow researchers to learn about the scope of large truck crashes 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 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 if 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 submitted 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) had zero reporting errors.(8) Frequent errors made by police across the three States included incorrect vehicle type/configuration, missing (or mismatched) diagrams and narratives, and incorrect carrier information.

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

Though researchers can learn about the scope of large truck crashes with statistics generated from the information contained in PARs, these statistics provide limited insight regarding the detailed 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, more than is possible with post-crash investigations. Therefore, if traffic safety research is going to take the next preventive step, it is important to acquire a more complete and in-depth understanding of why a crash occurred.

One approach that has been used by researchers involves naturalistic data collection, which 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 a near-crash. The significant advantage of naturalistic data collection is that, by knowing the events preceding a critical incident, it is possible to determine why such an incident happened and what could be done to prevent similar incidents in the future.

2. THE DROWSY DRIVER WARNING SYSTEM FIELD OPERATIONAL TEST

Under the sponsorship of the National Highway Transportation Safety Administration (NHTSA), researchers performed a field operational test (FOT) to investigate the safety benefits of a Drowsy Driver Warning System (DDWS) for CMV drivers under naturalistic driving (ND) conditions.[9] The tested DDWS employs a sensor to estimate percentage of eye closure (PERCLOS) as a measure of drowsiness. The DDWS FOT evaluated the benefits of the system by comparing the alertness levels and safety performance of drivers, both when using and when not using the device. The FOT also tested a control group of drivers never exposed to the DDWS. The DDWS FOT yielded approximately 20 terabytes (TB) of continuously recorded data, making it the largest known on-road study conducted by the U.S. Department of Transportation (USDOT) to date. In addition to data directly related to the DDWS, the project collected extensive normative data on driving conditions and traffic safety-related incidents.

The primary objective of the DDWS FOT was to determine the safety benefits and operational capabilities, limitations, and characteristics of a DDWS (or driver fatigue monitor [DFM]) that monitors drivers' drowsiness. The evaluation occurred in a ND environment in which data were collected from CMV drivers in normal driving operations. The participant sample included two different types of long-haul operations (truckload and less-than-truckload), and was intended to be generally representative of the long-haul CMV truck driver population.

In the DDWS FOT, drivers were assigned to either an experimental group using the DFM for 9 weeks (following a baseline period of 2 weeks), or a control group that had no active device (although the sensor was installed and recorded data passively). The authors were responsible for:

- Collecting the data.
- Reducing the data per a set of variables developed by the authors in consultation with NHTSA and the John A. Volpe National Transportation Systems Center (Volpe Center).
- Forwarding the data to the Volpe Center to help determine the validity of the DFM, therefore supporting the center's research analyses.

Because PERCLOS data (e.g., correlations of PERCLOS with driver error and performance) were part of the Volpe Center's original evaluation, they are not included in this report.

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3. PRELIMINARY ANALYSIS OF DATA COLLECTED IN THE DROWSY DRIVER WARNING SYSTEM FIELD OPERATIONAL TEST

The current report describes a project that leveraged data from the DDWS FOT to investigate a set of research issues relating more fundamentally to driver performance and crash causation, and not directly related to the safety benefits of the DDWS. A sample of the data collected in the DDWS FOT was used in the conducted analyses. The current report describes data collected during the DDWS FOT from May 2004 to May 2005.

Discussions with FMCSA identified four priority issues and study topics for exploratory analysis:

- Analysis of heavy vehicle (HV) safety events, including LV-HV interactions.
- Identification of countermeasures.
- Identification of driving patterns and work/rest schedules.
- Calculation of driver risk.

To investigate these issues and lay the foundation for broader and more extensive analyses, the analyses employed a database of classification variables used to compare four basic types of driving events: crashes, near-crashes, crash-relevant conflicts (also termed "incidents"), and baseline (control) epochs. These are defined and discussed below.

The NHTSA-sponsored 100-Car Naturalistic Driving Study[(1)] investigated crashes, near-crashes, and crash-relevant conflicts (incidents) from the LV driver's perspective. Below are definitions of a crash, near-crash, and crash-relevant conflict used in the study:

> Crash: Any contact with an object, either moving or fixed, at any speed in which kinetic energy was measurably transferred or dissipated. Objects included: other vehicles, roadside barriers, objects on or off the roadway, pedestrians, cyclists, or animals.
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In addition to these three event types, the current data reduction included a random sample of short driving time periods (called "baseline epochs") that functioned much as a control group:

> Baseline epoch: A 60-second time period randomly selected from the recorded dataset. Baseline epochs were described using many of the same variables and data elements used to describe and classify crashes, near-crashes, and incidents. Examples of such variables included ambient weather, roadway type, and driver distractions. The creation of a baseline dataset enabled the study to describe and characterize "normal" driving for the study sample and infer the increased or decreased risk associated with various conditions and driver behaviors and comparisons between the control (baseline) dataset and the incident dataset.

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

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

3.1 ISSUE 1: ANALYSIS OF HEAVY VEHICLE SAFETY EVENTS

The most fundamental analyses in the current study were descriptions and comparisons of the four major types of SCEs. Since the number of crashes was very low, statistical analyses with them was limited. Descriptions of near-crashes and crash-relevant conflicts provided information on the characteristics and conditions associated with these SCEs. Near-crashes were essentially extreme incidents, so a comparison of these two event types could also reveal the factors and conditions associated with increased risk. Description of baseline epochs characterized "normal" driving for the participants, including the proportion of time spent driving under various conditions (e.g., wet vs. dry, light vs. dark, divided vs. undivided highways) and the proportion of time that drivers exhibited various behaviors, such as eating, drinking, talking on a cell phone, etc..

Comparisons among the SCEs permitted inference regarding the increased risk of driver error associated with various factors. Since there were many more crash-relevant conflicts and baseline epochs than crashes or near-crashes, the combined total of all SCEs provided the most robust statistical basis for comparison with baseline epochs. Many of the statistical comparisons reported are between this aggregated risk category and the baseline (normal driving/non-risk) category.

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 Naturalistic Driving Study,[(1)] researchers ran a discriminant analysis (comparing crashes, near-crashes, and 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.

While some SCEs involved only the instrumented truck and driver, or V1, most involved interactions with other vehicles and drivers, or V2. Although the "V2" classification also included non-motorists, the majority were overwhelmingly LVs. Previous research indicates that LV-HV interactions are a source of many large truck crashes. A 2004 study on LV-HV interactions (the LV-HV Interaction Study) reviewed data from the FMCSA-sponsored Local/Short Haul (L/SH) Study and the Sleeper Berth Study to examine LV-HV interactions, and the results indicated that LV-HV interactions are a significant problem.[5] In 78 percent of the incidents reviewed, the LV driver was determined to have been the initiator of the critical event. One of the possible limitations of the research was that it did not involve instrumented LVs. That is, the incidents that were recorded were only from the HV drivers' perspective. This could have biased the findings because only the actions of the HV driver were recorded; thus, assumptions had to be made regarding the LV driver's behavior.

To address this limitation, a LV-HV incident interaction analysis was conducted with data collected from the 100-Car Naturalistic Driving Study.[1] In that study, LVs were instrumented with data collection equipment. Of the 246 LV-HV interaction incidents recorded in the 100-Car Naturalistic Driving Study, 138 (56 percent) were judged to have been the fault of the LV driver, while 79 (32 percent) were attributed to the HV driver. For the remaining 29 incidents (12 percent), it was unclear which vehicle driver was at fault.

A second possible limitation of the previous LV-HV Interaction Study was that the dataset was relatively small, containing approximately 1,200 hours of driving data.[5] In comparison, the DDWS FOT recorded approximately 50,000 hours of driving data. This large dataset provided a greater frequency and diversity of traffic events to analyze, as well as more power to detect statistically significant findings. Moreover, the addition of a baseline dataset permitted two major enhancements:

- Documentation of "normal" driving to better understand commercial driving conditions and events.
- Comparisons between the "risk" (i.e., crash-relevant conflict and near-crash) datasets and the "non-risk" baseline dataset to identify behavioral and situational factors associated with elevated crash risk.

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 is 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, the dynamic sensor triggers used to capture events responded primarily to evasive maneuvers by the CMV and did not flag events where the other vehicle made the only evasive maneuver. For this reason, the current study did not capture all LV-HV interactions and the data do not accurately characterize the percentage of all SCEs attributable to LVs versus HVs.

3.2 ISSUE 2: CRASH AND NEAR-CRASH ASSESSMENT AND COUNTERMEASURE IDENTIFICATION

Data acquired from the DDWS FOT allowed researchers to investigate crashes and near-crashes from the HV driver's perspective, thereby increasing the ability to identify potentially effective functional interventions. Based on the data directory classification variables described below, SCEs were assessed for the type of contributing factors involved, the frequency of each contributing factor, and the relative importance of each contributing factor identified. This analysis included both HV- and LV-initiated events, with the essential feature being a HV avoidance maneuver or other trigger.

A functional approach to identifying applicable countermeasures was conducted. Thus, rather than determining specific technologies or devices (e.g., a PERCLOS eyelid droop monitor or forward-looking radar) that would have likely prevented the crash, applicable functional countermeasures (e.g., countermeasures that increase driver alertness, increase driver recognition of a stopped/decelerating/slow vehicle in the lane ahead) were selected. Such a countermeasure might operate by preventing the genesis of the unsafe condition or by improving the driver's avoidance response to the unsafe condition. The primary interest was HV-based countermeasures, but applicable LV-based countermeasures in LV-HV SCEs were also identified.

Both the V1 and V2 data files contained variables identifying functional countermeasures that were applicable to the SCEs. More than one countermeasure concept could be applicable to a particular safety event. The countermeasure analysis tabulated the applicability of the various functional countermeasures. Analysts were instructed to answer the following question: "What functional intervention(s) or other change(s) would likely have prevented the genesis of this event or reduced its severity?" Below are examples of functional countermeasure concepts:

- Increase driver alertness (reduce drowsiness).
- Improve vehicle lane-keeping (prevent lane departures).
- Increase driver recognition/appreciation of stopped (or decelerating/slower) vehicle in the lane ahead.
- Increase driver attention to driving (increase general situation awareness).
- Reduce driving speed.

The same caveat regarding V1-initiated versus V2-initiated events discussed above under Issue 1 also applies to Issue 2. The events captured include large numbers of both HV and LV at-fault events and the functional countermeasures applicable to these events are identified. However, the proportion of such applicable countermeasures across the entire dataset does not characterize the profile of interventions needed to address all crashes involving HVs. By its nature, the current methodology primarily reveals functional interventions to prevent HV at-fault events.

3.3 ISSUE 3: DRIVING PATTERNS AND WORK/REST SCHEDULES

FMCSA's current hours-of-service (HOS) regulations for CMV drivers went into effect on January 4, 2004. However, on August 19, 2005 a revision in the rules affecting sleeper berth usage was announced by FMCSA. These were the first major changes in commercial driver HOS rules since the 1930s. Major features of the revised rules included the following:

- Each driver duty period must begin with at least 10 hours off duty, rather than the previous 8 hours.
- Drivers may drive up to 11 hours instead of the previous 10 hours, but are limited to 14 hours in a duty period.
- The 14-hour duty period may not be extended with off-duty time (e.g., for meals); an exception to this is sleeper berth time.
- The previous 60 hours on-duty in 7 consecutive days, or 70 hours in 8 consecutive days rules remain the same, except that drivers can now "restart" the 7/8-day period by taking at least 34 consecutive hours off-duty.

On July 16, 2004, the U.S. Court of Appeals in Washington, D.C. vacated the new FMCSA HOS rules in their entirety, and sent them back to FMCSA for review. The principal reason for this was the court's finding that FMCSA failed to adequately consider the impact of the new rule on driver health. Subsequently, Congress passed a law affirming and extending the new rules until September 2005. A change to the sleeper berth provisions of the rule became effective on October 1, 2005. The new rule requires split sleep in the sleeper berth to include at least one 8-hour period with a second period of at least 2 hours. This change was implemented after the current data collection effort, thus it is not relevant to the data being reported here.

Because of the above governmental actions and associated issues, there is intense interest in the effects of the HOS rules. This includes the question of how drivers were actually driving under the rules, and of course whether the rules have been supportive of improved driver alertness and safety. Accordingly, real-time driving data from the DDWS FOT were used to investigate the actual driving patterns of the CMV drivers in the DDWS FOT. In a separate report to address the 10 vs. 11 hours driving question, driving incidents occurring during the 10th hour of driving were compared to those occurring during the 11th hour of driving. [10]

Another critical parameter of the HOS rules is the number of work hours permitted. As noted, the maximum permitted tour-of-duty (with some exceptions) under the current HOS rules is 14 hours. This issue could not be addressed meaningfully in this dataset because the vehicle instrumentation was operative only when the vehicle was moving. Within the data stream collected for each driver there was no measure of on-duty hours.

The work-rest parameters available for analysis included day-of-week and hour-of-day. Data were time-stamped with these parameters for all SCEs, as well as for baseline epochs. Of course, different drivers in the study worked different hours and days, so one cannot draw direct conclusions from the daily and hourly data regarding fatigue effects associated with work time. However, drivers in the study most typically began their work weeks on Sunday evening or

Monday morning, and finished their work weeks on Friday evening or Saturday morning. Therefore, any discernible trend toward more SCEs later in the week could be interpreted as being indicative of a cumulative fatigue effect.

Time-of-day is a somewhat different variable because it is known to affect driver alertness and performance independently of time-on-task.(11) This is considered to be primarily due to biological circadian rhythm effects wherein alertness is biologically "programmed" to be highest in the mornings and early evenings and lowest during the overnight hours (after midnight to daybreak) and also during the afternoon. Thus there is value in correlating time-of-day to incident involvement to determine whether such time-of-day effects are apparent in driving safety measures.

The data from baseline epochs is itself informative regarding driving patterns. Few studies have been published providing day-of-week and time-of-day exposure data on normal driving. In the current study, these baseline distribution statistics will be compared to event statistics to discern relative risk. The baseline epoch data may be useful as a normative base for other studies employing crash data or other risk assessments.

3.4 ISSUE 4: CORRELATES OF DRIVER RISK

Many interacting factors affect CMV driver crash involvement. At any given time, CMV driver crash risk is affected by personal situational risk factors (e.g., driver hours of sleep the previous night), vehicle risk factors (e.g., condition of brakes), environmental factors (e.g., weather and roadway features), and, of course, risks created by other drivers and traffic. A fundamental question regarding CMV safety is the extent to which certain drivers are chronically at greater risk because of some relatively enduring personal trait, such as demographic factors (e.g., gender, age), personality factors (e.g., tendencies toward aggressiveness or risk-taking), performance abilities (e.g., dynamic vision), or medical conditions (e.g., sleep apnea).

The L/SH Study found support for the contention that a few high-risk drivers significantly contribute to the frequency of vehicle incidents and crashes.(12) They observed 42 L/SH drivers and found that 4 drivers, who drove 7 percent of the total driving hours, were involved in 39 percent of the high-drowsiness events. In addition, they found that six drivers, who drove 12 percent of the total driving hours, were involved in 38 percent of the critical incidents (crashes and near-crashes). The study of high-risk CMV drivers cited the L/SH Study and several other studies that found marked differences in risk within groups of drivers.(13,14) Moreover, multiple studies were reviewed for differential driver risk, and in every study they found a consistent pattern similar to the L/SH Study data. In addition, in a survey of fleet safety managers and CMV safety experts, it was found that there is strong support for the belief that the problem of high-risk drivers is real, significant, and long-term.

The current study reports data that further corroborates the finding of differential driver risk. In addition, this study compares differential risk to a variety of driver characteristics. An extensive pre-study survey administered to all study drivers obtained information such as driver education, marital status, personal happiness and adjustment, medical symptoms, alcohol, smoking, exercise, sleep habits, sociability, work stress, and self-reported drowsiness while driving. These driver data were entered into a study database, and responses on selected variables (those expected to have the highest relevance to safety) were correlated with driving incident rates. The degree of association of many of these metrics with driving safety measures is reported here. The performance of the experimental group was likely to be affected by the countermeasure; however, the groups were combined to increase statistical power, but only when both groups showed the same trends and with the caveat that the combined group includes both conditions.

The data analyzed in the current report were preliminary, so correlations of risk with personal factors are preliminary. The statistics will be useful for identifying the personal factors (e.g., age, education, personality, sleep hygiene) most associated with risk and thus are the most promising targets for fleet and industry-wide efforts to reduce risk.

3.5 SUMMARY

This report describes data that were leveraged from the DDWS FOT. Based on discussions with FMCSA, four priority issues and study topics were selected for exploratory investigation and analysis. They were:

- Analysis of HV safety events, including LV-HV interactions.
- Assessment of crashes and near-crashes, and identification of countermeasures.
- Identification of driving patterns and work/rest schedules.
- Calculation of driver risk.

As noted, DDWS PERCLOS data are not addressed in this report as they were part of the Volpe Center’s valuation of the DFM. This report describes preliminary results from the DDWS FOT dataset, including a variety of event- and safety-related variables. Although a wide range of variables and massive amounts of data are included, the results provided in this report do not represent all variables coded or data collected in the DDWS FOT.

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4. METHODOLOGY

The Task 1 and Task 2 reports for this project contain extensive information on the project methodology.[5,14] The information provided in this section is intended to supplement and update those discussions.

4.1 EXPERIMENTAL DESIGN

Twenty-four drivers were randomly assigned to the control group and 75 drivers were randomly assigned to the experimental group. The experimental design for the control group is A^9, while the experimental group followed an A^2B^9 design. In this design, A refers to the baseline (passive) condition and B refers to the treatment condition. The superscripts refer to the number of weeks driven. In the baseline condition, the DDWS monitored the driver, but did not provide any alerts (either auditory or visual). Conversely, the DDWS monitored the driver and provided the driver with alerts in the treatment condition.

4.2 PARTICIPANTS AND SETTING

Volunteer drivers from three fleets were selected based on the following qualifications:

- A significant proportion of their driving was at night.
- They did not wear glasses while driving.
- They had a low risk of dropping out or leaving the company.
- They passed vision and hearing tests.

The first two qualifications were important for the FOT because the DDWS device being tested does not work in the daytime or with drivers wearing glasses.

This report includes data from 95 drivers (98.9 percent male, 1.1 percent female) who completed the required number of weeks in data collection or withdrew from the study for one reason or another (e.g., terminated from the participating fleet). Each driver had a Class A commercial driver's license (CDL). The mean age of drivers was 39.5 years old (range = 24–60 years old). Sixty-two drivers identified themselves as Caucasian (65.1 percent), 30 as African American (31.6 percent), 1 as Asian American (1.1 percent), 1 as Native American (1.1. percent), and 1 as Latino American (1.1 percent). This sample was relatively diverse and similar to that in an American Trucking Associations (1994) study which reported that 23.1 percent of CMV drivers were minorities and 4.7 percent were women. Participants indicated driving a CMV for an average of 10 years and 5.6 months (range = 15 months–42 years). Data were collected for a total of 34,230 hours of driving time (mean hours per driver = 361.26 hours; range = 14–920 hours). It was estimated that drivers drove a total of 2.5 million miles during those hours. Table 1 displays the demographic characteristics of the experimental and control groups.

Table 1. Demographic characteristics for the control and experimental groups.

Characteristic	Control Group	Experimental Group
Number of Drivers	20	75
Gender	20 Males 0 Females	74 Males 1 Female
Age	Mean=36.4 Range=26–50	Mean=40.3 Range=24-60
Ethnicity	6 African American (30.0%) 13 Caucasian (65.0%) 1 Asian American (5.0%)	24 African American (32.0%) 1 Latino American (1.3%) 49 Caucasian (65.3%) 1 Native American (1.3%)
Experience Driving a CMV	Mean=8 years, 1.3 months Range=2–20 years	Mean=11 years, 1.2 months Range=16 months–42 years
Hours Driving an Instrumented Truck	Total=6,155 hours Mean=307.75 hours/driver Range=66–700 hours	Total=28,075 hours Mean=374 hours Range=14–920 hours

Drivers were employed among three fleets across nine different locations. Fleets A and B were line-haul operations, whereby a driver typically returns to the home base once per 24-hour period (5 days per week). For example, these drivers may take their truck out in the evening of Day 1, drive to their delivery location, deliver their load, and return to their home base the morning of Day 2. They would leave again the evening of Day 2 and repeat the process to complete their work week. Fleet C was involved in over-the-road, truckload operations. For over-the-road drivers, a typical schedule may include starting on Sunday evening and returning to their home base the following Friday afternoon.

4.3 PROCEDURES

4.3.1 Pre-screening Potential Participants

Potential participants were screened on various measures before they were allowed to collect data in instrumented trucks. First, potential drivers completed a pre-participation survey (see Appendix A). The authors contacted potential participants—drivers who completed the pre-participation survey—in order to assess their willingness to participate, describe the DDWS FOT, and schedule a meeting time for the screening process. During the screening process, a DDWS test was conducted to determine drivers whose eye closure was reliably detected and measured by the system. If the DDWS worked for the drivers (i.e., it was able to detect their eyes reliably), their visual acuity and hearing level was measured and documented. Drivers were required to drive without glasses because the DDWS does not reliably record data on people wearing glasses. Further, adequate hearing was required so drivers would be able to hear the DDWS's auditory alert. Drivers who did not pass the DDWS, visual, or auditory screening tests were not included in the study.

4.3.2 Pre-study Methods

If drivers passed the screening tests and agreed to participate in the study they completed an Informed Consent Form. After completing the Informed Consent Form, each driver was given a copy of the form for their records. Then drivers were given a pre-study survey to complete at home. This survey included demographic questions and questions about past driving experience. Drivers were asked to complete this survey and return it within a few days.

Before each driver began a rotation in the instrumented truck, the authors conducted fatigue management and DDWS instructional sessions at the fleet location (only drivers in the experimental condition received the DDWS instructional session). Fleet managers and non-participating drivers were also invited to these sessions. Drivers unable to attend the fatigue management class were provided with a summary of the materials presented. DDWS instruction was conducted immediately following the fatigue management class with the group of attendees.

As described earlier, the drivers were randomly assigned to either an experimental or control group for the on-road data collection. Just prior to beginning their first drive, the drivers in the experimental group were given detailed instruction on using the DDWS in their trucks. All drivers were instructed to press a button on the dashboard (after the event, not during the event) if they witnessed an incident or were involved in an incident. In the current study, some of the vehicle critical incident buttons were not functioning properly at the beginning of the data collection; thus critical incident button events are underrepresented in this preliminary dataset. All drivers were also instructed to wear an actigraphy watch on the wrist of his/her dominant hand. An actigraphy watch is an activity-monitoring device used to assess a participant's sleep quantity and quality. This device was the size of a wristwatch and was worn like a wristwatch. It provided an indication of whether or not the wrist was in motion and stored the data as a function of time. In effect, it indicated whether subjects "toss and turn" while sleeping. During the day, the device also provided an indication of activity level. The actigraphy unit is self-contained and makes no electrical contact with the subject. Figure 1 displays an actigraphy watch that was worn by participants in the DDWS FOT.

Figure 1. Photograph. Actigraphy watch that was worn by participants in the DDWS FOT.

4.3.3 On-road Methods

Data collection was conducted on the job while the drivers drove their instrumented trucks on normal business routes. All of the drivers were informed that researchers would download data from the instrumented trucks and actigraphy watches approximately once per week at the fleet distribution center. During this time, researchers swapped the hard drive (i.e., removed the current hard drive and replaced it with a new hard drive) and downloaded the data from the actigraphy watch. To help ensure successful data collection, the researchers regularly checked the DDWS and data acquisition system (DAS). This DAS check included gathering a frame of the video to help ensure that the cameras were operating properly. Data collection continued until the driver completed the required number of weeks of data collection (10 weeks of driving for drivers in the control group and 14 weeks for drivers in the experimental group).

When data collection was completed, the driver completed a post-study survey and a debriefing survey, was thanked for his/her participation, and signed a payment sheet. A check was mailed to the driver a few weeks after completing data collection. Drivers received $20 for completing the screening process, $30 for completing the pre-study survey and informed consent form, $75 for each week driving an instrumented truck, and an additional $250 for completing the required number of weeks driving an instrumented truck and the post-study survey. After payment was made, the next participant began his/her time in the instrumented truck. Prior to the second driver rotation, the researchers administered an identical fatigue management and DDWS information session. This rotation cycle continued until all drivers participated.

4.4 DATA COLLECTION PROCESS

Three forms of data were collected by the DAS:

- Video.
- Dynamic performance.
- Audio.

Data were continuously collected at approximately 4 megabytes per minute. Each driver drove for approximately 60 hours in a 7-day period. Assuming that all 103 drivers drove for 10–14 weeks, there was the potential for approximately 20 TB of data to be collected in the DDWS FOT. This was likely a high estimate, as the instrumented trucks and the DAS experienced occasional breakdowns and were not in service for the entire year-long data collection period.

Forty-six large trucks were instrumented with the DAS and the DFM. Each instrumented truck was driven by 3–5 different drivers for 10–14 weeks each. To ensure that enough hard drive space was available aboard the trucks, each had a 60–100 gigabyte stationary hard drive capable of storing several weeks of data. A separate removable hard drive was also part of the DAS. The data from the stationary hard drive was periodically copied to the removable hard drive. Every week, a researcher removed this hard drive and replaced it with a clean, removable hard drive.

4.4.1 Data Acquisition System

The DAS consisted of a computer that received and stored data from a network of sensors distributed around the vehicle. Data were stored on the system's external hard drive, which could store several weeks of driving data before it needed to be replaced. The DAS consisted of five major components:

- Encased unit that housed the computer and external hard drive.

- Dynamic sensors.
- Vehicle network
- Incident box
- Video cameras.

In addition, the DAS interfaced with the DFM and recorded data from it. Each component was active when the ignition system of the vehicle was activated. Therefore, the data were collected continuously whenever the truck was on and in motion.

A software program called "Loki" was developed to coordinate the data collection from the different sensor components and to integrate the data into a specific DAS output file called the truck performance data file. The encased unit that housed the computer and external hard drive was installed under the passenger's seat (Figure 2), or in the instrumented truck's rear cargo compartment (Figure 3). The organization of the DAS components is illustrated in Figure 4.

Figure 2. Photograph. Encased computer and external hard drive installed under the passenger seat.

Figure 3. Photograph. Encased computer and external hard drive installed in the instrumented truck's rear storage compartment.

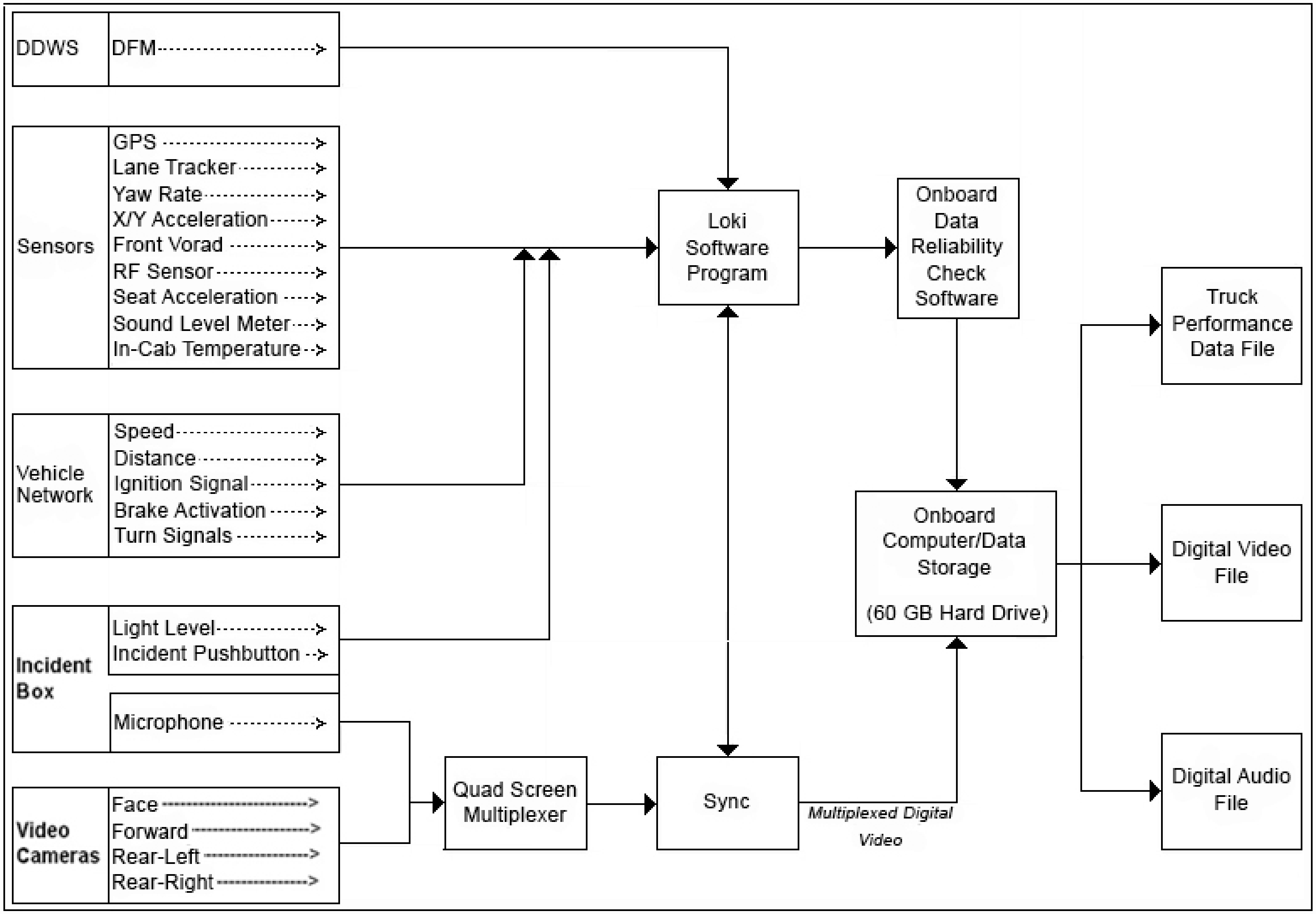

Figure 4. Flowchart. Organization of the DAS components.

The DAS, including the video cameras, sensor components, and computer and external hard drive became active when the ignition system of the vehicle was activated. The system remained active and recorded data as long as the engine was on and the vehicle was in motion. The system shut down in an orderly manner when the ignition was turned off. The system paused if the vehicle ceased motion for 15 minutes or longer.

There were three main DAS output files:

- Truck dynamic performance data.
- Digital video.
- Audio.

These files were stored on the DAS's external hard drive. The truck performance file contained the driver input measures (e.g., lateral and longitudinal acceleration, braking, etc.) and the truck measures (e.g., global position, light level, etc.). The digital video file contained the continuous video recorded during the run (a sample frame is shown in Figure 2). The audio file resulted from the driver pressing the critical incident button.

4.4.2 Driver Fatigue Monitor

The DFM was intended to detect drowsiness and warn drivers when their drowsiness exceeds a predetermined level (i.e., drowsiness threshold). This PERCLOS-estimation device has undergone extensive research and modifications based upon empirical data collection.[15] PERCLOS is a mathematically-defined eye-closure measure that has been demonstrated to highly correlate with a subject's performance degradation under varying conditions of sleep deprivation.[15,16,17] When the DFM estimates that PERCLOS has reached a predetermined threshold, visual and auditory alerts are presented to the driver. The DFM was mounted near the center of the dashboard with the DFM camera (upper part of the DFM) pointed toward the driver's face. Figure 5 shows the location of a DFM installed in a DDWS FOT truck.

Figure 5. Photograph. DFM installed in a DDWS FOT truck.

4.4.3 Dynamic Sensors

4.4.3.1 Global Positioning System

A global positioning device was included in the DAS and was used primarily for tracking the instrumented vehicles. Data output included measures of latitude, longitude, altitude, horizontal and vertical velocity, heading, and status/strength of satellite acquisition.

4.4.3.2 Lane Tracker

A lane tracker was included in the DAS. This device consisted of a single analog black and white camera, a computer with a frame grabber card, and an interface-to-vehicle car network that obtained ground speed. The “grabbed” video frames were not stored; instead, they were processed algorithmically in real time to calculate the vehicle position relative to road lane markings.

The lane tracker used in this study had two interfaces for communication: a dynamic link library version with exposed functionality and serial protocol. The device was configured to operate at 10 hertz (Hz) on a 266 megahertz (MHz) computer or up to 30 Hz on an 800 MHz (or better) computer. The following variables were reported by the lane tracker:

- Distance from center of car to left and right lane markings (estimated max error <6 inches; average error < 2 inches).
- Angular offset between car centerline and road centerline (estimated max error <1 degree).
- Approximate road curvature.
- Confidence in reported values for each marking found.

- Marking characteristics, such as dashed vs. solid and double versus single.
- Status information, such as in lane or solid line crossed.

Once installed, the lane tracking device automatically calibrated to determine camera position.

4.4.3.3 Yaw Rate

A yaw rate (gyro) sensor was included in the DAS and provided a measure of steering instability (i.e., jerky steering movements).

4.4.3.4 X/Y Accelerometer

Accelerometers instrumented in the truck were used to measure longitudinal (x) and lateral (y) accelerations.

4.4.3.5 Front Collision Warning System

A radar-based collision warning system forward object detection unit was installed on the front of the instrumented truck (see Figure 6). This front collision warning system provided a measure of range to lead vehicles. From the range measure, range rate and time-to-collision (TTC) were also derived. The collision warning system was used for passive data collection and did not display information to the driver.

Figure 6. Grouped photograph. Collision warning system on the front of the instrumented truck.

4.4.3.6 Radio Frequency Sensor

The radio frequency sensor detected when the driver used a wireless device. For example, if the driver used a wireless phone, a flag was entered into the dataset to allow for quick identification of the event. However, the radio frequency sensor in the current study never consistently worked as intended, thus no useable data were obtained from it.

4.4.4 Vehicle Network

The Society of Automotive Engineers' (SAE) automotive diagnostic protocol (standard) J1587defines the format of messages and data that are collected by large truck onboard microprocessors.[18] These microprocessors are installed on the vehicle at the truck manufacturing facility. Thus, the "vehicle network" refers to a from-the-factory onboard data collection system. Depending upon the truck model, year, and manufacturer, there are several data network protocols or standards that are used with HVs, including those defined by SAE

J1708, J1939, and J1587.[18,19,20] An interface was developed to access the data from the network and merge it into the DAS dataset. Some of the typical measures found on the vehicle network of most large trucks include, but are not limited to: vehicle speed, distance since vehicle start-up, ignition signal, throttle position, and brake pressure. In addition to the truck network measures, other driver input measures that were collected with sensors include right and left turn signal and headlight status (on/off).

4.4.4.1 Light Level

The in-cab ambient illumination level was recorded by a light meter. Note that the ambient light level was also measured by the DFM.

4.4.4.2 Incident Box and Pushbutton

When the driver was involved in a critical incident, he/she was instructed to push a red button on the incident box (Figure 7). This pushbutton opened an audio channel for 30 seconds. During that time, the driver provided a verbal report of what occurred via a microphone built into the incident box.

Figure 7. Photograph. Incident box used in the DDWS FOT.

4.4.5 Video Cameras

Digital video cameras continuously recorded the driver and the driving environment, and multiplexed the four images into a single image. The four camera views were:

- Forward.
- Driver's face.
- Rear-facing left.
- Rear-facing right.

The forward-facing and rear-facing camera views provided good coverage of the driving environment. The face view provided coverage of the driver's face and allowed researchers to conduct eye glance analysis and manual PERCLOS assessment. Figure 8 shows the camera direction and approximate fields-of-view for the four cameras.

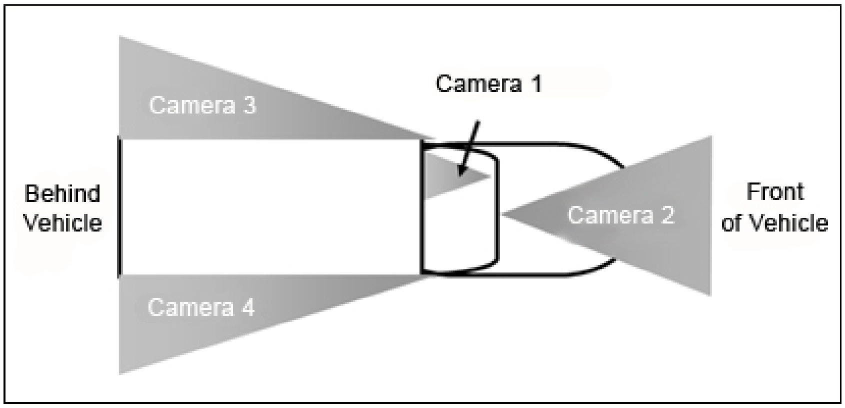

Figure 8. Diagram. Camera directions and approximate fields of view.

As shown in Figure 9, the four camera images were multiplexed into a single image which was saved in a digital video data file. A time-stamp (frame number) was also included in the data file but was not displayed on the screen. The frame number was used to time-synchronize the video and the truck/performance data.

Figure 9. Image. Split-screen presentation of the four camera views.

The digital video files did not contain continuous audio. However, as noted previously, the driver could press the incident pushbutton and record a verbal comment for 30 seconds. This audio data is recorded together with the video data.

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5. DATA REDUCTION AND ANALYSIS SOFTWARE

A data reduction and analysis program was developed to support the analyses described earlier in this report. The following sections provide details of this software, including screen shots of the user interface.

5.1 DATA DIRECTORY

As in the analysis of motor vehicle crashes from PARs, the analysis of SCEs 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.). For the current analyses, all events were coded based on the data directory and, once coded, comparisons were made on variables or data elements in the directory.

A detailed and comprehensive data directory of variables and data elements can be found in Appendix B. The data directory included classification variables relating to each overall SCE, as well as to V1 and (to a limited extent) V2. Specification of the data directory was critical since it defined and delimited the possible analyses from the data. The data directory was refined as new events and/or conditions arose in these analyses.

There were three primary steps in performing the data reduction and analysis for the events:

1. Identifying potential events, mostly through the use of an 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.

5.2 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 may or may not have involved an interaction with another vehicle. To find events of interest, a specially-developed software program scanned the dataset for notable actions, including hard braking, quick steering maneuvers, short TTCs, and lane deviations. To identify these actions, threshold values (e.g., triggers) were developed (as shown in Table 2).

Table 2. Triggers and trigger values used to identify critical incidents.

Trigger Type	Description
Longitudinal Acceleration	(1) Acceleration or deceleration greater than or equal to │0.35 g│. Speed greater than or equal to 15 miles per hour (mi/h). (2) Acceleration or deceleration greater than or equal to │0.5 g│. Speed less than or equal to 15 mi/h.
TTC	(3) A forward TTC value of less than or equal to 1.8 seconds, coupled with a range of less than or equal to 150 feet, a target speed of greater than or equal to 5 mi/h, a yaw rate of less than or equal to │4 degrees/sec│, and an azimuth of less than or equal to │0.8 degrees│. (4) A forward TTC value of less than or equal to 1.8 seconds, coupled with an acceleration or deceleration greater than or equal to │0.35 g│, a forward range of less than or equal to 150 feet, a yaw rate of less than or equal to │4 degrees/sec│, and an azimuth of less than or equal to │0.8 degrees│.
Swerve	(5) Swerve value of greater than or equal to 3. Speed greater than or equal to 15 mi/h.
Critical Incident Button	(6) Activated by the driver upon pressing a button, located by the driver's visor, when an incident occurred that he/she deemed critical.
Analyst Identified	(7) Event that was identified by a data reductionist 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 Naturalistic Driving Study and from examining crashes in the current dataset. The first five trigger types are parametric variables; the last two (incident button and analyst-identified) are non-parametric (Yes or No).

5.3 CHECKING THE VALIDITY OF THE TRIGGERED EVENTS

The software scanned the dataset and potential events of interest were identified for review. A 90-second epoch was created for each identified event (1 minute prior to the trigger, 30 seconds after the trigger). The result of the automatic scan was an event dataset that included both valid and invalid events.

Valid events were those events in which dynamic-motion values were recorded and were verifiable in the video and other sensor data from the event (also identified by the critical incident button or the analyst). Invalid events were those events in which sensor readings were spurious due to 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 SCEs, even though their trigger values were valid ("true triggers"). In non-conflict events, the sensor reading was correct (e.g., 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 90-second epoch.

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 was that lower trigger values resulted in relatively few missed events. The goal 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 10 shows an example of a valid trigger for longitudinal acceleration (LA). In this example, the trigger chart shows the trigger at the same point that the Accel_X plot shows the value reached -0.37 g indicating a sharp deceleration of the vehicle. For this example, the LA trigger was set at ±0.35 so that anytime the software detected an LA with a magnitude greater than ±0.35, a trigger was created. Looking closely at the video in the top right quadrant, a vehicle can be seen in front (and to the right) of the subject vehicle. At this point, a tractor-trailer has begun to change lanes directly in the lane in front of the instrumented vehicle and the driver of the instrumented truck brakes to avoid it.

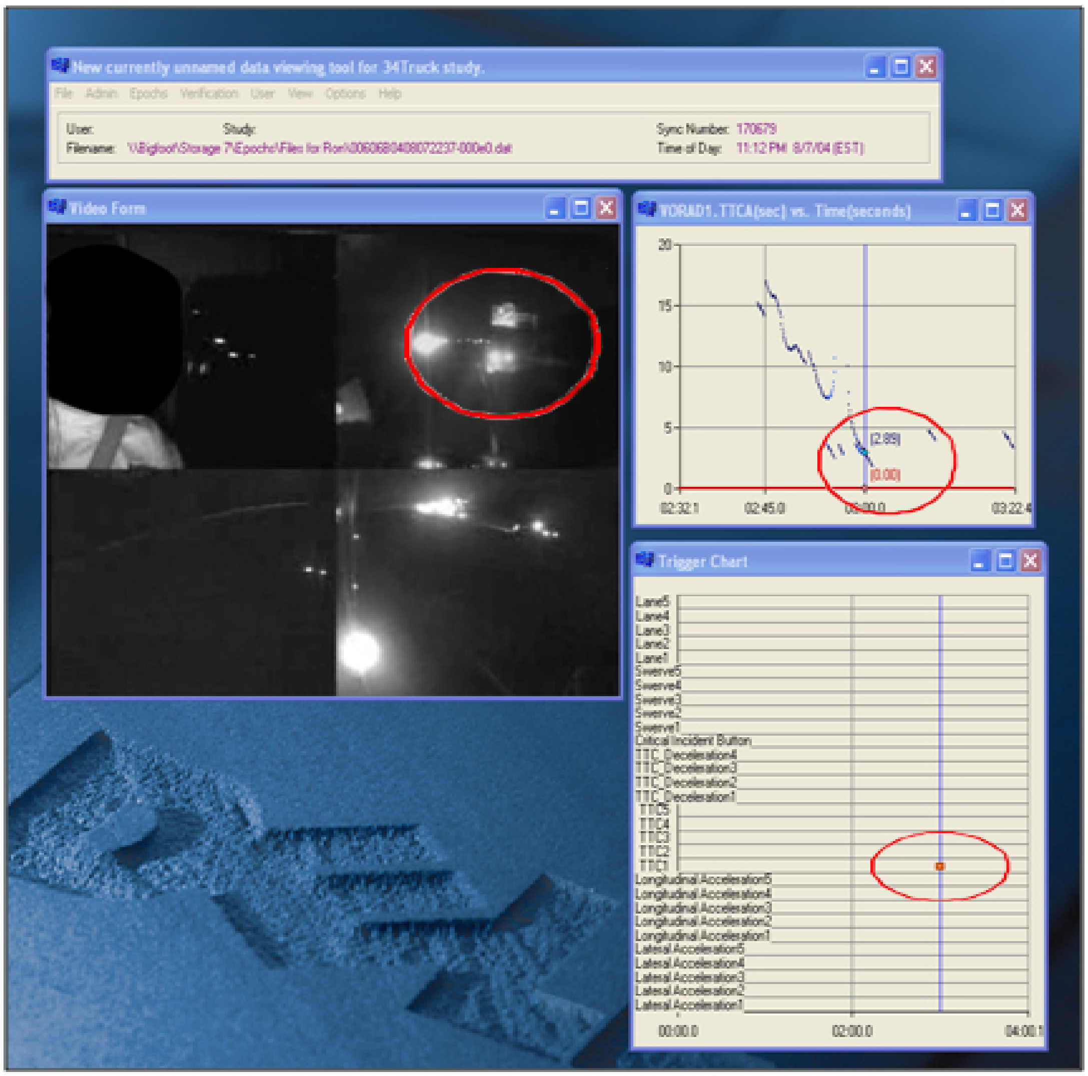

Figure 10.Screenshot. Example of a validated trigger where the LA was of greater magnitude than the preset value of -0.35 g.

Figure 11. shows an example of a non-conflict that had a valid swerve (quick steering) trigger. During this event, the driver was changing lanes. The trigger chart shows that the trigger appeared when the swerve value reached 3.68 (the value for this trigger was set at ≥ 3.0). After reviewing the video, it was seen that there were no vehicles in front of or to the side of the instrumented vehicle and he was simply changing lanes.

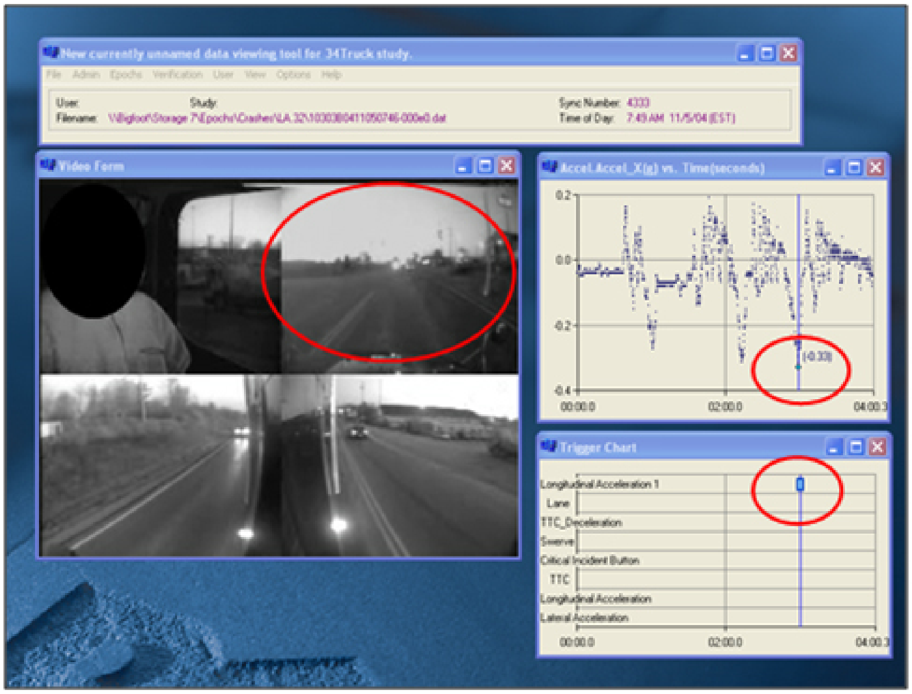

Figure 11. Screenshot. Example of a non-conflict event where the driver's swerve was at 3.68.

5.4 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 analyst with a series of variables consisting either of a blank space for entry of specific comments (e.g., Element 52, Event Comments) or provided pull-down menus for the 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 might be selected. For a few variables, however, the analyst could select up to four codes that were applicable. For example, analysts could select multiple potential distraction behaviors (Directory Element 39).

The database software automatically coded many of the variables. These automatically-coded variables reflect data recorded from sensors in the subject vehicle; examples include vehicle number, driver subject number, date, time, and average PERCLOS values over various time intervals. Although these variables were coded automatically, they were listed in the data directory to provide readers and reviewers with a full picture of the variables that were available to support analyses of the data.

5.4.1 Observer Rating of Drowsiness

Below is a summary of some of the most salient and important associations among driver characteristics and between these driver characteristics and risk measures. All of these statements apply to total SCEs (i.e., crashes—including tire strikes, near-crashes, and crash-relevant conflicts). As previously mentioned, data for the 75 experimental drivers (i.e., with the DFM active) and 20 control drivers (DFM functioned as a passive sensor) were aggregated for this analysis. The following statements apply to the total group of 95 participating drivers. The variable "*r*" refers to the Pearson product moment correlation coefficient (a measure of the linear correlation between two variables, giving a value between +1 and −1 inclusive).

One of the methods employed in the DDWS FOT was assessment of drowsiness by data analysts, or observer rating of drowsiness (ORD). The procedure for ORD in the DDWS FOT was developed and first used in the Accident Analysis and Prevention Study.[(21)] That study demonstrated that ORD could have good intra-rater and inter-rater reliability and that the measure correlated highly with eye closure measures such as PERCLOS and AVECLOS (mean percent eye closure). The Pearson product moment correlation coefficient (r) = + 0.7 – 0.9.

Data analysts were instructed to watch the driver's face and body language for 1 minute prior to the incident flag. As described in the Accident Analysis and Prevention Study, signs indicative of drowsiness include rubbing face or eyes, facial contortions, moving restlessly in the seat, and slow eyelid closures. Data analysts were trained to look for these signs of drowsiness and make a subjective, but specific assessment of the level of drowsiness. After watching the video data for 1 minute prior to an event trigger, data analysts employed a rating scale to record an ORD level (Figure 12). The rating scale used in the Accident Analysis and Prevention Study,[(21)] was printed on paper and analysts in that study marked a point on the horizontal line. In the DDWS FOT, analysts moved a cursor on a computer monitor to the desired ORD. ORD was recorded using a 100-point continuous rating scale where a number from 0 to 100 was assigned based on the linear position chosen by the analyst. Comparisons of analyst ORD ratings in a series of quality control test cases indicated an average inter-rater standard deviation of 13.5 for assigned ORDs. This implies that about two-thirds of analyst ORD assignments fell within that interval of a hypothetical "true" mean ORD for the case, assuming an underlying normal distribution.

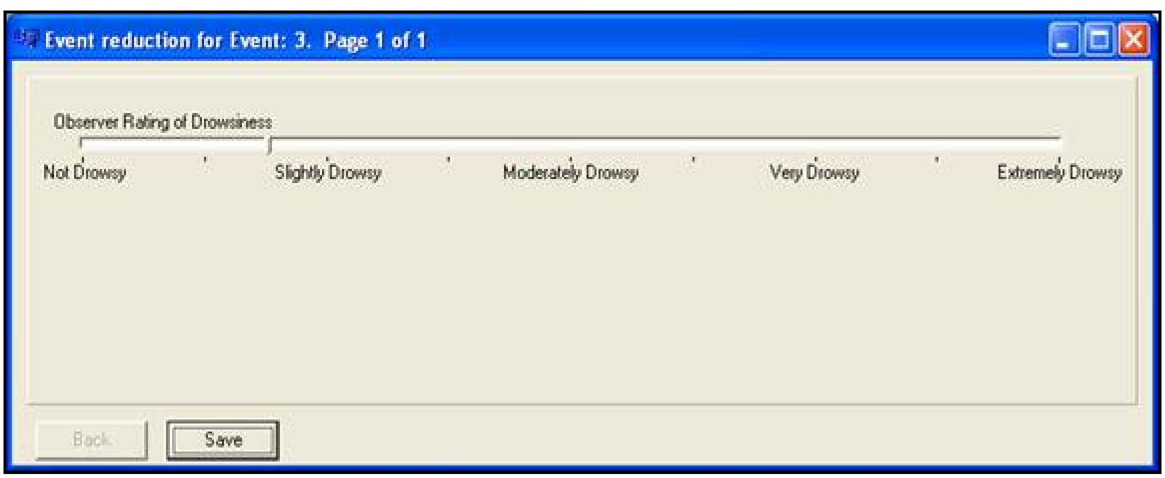

Figure 12. Screenshot. ORD rating scale used by data analysts.

5.4.2 Baseline Epochs

A random sample of 1,072 baseline epochs, each 60 seconds in length, was selected for data reduction. Data reductionists used the data directory to code a variety of variables from these 1,072 randomly selected baseline driving epochs or brief driving periods. Ordinarily, one random baseline epoch was selected for each driver-week of data collection. Baseline epochs were described using many of the same variables used to describe SCEs. In particular, their conditions of occurrence were recorded. In the current analysis, coded data on the 1,072 baseline epochs were compared to 915 SCEs.

5.5 ENSURING DATA CODING ACCURACY AND HIGH INTER-RATER RELIABILITY

To support accurate and consistent coding, a quality control procedure was established for the data coding. A key part of this was the testing of inter-rater reliability among analysts for test cases, with associated refresher training for analysts on difficult or uncertain coding issues. Two "test" events were selected each week and used to assess coding accuracy and inter-rater reliability of the coding. These events included some combination of crashes (if available), near-crashes, and crash-relevant conflicts. Baseline epochs were not used as test events because their codes are a smaller and less problematic subset of the codes for other events. The two "test" events were selected to include a variety of scenarios (e.g., V1-only versus two-vehicle) and potential coding issues (e.g., pre-crash and causation variable coding).

Each of the two test events was coded by expert analysts who came to an agreement on the correct coding for each variable in the data directory. Next, each data analyst coded the two events and their codes were compared to those of the expert analysts. The results helped to determine if analysts were correctly coding the events and identified analysts who were making more frequent coding errors. Those analysts received additional training, supervision, and quality control oversight. This approach led to continuous improvement and refinement in the coding rules as well as better quality control of the coding. Analyst judgment played a role in the coding of some variables, but the goal was to make all coding guidelines and decision rules as explicit as possible.

These procedures continued throughout the entire data reduction process. Discrepancies in coding by analysts were an indication that either clarifications or revisions were needed in the coding directory or other protocols; or the analyst needed additional training or other corrective guidance regarding coding decisions. Analysts with the highest performance levels were assigned more responsible roles in the study, including quality checking of other analysts. Those with lower performance levels were limited to coding baseline epochs (the easiest coding assignment). Since the coding of some variables was based on analyst judgment (both perception and interpretation of the event), 100 percent agreement and reliability were not realistic goals. Nevertheless, the authors believe that the system and procedures employed helped to sustain high coding performance levels during the project.

6. RESULTS

The current data were leveraged from the DDWS FOT. The current report describes data collection efforts in the DDWS FOT from May 2004 to May 2005. This dataset is preliminary and does not include all the data collected in the DDWS FOT. The current dataset included a total of 915 SCEs and 1,072 baseline epochs. Of the 915 SCEs in the dataset, 28 were crashes (14 tire strikes), 98 were near-crashes, and 789 were crash-relevant conflicts. Baseline epochs were brief 60-second time periods that were randomly selected from the recorded dataset. Baseline epochs were described using many of the same variables and data elements used to describe and classify SCEs. As described above, SCEs were identified in one of three ways:

- The dynamic sensor data surpassed a pre-determined criterion.
- The driver pressed the critical incident button.
- The analyst reviewed and identified the event.

Table 3 displays the distribution of trigger types in the current dataset for crashes, tire strikes, near-crashes, and crash-relevant conflicts.

Table 3. Distribution of trigger types.

Trigger Type	Crashes: Number (Percentage)	Crashes: Number of Tire Strikes (Percentage)	Near-crashes: Number (Percentage)	Crash-relevant Conflicts: Number (Percentage)	Total SCEs: Number (Percentage)
Critical Incident Button	0 (0.0%)	4 (28.6%)	0 (0.0%)	1 (0.1%)	5 (0.5%)
Longitudinal Acceleration	4 (28.6%)	0 (0.0%)	40 (40.8%)	473 (59.9%)	517 (56.5%)
Forward TTC	0 (0.0%)	2 (14.3%)	0 (0.0%)	95 (12.0%)	97 (10.6%)
Swerve	4 (28.6%)	0 (0.0%)	39 (39.8%)	157 (19.9%)	200 (21.9%)
Longitudinal Acceleration & Forward TTC	0 (0.0%)	0 (0.0%)	4 (4.1%)	27 (3.4%)	31 (3.4%)
Longitudinal Acceleration & Swerve	1 (7.1%)	0 (0.0%)	10 (10.2%)	14 (1.8%)	25 (2.7%)
Forward TTC & Swerve	0 (0.0%)	0 (0.0%)	0 (0.0%)	15 (1.9%)	15 (1.6%)
Longitudinal Acceleration & Swerve & Forward TTC	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.4%)	4 (0.4%)
Analyst Identified	5 (35.7%)	8 (57.1%)	4 (4.1%)	4 (0.5%)	21 (2.3%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1 ISSUE 1: ANALYSIS OF HEAVY VEHICLE SAFETY EVENTS

The data presented in this section were based on data analysts' assessments of the video and dynamic sensor data. The data analysts recorded their assessments of the video and dynamic sensor data by using the data directory (see Appendix B). As described above, the data directory contained the list of data variables and elements used to code ND events. Largely, these variables and data elements were selected to be compatible with major existing crash databases (e.g., the General Estimates System [GES], the Fatality Analysis Reporting System [FARS], and the Large Truck Crash Causation Study [LTCCS]). In addition to established variables from national crash data files, other supplemental variables were included to address particular issues not otherwise addressed. Most of these were also derived from other research sources.

Like most crash databases, the data directory used in this study was organized into several major categories based on whether the variable applied to the whole event or to one of the drivers/vehicles. As mentioned earlier in the report, classification variables relating to each overall SCE were identified in regard to the vehicles involved: V1, the instrumented vehicle (large truck) and driver, and (to a limited extent) V2, the other involved vehicle and driver—or, if applicable, the involved non-motorist. Since much more information was available for V1 than for V2, there are many more variables for V1.

6.1.1 Number of Vehicles Involved

Table 4 shows the frequency and percentage of vehicles involved in crashes, tire strikes, near-crashes, and crash-relevant conflicts in the dataset. Most of the SCEs involved two vehicles (64.8 percent); a smaller percentage were classified as V1 only (29.2 percent). Most crashes involved V1 only (57.1 percent) or V1 plus an animal (28.6 percent). All of the tire strike events involved V1 only (100 percent). Two vehicles were involved in most of the near-crashes (49 percent) and crash-relevant conflicts (68.9 percent). While SCEs were primarily two-vehicle, note that most crashes and tire strikes involved V1 only.

Table 4. Frequency and percentage of the number of vehicles involved.

Number of Vehicles Involved	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
1 Vehicle (V1 Only)	8 (57.1%)	14 (100.0%)	36 (36.7%)	209 (26.5%)	267 (29.2%)
2 Vehicles	1 (7.1%)	0 (0.0%)	48 (49.0%)	544 (68.9%)	593 (64.8%)
3 Vehicles	1 (7.1%)	0 (0.0%)	3 (3.1%)	22 (2.8%)	26 (2.8%)
4 Vehicles	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Subject Vehicle + Pedestrian	0 (0.0%)	0 (0.0%)	3 (3.1%)	2 (0.3%)	5 (0.5%)
Subject Vehicle + Pedalcyclist	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Subject Vehicle + Animal	4 (28.6%)	0 (0.0%)	8 (8.2%)	11 (1.4%)	23 (2.5%)

Number of Vehicles Involved	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%	0 (0.0%	0 (0.0%
Total	**14** **100.0%**	**14** **100.0%**	**98** **100.0%**	**789** **100.0%**	**915** **100.0%**

6.1.2 Vehicle Types

Table 5 shows the frequency and percentage of Vehicle Types in crashes, tire strikes, near-crashes, and crash-relevant conflicts in the 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 automobile (30.8 percent) or V1 only (29.3 percent). Four of the crashes (28.6 percent) involved V1 hitting a deer.

Table 5. Frequency and percentage of vehicle types.

Vehicle Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Single-vehicle Event (V1-Only)	8 (57.1%)	14 (100.0%)	36 (36.7%)	210 (26.6%)	268 (29.3%)
Automobile	1 (7.1%)	0 (0.0%)	20 (20.4%)	261 (33.1%)	282 (30.8%)
Van (Minivan or Standard Van)	0 (0.0%)	0 (0.0%)	3 (3.1%)	43 (5.4%)	46 (5.0%)
Pickup Truck	0 (0.0%)	0 (0.0%)	9 (9.2%)	68 (8.6%)	77 (8.4%)
Sport Utility Vehicle (SUV) (Includes Jeep)	1 (7.1%)	0 (0.0%)	3 (3.1%)	73 (9.3%)	77 (8.4%)
Bus (Transit or Motorcoach)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
School Bus	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Single-unit Truck (Includes Panel Van and Moving Van)	0 (0.0%)	0 (0.0%)	3 (3.1%)	13 (1.6%)	16 (1.7%)
Tractor-trailer	0 (0.0%)	0 (0.0%)	10 (10.2%)	80 (10.1%)	90 (9.8%)
Vehicle Pulling Trailer (Other than Tractor-trailer)	0 (0.0%)	0 (0.0%)	1 (1.0%)	12 (1.5%)	13 (1.4%)
Motorcycle or Moped	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
Emergency Response Vehicle (Police, Fire, Emergency Medical Service—Responding)	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
Other Vehicle Type	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)
Pedestrian	0 (0.0%)	0 (0.0%)	3 (3.1%)	2 (0.3%)	5 (0.5%)

Vehicle Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Pedalcyclist	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Deer	4 (28.6%)	0 (0.0%)	6 (6.1%)	8 (1.0%)	18 (2.0%)
Other Animal	0 (0.0%)	0 (0.0%)	2 (2.0%)	3 (0.4%)	5 (0.5%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (1.1%)	9 (1.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.3 Relevant Objects

Table 6 shows the frequency and percentage of relevant objects in crashes, tire strikes, near-crashes, and crash-relevant conflicts. "Relevant objects" refers to the most relevant object that was struck in a crash or which constituted a crash threat for near-crashes and crash-relevant conflicts (excluding other moving vehicles, people, and animals). Not including all the "not applicable" relevant objects, the most frequent relevant objects in the SCEs were a post, pole, or support (1.7 percent), guardrail (1.7 percent), curb (1.6 percent), culvert or ditch (1.3 percent), construction barrel (1 percent), construction cone (1 percent), and parked motor vehicle (0.9 percent).

Table 6. Frequency and percentage of relevant objects.

Relevant Object	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Not Applicable (Single-vehicle Event; No Object)	0 (0.0%)	0 (0.0%)	11 (11.2%)	156 (19.8%)	167 (18.3%)
Not Applicable (Two-vehicle Event, Pedestrian, Pedalcyclist, Animal)	6 (42.9%)	0 (0.0%)	60 (61.2%)	574 (72.8%)	640 (69.9%)
Parked Motor Vehicle	1 (7.1%)	0 (0.0%)	3 (3.1%)	4 (0.5%)	8 (0.9%)
Fixed Object: Building	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Impact Attenuator	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Fixed Object: Bridge Structure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Guardrail	0 (0.0%)	0 (0.0%)	3 (3.1%)	13 (1.6%)	16 (1.7%)
Fixed Object: Concrete Traffic Barrier	0 (0.0%)	1 (7.1%)	2 (2.0%)	0 (0.0%)	3 (0.3%)
Fixed Object: Post, Pole or Support	0 (0.0%)	1 (7.1%)	4 (4.1%)	11 (1.4%)	16 (1.7%)

Relevant Object	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Fixed Object: Culvert or Ditch	0 (0.0%)	0 (0.0%)	4 (4.1%)	8 (1.0%)	12 (1.3%)
Fixed Object: Curb	0 (0.0%)	12 (85.7%)	1 (1.0%)	2 (0.3%)	15 (1.6%)
Fixed Object: Embankment	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Fixed Object: Fence	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Fixed Object: Wall	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Fire Hydrant	1 (7.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Fixed Object: Shrubbery or Bush	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Tree (Not Overhang)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Boulder	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Loading Dock	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Loading Equipment	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Fixed Object: Cargo	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Overhanging: Tree Branch	1 (7.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Overhanging: Overhanging Part of Sign or Post	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Overhanging: Bridge/Overpass	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Overhanging: Building	0 (0.0%)	0 0.0%)	0 0.0%)	0 0.0%)	0 0.0%)
Overhanging: Telephone/Electrical Wires	1 (7.1%)	0 0.0%)	0 0.0%)	0 0.0%)	1 0.1%)
Non-fixed Object: Vehicle Parts, including Tire	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Non-fixed Object: Spilled Cargo	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-fixed Object: Dead Animal in Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Non-fixed Object: Broken Tree Limbs or Other Tree/Shrub Parts	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-fixed Object: Trash/Debris	1 (7.1%)	0 (0.0%)	2 (2.0%)	4 (0.5%)	7 (0.8%)
Non-fixed Object: Construction Barrel	1 (7.1%)	0 (0.0%)	5 (5.1%)	3 (0.4%)	9 (1.0%)
Non-fixed Object: Construction Cone	2 (14.3%)	0 (0.0%)	3 (3.1%)	4 (0.5%)	9 (1.0%)

Relevant Object	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%V	3 (0.4%)	3 (0.3%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.4 Vehicle Positions

Table 7 shows the frequency and percentage of vehicle positions. 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 the adjacent right lane to V1 were coded B, C, D, or E depending on position. Figure 13 shows a diagram of V1 with the corresponding vehicle position codes. Not including all the "not applicable" events, the most frequent vehicle positions of V2 in the SCEs were the front of V1 (coded A, 42 percent), the passenger-side front quarter panel of the V1 cab (coded B, 16.9 percent), and the driver-side front quarter panel of the V1 cab (coded J, 15.8 percent). However, a large percentage of the tire strikes (35.7 percent) occurred on the passenger-side rear quarter panel of the V1 trailer (i.e., the front set of rear tires on the trailer, coded D).

Table 7. Frequency and percentage of vehicle positions.

V2 Position in Relation to V1	Crashes (and Percentage)	Crashes: Tire Strikes (and Percentage)	Near-crashes (and Percentage)	Crash-relevant Conflicts (and Percentage)	Total SCEs (and Percentage)
Not Applicable (Single-vehicle Event)	0 (0.0%)	0 (0.0%)	9 (9.2%)	156 (19.8%)	165 (18.0%)
A–Front	7 (50.0%)	2 (14.3%)	33 (33.7%)	342 (43.3%)	384 (42.0%)
B–Right Side, Front	0 (0.0%)	0 (0.0%)	21 (21.4%)	134 (17.0%)	155 (16.9%)
C–Right Side, Rear Set of Front Tires	1 (7.1%)	0 (0.0%)	1 (1.0%)	12 (1.5%)	14 (1.5%)
D–Right Side, Front Set of Rear Tires	0 (0.0%)	5 (35.7%)	2 (2.0%)	5 (0.6%)	12 (1.3%)
E–Right Side, Rear	1 (7.1%)	2 (14.3%)	0 (0.0%)	2 (0.3%)	5 (0.5%)
F–Rear	1 (7.1%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	5 (0.5%)
G–Left Side, Rear	1 (7.1%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	4 (0.4%)
H–Left Side, Front Set of Rear Tires	1 (7.1%)	1 (7.1%)	8 (8.2%)	6 (0.8%)	16 (1.7%)
I–Left Side, Rear Set of Front Tires	0 (0.0%)	0 (0.0%)	2 (2.0%)	7 (0.9%)	9 (1.0%)

V2 Position in Relation to V1	Crashes (and Percentage)	Crashes: Tire Strikes (and Percentage)	Near-crashes (and Percentage)	Crash-relevant Conflicts (and Percentage)	Total SCEs (and Percentage)
J–Left Side, Front	1 (7.1%)	4 (28.6%)	21 (21.4%)	119 (15.1%)	145 (15.8%)
K–Top	1 (7.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

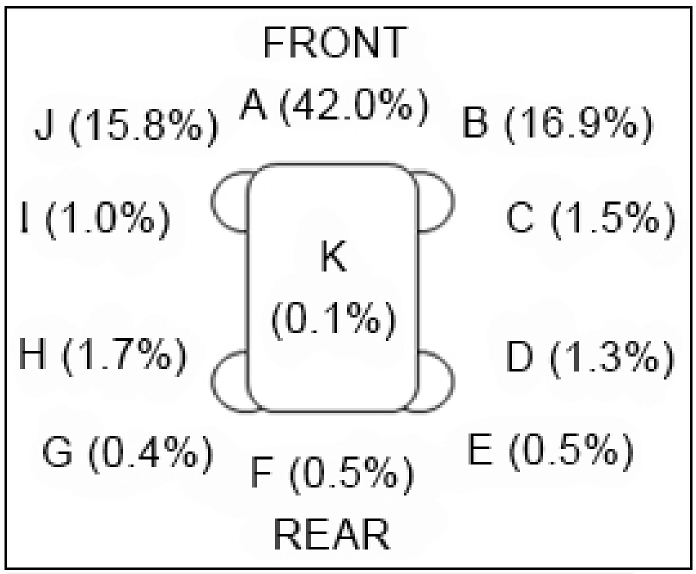

Figure 13. Diagram. Relative position of V1 (K) to V2 (percentages refer to total SCEs).

6.1.5 V1 Pre-event Movements

Table 8 shows the frequency and percentage of V1 pre-event movements. The pre-event movement describes the movement of the vehicle immediately prior to the critical event time envelope and vehicle motions that place the vehicle(s) on a collision path.[22] The most frequent V1 pre-event movements for SCEs were going straight (59.3 percent) and decelerating in traffic lane (18.5 percent).

Table 8. Frequency and percentage of V1 pre-event movements.

V1 Pre-event Movement	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Going Straight	4 (28.6%)	0 (0.0%)	51 (52.0%)	488 (61.9%)	543 (59.3%)
Decelerating in Traffic Lane	3 (21.4%)	2 (14.3%)	16 (16.3%)	148 (18.8%)	169 (18.5%)
Accelerating in Traffic Lane	0 (0.0%)	0 (0.0%)	8 (8.2%)	38 (4.8%)	46 (5.0%)

V1 Pre-event Movement	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Starting in Traffic Lane	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
Stopped in Traffic Lane	0 (0.0%)	0 (0.0%)	2 (2.0%)	1 (0.1%)	3 (0.3%)
Passing or Overtaking Another Vehicle	1 (7.1%)	0 (0.0%)	1 (1.0%)	16 (2.0%)	18 (2.0%)
Disabled or Parked in Travel Lane	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Leaving a Parking Position, Moving Forward	0 (0.0%)	0 (0.0%)	3 (3.1%)	2 (0.3%)	5 (0.5%)
Leaving a Parking Position, Backing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Entering a Parking Position, Moving Forward	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Entering a Parking Position, Backing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Turning Right	1 (7.1%)	9 (64.3%)	3 (3.1%)	6 (0.8%)	19 (2.1%)
Turning Left	2 (14.3%)	0 (0.0%)	2 (2.0%)	4 (0.5%)	8 (0.9%)
Making a U-turn	0 (0.0%)	1 (7.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Backing (Other than Parking)	0 (0.0%)	1 (7.1%)	0 (0.0%)	1 (0.1%)	2 (0.2%)
Negotiating a Curve	0 (0.0%)	0 (0.0%)	6 (6.1%)	24 (3.0%)	30 (3.3%)
Changing Lanes	2 (14.3%)	0 (0.0%)	4 (4.1%)	49 (6.2%)	55 (6.0%)
Merging	0 (0.0%)	1 (7.1%)	1 (1.0%)	8 (1.0%)	10 (1.1%)
Successful Avoidance Maneuver to a Previous Critical Event	1 (7.1%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	4 (0.4%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.6 V2 Pre-event Movements

Table 9 shows the frequency and percentage of V2 pre-event movements. Not including the single-vehicle events, the most frequent V2 pre-event movements for SCEs were decelerating in traffic lane (32.8 percent) and going straight (30.4 percent).

Table 9. Frequency and percentage of V2 pre-event movements.

V2 Pre-event Movement	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
Going Straight	0 (0.0%)	0 (0.0%)	14 (27.5%)	174 (30.8%)	188 (30.4%)
Decelerating in Traffic Lane	0 (0.0%)	0 (0.0%)	11 (21.6%)	192 (34.0%)	203 (32.8%)
Accelerating in Traffic Lane	0 (0.0%)	0 (0.0%)	1 (2.0%)	3 (0.5%)	4 (0.6%)
Starting in Traffic Lane	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
Stopped in Traffic Lane	1 (50.0%)	0 (0.0%)	8 (15.7%)	44 (7.8%)	53 (8.6%)
Passing or Overtaking Another Vehicle	0 (0.0%)	0 (0.0%)	4 (7.8%)	16 (2.8%)	20 (3.2%)
Disabled or Parked in Travel Lane	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (1.1%)	6 (1.0%)
Leaving a Parking Position, Moving Forward	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
Leaving a Parking Position, Backing	0 (0.0%)	0 (0.0%)	1 (2.0%)	1 (0.2%)	2 (0.3%)
Entering a Parking Position, Moving Forward	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
Entering a Parking Position, Backing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Turning Right	0 (0.0%)	0 (0.0%)	1 (2.0%)	12 (2.1%)	13 (2.1%)
Turning Left	0 (0.0%)	0 (0.0%)	3 (5.9%)	15 (2.7%)	18 (2.9%)
Making a U-turn	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
Backing (Other than Parking)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Negotiating a Curve	0 (0.0%)	0 (0.0%)	1 (2.0%)	12 (2.1%)	13 (2.1%)
Changing Lanes	0 (0.0%)	0 (0.0%)	5 (9.8%)	43 (7.6%)	48 (7.8%)
Merging	0 (0.0%)	0 (0.0%)	2 (3.9%)	28 (5.0%)	30 (4.9%)
Successful Avoidance Maneuver to a Previous Critical Event	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
Unknown	1 (50.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	6 (1.0%)
Total	**2 (100.0%)**	**0 (0.0%)**	**51 (100.0%)**	**565 (100.0%)**	**618 (100.0%)**

6.1.7 V1 Critical Pre-crash Events

Table 10 shows the frequency and percentage of V1 critical pre-crash events. The critical pre-crash event refers to the maneuver or incident that made the event imminent.[22] As shown in Table 10, the predominant V1 critical pre-crash events for SCEs were:

- V2 in lane, traveling in same direction while decelerating (24 percent).
- V1 decelerating (18.8 percent).

The V1 critical pre-crash events for crashes were more varied; most crashes involved some avoidance of an animal or object. The most frequent V1 critical pre-crash events for crashes were:

- Animal in roadway (28.6 percent).
- Object in roadway (21.4 percent).
- Object approaching roadway (14.3 percent).
- V1 traveling toward or off the edge of the road on the right side (14.3 percent).

The V1 critical pre-crash events for near-crashes were also varied. Most of the V1 critical pre-crash events for near-crashes involved V1 leaving its lane (16.3 percent) or going off the road (15.3 percent), V2 encroaching into V1's lane from an adjacent lane (21.5 percent), or an animal or object in the roadway (19 percent).

Table 10. Frequency and percentage of V1 critical pre-crash events.

Category	V1 Critical Pre-crash Event	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
V1 LOSS OF CONTROL DUE TO:	Blowout or Flat Tire	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Stalled Engine	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Disabling Vehicle Failure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Non-disabling Vehicle Problem	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Poor Road Conditions	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Traveling Too Fast for Conditions	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)
V1 LOSS OF CONTROL DUE TO:	Jack-knife	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Cargo Shift	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Braking	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Category	V1 Critical Pre-crash Event	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
V1 LOSS OF CONTROL DUE TO:	Steering	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 LOSS OF CONTROL DUE TO:	Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 TRAVELING:	Toward or Over the Lane Line on Left Side of Travel	0 (0.0%)	0 (0.0%)	9 (9.2%)	59 (7.5%)	68 (7.4%)
V1 TRAVELING:	Toward or Over the Lane Line on Right Side of Travel	0 (0.0%)	0 (0.0%)	7 (7.1%)	42 (5.3%)	49 (5.4%)
V1 TRAVELING:	Toward or Off the Edge of the Road on the Left Side	0 (0.0%)	8 (57.1%)	7 (7.1%)	10 (1.3%)	25 (2.7%)
V1 TRAVELING:	Toward or Off the Edge of the Road on the Right Side	2 (14.3%)	6 (42.9%)	8 (8.2%)	39 (4.9%)	55 (6.0%)
V1 TRAVELING:	End Departure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V1 TRAVELING:	Turning Left at Intersection	1 (7.1%)	0 (0.0%)	3 (3.1%)	9 (1.1%)	13 (1.4%)
V1 TRAVELING:	Turning Right at Intersection	0 (0.0%)	0 (0.0%)	1 (1.0%)	9 (1.1%)	10 (1.1%)
V1 TRAVELING:	Crossing Over (Passing through) Intersection	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
V1 TRAVELING:	This Vehicle Decelerating	1 (7.1%)	0 (0.0%)	1 (1.0%)	170 (21.5%)	172 (18.8%)
V1 TRAVELING:	This Vehicle Accelerating	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.0%)	8 (0.9%)
V1 TRAVELING:	Unknown Travel Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 IN LANE:	Other Vehicle Stopped	1 (7.1%)	0 (0.0%)	5 (5.1%)	38 (4.8%)	44 (4.8%)
V2 IN LANE:	Traveling in Same Direction With Lower Steady Speed	0 (0.0%)	0 (0.0%)	1 (1.0%)	47 (6.0%)	48 (5.2%)
V2 IN LANE:	Traveling in Same Direction While Decelerating	0 (0.0%)	0 (0.0%)	9 (9.2%)	211 (26.7%)	220 (24.0%)
V2 IN LANE:	Traveling in Same Direction with Higher Speed	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
V2 IN LANE:	Traveling in Opposite Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
V2 IN LANE:	In Crossover	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
V2 IN LANE:	Backing	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)

Category	V1 Critical Pre-crash Event	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
V2 IN LANE:	Unknown Direction of Travel	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Adjacent Lane (Same Direction), Toward or Over Left Lane Line	0 (0.0%)	0 (0.0%)	13 (13.3%)	26 (3.3%)	39 (4.3%)
V2 ENCROACHING INTO LANE:	From Adjacent Lane (Same Direction), Toward or Over Right Lane Line	0 (0.0%)	0 (0.0%)	8 (8.2%)	55 (7.0%)	63 (6.9%)
V2 ENCROACHING INTO LANE:	From Opposite Direction, Toward or Over Left Lane Line	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)
V2 ENCROACHING INTO LANE:	From Opposite Direction, Toward or Over Right Lane Line	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Parking Lane	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
V2 ENCROACHING INTO LANE:	From Crossing Street, Turning into Same Direction	0 (0.0%)	0 (0.0%)	1 (1.0%)	8 (1.0%)	9 (1.0%)
V2 ENCROACHING INTO LANE:	From Crossing Street, Across Path	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
V2 ENCROACHING INTO LANE:	From Crossing Street, Turning into Opposite Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
V2 ENCROACHING INTO LANE:	From Crossing Street, Intended Path Not Known	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Driveway, Turning into Same Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Driveway, Across Path	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
V2 ENCROACHING INTO LANE:	From Driveway, Turning into Opposite Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Driveway, Intended Path Not Known	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
V2 ENCROACHING INTO LANE:	From Entrance to Limited Access Highway	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
V2 ENCROACHING INTO LANE:	Encroachment by Other Vehicle; Details Unknown	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedestrian in Roadway	0 (0.0%)	0 (0.0%)	3 (3.1%)	2 (0.3%)	5 (0.5%)

Category	V1 Critical Pre-crash Event	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedestrian Approaching Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedestrian; Unknown Location	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedalcyclist or Other Non-Motorist in Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedalcyclist or Other Non-Motorist Approaching Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST:	Pedalcyclist or Other Non-Motorist; Unknown Location	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
OBJECT OR ANIMAL:	Animal in Roadway	4 (28.6%)	0 (0.0%)	8 (8.2%)	11 (1.4%)	23 (2.5%)
OBJECT OR ANIMAL:	Animal Approaching Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
OBJECT OR ANIMAL:	Animal; Unknown Location	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
OBJECT OR ANIMAL:	Object in Roadway	3 (21.4%)	0 (0.0%)	10 (10.2%)	11 (1.4%)	24 (2.6%)
OBJECT OR ANIMAL:	Object Approaching Roadway	2 (14.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.2%)
OBJECT OR ANIMAL:	Object; Unknown Location	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
OTHER:	Other Critical Pre-crash Event	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
OTHER:	Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.8 V1 Critical Reasons

Table 11 shows the frequency and percentage of V1 critical reasons (CRs) for SCEs. The CR is the primary reason for which the event occurred.[21]. For completeness, the table includes the 175 (19.1 percent) SCEs for which the CR was coded to the other vehicle. Only one CR was coded for each SCE (i.e., either coded to V1 or V2, but not both). The most frequent V1 CRs for SCEs were:

- Inadequate evasive action (14 percent).
- Internal distraction (10.8 percent).

- External distraction (6.2 percent).
- Misjudgment of gap or others' speed (5.7 percent).
- Too fast for conditions (5.4 percent).

More than half of the crashes had an environment-related (other) V1 CR, such as animal in roadway (28.6 percent) or object in roadway (28.6 percent).

Table 11. Frequency and percentage of V1 CRs.

Category	V1 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
NO CATEGORY	CR Not Coded to This Vehicle	1 (7.1%)	0 (0.0%)	29 (29.6%)	145 (18.4%)	175 (19.1%)
DRIVER-RELATED FACTOR—Critical Non-performance Error:	Asleep	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
DRIVER-RELATED FACTOR—Critical Non-performance Error:	Heart Attack or Other Physical Impairment of the Ability to Act	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Critical Non-performance Error:	Drowsiness, Fatigue, or Other Reduced Alertness	0 (0.0%)	0 (0.0%)	1 (1.0%)	10 (1.3%)	11 (1.2%)
DRIVER-RELATED FACTOR—Critical Non-performance Error:	Other Critical Non-performance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Critical Non-performance Error:	Unknown Critical Non-performance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Recognition Error:	Inattention (i.e., Daydreaming)	0 (0.0%)	0 (0.0%)	1 (1.0%)	22 (2.8%)	23 (2.5%)
DRIVER-RELATED FACTOR—Recognition Error:	Internal Distraction	1 (7.1%)	0 (0.0%)	15 (15.3%)	83 (10.5%)	99 (10.8%)
DRIVER-RELATED FACTOR—Recognition Error:	External Distraction	1 (7.1%)	0 (0.0%)	6 (6.1%)	50 (6.3%)	57 (6.2%)
DRIVER-RELATED FACTOR—Recognition Error:	Inadequate Surveillance (e.g., Failed to Look)	0 (0.0%)	0 (0.0%)	8 (8.2%)	23 (2.9%)	31 (3.4%)
DRIVER-RELATED FACTOR—Recognition Error:	Other Recognition Error	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (1.3%)	10 (1.1%)
DRIVER-RELATED FACTOR—Recognition Error:	Unknown Recognition Error	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.8%)	6 (0.7%)

Category	V1 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
DRIVER-RELATED FACTOR—Decision Error:	Too Fast for Conditions	0 (0.0%)	0 (0.0%)	4 (4.1%)	45 (5.7%)	49 (5.4%)
DRIVER-RELATED FACTOR—Decision Error:	Too Slow for Traffic Stream	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Misjudgment of Gap or Others' Speed	1 (7.1%)	0 (0.0%)	2 (2.0%)	49 (6.2%)	52 (5.7%)
DRIVER-RELATED FACTOR—Decision Error:	Following Too Closely to Respond to Unexpected Actions	0 (0.0%)	0 (0.0%)	2 (2.0%)	42 (5.3%)	44 (4.8%)
DRIVER-RELATED FACTOR—Decision Error:	False Assumption of Other Road Users Actions	0 (0.0%)	0 (0.0%)	0 (0.0%)	26 (3.3%)	26 (2.8%)
DRIVER-RELATED FACTOR—Decision Error:	Apparently Intentional Sign/Signal Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
DRIVER-RELATED FACTOR—Decision Error:	Illegal U-turn	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
DRIVER-RELATED FACTOR—Decision Error:	Other Illegal Maneuver	0 (0.0%)	0 (0.0%)	0 (0.0%)	18 (2.3%)	18 (2.0%)
DRIVER-RELATED FACTOR—Decision Error:	Failure to Turn on Head Lamps	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Inadequate Evasive Action (e.g., Braking Only, Not Braking and Steering)	0 (0.0%)	0 (0.0%)	3 (3.1%)	125 (15.8%)	128 (14.0%)
DRIVER-RELATED FACTOR—Decision Error:	Aggressive Driving: Intimidation	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
DRIVER-RELATED FACTOR—Decision Error:	Aggressive Driving: Wanton, Neglectful or Reckless Behavior	0 (0.0%)	1 (7.1%)	0 (0.0%)	7 (0.9%)	8 (0.9%)
DRIVER-RELATED FACTOR—Decision Error:	Other Decision Error	0 (0.0%)	1 (7.1%)	1 (1.0%)	15 (1.9%)	17 (1.9%)
DRIVER-RELATED FACTOR—Decision Error:	Unknown Decision Error	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Category	V1 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Recognition or Decision Error (Unknown Which)	0 (0.0%)	0 (0.0%)	5 (5.1%)	0 (0.0%)	5 (0.5%)
DRIVER-RELATED FACTOR—Performance Error:	Panic/Freezing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Performance Error:	Over-compensation	0 (0.0%)	0 (0.0%)	0 (0.0%)	15 (1.9%)	15 (1.6%)
DRIVER-RELATED FACTOR—Performance Errors:	Poor Directional Control	2 (14.3%)	3 (21.4%)	6 (6.1%)	18 (2.3%)	29 (3.2%)
DRIVER-RELATED FACTOR—Performance Error:	Other Performance Error	0 (0.0%)	0 (0.0%)	1 (1.0%)	40 (5.1%)	41 (4.5%)
DRIVER-RELATED FACTOR—Performance Error:	Unknown Performance Error	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
DRIVER-RELATED FACTOR—Performance Error:	Type of Driver Error Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Tires/Wheels Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Brakes Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Steering Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Cargo Shifted	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Trailer Attachment Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Suspension Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Lights Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Vehicle-related Vision Obstructions	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Body, Doors, Hood Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Jack-knifed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Category	V1 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
VEHICLE-RELATED FACTOR:	Other Vehicle Failure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Unknown Vehicle Failure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Signs/Signals Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Signs/Signals Erroneous/ Defective	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	View Obstructions by Roadway Design	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	View Obstructed by Other Vehicles Crash Circumstance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Roadway Geometry	0 (0.0%)	9 (64.3%)	1 (1.0%)	6 (0.8%)	16 (1.7%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Sight Distance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Other	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Maintenance Problems	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Slick Roads	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Other Highway-related Condition	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Rain, Snow	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Fog	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)

Category	V1 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Wind Gust	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Other Weather-related Condition	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Glare	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Blowing Debris	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Animal in Roadway (No Driver Error)	4 (28.6%)	0 (0.0%)	6 (6.1%)	12 (1.5%)	22 (2.4%)
ENVIRONMENT-RELATED FACTOR—Other:	Pedestrian or Pedalcyclist in Roadway	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
ENVIRONMENT-RELATED FACTOR—Other:	Object in Roadway	4 (28.6%)	0 (0.0%)	4 (4.1%)	10 (1.3%)	18 (2.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Other Sudden Change in Ambience	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Unknown Reason for Critical Event	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.9 V2 Critical Reasons

Table 12 shows the frequency and percentage of V2 CRs for SCEs. 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. Not including the single-vehicle events or events where a CR was not coded to V2, the most frequent V2 CR for SCEs was apparent recognition or decision error, unknown which (13.4 percent). This code was relatively frequent because of the inherent uncertainty in deducing the nature of a driver error from observation of the vehicle action without observing the driver, as was always the case for V2. Other CRs were:

- Apparent recognition failure (2.6 percent).
- Other decision error (2.4 percent).
- Aggressive driving: wanton, neglectful, or reckless behavior (2.1 percent).

The largest percentage of V2 CRs for near-crashes was coded with apparent recognition error (14.8 percent).

Table 12. Frequency and percentage of V2 CRs.

Category	V2 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
NO CATEGORY:	CR Not Coded to This Vehicle	1 (50.0%)	0 (0.0%)	29 (53.7%)	416 (74.0%)	446 (72.2%)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Critical Non-performance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Recognition Error	0 (0.0%)	0 (0.0%)	8 (14.8%)	8 (1.4%)	16 (2.6%)
DRIVER-RELATED FACTOR—Decision Error:	Too Fast for Conditions	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
DRIVER-RELATED FACTOR—Decision Error:	Too Slow for Traffic Stream	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (1.6%)	9 (1.5%)
DRIVER-RELATED FACTOR—Decision Error:	Following Too Closely to Respond to Unexpected Actions	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	False Assumption of Other Road Users Actions	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	5 (0.8%)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Intentional Sign/Signal Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
DRIVER-RELATED FACTOR—Decision Error:	Illegal U-turn	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Other Illegal Maneuver	0 (0.0%)	0 (0.0%)	1 (1.9%)	6 (1.1%)	7 (1.1%)
DRIVER-RELATED FACTOR—Decision Error:	Failure to Turn on Head Lamps	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Inadequate Evasive Action (e.g., Braking Only, Not Braking and Steering)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Aggressive Driving: Intimidation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
DRIVER-RELATED FACTOR—Decision Error:	Aggressive Driving: Wanton, Neglectful or Reckless Behavior	0 (0.0%)	0 (0.0%)	4 (7.4%)	9 (1.6%)	13 (2.1%)
DRIVER-RELATED FACTOR—Decision Error:	Other Decision Error	0 (0.0%)	0 (0.0%)	2 (3.7%)	13 (2.3%)	15 (2.4%)

Category	V2 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
DRIVER-RELATED FACTOR—Decision Error:	Unknown Decision Error	0 (0.0%)	0 (0.0%)	1 (1.9%)	2 (0.4%)	3 (0.5%)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Recognition or Decision Error, Unknown Which	0 (0.0%)	0 (0.0%)	6 (11.1%)	77 (13.7%)	83 (13.4%)
DRIVER-RELATED FACTOR—Decision Error:	Apparent Performance Error	0 (0.0%)	0 (0.0%)	1 (1.9%)	5 (0.9%)	6 (1.0%)
DRIVER-RELATED FACTOR—Decision Error:	Type of Driver Error Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Tires/Wheels Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Brakes Failed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
VEHICLE-RELATED FACTOR:	Apparent Other Vehicle Failure	0 (0.0%)	0 (0.0%)	1 (1.9%)	2 (0.4%)	3 (0.5%)
VEHICLE-RELATED FACTOR:	Unknown Vehicle Failure	0 (0.0%)	0 (0.0%)	1 (1.9%)	1 (0.2%)	2 (0.3%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Signs/Signals Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Signs/Signals Erroneous/Defective	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	View Obstructed by Roadway Design	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	View Obstructed by Other Vehicles Crash Circumstance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Roadway Geometry	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Sight Distance	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Road Design: Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Category	V2 CR	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Maintenance Problems	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Slick Roads	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Highway-related:	Other Highway-related Condition	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%
ENVIRONMENT-RELATED FACTOR—Weather-related:	Rain, Snow	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Fog	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Wind Gust	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Weather-related:	Other Weather-related Condition	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Glare	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Blowing Debris	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Animal in Roadway (No Driver Error)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Pedestrian or Pedalcyclist in Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Object in Roadway	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Other Sudden Change in Ambience	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ENVIRONMENT-RELATED FACTOR—Other:	Unknown Reason for Critical Event	1 (50.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	4 (0.6%)
	Total	**2 (100.0%)**	**0 (0.0%)**	**54 (100.0%)**	**562 (100.0%)**	**618 (100.0%)**

6.1.10 Critical Reasons and Observer Ratings of Drowsiness

The following analysis was based on 86 SCEs in which the V1 truck driver was designated at fault and identified by data analysts with an ORD value ≥40 (i.e., the driver was considered highly drowsy by the data analyst). For simplicity, these are termed "V1 at-fault & drowsy" SCEs. Table 13 displays the CRs for the 86 V1 at-fault & drowsy SCEs. It shows that 11 of the 86 V1 at-fault & drowsy SCEs (12.8 percent) were assigned a CR of asleep or drowsy/fatigued/reduced alertness. Most of the V1 at-fault & drowsy SCEs were recognition and decision errors, including:

- Recognition errors—failure or delay in perceiving a crash threat (32.6 percent).
- Decision errors, which include both driving misbehaviors and judgment errors (40.7 percent).

These results show that high driver drowsiness was associated with many different types of crash situations and driver errors other than asleep at the wheel or loss of alertness per se.

Table 13. CRs for the V1 at-fault and drowsy SCEs.

Category	CRs	Frequency of CRs Where Driver 1 Was Drowsy	Percentage of CRs Where Driver 1 Was Drowsy
D1 Critical Non-performance Error:	Asleep	1	1.2%
D1 Critical Non-performance Error:	Drowsiness, Fatigue, or Other Reduced Alertness	10	11.6%
	Total:	**11**	**12.8%**
D1 Recognition Error:	Inattention	7	8.1%
D1 Recognition Error:	Internal Distraction	6	7.0%
D1 Recognition Error:	External Distraction	12	14.0%
D1 Recognition Error:	Inadequate Surveillance	1	1.2%
D1 Recognition Error:	Unknown Recognition Error	2	2.3%
	Total:	**28**	**32.6%**
D1 Decision Error:	Too Fast for Conditions	7	8.1%
D1 Decision Error:	Misjudgment of Gap or Other's Speed	7	8.1%
D1 Decision Error:	Following Too Closely to Respond to Unexpected Actions	1	1.2%
D1 Decision Error:	False Assumption of Road Users Actions	2	2.3%
D1 Decision Error:	Other Illegal Maneuver	2	2.3%
D1 Decision Error:	Inadequate Evasive Action	12	14.0%
D1 Decision Error:	Aggressive Driving: Wanton Neglectful or Reckless Behavior	1	1.2%
D1 Decision Error:	Other Decision Error	3	3.5%
	Total:	**35**	**40.7%**
Other:	**D1 Recognition or Decision Error (Unknown Which)**	1	1.2%
Other:	**D1 Performance Errors**	11	12.8%
	Grand Total:	**86**	**100%**

6.1.11 Driver at Fault

Table 14 displays the distribution of driver at-fault designations. 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 14; all single-vehicle events were excluded. There were a few events in which it was difficult to assign fault to V1 or V2, thus the event was coded as "unknown." There were some events in which both V1 and V2 were at-fault; in those cases, "no fault" was coded. As discussed earlier in the report, the vehicle-based sensor suite employed in the study is better suited for detecting V1-initiated actions than V2-initiated actions, and thus there is a predominance of V1 at-fault events in this dataset. This is especially true for low-severity events. When considering higher severity events, such as crashes and near-crashes, the distribution of assigned fault is split evenly between V1 and V2.

Table 14. Distribution of driver at-fault designations.

Driver At Fault	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
V1	1 (50.0%)	0 (0.0%)	26 (48.1%)	417 (73.3%)	444 (71.0%)
V2	1 (50.0%)	0 (0.0%)	28 (51.9%)	145 (25.5%)	174 (27.8%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
No Fault	0 (0.0%)	0 (0.0%)	0 (0.0%	5 (0.9%)	5 (0.8%)
Total	**2 (100.0%)**	**0 (0.0%)**	**54 (100.0%)**	**569 (100.0%)**	**625 (100.0%)**

6.1.12 V1 Attempted Avoidance Maneuvers

Table 15 displays the frequency and percentage of V1 avoidance maneuvers. Obviously, the V1 attempted avoidance maneuvers in crashes and tire strikes were unsuccessful or not present, while the V1 attempted avoidance maneuvers were successful or not present in near-crashes and crash-relevant conflicts. More than half of the V1 attempted avoidance maneuvers for SCEs involved braking with no lockup. A large percentage of crashes and tire strikes involved no V1 avoidance maneuver. Interestingly, 42.9 percent of the V1 attempted avoidance maneuvers for near-crashes involved the V1 driver braking and steering to the right or left (once again, no lockup or lockup unknown). This avoidance maneuver, braking and steering, implies the driver believed that braking alone was insufficient to avoid the other vehicle/object. Of course, the detection of events is, in general, largely dependent on evasive maneuvers which create detectable dynamic triggers. This is especially true of non-crashes where there is no impact

Table 15. Frequency and percentage of V1 attempted avoidance maneuvers.

V1 Attempted Avoidance Maneuver	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
No Avoidance Maneuver	5 (35.7%)	4 (28.6%)	1 (1.0%)	4 (0.5%)	14 (1.5%)
Braking (No Lockup or Lockup Unknown)	4 (28.6%)	2 (14.3%)	27 (27.6%)	462 (58.6%)	495 (54.1%)
Braking (Lockup)	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.4%)	4 (0.4%)
Releasing Brakes	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Steered to Left	0 (0.0%)	1 (7.1%)	7 (7.1%)	59 (7.5%)	67 (7.3%)
Steered to Right	1 (7.1%)	1 (7.1%)	4 (4.1%)	37 (4.7%)	43 (4.7%)
Braked and Steered to Left (No Lockup or Lockup Unknown)	3 (21.4%)	1 (7.1%)	15 (15.3%)	69 (8.7%)	88 (9.6%)
Braked and Steered to Left (Lockup)	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
Braked and Steered to Right (No Lockup or Lockup Unknown)	0 (0.0%)	1 (7.1%)	27 (27.6%)	79 (10.0%)	107 (11.7%)
Braked and Steered to Right (Lockup)	0 (0.0%)	0 (0.0%)	2 (2.0%)	1 (0.1%)	3 (0.3%)
Accelerated	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Accelerated and Steered to Left	0 (0.0%)	4 (28.6%)	2 (2.0%)	30 (3.8%)	36 (3.9%)
Accelerated and Steered to Right	0 (0.0%)	0 (0.0%)	0 (0.0%)	12 (1.5%)	12 (1.3%)
Released Gas Pedal without Braking	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
Released Gas Pedal without Braking and Steered to Left	1 (7.1%)	0 (0.0%)	6 (6.1%)	14 (1.8%)	21 (2.3%)
Released Gas Pedal without Braking and Steered to Right	0 (0.0%)	0 (0.0%)	5 (5.1%)	13 (1.6%)	18 (2.0%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Unknown if Driver Attempted Any Corrective Action	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.13 V2 Attempted Avoidance Maneuvers

Table 16 shows the frequency and percentage of V2 attempted avoidance maneuvers. As the analysis of the current dataset was based largely on the occurrence of V1 triggers, many possible

V2 avoidance maneuvers were not seen. Not surprisingly, 65.9 percent of the V2 attempted avoidance maneuvers were coded as "no avoidance maneuver."

Table 16. Frequency and percentage of V2 attempted avoidance maneuvers.

V2 Attempted Avoidance Maneuver	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
No Avoidance Maneuver	1 (50.0%)	0 (0.0%)	22 (42.3%)	386 (68.1%)	409 (65.9%)
Braking (No Lockup or Lockup Unknown)	0 (0.0%)	0 (0.0%)	1 (1.9%)	19 (3.4%)	20 (3.2%)
Braking (Lockup)	0 (0.0%)	0 (0.0%)	1 (1.9%)	0 (0.0%)	1 (0.2%)
Releasing Brakes	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
Steered to Left	0 (0.0%)	0 (0.0%)	4 (7.7%)	9 (1.6%)	13 (2.1%)
Steered to Right	0 (0.0%)	0 (0.0%)	6 (11.5%)	27 (4.8%)	33 (5.3%)
Braked and Steered to Left (No Lockup or Lockup Unknown)	0 (0.0%)	0 (0.0%)	2 (3.8%)	6 (1.1%)	8 (1.3%)
Braked and Steered to Left (Lockup)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Braked and Steered to Right (No Lockup or Lockup Unknown)	0 (0.0%)	0 (0.0%)	2 (3.8%)	15 (2.6%)	17 (2.7%)
Braked and Steered to Right (Lockup)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Accelerated	0 (0.0%)	0 (0.0%)	5 (9.6%)	22 (3.9%)	27 (4.3%)
Accelerated and Steered to Left	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.4%)	8 (1.3%)
Accelerated and Steered to Right	0 (0.0%)	0 (0.0%)	5 (9.6%)	11 (1.9%)	16 (2.6%)
Other	0 (0.0%)	0 (0.0%)	1 (1.9%)	1 (0.2%)	2 (0.3%)
Unknown if Driver Attempted Any Corrective Action	1 (50.0%)	0 0.0%	3 5.8%	62 10.9%	66 10.6%
Total	**2 100.0%**	**0 0.0%**	**52 100.0%**	**567 100.0%**	**621 100.0%**

6.1.14 V1 Accident Types

Table 17 displays the frequency and percentage of V1 accident types. Accident types categorize the collisions of drivers involved in crashes. However, since most of the events in ND are not crashes but rather near-crashes or other traffic conflicts, analysts are 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 where 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 may be seen in Figure 14 and in the data directory in Appendix B.

The most frequent V1 accident types for SCEs were rear-end, striking, lead vehicle (V2) decelerating (V1 Accident Type 28, 28.4 percent); straight crossing paths, specifics unknown or other (V1 Accident Types 90–91, 13.7 percent); rear-end, striking, lead vehicle (V2) slower (V1 Accident Type 24, 9.3 percent); and same direction sideswipe, non-encroaching vehicle (V1 Accident Type 45, 9.2 percent). Half of the crashes involved an object or pedestrian/animal (V1 Accident Types 12–13). A large proportion of V1 accident types for near-crashes were same direction sideswipe, non-encroaching vehicle (V1 Accident Type 45, 21.4 percent).

Table 17. Frequency and percentage of V1 accident types.

V1 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
01-05: Right Roadside (or Lane) Departure	2 (14.3%)	7 (50.0%)	16 (16.3%)	47 (6.0%)	72 (7.9%)
06-10: Left Roadside (or Lane) Departure	2 (14.3%)	7 (50.0%)	5 (5.1%)	10 (1.3%)	24 (2.6%)
12: Stationary Object	3 (21.4%)	0 (0.0%)	14 (14.3%)	26 (3.3%)	43 (4.7%)
13: Pedestrian/Animal	4 (28.6%)	0 (0.0%)	11 (11.2%)	14 (1.8%)	29 (3.2%)
11, 14-16: Other Forward Impact (Not With Vehicle in Transport)	1 (7.1%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	4 (0.4%)
20: Rear-End, Striking, Lead Vehicle (V2) Stopped	1 (7.1%)	0 (0.0%)	5 (5.1%)	43 (5.4%)	49 (5.4%)
21-23: Rear-End, Struck, V1 Stopped	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
24: Rear-End, Striking, Lead Vehicle (V2) Slower	0 (0.0%)	0 (0.0%)	2 (2.0%)	83 (10.5%)	85 (9.3%)
25-27: Rear-End, Struck, V1 Slower	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
28: Rear-End, Striking, Lead Vehicle (V2) Decelerating	0 (0.0%)	0 (0.0%)	10 (10.2%)	250 (31.7%)	260 (28.4%)
29-31: Rear-End, Struck, V1 Decelerating	1 (7.1%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	4 (0.4%)
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%)	0 (0.0%)	0 (0.0%)

V1 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
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%)	0 (0.0%)	0 (0.0%)
45: Same Direction Sideswipe, Non-Encroaching Vehicle	0 (0.0%)	0 (0.0%)	21 (21.4%)	63 (8.0%)	84 (9.2%)
46-47: Same Direction Sideswipe, Encroaching Vehicle	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
44, 48-49: Same Direction Sideswipe, Other	0 (0.0%)	0 (0.0%)	3 (3.1%)	27 (3.4%)	30 (3.3%)
50, 64: Head-on or Opposite Direction Sideswipe, Encroaching Vehicle	0 (0.0%)	0 (0.0%)	3 (3.1%)	27 (3.4%)	30 (3.3%)
51, 65: Head-on or Opposite Direction Sideswipe, Non-encroaching Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
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%)	2 (0.3%)	2 (0.2%)
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%)	0 (0.0%)	0 (0.0%)
68, 70, 72: Turn Across Path, Turning Vehicle	0 (0.0%)	0 (0.0%)	1 (1.0%)	7 (0.9%)	8 (0.9%)
69, 71, 73: Turn Across Path, Vehicle Going Straight	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
76, 78, 80, 82: Turn into Path, Turning Vehicle	0 (0.0%)	0 (0.0%)	2 (2.0%)	14 (1.8%)	16 (1.7%)
77, 79, 81, 83: Turn into Path, Vehicle Going Straight	0 (0.0%)	0 (0.0%)	3 (3.1%)	22 (2.8%)	25 (2.7%)
74, 75, 84, 85: Other Turning Event/Role, Specifics Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
86, 88: Straight Crossing Paths, Striking Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (0.9%)	7 (0.8%)
87, 89: Straight Crossing Paths, Struck Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)

V1 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
90-91: Straight Crossing Paths, Specifics Unknown or Other	0 (0.0%)	0 (0.0%)	1 (1.0%)	124 (15.7%)	125 (13.7%)
92: Backing Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
93: Struck Vehicle, Other Vehicle Backing	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
98-99: Other or Unknown Accident Type	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.15 V2 Accident Types

Table 18 shows the frequency and percentage of V2 accident types. 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, V2 decelerating (V2 Accident Types 29–31, 41.9 percent) and rear-end, struck, V2 slower (V2 Accident Types 25–27, 13.6 percent).

Table 18. Frequency and percentage of V2 accident types.

V2 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
01-05: Right Roadside (or Lane) Departure	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%)
12: Stationary Object	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%)
11, 14-16: Other Forward Impact (Not With Vehicle in Transport)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
20: Rear-end, Striking, Lead Vehicle (V2) Stopped	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
21-23: Rear-end, Struck, V2 Stopped	1 (50.0%)	0 (0.0%)	5 (9.8%)	43 (7.6%)	49 (7.9%)
24: Rear-end, Striking, Lead Vehicle (V2) Slower	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
25-27: Rear-end, Struck, V2 Slower	0 (0.0%)	0 (0.0%)	2 (3.9%)	82 (14.5%)	84 (13.6%)

V2 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
28: Rear-end, Striking, Lead Vehicle (V2) Decelerating	1 (50.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	5 (0.8%)
29-31: Rear-end, Struck, V2 Decelerating	0 (0.0%)	0 (0.0%)	10 (19.6%)	249 (44.1%)	259 (41.9%)
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%)	0 (0.0%)	0 (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%)	0 (0.0%)	0 (0.0%)
45: Same Direction Sideswipe, Non-encroaching Vehicle	0 (0.0%)	0 (0.0%)	5 (9.8%)	31 (5.5%)	36 (5.8%)
46-47: Same Direction Sideswipe, Encroaching Vehicle	0 (0.0%)	0 (0.0%)	13 (25.5%)	46 (8.1%)	59 (9.5%)
44, 48-49: Same Direction Sideswipe, Other	0 (0.0%)	0 (0.0%)	7 (13.7%)	17 3.0%	24 (3.9%)
50, 64: Head-on or Opposite Direction Sideswipe, Encroaching Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
51, 65: Head-on or Opposite Direction Sideswipe, Non-Encroaching Vehicle	0 (0.0%)	0 (0.0%)	3 (5.9%)	27 (4.8%)	30 (4.9%)
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%)	0 (0.0%)	0 (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%)	2 (0.4%)	2 (0.3%)
68, 70, 72: Turn Across Path, Turning Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (1.1%)	6 (1.0%)
69, 71, 73: Turn Across Path, Vehicle Going Straight	0 (0.0%)	0 (0.0%)	1 (2.0%)	5 (0.9%)	6 (1.0%)
76, 78, 80, 82: Turn into Path, Turning Vehicle	0 (0.0%)	0 (0.0%)	3 (5.9%)	22 (3.9%)	25 (4.0%)

V2 Accident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
77, 79, 81, 83: Turn into Path, Vehicle Going Straight	0 (0.0%)	0 (0.0%)	2 (3.9%)	14 (2.5%)	16 (2.6%)
74, 75, 84, 85: Other Turning Event/Role, Specifics Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
86, 88: Straight Crossing Paths, Striking Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
87, 89: Straight Crossing Paths, Struck Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (1.2%)	7 (1.1%)
90-91: Straight Crossing Paths, Specifics Unknown or Other	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 (0.2%)	1 (0.2%)
93: Struck Vehicle, Other Vehicle Backing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
98-99: Other or Unknown Accident Type	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**2 (100.0%)**	**0 (100.0%)**	**51 (100.0%)**	**565 100.0%**	**618 100.0%**

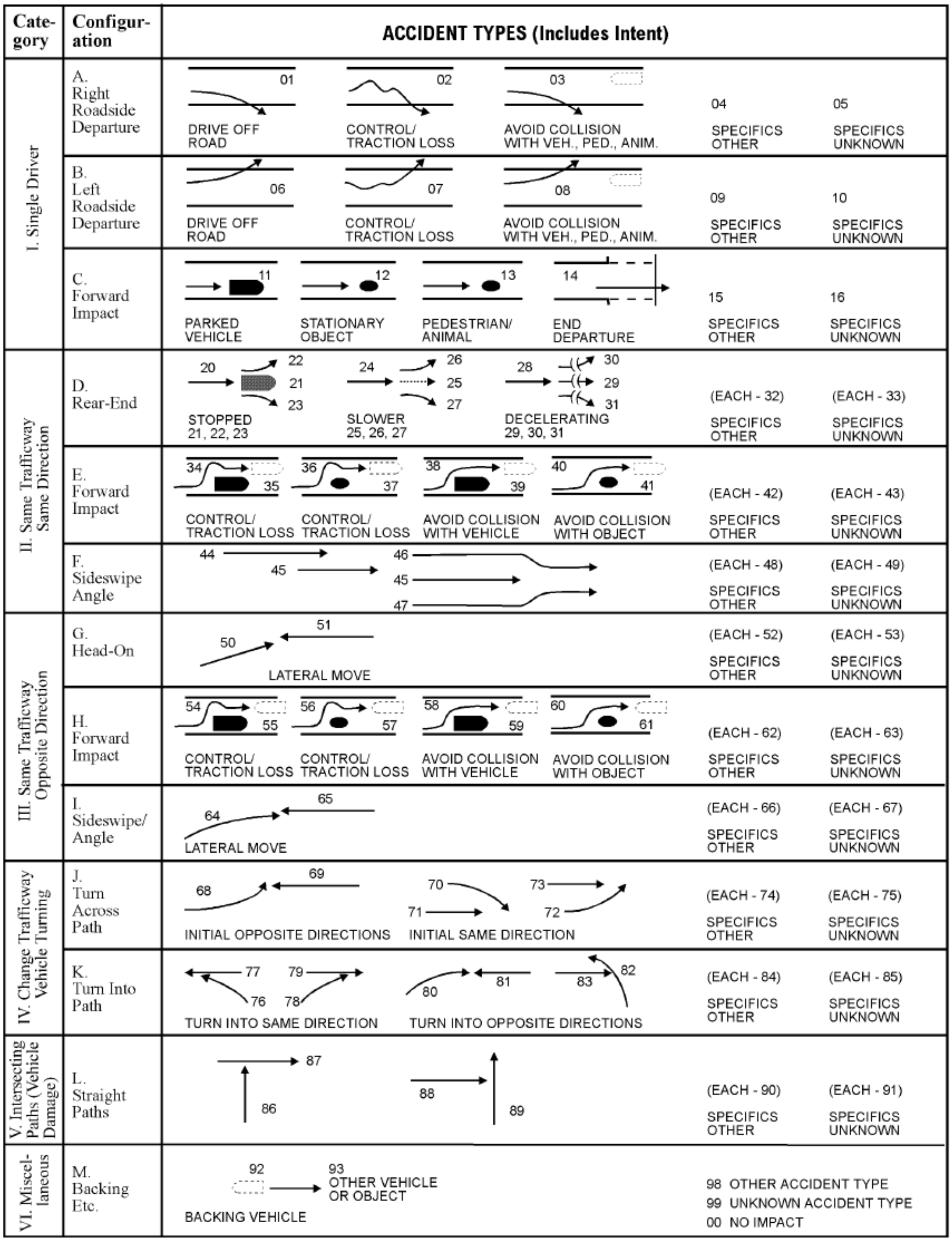

Figure 14. Chart. Description of the LTCCS accident types.

6.1.16 V1 Incident Types

Table 19 shows the frequency and percentage of V1 incident types. 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 and crash-relevant conflicts.[5] The most frequent V1 incident types for SCEs were late braking (and/or steering) for stopped/stopping traffic (V1 Incident Type 31, 25.4 percent); other single-vehicle event (V1 Incident Type 67, 19.3 percent); and close proximity to turning vehicle (V1 Incident Type 69, 9.1 percent). For the more severe SCEs, including crashes, tire strikes, and near-crashes, the V1 incident types included conflict with animal/pedestrian/pedalcyclist/object in or on side of roadway (V1 Incident Types 65–66).

Table 19. Frequency and percentage of V1 incident types.

V1 Incident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
1	0 (0.0%)	0 (0.0%)	3 (3.1%)	11 (1.4%)	14 (1.5%)
2	0 (0.0%)	0 (0.0%)	6 (6.1%)	11 (1.4%)	17 (1.9%)
5	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%)	0 (0.0%)	0 (0.0%)
7	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
8	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
9	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%)
11	0 (0.0%)	0 (0.0%)	0 (0.0%)	20 (2.5%)	20 (2.2%)
12	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (0.9%)	7 (0.8%)
13	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
14	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.0%)	8 (0.9%)
15	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%)	0 (0.0%)	0 (0.0%)
17	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
18	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
19	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
20	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
21	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
22	0 (0.0%)	0 (0.0%)	2 (2.0%)	0 (0.0%)	2 (0.2%)
23	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.8%)	6 (0.7%)
24	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%)	1 (0.1%)	1 (0.1%)
26	0 (0.0%)	0 (0.0%)	10 (10.2%)	34 (4.3%)	44 (4.8%)
27	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.8%)	6 (0.7%)
28	0 (0.0%)	0 (0.0%)	5 (5.1%)	10 (1.3%)	15 (1.6%)
29	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.4%)	4 (0.4%)
30	1 (7.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
31	1 (7.1%)	0 (0.0%)	12 (12.2%)	219 (27.8%)	232 (25.4%)
32	0 (0.0%)	0 (0.0%)	2 (2.0%)	18 (2.3%)	20 (2.2%)
33	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
34	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)

V1 Incident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
35	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)
36	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%)	1 (0.1%)	1 (0.1%)
38	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 (0.3%)	2 (0.2%)
40	0 (0.0%)	0 (0.0%)	1 (1.0%)	9 (1.1%)	10 (1.1%)
41	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42	0 (0.0%)	0 (0.0%)	0 (0.0%)	13 (1.6%)	13 (1.4%)
43	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%)
45	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
46	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
47	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
48	0 (0.0%)	0 (0.0%)	0 (0.0%)	35 (4.4%)	35 (3.8%)
49	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
50	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
51	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%)	0 (0.0%)	0 (0.0%)
53	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
54	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
56	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
57	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.4%)	4 (0.4%)
58	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
59	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%)	5 (0.6%)	5 (0.5%)
61	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
62	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
63	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
64	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (0.9%)	7 (0.8%)
65	7 (50.0%)	2 (14.3%)	22 (22.4%)	36 (4.6%)	67 (7.3%)
66	4 (28.6%)	4 (28.6%)	13 (13.3%)	30 (3.8%)	51 (5.6%)
67	1 (7.1%)	8 (57.1%)	12 (12.2%)	156 (19.8%)	177 (19.3%)
68	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 0.4%)	3 0.3%)
69	0 (0.0%)	0 (0.0%)	2 (2.0%)	81 (10.3%)	83 (9.1%)
70	0 (0.0%)	0 (0.0%)	1 (1.0%)	5 (0.6%)	6 (0.7%)
71	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
72	0 (0.0%)	0 0.0%	2 (2.0%)	2 (0.3%)	4 (0.4%)
73	0 (0.0%)	0 0.0%	0 (0.0%)	1 (0.1%)	1 (0.1%)
99	0 (0.0%)	0 0.0%	1 (1.0%)	1 (0.1%)	2 (0.2%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.17 V2 Incident Types

Table 20 shows the frequency and percentage of V2 incident types. Not including the single-vehicle events, the most frequent V2 incident types for SCEs were late braking (and/or steering) for stopped/stopping traffic (V2 Incident Type 30, 37.4 percent) and close proximity to turning vehicle (V2 Incident Type 68, 13.4 percent).

Table 20. Frequency and percentage of V2 incident types.

V2 Incident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
1	0 (0.0%)	0 (0.0%)	6 (11.8%)	11 (1.9%)	17 (2.7%)
2	0 (0.0%)	0 (0.0%)	3 (5.9%)	11 (1.9%)	14 (2.3%)
5	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%)	0 (0.0%)	0 (0.0%)
7	0(0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
8	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
9	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%)
11	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (1.2%)	7 (1.1%)
12	0 (0.0%)	0 (0.0%)	0 (0.0%)	20 (3.5%)	20 (3.2%)
13	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.4%)	8 (1.3%)
14	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
15	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%)	0 (0.0%)	0 (0.0%)
17	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
18	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
19	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
20	0\ (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
21	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
22	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
23	0 (0.0%)	0 (0.0%)	2 (3.9%)	0 (0.0%)	2 (0.3%)
24	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
25	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%)	6 (1.1%)	6 (1.0%)
27	0 (0.0%)	0 (0.0%)	10 (19.6%)	34 (6.0%)	44 (7.1%)
28	0 (0.0%)	0 (0.0%)	1 (2.0%)	3 (0.5%)	4 (0.6%)
29	0 (0.0%)	0 (0.0%)	5 (9.8%)	10 (1.8%)	15 (2.4%)
30	1 (50.0%)	0 (0.0%)	12 (23.5%)	219 (38.6%)	232 (37.4%)
31	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)
32	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
33	0 (0.0%)	0 (0.0%)	2 (3.9%)	18 (3.2%)	20 (3.2%)
34	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	5 (0.8%)
35	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	5 (0.8%)
36	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
37	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
38	0 (0.0%)	0 (0.0%)	1 (2.0%)	1 (0.2%)	2 (0.3%)
39	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (1.6%)	9 (1.5%)
40	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
41	0 (0.0%)	0 (0.0%)	0 (0.0%)	13 (2.3%)	13 (2.1%)
42	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
43	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V2 Incident Type	Crashes (Percentage)	Crashes: Tire Strikes (Percentage)	Near-crashes (Percentage)	Crash-relevant Conflicts (Percentage)	Total SCEs (Percentage)
44	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%)	1 (0.2%)	1 (0.2%)
46	0 (0.0%)	0 (0.0%)	1 (2.0%)	4 (0.7%)	5 (0.8%)
47	0 (0.0%)	0 (0.0%)	0 (0.0%)	35 (6.2%)	35 (5.6%)
48	0 (0.0%)	0 (0.0%)	0 (0.0%	1 (0.2%)	1 (0.2%)
49	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
50	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
51	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
52	0 (0.0%)	0 (0.0%)	1 (2.0%)	2 (0.4%)	3 (0.5%)
53	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
54	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
56	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
57	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
58	0 (0.0%)	0 (0.0%)	1 (2.0%)	2 (0.4%)	3 (0.5%)
59	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	5 (0.8%)
60	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%)	0 (0.0%)	0 (0.0%)
62	0 (0.0%)	0 (0.0%)	0 (0.0%0	0 (0.0%)	0 (0.0%)
63	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (1.2%)	7 (1.1%)
64	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
65	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%)
67	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
68	0 (0.0%)	0 (0.0%)	2 (3.9%)	81 (14.3%)	83 (13.4%)
69	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
70	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
71	0 (0.0%)	0 (0.0%)	1 (2.0%)	5 (0.9%)	6 (1.0%)
72	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
73	0 (0.0%)	0 (0.0%)	2 (3.9%)	2 (0.4%)	4 (0.6%)
99	0 (0.0%)	0 (0.0%)	1 (2.0%)	1 (0.2%)	2 (0.3%)
Total	**2 (100.0%)**	**0 (0.0%)**	**51 (100.0%)**	**567 (100.0%)**	**620 (100.0%)**

Table 21 contains the descriptions of SCEs.

Table 21. Description of incident types.

Incident Type	Description
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
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.

Incident Type	Description
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.

Incident Type	Description
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.
68–69: 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.

6.1.18 Driver Wearing Safety Belt

Table 22 displays the frequency and percentage of V1 driver safety belt use for crashes, tire strikes, near-crashes, crash-relevant conflicts, SCEs, and baseline epochs. This is one of a number of variables in the dataset for which data were collected for a random sample of baseline epochs as well as for SCEs. The percentage of V1 drivers who were wearing their safety belts during SCEs (55.1 percent) was similar to the number in baseline epochs (58.3 percent). The percentages were lower during near-crashes (51 percent), tire strikes (21.4 percent), and crashes (42.9 percent). However, a chi-square based on (3 Safety Belt Codes) times (Total SCEs plus Baseline Epoch) did not show any significant differences ($x^2_{(8)} = 12.386$, $p > .05$).

Table 22. Frequency and percentage of safety belt use for V1 drivers.

V1 Driver Wearing Safety Belt	Crashes	Crash: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Yes	6 (42.9%)	3 (21.4%)	50 (51.0%)	445 (56.4%)	504 (55.1%)	625 (58.3%)
No	8 (57.1%)	11 (78.6%)	48 (49.0%)	342 (43.3%)	409 (44.7%)	444 (41.4%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)	3 (0.3%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.19 V1 "Vision-obscured-by" Codes

Table 23 shows the frequency and percentage of "vision-obscured-by" codes, a variable which was coded for V1 only. The majority of SCEs did not involve a visual obstruction. When a visual obstruction was present, it typically involved rain, snow, fog, smoke, sand, dust, or glare.

Table 23. Frequency and percentage of "vision-obscured-by" for V1 drivers.

V1 Driver Vision Obscured by:	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
No Obstruction	10 (71.4%)	13 (92.9%)	90 (91.8%)	705 (89.4%)	818 (89.4%)
Rain, Snow, Fog, Smoke, Sand, Dust	2 (14.3%)	0 (0.0%)	3 (3.1%)	28 (3.5%)	33 (3.6%)
Reflected Glare, Sunlight, Headlights	2 (14.3%)	0 (0.0%)	2 (2.0%)	28 (3.5%)	32 (3.5%)
Curve or Hill	0 (0.0%)	1 (7.1%)	0 (0.0%)	8 (1.0%)	9 (1.0%)
Building, Billboard, or Other Design Features (Includes Signs, Embankments)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Trees, Crops, Vegetation	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Moving Vehicle (Including Load)	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
Parked Vehicle	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
Splash or Spray of Passing Vehicle	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%)
Inadequate Lighting System (Includes Vehicle/Object in Dark Area)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Obstruction Inside Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mirrors	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%)

V1 Driver Vision Obscured by:	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Broken or Improperly Cleaned Windshield	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
Other Vehicle or Object in Blind Spot	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
Vision Obscured—No Details	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%)	1 (0.1%)	1 (0.1%)
Unknown Whether Vision Was Obstructed	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.0%)	8 (0.9%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**

6.1.20 V1 Potential Distractions

Table 24 shows the frequency and percentage of potential distractions for the V1 driver. Data reductionists were instructed to code up to four potential distractions observed during 10 seconds prior to the max/min trigger value or during the final 10 seconds of the baseline epoch. 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 those 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 (34.8 percent), look at right-side mirror/out right-side window (25.1 percent), and look down at lap, floor, etc. (15 percent). These were surprisingly similar to the baseline epochs. Given the similarity of potential distractions between SCEs and baseline epochs, one might conclude that engaging in a distraction does not increase a drivers' risk of being involved in a SCE. However, perhaps a more appropriate explanation for the results relates to 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 this dataset, it appeared that drivers engage in many potentially distracting events but the occurrence of these events did not necessarily predict event involvement. This is an area for possible 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, and how best to capture these to quantify risk associated with various potentially distracting behaviors.

Table 24. Frequency and percentage of potential distractions for V1 drivers.

V1 Driver Potential Distractions	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
None Observed	1 (7.1%)	6 (42.9%)	8 (8.2%)	101 (12.8%)	116 (12.7%)	107 (10.0%)
Looked but Did Not See	0 (0.0%)	0 (0.0%)	2 (2.0%)	31 (3.9%)	33 (3.6%)	0 (0.0%)
Interact with or Look at Other Occupant(s)	0 (0.0%)	0 (0.0%)	2 (2.0%	8 (1.0%)	10 (1.1%)	21 (2.0%)

V1 Driver Potential Distractions	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Interact with or Look at Pet in Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Look at/for Object in Vehicle	0 (0.0%)	0 (0.0%)	9 (9.2%)	54 (6.8%)	63 (6.9%)	139 (13.0%)
Reach for Object in Vehicle	2 (14.3%)	0 (0.0%)	11 (11.2%)	72 (9.1%)	85 (9.3%)	81 (7.6%)
Talk/Listen to Hand-held Phone	0 (0.0%)	0 (0.0%)	3 (3.1%)	26 (3.3%)	29 (3.2%)	29 (2.7%)
Talk/Listen to Hands-free Phone	0 (0.0%)	0 (0.0%)	2 (2.0%)	23 (2.9%)	25 (2.7%)	53 (4.9%)
Talk/Listen to CB Radio or Other Device	1 (7.1%)	0 (0.0%)	1 (1.0%)	9 (1.1%)	11 (1.2%)	41 (3.8%)
Dial Hand-held Phone	0 (0.0%)	0 (0.0%)	1 (1.0%)	7 (0.9%)	8 (0.9%)	4 (0.4%)
Dial Hands-free Phone	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.3%)
Operate Personal Digital Device (PDA) (Inputting or Reading)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Adjust Instrument Panel (Includes Climate Control, Radio, CD)	0 (0.0%)	0 (0.0%)	0 (0.0%)	13 (1.6%)	13 (1.4%)	16 (1.5%)
Look at Left-side Mirror/out Left-side Window	7 (50.0%)	0 (0.0%)	42 (42.9%)	269 (34.1%)	318 (34.8%)	463 (43.2%)
Look at Right-Side Mirror/out Right-side Window	5 (35.7%)	8 (57.1%)	27 (27.6%)	190 (24.1%)	230 (25.1%)	210 (19.6%)
Look in Sleeper Berth	1 (7.1%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	6 (0.7%)	4 (0.4%)
Shift Gears	0 (0.0%)	2 (14.3%)	3 (3.1%)	29 (3.7%)	34 (3.7%)	4 (0.4%)
Look Down (at Lap, Floor, etc.)	1 (7.1%)	0 (0.0%)	21 (21.4%)	115 (14.6%)	137 (15.0%0)	122 (11.4%)
Use/Reach Other Device	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)	2 (0.2%)
Appears Drowsy, Sleepy, Asleep, Fatigued	3 (21.4%)	0 (0.0%)	19 (19.4%)	142 (18.0%)	164 (17.9%	211 (19.7%)
Look at Previous Crash or Highway Incident	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Look at Construction Zone Signs, Barriers, Flag Person, etc.	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)	0 (0.0%)
Look at Outside Person	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)	0 (0.0%)
Look at Undetermined Outside Event, Person, or Object	3 (21.4%)	0 (0.0%)	5 (5.1%)	64 (8.1%)	72 (7.9%)	49 (4.6%)
Eat with Utensil	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Eat without Utensil (Includes Chewing, Other Than Gum; e.g., Toothpick)	0 (0.0%)	0 (0.0%)	3 (3.1%)	25 (3.2%)	28 (3.1%)	46 (4.3%)
Drink from Covered Container (e.g., with Straw)	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)	6 (0.6%)

V1 Driver Potential Distractions	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Drink from Open Container	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	13 (1.2%)
Chewing Gum	2 (14.3%)	1 (7.1%)	10 (10.2%)	54 (6.8%)	67 (7.3%)	83 (7.7%)
Smoking-related Behavior—Reaching, Lighting, Extinguishing	1 (7.1%)	0 (0.0%)	2 (2.0%)	6 (0.8%)	9 (1.0%)	10 (0.9%)
Smoking-related Behavior—Other (e.g., Cigarette in Hand/Mouth)	1 (7.1%)	0 (0.0%)	2 (2.0%)	34 (4.3%)	37 (4.0%)	66 (6.2%)
Read Book, Newspaper, etc.	0 (0.0%)	0 (0.0%)	3 (3.1%)	3 (0.4%)	6 (0.7%)	8 (0.7%)
Read/Look at Map	0 (0.0%)	1 (7.1%)	1 (1.0%)	7 (0.9%)	9 (1.0%)	6 (0.6%)
Write in Notebook, etc.	0 (0.0%)	0 (0.0%)	1 (1.0%)	1 (0.1%)	2 (0.2%)	1 (0.1%)
Talk/Sing/Dance with No Indication of Passenger	0 (0.0%)	0 (0.0%)	9 (9.2%)	53 (6.7%)	62 (6.8%)	49 (4.6%)
Handle/Interact with Dispatching, Electronic Recording, or Navigational Device	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	1 (0.1%)
Read/Look at Dispatching, Electronic Recording, or Navigational Device	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)	11 (1.0%)
Comb/Brush/Fix Hair	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Apply Make-up	0 (0.0%0	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Shave	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Brush/Floss Teeth	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Bite Nails/Cuticles	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)	15 (1.4%)
Remove/Adjust Jewelry	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.3%)
Remove/Insert Contact Lenses	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Other Personal Hygiene	1 (7.1%)	0 (0.0%)	7 (7.1%)	83 (10.5%)	91 (9.9%)	128 (11.9%)
Put on/Remove/Adjust Sunglasses	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)	3 (0.3%)
Put on/Remove/Adjust Hat	1 (7.1%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	4 (0.4%)	4 (0.4%)
Put on/Remove/Adjust Seatbelt	0 (0.0%)	1 (7.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Look at/Handle DFM	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (0.9%)	7 (0.8%)	12 (1.1%)

V1 Driver Potential Distractions	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Look at/Handle DAS	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%)	3 (3.1%)	9 (1.1%)	12 (1.3%)	32 (3.0%)
Total	**30 (214.3%)**	**19 (135.7%)**	**199 (203.1%)**	**1,467 (185.9%)**	**1,715 (187.4%)**	**2,058 (192.0%)**
SCE Total	***14 (100%)***	***14 (100%)***	***98 (100%)***	***789 (100%)***	***915 (100%)***	***1,071 (100%)***

6.1.21 V1 Driver Actions/Factors/Behaviors

Table 25 displays the frequency and percentage of V1 driver actions/factors/behaviors. Data reductionists coded up to four V1 items believed to have relevance 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 driver actions/factors/behaviors for SCEs were inattentive or distracted (39.6 percent), excessive braking/deceleration creating potential hazard (25.6 percent), drowsy, sleepy, asleep, fatigued, other reduced alertness (14.2 percent), and inadequate evasive action (14.1 percent). Not surprisingly, almost all of the tire strikes (85.7 percent) involved some type of improper turn. More than a quarter (28.6 percent) of the crashes were coded as the V1 driver being unfamiliar with the roadway. More than half of the near-crashes (55.1 percent) involved the V1 driver avoiding an object, pedestrian, animal, or other vehicle.

Table 25. Frequency and percentage of V1 driver actions/factors/behaviors.

V1 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
None Observed	0 (0.0%)	0 (0.0%)	6 (6.1%)	94 (11.9%)	100 (10.9%)
Apparent Excessive Speed for Conditions or Location (Does Not Include Tailgating, Unless Above Speed Limit)	1 (7.1%)	0 (0.0%)	4 (4.1%)	33 (4.2%)	38 (4.2%)
Drowsy, Sleepy, Asleep, Fatigued, Other Reduced Alertness	3 (21.4%)	0 (0.0%)	19 (19.4%)	108 (13.7%)	130 (14.2%)
Angry	0 (0.0%)	0 (0.0%)	4 (4.1%)	26 (3.3%)	30 (3.3%)
Other Emotional State	0 (0.0%)	0 (0.0%)	1 (1.0%)	5 (0.6%)	6 (0.7%)
Inattentive or Distracted	5 (35.7%)	1 (7.1%)	44 (44.9%)	312 (39.5%)	362 (39.6%)
Driving Slowly; Below Speed Limit or in Relation to Other Traffic	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Illegal Passing (i.e., Across Double Line)	0 (0.0%)	0 (0.0%)	0 (0.0%)	32 (4.1%)	32 (3.5%)

V1 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Passing on Right	0 (0.0%)	0 (0.0%)	0 (0.0%)	20 (2.5%)	20 (2.2%)
Other Improper or Unsafe Passing	0 (0.0%)	0 (0.0%)	1 (1.0%)	37 (4.7%)	38 (4.2%)
Cutting in Too Close in Front of Other Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (1.0%)	8 (0.9%)
Cutting in at Safe Distance but Then Decelerated, Causing Conflict	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Cutting in Too Close Behind Other Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	11 (1.4%)	11 (1.2%)
Making Turn From Wrong Lane (e.g., Across Lanes)	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
Did Not See Other Vehicle During Lane Change or Merge	0 (0.0%)	0 (0.0%)	6 (6.1%)	13 (1.6%)	19 (2.1%)
Aggressive Driving, Specific, Directed Menacing Actions	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
Aggressive Driving, Other	0 (0.0%)	0 (0.0%)	2 (2.0%)	5 (0.6%)	7 (0.8%)
Wrong Side of Road, Not Overtaking (Includes Partial or Full Drift into Oncoming Lane)	0 (0.0%)	0 (0.0%)	3 (3.1%)	36 (4.6%)	39 (4.3%)
Following Too Close	0 (0.0%)	0 (0.0%)	3 (3.1%)	55 (7.0%)	58 (6.3%)
Inadequate Evasive Action	0 (0.0%)	0 (0.0%)	6 (6.1%)	123 (15.6%)	129 (14.1%)
Failed to Signal, or Improper Signal	0 (0.0%)	0 (0.0%)	2 (2.0%)	7 (0.9%)	9 (1.0%)
Improper Turn: Wide Tight Turn	0 (0.0%)	6 (42.9%)	1 (1.0%)	11 (1.4%)	18 (2.0%)
Improper Turn: Cut Corner on Left Turn	1 (7.1%)	1 (7.1%)	3 (3.1%)	1 (0.1%)	6 (0.7%)
Other Improper Turning	1 (7.1%)	5 (35.7%)	4 (4.1%)	7 (0.9%)	17 (1.9%)
Improper Backing, Did Not See	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Improper Backing, Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Improper Start From Parked Position	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Disregarded Officer or Watchman	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Signal Violation, Apparently Did Not See Signal	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Signal Violation, Intentionally Ran Red Light	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Signal Violation, Tried to Beat Signal Change	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Stop Sign Violation, Apparently Did Not See Stop Sign	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V1 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Stop Sign Violation, Intentionally Ran Stop Sign at Speed	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Stop Sign Violation, Rolling Stop	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Other Sign (e.g., Yield) Violation, Apparently Did Not See Sign	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Other Sign (e.g., Yield) Violation, Intentionally Disregarded	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Other Sign Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-signed Crossing Violation (e.g., Driveway Entering Roadway)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Right-of-way Error in Relation to Other Vehicle or Person, Apparent Recognition Failure	0 (0.0%)	0 (0.0%)	3 (3.1%)	14 (1.8%)	17 (1.9%)
Right-of-way Error in Relation to Other Vehicle or Person, Apparent Decision Failure	0 (0.0%)	0 (0.0%)	1 (1.0%)	10 (1.3%)	11 (1.2%)
Right-of-way Error in Relation to Other Vehicle or Person, Other or Unknown Cause	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)
Sudden or Improper Stopping on Roadway	0 (0.0%)	0 (0.0%)	1 (1.0%)	11 (1.4%)	12 (1.3%)
Parking in Improper or Dangerous Location (e.g., Shoulder)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Speeding or Other Unsafe Actions in Work Zone	1 (7.1%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	6 (0.7%)
Failure to Dim Headlights	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Driving without Lights or Insufficient Lights	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Avoiding Pedestrian	0 (0.0%)	0 (0.0%)	3 (3.1%)	2 (0.3%)	5 (0.5%)
Avoiding Other Vehicle	1 (7.1%)	0 (0.0%)	26 (26.5%)	60 (7.6%)	87 (9.5%)
Avoiding Animal	0 (0.0%)	0 (0.0%)	7 (7.1%)	8 (1.0%)	15 (1.6%)
Avoiding Object	1 (7.1%)	3 (21.4%)	18 (18.4%)	26 (3.3%)	48 (5.2%)
Apparent Unfamiliarity with Roadway	4 (28.6%)	1 (7.1%)	4 (4.1%)	29 (3.7%)	38 (4.2%)
Apparent Unfamiliarity with Vehicle (e.g., Displays and Controls)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Use of Cruise Control Contributed to Late Braking (Does Not Imply Malfunction of Cruise Control System)	1 (7.1%)	0 (0.0%)	1 (1.0%)	23 (2.9%)	25 (2.7%)
Excessive Braking/Deceleration Creating Potential Hazard	0 (0.0%)	0 (0.0%)	18 (18.4%)	216 (27.4%)	234 (25.6%)
Loss of Control on Slippery Road Surface	0 (0.0%)	0 (0.0%)	1 (1.0%)	2 (0.3%)	3 (0.3%)
Loss of Control on Dry (or Unknown) Surface	0 (0.0%)	0 (0.0%)	1 (1.0%)	7 (0.9%)	8 (0.9%)

V1 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Apparent Vehicle Failure (e.g., Bakes)	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%)	4 (0.5%)	4 (0.4%)
Total	**19 (135.7%)**	**17 (121.4%)**	**195 (199.0%)**	**1,378 (174.7%)**	**1,609 (175.8%)**
SCE Total	***14 (100%)***	***14 (100%)***	***98 (100%)***	***789 (100%)***	***915 (100%)***

6.1.22 V2 Driver Actions/Factors/Behaviors

Table 26 shows the frequency and percentage of V2 driver actions/factors/behaviors. 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 action/factor/behavior was observed, the most frequent driver actions/factors/behaviors for SCEs were excessive braking/deceleration creating potential hazard (11.3 percent), cutting in, too close in front of other vehicle (10.1 percent), right-of-way error in relation to other vehicle or person (6.8 percent), and driving slowly; below speed limit or in relation to other traffic (6.6 percent).

Table 26. Frequency and percentage of V2 driver actions/factors/behaviors.

V2 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
None Observed	1 (50.0%)	0 (0.0%)	15 (17.4%)	226 (34.4%)	242 (32.5%)
Apparent Excessive Speed for Conditions or Location (Does Not Include Tailgating, Unless Above Speed Limit)	0 (0.0%)	0 (0.0%)	1 (1.2%)	1 (0.2%)	2 (0.3%)
Vehicle "Drift" or "Slow Weave" Consistent with Possible Drowsy/Distracted Driving	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (1.4%)	9 (1.2%)
Erratic Steering, Weaving, Lane Break, or Other Vehicle Motion Consistent with Possible Alcohol-impaired Driving	0 (0.0%)	0 (0.0%)	4 (4.7%)	0 (0.0%)	4 (0.5%)
Driving Slowly; Below Speed Limit or in Relation to Other Traffic	0 (0.0%)	0 (0.0%)	4 (4.7%)	45 (6.8%)	49 (6.6%)
Illegal Passing (i.e., Across Double Line)	0 (0.0%)	0 (0.0%)	1 (1.2%)	2 (0.3%)	3 (0.4%)
Passing on Right	0 (0.0%)	0 (0.0%)	1 (1.2%)	9 (1.4%)	10 (1.3%)
Other Improper or Unsafe Passing	0 (0.0%)	0 (0.0%)	3 (3.5%)	14 (2.1%)	17 (2.3%)

V2 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Cutting in Too Close in Front of Other Vehicle	0 (0.0%)	0 (0.0%)	13 (15.1%)	62 (9.4%)	75 (10.1%)
Cutting in at Safe Distance but Then Decelerated, Causing Conflict	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (1.5%)	10 (1.3%)
Cutting in Too Close Behind Other Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.6%)	4 (0.5%)
Making Turn from Wrong Lane (e.g., Across Lanes)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.6%)	4 (0.5%)
Did Not See Other Vehicle During Lane Change or Merge	0 (0.0%)	0 (0.0%)	8 (9.3%)	14 (2.1%)	22 (3.0%)
Driving in Other Vehicle's Blind Zone	0 (0.0%)	0 (0.0%)	1 (1.2%)	0 (0.0%)	1 (0.1%)
Aggressive Driving, Specific, Directed Menacing Actions	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Aggressive Driving, Other	0 (0.0%)	0 (0.0%)	5 (5.8%)	8 (1.2%)	13 (1.7%)
Wrong Side of Road, Not Overtaking (Includes Partial or Full Drift into Oncoming Lane)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (1.4%)	9 (1.2%)
Following Too Close	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.3%)
Inadequate Evasive Action	0 (0.0%)	0 (0.0%)	1 (1.2%)	9 (1.4%)	10 (1.3%)
Failed to Signal, or Improper Signal	0 (0.0%)	0 (0.0%)	4 (4.7%)	31 (4.7%)	35 (4.7%)
Improper Turn: Wide Right Turn	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.8%)	5 (0.7%)
Improper Turn: Cut Corner on Left Turn	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Other Improper Turning	0 (0.0%)	0 (0.0%)	2 (2.3%)	12 (1.8%)	14 (1.9%)
Improper Backing, Apparently Did Not See	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Improper Backing, Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Improper Start From Parked Position	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Disregarded Officer or Watchman	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Signal Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Signal Violation, Tried to Beat Signal Change	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Stop Sign Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Stop Sign Violation, Rolling Stop	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V2 Driver Actions/Factors/ Behaviors	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
Other Sign (e.g., Yield) Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Other Sign Violation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Non-signed Crossing Violation (e.g., Driveway Entering Roadway)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Right-of-way Error in Relation to Other Vehicle or Person	0 (0.0%)	0 (0.0%)	7 (8.1%)	44 (6.7%)	51 (6.8%)
Sudden or Improper Stopping on Roadway	0 (0.0%)	0 (0.0%)	1 (1.2%)	9 (1.4%)	10 (1.3%)
Parking in Improper or Dangerous Location (e.g., Shoulder)	0 (0.0%)	0 (0.0%)	0 (0.0%)	11 (1.7%)	11 (1.5%)
Speeding or Other Unsafe Actions in Work Zone	0 (0.0%)	0 (0.0%)	1 (1.2%)	0 (0.0%)	1 (0.1%)
Failure to Dim Headlights	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Driving without Lights or Insufficient Lights	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.3%)
Avoiding Pedestrian	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Avoiding Other Vehicle	0 (0.0%)	0 (0.0%)	9 (10.5%)	19 (2.9%)	28 (3.8%)
Avoiding Animal	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Avoiding Object	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Excessive Braking/Deceleration Creating Potential Hazard	0 (0.0%)	0 (0.0%)	4 (4.7%)	80 (12.2%)	84 (11.3%)
Loss of Control on Slippery Road Surface	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.1%)
Loss of Control on Dry (or Unknown) Surface	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Apparent Vehicle Failure (e.g., Brakes)	0 (0.0%)	0 (0.0%)	1 (1.2%)	2 (0.3%)	3 (0.4%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.8%)	5 (0.7%)
Unknown	1 (50.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	3 (0.4%)
Total	**2 (100.0%)**	**0 (0.0%)**	**86 (100.0%)**	**657 (100.0%)**	**745 (100.0%)**
SCE Total	***14 (100%)***	***14 (100%)***	***98 (100%)***	***789 (100%)***	***915 (100%)***

6.1.23 Light Condition

Table 27 displays the frequency and percentage of light conditions. Most of the SCEs occurred during the daylight (73.4 percent) or dark (17.9 percent). While this was also true for baseline epochs, the distribution was somewhat different (56.1 percent occurred during the daylight, and 37.5 percent occurred during the dark). A chi-square based on (5 Light Conditions) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(4)} = 101.24$, $p < 0.05$).

Adjusted standardized residuals that are ≤ –2 or ≥ 2 indicate a significant difference between the observed and expected count. The adjusted standardized residuals showed the observed frequency of SCEs during the daylight and during dark but lighted conditions were more than expected (i.e., more SCEs occurred during the daylight and dark but lighted conditions than expected given the distribution of data). The converse was true for baseline epochs that occurred during the daylight and dark but lighted conditions.

Table 27. Frequency and percentage of light conditions.

Light Condition	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Daylight	10 (71.4%)	10 (71.4%)	64 (65.3%)	588 (74.5%)	672 (73.4%)	605 (56.4%)
Dark	3 (21.4%)	3 (21.4%)	21 (21.4%)	137 (17.4%)	164 (17.9%)	402 (37.5%)
Dark but Lighted	1 (7.1%)	1 (7.1%)	13 (13.3%)	46 (5.8%)	61 (6.7%)	38 (3.5%)
Dawn	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (0.9%)	7 (0.8%)	15 (1.4%)
Dusk	0 (0.0%)	0 (0.0%)	0 (0.0%)	11 (1.4%)	11 (1.2%)	12 (1.1%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.24 Weather Conditions

Table 28 shows the frequency and percentage of weather conditions. Almost all the SCEs (93.9 percent) occurred when there were no adverse weather conditions. An almost identical percentage of baseline epochs (92.8 percent) occurred during no adverse weather conditions. While a slightly higher percentage of crashes (14.3 percent) occurred in the rain as compared to baseline epochs (6.4 percent), a chi-square based on (8 Weather Conditions) times (Total SCEs plus Baseline Epoch) did not show a significant difference ($x^2_{(7)} = 3.297$, $p > 0.05$).

Table 28. Frequency and percentage of weather conditions

Weather	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
No Adverse Conditions	11 (78.6%)	14 (100.0%)	91 (92.9%)	743 (94.2%)	859 (93.9%)	995 (92.8%)
Rain	2 (14.3%)	0 (0.0%)	7 (7.1%)	38 (4.8%)	47 (5.1%)	69 (6.4%)
Sleet	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	1 (0.1%)

Weather	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Snow	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)	3 (0.3%)
Fog	1 (7.1%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	3 (0.3%)	2 (0.2%)
Rain and Fog	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)	1 (0.1%)
Sleet and Fog	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%)	1 (0.1%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.25 Roadway Surface Conditions

Table 29 shows the frequency and percentage of roadway surface conditions. Almost all the SCEs (91.8 percent) and baseline epochs (90.4 percent) occurred when the roadway was dry. While a higher percentage of crashes (21.4 percent) occurred when the roadway was wet compared to the baseline epochs (9.1 percent), a chi-square based on (6 Roadway Surface Conditions) times (Total SCEs plus Baseline Epoch) did not show a significant difference ($x^2_{(5)}$ = 3.966, $p > 0.05$).

Table 29. Frequency and percentage of roadway surface conditions.

Roadway Surface	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Dry	11 (78.6%)	14 (100.0%)	89 (90.8%)	726 (92.0%)	840 (91.8%)	969 (90.4%)
Wet	3 (21.4%)	0 (0.0%)	9 (9.2%)	57 (7.2%)	69 (7.5%)	98 (9.1%)
Snow or Slush	0 (0.0%	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)	5 (0.5%)
Ice	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%)	1 (0.1%)	1 (0.1%)	0 (0.0%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.26 Relation-to-junction

Table 30 shows the frequency and percentage of relation-to-junction codes. Most of the SCEs occurred in a non-junction (51.9 percent), intersection-related (30.3 percent), or entrance/exit ramp (11.1 percent). Over half of the tire strikes (57.1 percent) and 14.3 percent of the crashes occurred in a parking lot. A chi-square based on (10 Relation-to-Junction Codes) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(9)}$ = 589.855, $p < 0.05$).

The adjusted standardized residuals showed that the observed frequency of SCEs that occurred on non-junctions was less than expected. More SCEs than expected occurred for the following: intersection, intersection-related, parking lot, entrance/exit ramp, rail grade crossing, and “other.” These results suggest that non-junctions were relatively low risk areas but that other types of locations with more traffic activity or potential conflicts were associated with increased risk.

Table 30. Frequency and percentage of relation-to-junction codes.

Relation-to-junction	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Non-junction	11 (78.6%)	2 (14.3%)	57 (58.2%)	405 (51.3%)	475 (51.9%)	1048 (97.8%)
Intersection	0 (0.0%)	8 (57.1%)	2 (2.0%)	20 (2.5%)	30 (3.3%)	5 (0.5%)
Intersection-related	1 (7.1%)	3 (21.4%)	15 (15.3%)	258 (32.7%)	277 (30.3%)	3 (0.3%)
Driveway	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	2 (0.2%)	0 (0.0%)
Parking Lot	2 (14.3%)	1 (7.1%)	5 (5.1%)	2 (0.3%)	10 (1.1%)	0 (0.0%)
Entrance/Exit Ramp	0 (0.0%)	0 (0.0%)	15 (15.3%)	87 (11.0%)	102 (11.1%)	13 (1.2%)
Rail Grade Crossing	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.6%)	5 (0.5%)	0 (0.0%)
On a Bridge	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)	2 (0.2%)
Crossover-related	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)	1 (0.1%)
Other	0 (0.0%)	0 (0.0%)	3 (3.1%)	6 (0.8%)	9 (1.0%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.27 Trafficway Flow

Table 31 displays the frequency and percentage of trafficway flow codes. Most of the SCEs occurred on a divided trafficway (61.1 percent), while 28.8 percent occurred on a road that was not physically divided. A higher percentage of baseline epochs occurred on a divided trafficway (89.5 percent). A chi-square based on (5 Trafficway Flow Codes) times (Total SCEs plus Baseline Epoch) showed a significant difference
($x^2_{(4)} = 222.441$, $p < 0.05$).

The adjusted standardized residuals showed that the observed frequency of SCEs occurring on a divided trafficway was less than expected. The frequencies of SCEs that occurred on all but the divided trafficways were more than expected. These results suggest that divided highways were associated with relatively lower risk, and undivided roads (and various other trafficway flow variations) were associated with increased risk.

An odds ratio was calculated for trafficway flow codes. The odds ratio is a method of determining the odds of some outcome (e.g., a crash) when comparing the presence of an activity or situation to its absence. In this analysis the two groups were total SCEs and baseline epochs.

An odds ratio of “1” implies the event is equally likely in both groups. An odds ratio greater than “1” implies the event is more likely in the first group while an odds ratio less than “1” implies that the event is less likely in the first group.[23] Drivers were 5.4 times more likely to be involved in a SCE if it occurred on a road that was not physically divided.

Table 31. Frequency and percentage of trafficway flow codes.

Trafficway Flow	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Not Physically Divided (Center Two-way Turn Lane)	0 (0.0%)	1 (7.1%)	1 (1.0%)	46 (5.8%)	48 (5.2%)	14 (1.3%)
Not Physically Divided (Two-way Trafficway)	5 (35.7%)	5 (35.7%)	23 (23.5%)	227 (28.8%)	260 (28.4%)	84 (7.8%)
Divided	8 (57.1%)	3 (21.4%)	66 (67.3%)	482 (61.1%)	559 (61.1%)	959 (89.5%)
One-way Trafficway	1 (7.1%)	2 (14.3%)	5 (5.1%)	32 (4.1%)	40 (4.4%)	15 (1.4%)
Unknown	0 (0.0%)	3 (21.4%)	3 (3.1%)	2 (0.3%)	8 (0.9%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.28 Number of Travel Lanes for Undivided Highways

Table 32 shows the frequency and percentage of number of travel lanes for undivided highways only. Most of the SCEs on undivided highways occurred on roadways with two (60.1 percent), three (16.5 percent), or five (12.1 percent) travel lanes. Almost all of the baseline epochs occurred on roadways with two travel lanes (76.5 percent) or five travel lanes (11.2 percent).

Table 32. Frequency and percentage of number of travel lanes for undivided highways.

Number of Travel Lanes	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.0%)
2	4 (80.0%)	4 (66.7%)	16 (66.7%)	164 (60.1%)	188 (61.0%)	75 (76.5%)
3	0 (0.0%)	0 (0.0%)	4 (16.7%)	45 (16.5%)	49 (15.9%)	7 (7.1%)
4	0 (0.0%)	1 (16.7%)	0 (0.0%)	23 (8.4%)	24 (7.8%)	4 (4.1%)
5	0 (0.0%)	0 (0.0%)	2 (8.3%)	33 (12.1%)	35 (11.4%)	11 (11.2%)
6	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (2.2%)	6 (1.9%)	0 (0.0%)
7+	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unknown	1 (20.0%)	1 (16.7%)	2 (8.3%)	2 (0.7%)	6 (1.9%)	0 (0.0%)
Total	**5 (100.0%)**	**6 (100.0%)**	**24 (100.0%)**	**273 (100.0%)**	**308 (100.0%)**	**98 (100.0%)**

6.1.29 Number of Travel Lanes for Divided Highways and One-way Traffic

Table 33 shows the frequency and percentage of number of travel lanes for divided highways and roads with one-way traffic. Most of the SCEs occurred on divided highways and one-way roadways with two (35.9 percent), three (29.7 percent), or four (22.4 percent) travel lanes. Almost all of the baseline epochs occurred on divided highways and one-way roadways with two (74.1 percent) or three (16.6 percent) travel lanes. Almost all of the crashes occurred on divided highways and one-way roadways with two lanes (88.9 percent).

Table 33. Frequency and percentage of number of travel lanes for divided highways and one-way traffic.

Number of Travel Lanes	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
1	0 (0.0%)	3 (60.0%)	4 (5.6%)	27 (5.3%)	34 (5.7%)	10 (1.0%)
2	8 (88.9%)	0 (0.0%)	31 (43.7%)	176 (34.2%)	215 (35.9%)	722 (74.1%)
3	1 (11.1%)	2 (40.0%)	18 (25.4%)	157 (30.5%)	178 (29.7%)	162 (16.6%)
4	0 (0.0%)	0 (0.0%)	16 (22.5%)	118 (23.0%)	134 (22.4%)	72 (7.4%)
5	0 (0.0%)	0 (0.0%)	2 (2.8%)	25 (4.9%)	27 (4.5%)	8 (0.8%)
6	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (1.4%)	7 (1.2%)	0 (0.0%)
7+	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.6%)	3 (0.5%)	0 (0.0%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)	0 (0.0%)
Total	**9 (100.0%**	**5 (100.0%)**	**71 (100.0%)**	**514 (100.0%)**	**599 (100.0%)**	**974 (100.0%)**

6.1.30 Roadway Alignment

Table 34 shows the frequency and percentage of roadway alignment codes. More than 90 percent of both SCEs and baseline epochs occurred on straight roadways.

Table 34. Frequency and percentage of roadway alignment codes.

Roadway Alignment	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Straight	12 (85.7%)	9 (64.3%)	88 (89.8%)	724 (91.8%)	833 (91.0%)	970 (90.5%)
Curve Right	1 (7.1%)	3 (21.4%)	5 (5.1%)	40 (5.1%)	49 (5.4%)	49 (4.6%)
Curve Left	1 (7.1%)	1 (7.1%)	5 (5.1%)	25 (3.2%)	32 (3.5%)	53 (4.9%)
Unknown	0 (0.0%)	1 (7.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.31 Roadway Profiles

Table 35 displays the frequency and percentage of roadway profiles. About 93 percent of both SCEs and baseline epochs occurred on a level roadway. However, a chi-square based on (5 Roadway Profiles) times (Total SCEs plus Baseline Epoch) showed a significant difference between the SCE and baseline distributions ($x^2_{(4)} = 19.546$, $p < 0.05$). The adjusted standardized residuals showed the observed frequency of SCEs that occurred on a road downgrade were less than expected, and the frequency of SCEs that occurred on an upgrade were more than expected.

Table 35. Frequency and percentage of roadway profiles.

Roadway Profile	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Level	14 (100.0%)	12 (85.7%)	97 (99.0%)	729 (92.4%)	852 (93.1%)	992 (92.5%)
Grade Up	0 (0.0%)	1 (7.1%)	1 (1.0%)	46 (5.8%)	48 (5.2%)	32 (3.0%)
Grade Down	0 (0.0%)	1 (7.1%)	0 (0.0%)	14 (1.8%)	15 (1.6%)	45 (4.2%)
Hillcrest	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.3%)
Sag	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.32 Traffic Density

Table 36 shows the frequency and percentage of traffic density codes based on level of service (LOS). The traffic density is listed in increasing order from LOS A (free-flowing traffic) to LOS F (severe bottleneck—too many vehicles for road capacity). A broader definition for each level of service (LOS) can be viewed in Appendix B. Most of the SCEs occurred in LOS A (59.3 percent), B (23.6 percent), or C (10.8 percent) traffic densities. Almost all (96.7 percent) of the baseline epochs occurred in LOS A or LOS B traffic densities. A chi-square based on (7 Traffic Density Codes) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(6)} = 115.744$, $p < 0.05$).

The adjusted standardized residuals showed the observed frequency of SCEs that occurred in LOS A traffic density were less than expected. The frequencies of SCEs that occurred in LOS C or LOS E traffic densities were more than expected. Drivers were 5.9 times more likely to be involved in a SCE if the traffic density was LOS C–F. This demonstrates the increased risk associated with increased traffic density.

Table 36. Frequency and percentage of traffic density codes.

Traffic Density	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
LOS A	13 (92.9%)	9 (64.3%)	61 (62.2%)	460 (58.3%)	543 (59.3%)	778 (72.6%)
LOS B	1 (7.1%)	1 (7.1%)	21 (21.4%)	193 (24.5%)	216 (23.6%)	258 (24.1%)

Traffic Density	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
LOS C	0 (0.0%)	4 (28.6%)	11 (11.2%)	84 (10.6%)	99 (10.8%)	33 (3.1%)
LOS D	0 (0.0%)	0 (0.0%)	1 (1.0%)	36 (4.6%)	37 (4.0%)	3 (0.3%)
LOS E	0 (0.0%)	0 (0.0%)	2 (2.0%)	14 (1.8%)	16 (1.7%)	0 (0.0%)
LOS F	0 (0.0%)	0 (0.0%)	2 (2.0%)	1 (0.1%)	3 (0.3%)	0 (0.0%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.33 Construction Zones

Table 37 shows the frequency and percentage of construction-zone-related events. Most of the SCEs did not occur in construction zones (93.9 percent); 21.4 percent of the crashes did occur in construction zones. Almost all of the baseline epochs occurred in non-construction zones (99.3 percent). A chi-square based on (4 Construction-zone-related Codes) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(3)} = 45.963$, $p < 0.05$).

The adjusted standardized residuals showed that the observed frequency of SCEs occurring in construction zones or construction zone-related areas were greater than expected. An odds ratio was calculated for the combined construction zone and construction zone-related events. Drivers were 8.5 times more likely to be involved in a SCE if they were traveling in a construction zone or a construction-zone-related area.

Table 37. Frequency and percentage of construction-zone-related events.

Construction-zone-related	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total Safety-critical Events	Baseline Epochs
Not Construction-zone-related	11 (78.6%)	13 (92.9%)	86 (87.8%)	749 (94.9%)	859 (93.9%)	1064 (99.3%)
Construction Zone	3 (21.4%)	1 (7.1%)	9 (9.2%)	30 (3.8%)	43 (4.7%)	7 (0.7%)
Construction-zone-related	0 (0.0%)	0 (0.0%)	2 (2.0%)	10 (1.3%)	12 (1.3%)	1 (0.1%)
Unknown	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)	0 (0.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.34 Pre-event Speeds for All Events

Table 38 shows the frequency and percentage of pre-event speed for all events, including both single-vehicle and multivehicle events. The pre-event speeds were coded for the period just prior to the occurrence of the SCE and/or just prior to any avoidance maneuver for V1. For example, when braking was involved, the pre-event speed was the speed just prior to the beginning of braking for V1. For baseline epochs, data reductionists coded the speed at the end of the 60-second baseline interval. The frequency of SCEs was evenly distributed among the pre-event speed blocks; however, very few SCEs occurred when the pre-event speed was more than 70 mi/h. Most of the crashes (50 percent) and tire strikes (92.9 percent) occurred at pre-event speeds of equal to or less than 30 mi/h. The majority of baseline epochs occurred at pre-event speeds of 51–70 mi/h (83.1 percent). However, a chi-square based on (6 Pre-event Speeds for All Events) times (Total SCEs plus Baseline Epoch) was significant ($x^2_{(5)} = 530.77$, $p < 0.05$).

The adjusted standardized residuals showed the observed frequency of SCEs that occurred during speeds of 0–30, 31–40, and 41–50 mi/h were greater than expected. The frequencies of SCEs that occurred during speeds of 51–60 mi/h were less than expected. An odds ratio was calculated for the combined SCEs with pre-event speeds less than 50 mi/h. Drivers were 9 times more likely to be involved in a SCE if they were traveling below 50 mi/h.

Table 38. Frequency and percentage of pre-event speeds for all events.

Pre-event Speed	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
0–30 mi/h	7 (50.0%)	13 (92.9%)	25 (25.5%)	194 (24.6%)	239 (26.1%)	33 (3.1%)
31–40 mi/h	2 (14.3%)	1 (7.1%)	18 (18.4%)	157 (19.9%)	178 (19.5%)	50 (4.7%)
41–50 mi/h	0 (0.0%)	0 (0.0%)	15 (15.3%)	144 (18.3%)	159 (17.4%)	88 (8.2%)
51–60 mi/h	3 (21.4%)	0 (0.0%)	26 (26.5%)	220 (27.9%)	249 (27.2%)	469 (43.8%)
61–70 mi/h	2 (14.3%)	0 (0.0%)	14 (14.3%)	71 (9.0%)	87 (9.5%)	421 (39.3%)
70+ mi/h	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)	11 (1.0%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.1.35 Pre-event Speeds for Single-vehicle Events

Table 39 shows the frequency and percentage of pre-event speeds for single-vehicle events. It is evident that lower pre-event speeds were associated with increased event risk. However, a chi-square based on (6 Pre-event Speeds for Single-vehicle Events) times (Total SCEs plus Baseline Epoch) was significant ($x^2_{(5)} = 464.6$, $p < .05$).

The adjusted standardized residuals showed that the observed frequencies of single-vehicle SCEs that occurred during speeds of 0–30, 31–40, and 41–50 mi/h were greater than expected. The frequencies of single-vehicle SCEs that occurred during speeds of 51–60, 61–70, and more than 70 mi/h were less than expected. An odds ratio was calculated for the combined single-vehicle SCEs with pre-event speeds less than 50 mi/h. Drivers were 8.4 times more likely to be involved in a single-vehicle SCE if they were traveling below 50 mi/h.

Table 39. Frequency and percentage of pre-event speeds for single-vehicle events.

Pre-event Speed	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total Safety-critical Events	Baseline Epochs
0–30 mi/h	6 (50.0%)	13 (92.9%)	11 (25.0%)	41 (18.6%)	71 (24.5%)	33 (3.1%)
31–40 mi/h	1 (8.3%)	1 (7.1%)	6 (13.6%)	44 (20.0%)	52 (17.9%)	50 (4.7%)
41–50 mi/h	0 (0.0%)	0 (0.0%)	9 (20.5%)	46 (20.9%)	55 (19.0%)	88 (8.2%)
51–60 mi/h	3 (25.0%)	0 (0.0%)	11 (25.0%)	67 (30.5%)	81 (27.9%)	469 (43.8%)
61–70 mi/h	2 (16.7%)	0 (0.0%)	7 (15.9%)	20 (9.1%)	29 (10.0%)	421 (39.3%)
70+ mi/h	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.9%)	2 (0.7%)	11 (1.0%)
Total	**12 (100.0%)**	**14 (100.0%)**	**44 (100.0%)**	**220 (100.0%)**	**290 (100.0%)**	**1,072 (100.0%)**

6.1.36 Pre-event Speeds for Multivehicle Events

Table 40 shows the frequency and percentage of pre-event speed for multivehicle events. Again, in this dataset lower speeds are associated with increased incident risk. However, a chi-square based on (6 Pre-event Speeds for Multiple-vehicle Events) times (Total SCEs plus Baseline Epoch) was significant ($x^2_{(5)} = 289.06$, $p < 0.05$).

The adjusted standardized residuals showed that the observed frequency of multivehicle SCEs that occurred during speeds of 0–30, 31–40, and 41–50 mi/h were greater than expected. The frequencies of multiple vehicle SCEs that occurred during speeds of 51–60 and 61–70 mi/h were less than expected. An odds ratio was calculated for the combined multivehicle SCEs with pre-event speeds less than 50 mi/h. Drivers were 9 times more likely to be involved in a multivehicle SCE if they were traveling below 50 mi/h.

Table 40. Frequency and percentage of pre-event speeds for multiple vehicle events.

Pre-event Speed	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
0–30 mi/h	1 (50.0%)	0 (0.0%)	14 (25.9%)	153 (26.9%)	168 (26.9%)	33 (3.1%)
31–40 mi/h	1 (50.0%)	0 (0.0%)	12 (22.2%)	113 (19.9%)	126 (20.2%)	50 (4.7%)
41–50 mi/h	0 (0.0%)	0 (0.0%)	6 (11.1%)	98 (17.2%)	104 (16.6%)	88 (8.2%)
51–60 mi/h	0 (0.0%)	0 (0.0%)	15 (27.8%)	153 (26.9%)	168 (26.9%)	469 (43.8%)
61–70 mi/h	0 (0.0%)	0 (0.0%)	7 (13.0%)	51 (9.0%)	58 (9.3%)	421 (39.3%)
70+ mi/h	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)	11 (1.0%)
Total	**2 (100.0%)**	**0 (0.0%)**	**54 (100.0%)**	**569 (100.0%)**	**625 (100.0%)**	**1,072 (100.0%)**

6.2 SUMMARY OF RESULTS FOR ISSUE 1: ANALYSIS OF HEAVY-VEHICLE SAFETY EVENTS RESULTS

Below is a summary of the most salient and important results. Unless otherwise noted, these statements apply to total SCEs (i.e., crashes plus tire strikes plus near-crashes plus crash-relevant conflicts).

- About two-thirds of the observed SCEs involved two vehicles.
- In SCEs involving two vehicles, the most common vehicle position was V2 in front of V1.
- V1 was usually going straight when SCEs developed.
- In two-vehicle events, V2 was usually going straight or decelerating in its traffic lane.
- The most common critical events for V1 were:
  - Other vehicle traveling in the same lane and decelerating.
  - This vehicle decelerating.
- When assigned to V1, the most common CRs were (in descending order):
  - Inadequate evasive action.
  - Internal distraction.
  - External distraction.
  - Misjudgment of gap or other’s speed.
  - Too fast for conditions.
- When assigned to V2, the most common CR was recognition or decision failure (often it was unknown which).
- In 71 percent of multivehicle events, V1 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 V1-precipitated events.
- The most common V1 avoidance maneuver was braking, often with concurrent steering.
- Most often, there was no V2 avoidance maneuver. As noted, this is in part a reflection of the event detection methodology.
- The most common V1 accident types (which, for non-crashes represents an extrapolation of the potential crash) were:
  - Rear-end, striking, lead vehicle (V2) decelerating.
  - Straight crossing paths, specifics unknown or other.
  - Rear-end, striking, lead vehicle (V2) slower.
  - Same direction sideswipe, non-encroaching vehicle.

- The most common V1 incident types were:
  - Late braking (and/or steering) for stopped/stopping traffic.
  - Single-vehicle event.
  - Close proximity to turning vehicle.
- In random baseline epochs, 58.3 percent of drivers were observed to be wearing safety belts. Safety belt use in crashes, near-crashes, and other SCEs was somewhat lower, but the differences were not statistically significant.
- Few SCEs involved visual obstructions.
- During 10-second intervals before SCEs and during baseline epochs, drivers were generally observed to engage in potentially distracting behavior. However, these occurred no more frequently in SCEs than baseline epochs.
- The most frequent V1 Driver Actions/Factor/Behaviors contributing to event causation were:
  - Inattentive/distracted.
  - Excessive braking/deceleration creating potential hazard.
  - Drowsy, sleepy, asleep, fatigued, other reduced alertness (based on an ORD criterion).
  - Inadequate evasive action.
- Most SCEs occurred during daylight, and the proportion was significantly greater than that for baseline epochs.
- Most SCEs occurred during clear weather, and adverse weather did not significantly increase event risk.
- Most SCEs occurred on dry roadway surfaces.
- About half of all SCEs occurred in non-junction sections of roadway, but event risk compared to baseline epochs was much greater at locations like intersections and ramps.
- Most SCEs occurred on divided highways, but event risk compared to baseline epochs was much greater on non-divided highways.
- Most SCEs occurred on straight roadways, and roadway alignment was not a factor significantly associated with risk.
- Most SCEs occurred on level surfaces. However, there was an association of road upgrades with increased risk and downgrades with decreased risk.
- Most SCEs occurred in low traffic density, but increased traffic density was strongly associated with increased risk.
- Surprisingly, lower vehicle speeds were associated with increased event risk. This counterintuitive finding is presumed to reflect interaction with other traffic and with the relatively restrictive roadway geometries associated with roads with lower speed limits.

6.3 ISSUE 2: COUNTERMEASURE IDENTIFICATION

Based on the variables relating to the event scenario, pre-event actions and states, and event causation, one of three senior analysts identified applicable functional countermeasures for each SCE. For crashes, an applicable V1 functional countermeasure was one that would likely have prevented the crash, either by preventing the genesis of the unsafe condition or by improving the driver response to the unsafe condition. The countermeasures listed are functional rather than device-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 a SCE could be coded. A table of functional countermeasures and coding rules for them is listed in Appendix B. The coding of functional countermeasures was based both on algorithmic determination from previous coded variables and on senior analyst judgment.

Various coding rules were established to make the coding more reliable and explicit. Note that 10 (improve general driver situation awareness and/or defensive driving) was not coded if 1 (increase driver alertness [reduce drowsiness]) and/or 8 (increase driver attention to forward scene) were coded. The coding rules (see Table 41and Table 42) included the following codes:

- 12 (reduce travel speed) included all road configurations, thus was inclusive of 14–16 (reduce speed on curves or turns; reduce speed at or on exits, including ramps; limit top speed to 70 mi/h, except on downgrades). However, it did not include all speeding above the speed limit.
- 17 (increase driver recognition of specific highway crash threats: stopped vehicle(s) in lane ahead, traveling in same direction) and 18 (increase driver recognition of specific highway crash threats: moving/decelerating vehicle in lane ahead, traveling in same direction) had a reciprocal relationship with 32 (provide warning to prevent rear encroachment or tailgating by other vehicle). That is, if one vehicle was coded 17 or 18, the other vehicle was coded 32.
- 29 (increase forward headway during vehicle following) applied to tailgating scenarios, not rapid closing scenarios (e.g., with a stopped or decelerating vehicle).
- 40 (aid to vertical clearance estimation) was used when V1 hit or had the potential to hit an overhanging object (e.g., tree limb).
- 98 (driver error and/or vehicle failure apparent, but countermeasure unknown) and 99 (unknown) were not coded if other countermeasures were coded.

6.3.1 V1 Countermeasures

Table 41 shows the frequency and percentage of V1 countermeasure codes. As 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:

- 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).
- Improve general driver situation awareness and/or defensive driving (13 percent).

The most frequent V1 countermeasures for the 14 actual crashes were:

- Prevent animals from crossing roadways (28.6 percent).
- Increase driver alertness (reduce drowsiness) (21.4 percent).
- Provide driver with navigation system (14.3 percent).
- Aid to vertical clearance estimation (14.3 percent).
- Improve driver response execution of crossing or turning maneuver at intersections—performance failure (14.3 percent).

Table 41. Frequency and percentage of V1 countermeasures.

V1 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
No Countermeasure Applicable	1 (7.1%)	0 (0.0%)	18 (18.4%)	124 (15.7%)	143 (15.6%)
1–Increase Driver Alertness (Reduce Drowsiness)	3 (21.4%)	0 (0.0%)	7 (7.1%)	38 (4.8%)	48 (5.2%)
3–Prevent “Drift” Lane Departures	0 (0.0%	0 (0.0%)	4 (4.1%)	18 (2.3%)	22 (2.4%)
4–Improve Vehicle Control on Curves	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
5–Improve Vehicle Control on Slippery Road Surfaces	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
6–Improve Vehicle Control During Braking	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
7–Improve Vehicle Control During Evasive Steering	0 (0.0%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (0.1%)
8–Increase Driver Attention to Forward Scene	3 (21.4%)	0 (90.0%)	28 (28.6%)	138 (17.5%)	169 (18.5%)
9–Improve Driver Use of Mirrors or Provide Better Information from Mirrors	0 (0.0%)	0 (0.0%)	3 (3.1%)	1 (0.1%)	4 (0.4%)
10–Improve General Driver Situation Awareness and/or Defensive Driving	1 (7.1%)	0 (0.0%)	9 (9.2%)	109 (13.8%)	119 (13.0%)
12–Reduce Travel Speed	0 (0.0%)	0 (0.0%)	3 (3.1%)	47 (6.0%)	50 (5.5%)
13–Reduce Speed on Downgrades	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
14–Reduce Speed on Curves or Turns	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
15–Reduce Speed at or on Exits (Including Ramps)	0 (0.0%)	0 (0.0%)	1 (1.0%)	4 (0.5%)	5 (0.5%)
16–Limit Top Speed to 70 mi/h (Except on Downgrades)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V1 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
17–Increase Driver Recognition of Specific Highway Crash Threats: Stopped Vehicle(s) in Lane Ahead, Traveling in Same Direction	1 (7.1%)	0 (0.0%)	4 (4.1%)	13 (1.6%)	18 (2.0%)
18–Increase Driver Recognition of Specific Highway Crash Threats: Moving/Decelerating Vehicle(s) in Lane Ahead, Traveling in Same Direction	0 (0.0%)	0 (0.0%)	6 (6.1%)	166 (21.0%)	172 (18.8%)
19–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane on Highway	0 (0.0%)	0 (0.0%)	3 (3.1%)	6 (0.8%)	9 (1.0%)
20–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane on Highway	0 (0.0%)	0 (0.0%)	1 (1.0%)	3 (0.4%)	4 (0.4%)
21–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane During Merging Maneuver	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
22–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane During Merging Maneuver	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.5%)	4 (0.4%)
23–Increase Driver Recognition or Gap Judgment re: Crossing or Oncoming Traffic at Intersections	0 (0.0%)	0 (0.0%)	1 (1.0%)	8 (1.0%)	9 (1.0%)
25–Improve Driver Response Execution of Crossing or Turning Maneuver at Intersections (Performance Failure)	2 (14.3%)	5 (35.7%)	2 (2.0%)	7 (0.9%)	16 (1.7%)
26–Improve Driver Recognition/Gap Judgment/Response Execution at Intersection	0 (0.0%)	0 (0.0%)	0 (0.0%)	13 (1.6%)	13 (1.4%)
27–Improve Driver Compliance with Intersection Traffic Signal Controls (Both Intentional and Unintentional Intersection Control Violations)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
28–Improve Driver Compliance with Intersection Traffic Sign Controls	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
29–Increase Forward Headway During Vehicle Following	0 (0.0%)	0 (0.0%)	2 (2.0%)	59 (7.5%)	61 (6.7%)
30–Improve Driver Night Vision in the Forward Field	0 (0.0%)	0 (0.0%)	5 (5.1%)	6 (0.8%)	11 (1.2%)
32–Provide Warning to Prevent Rear Encroachment or Tailgating by Other Vehicle	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
33–Provide Advisory to Driver Regarding Reduced Road-tire Friction (i.e., Associated with Slippery Roads)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
34–Prevent Vehicle Mechanical Failure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V1 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
36–Prevent Splash and Spray from This Vehicle Affecting Other Vehicle(s)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
37–Improve Driver Recognition/Gap Judgment Relating to Oncoming Vehicle During Passing Maneuver	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.4%)	3 (0.3%)
38–Prevent Animals from Crossing Roadways	4 (28.6%)	0 (0.0%)	9 (9.2%)	11 (1.4%)	24 (2.6%)
39–Provide Driver with Navigation System	2 (14.3%)	1 (7.1%)	1 (1.0%)	15 (1.9%)	19 (2.1%)
40–Aid to Vertical Clearance Estimation	2 (14.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.2%)
41–Prevent/Reduce Trailer Off-tracking Outside Travel Lane or Path	0 (0.0%)	7 (50.0%)	5 (5.1%)	11 (1.4%)	23 (2.5%)
42–Provide Advance Warning of Need to Stop at Traffic Sign or Signal	0 (0.0%)	0 (0.0%)	3 (3.1%)	72 (9.1%)	75 (8.2%)
98–Driver Error and/or Vehicle Failure Apparent, but Countermeasure Unknown	1 (7.1%)	2 (14.3%)	0 (0.0%)	28 (3.5%)	31 (3.4%)
99–Unknown	1 (7.1%)	0 (0.0%)	2 (2.0%)	11 (1.4%)	14 (1.5%)
Total	**21 (150.0%)**	**15 (107.1%)**	**119 (121.4%)**	**920 (116.6%)**	**1,075 (117.5%)**
SCE Total	***14 (100%)***	***14 (100%)***	***98 (100%)***	***789 (100%)***	***915 (100%)***

6.3.2 V2 Countermeasures

Table 42 displays the frequency and percentage of V2 countermeasure codes. As more than one V2 countermeasure could be selected for each SCE, the column totals may exceed 100 percent. Not including the single-vehicle or the SCEs where no V2 countermeasure was coded, the most frequent V2 countermeasures for SCEs 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).
- Increase driver recognition of specific highway crash threats: vehicle in left adjacent lane during merging maneuver (4.8 percent).

Table 42. Frequency and percentage of V2 countermeasures.

V2 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
No Countermeasure Applicable	1 (50.0%)	0 (0.0%)	26 (45.6%)	271 (47.5%)	298 (47.3%)
1–Increase Driver Alertness (Reduce Drowsiness)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
3–Prevent “Drift” Lane Departures	0 (0.0%)	0 (0.0%)	3 (5.3%)	5 (0.9%)	8 (1.3%)
4–Improve Vehicle Control on Curves	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
5–Improve Vehicle Control on Slippery Road Surfaces	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
6–Improve Vehicle Control During Braking	0 (0.0%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	1 (0.2%)
7–Improve Vehicle Control During Evasive Steering	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
8–Increase Driver Attention to Forward Scene	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
9–Improve Driver Use of Mirrors or Provide Better Information from Mirrors	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
10–Improve General Driver Situation Awareness and/or Defensive Driving	0 (0.0%)	0 (0.0%)	1 (1.8%)	4 (0.7%)	5 (0.8%)
12–Reduce Travel Speed	0 (0.0%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	1 (0.2%)
13–Reduce Speed on Downgrades	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
14–Reduce Speed on Curves or Turns	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
15–Reduce Speed at or on Exits (Including Ramps)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
16– Limit Top Speed to 70 mi/h (Except on Downgrades)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
17–Increase Driver Recognition of Specific Highway Crash Threats: Stopped Vehicle(s) in Lane Ahead, Traveling in Same Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
18–Increase Driver Recognition of Specific Highway Crash Threats: Moving/Decelerating Vehicle(s) in Lane Ahead, Traveling in Same Direction	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.7%)	4 (0.6%)
19–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane on Highway	0 (0.0%)	0 (0.0%)	4 (7.0%)	32 (5.6%)	36 (5.7%)
20–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane on Highway	0 (0.0%)	0 (0.0%)	6 (10.5%)	19 (3.3%)	25 (4.0%)

V2 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
21–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane During Merging Maneuver	0 (0.0%)	0 (0.0%)	2 (3.5%)	28 (4.9%)	30 (4.8%)
22–Increase Driver Recognition of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane During Merging Maneuver	0 (0.0%)	0 (0.0%)	2 (3.5%)	4 (0.7%)	6 (1.0%)
23–Increase Driver Recognition or Gap Judgment re: Crossing or Oncoming Traffic at Intersections	0 (0.0%)	0 (0.0%)	2 (3.5%)	14 (2.5%)	16 (2.5%)
25–Improve Driver Response Execution of Crossing or Turning Maneuver at Intersections (Performance Failure)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	1 (0.2%)
26–Improve Driver Recognition/Gap Judgment/Response Execution at Intersection	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
27–Improve Driver Compliance with Intersection Traffic Signal Controls (Both Intentional and Unintentional Intersection Control Violations)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
28–Improve Driver Compliance with Intersection Traffic Sign Controls	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
29–Increase Forward Headway During Vehicle Following	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
30–Improve Driver Night Vision in the Forward Field	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
32–Provide Warning to Prevent Rear Encroachment or Tailgating by Other Vehicle	0 (0.0%)	0 (0.0%)	5 (8.8%)	150 (26.3%)	155 (24.6%)
33–Provide Advisory to Driver Regarding Reduced Road-tire Friction (i.e., Associated with Slippery Roads)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
34–Prevent Vehicle Mechanical Failure	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.5%)	3 (0.5%)
36–Prevent Splash and Spray from This Vehicle Affecting Other Vehicle(s)	0 (0.0%)	0 (0.0%)	0 (0.0%0	0 (0.0%)	0 (0.0%)
37–Improve Driver Recognition/Gap Judgment Relating to Oncoming Vehicle During Passing Maneuver	0 (0.0%)	0 (0.0%)	1 (1.8%)	1 (0.2%)	2 (0.3%)
38–Prevent Animals From Crossing Roadways	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
39–Provide Driver with Navigation System	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
40–Aid to Vertical Clearance Estimation	0 (0.0%)	0 (0.0%	0 (0.0%)	0 (0.0%)	0 (0.0%)
41–Prevent/Reduce Trailer Off-tracking Outside Travel Lane or Path	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)
42–Provide Advance Warning of Need to Stop at Traffic Sign or Signal	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

V2 Countermeasures	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs
98–Driver Error and/or Vehicle Failure Apparent, But Countermeasure Unknown	0 (0.0%)	0 (0.0%)	3 (5.3%)	21 (3.7%)	24 (3.8%)
99–Unknown	1 (50.0%)	0 (0.0%)	0 (0.0%)	8 (1.4%)	9 (1.4%)
Total	**2 (100.0%)**	**0 (0.0%)**	**57 (100.0%)**	**571 (100.0%)**	**630 (100.0%)**
SCE Total	***14 (100%)***	***14 (100%)***	***98 (100%)***	***789 (100%)***	***915 (100%)***

6.3.3 Summary of Results for Issue 2: Countermeasure Identification

Since the methodology primarily captured events with V1 avoidance maneuvers (such as hard braking), the relevant countermeasures identified were often related to improving braking response or other avoidance maneuvers to crash threats in the forward direction. The most frequent V1 functional countermeasures involved improving driver recognition of forward threats, increasing driver attention to the forward scene, and improving driver situation awareness and/or defensive driving. The single most frequent functional countermeasure for V2 was reciprocal to the above; that is, providing a warning in order to prevent rear encroachment or tailgating by the other vehicle.

6.4 ISSUE 3: DRIVING PATTERNS AND WORK/REST SCHEDULES

Driving data from the DDWS FOT were used to investigate the driving patterns of the CMV drivers who participated. Since the vehicle instrumentation was operative only when the vehicle was moving, the current analysis was limited to driving-related parameters (e.g., hours driving) as opposed to all work-related parameters (e.g., hours off duty or total hours on duty). Nevertheless, the dataset provided an accurate representation of fundamental driving patterns and work/rest schedules, such as daily and weekly hours driven (total duration and patterns) and non-driving episodes (number and duration). These statistics were calculated for all drivers included in the current dataset.

6.4.1 Day-of-week for All Events

Table 43 displays the frequency and percentage of day-of-week codes for all SCEs, including both single and multivehicle events. For the most part, the SCEs were evenly distributed among each day of the week; however, few of the SCEs occurred on a Sunday or Saturday. A similar distribution was found for baseline epochs. A chi-square based on (7 Day-of-Week Codes for All Events) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(6)} = 21.126$, $p < 0.05$). The adjusted standardized residuals showed that the observed frequencies of SCEs that occurred on a Monday or Tuesday were less than expected. The frequency of SCEs that occurred on a Friday was more than expected.

Table 43. Frequency and percentage of day-of-week codes for all events.

Day-of-week	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Sunday	1 (7.1%)	2 (14.3%)	5 (5.1%)	67 (8.5%)	75 (8.2%)	70 (6.5%)
Monday	2 (14.3%)	1 (7.1%)	10 (10.2%)	114 (14.4%)	127 (13.9%)	192 (17.9%)
Tuesday	1 (7.1%)	2 (14.3%)	19 (19.4%)	132 (16.7%)	154 (16.8%)	220 (20.5%)
Wednesday	3 (21.4%)	3 (21.4%)	30 (30.6%)	140 (17.7%)	176 (19.2%)	190 (17.7%)
Thursday	2 (14.3%)	4 (28.6%)	15 (15.3%)	138 (17.5%)	159 (17.4%)	172 (16.0%)
Friday	3 (21.4%)	1 (7.1%)	14 (14.3%)	155 (19.6%)	173 (18.9%)	150 (14.0%)
Saturday	2 (14.3%)	1 (7.1%)	5 (5.1%)	43 (95.4%)	51 (5.6%)	78 (7.3%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.4.2 Day-of-week for Single-vehicle Events

Table 44 shows the frequency and percentage of day-of-week codes for single-vehicle events. For the most part, the SCEs were evenly distributed among each day of the week; however, fewer of the SCEs occurred on a Sunday or Saturday. A similar distribution was found for baseline epochs. A chi-square based on (7 Day-of-week Codes for Single-vehicle Events) times (Total SCEs plus Baseline Epoch) did not show a significant difference ($x^2_{(6)} = 8.285$, $p > 0.05$).

Table 44. Frequency and percentage of day-of-week codes for single-vehicle events.

Day-of-week	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Sunday	1 (8.3%)	2 (14.3%)	2 (4.5%)	21 (9.5%)	26 (9.0%)	70 (6.5%)
Monday	2 (16.7%)	1 (7.1%)	5 (11.4%)	31 (14.1%)	39 (13.4%)	192 (17.9%)
Tuesday	1 (8.3%)	2 (14.3%)	10 (22.7%)	55 (25.0%)	68 (23.4%)	220 (20.5%)
Wednesday	3 (25.0%)	3 (21.4%)	11 (25.0%)	38 (17.3%)	55 (19.0%)	190 (17.7%)
Thursday	2 (16.7%)	4 (28.6%)	8 (18.2%)	27 (12.3%)	41 (14.1%)	172 (16.0%)
Friday	2 (16.7%)	1 (7.1%)	6 (13.6%)	37 (16.8%)	46 (15.9%)	150 (14.0%)
Saturday	1 (8.3%)	1 (7.1%)	2 (4.5%)	11 (5.0%)	15 (5.2%)	78 (7.3%)
Total	**12 (100.0%)**	**14 (100.0%)**	**44 (100.0%)**	**220 (100.0%)**	**290 (100.0%)**	**1,072 (100.0%)**

6.4.3 Day-of-week for Multivehicle Events

Table 45 shows the frequency and percentage of day-of-week codes for multivehicle events. For the most part, the SCEs were evenly distributed among each day of the week; however, fewer of the SCEs occurred on a Sunday or Saturday. A similar distribution was found for baseline epochs. A chi-square based on (7 Day-of-week Codes for Multiple-vehicle Events) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(6)} = 27.959$, $p < 0.05$). The adjusted standardized residuals showed that the observed frequencies of multivehicle SCEs that occurred on a Monday or Tuesday were less than expected. The frequency of multivehicle SCEs that occurred on a Friday was more than expected.

Table 45. Frequency and percentage of day-of-week codes for multivehicle events.

Day-of-week	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Sunday	0 (0.0%)	0 (0.0%)	3 (5.6%)	46 (8.1%)	49 (7.8%)	70 (6.5%)
Monday	0 (0.0%)	0 (0.0%)	5 (9.3%)	83 (14.6%)	88 (14.1%)	192 (17.9%)
Tuesday	0 (0.0%)	0 (0.0%)	9 (16.7%)	77 (13.5%)	86 (13.8%)	220 (20.5%)
Wednesday	0 (0.0%)	0 (0.0%)	19 35.2%)	102 (17.9%)	121 (19.4%)	190 (17.7%)
Thursday	0 (0.0%)	0 (0.0%)	7 (13.0%)	111 (19.5%)	118 (18.9%)	172 (16.0%)
Friday	1 (50.0%)	0 (0.0%)	8 (14.8%)	118 (20.7%)	127 (20.3%)	150 (14.0%)
Saturday	1 (50.0%)	0 (0.0%)	3 5.6%)	32 (5.6%)	36 (5.8%)	78 (7.3%)
Total	**2 (100.0%)**	**0 (0.0%)**	**54 (100.0%)**	**569 (100.0%)**	**625 (100.0%)**	**1,072 (100.0%)**

6.4.4 Time-of-day for All Events

Table 46 shows the frequency and percentage of time-of-day codes for all SCEs, including single- and multivehicle events. Most of the SCEs occurred between 7 a.m.–11:59 p.m. The highest frequency of SCEs occurred between 9 a.m.–6:59 p.m. The baseline epochs were much more evenly distributed among the 1-hour time blocks. A chi-square based on (24 Time-of-day Codes for All Events) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(23)} = 112.350$, $p < 0.05$).

The adjusted standardized residuals showed that the observed frequency of SCEs that occurred during the midnight–12:59 a.m., 1–1:59 a.m., 2–2:59 a.m., 3–3:59 a.m., 4–4:59 a.m., and 5–5:59 a.m. time blocks were less than expected. The frequency of SCEs that occurred during the 1–1:59 p.m., 2–2:59 p.m., 3–3:59 p.m., and 4–4:59 p.m. time blocks were more than expected.

Table 46. Frequency and percentage of time-of-day codes for all events.

Time-of-Day	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
Midnight–12:59 a.m.	0 (0.0%)	0 (0.0%)	4 (4.1%)	16 (2.0%)	20 (2.2%)	36 (3.4%)
1–1:59 a.m.	2 (14.3%)	0 (0.0%)	4 (4.1%)	9 (1.1%)	15 (1.6%)	29 (2.7%)
2–2:59 a.m.	0 (0.0%)	0 (0.0%)	2 (2.0%)	7 (0.9%)	9 (1.0%)	28 (2.6%)
3–3:59 a.m.	1 (7.1%)	0 (0.0%)	0 (0.0%)	8 (1.0%)	9 (1.0%)	45 (4.2%)
4–4:59 a.m.	0 (0.0%)	0 (0.0%)	5 (5.1%)	8 (1.0%)	13 (1.4%)	29 (2.7%)
5–5:59 a.m.	0 (0.0%)	1 (7.1%)	1 (1.0%)	7 (0.9%)	9 (1.0%)	29 (2.7%)
6–6:59 a.m.	0 (0.0%)	1 (7.1%)	2 (2.0%)	13 (1.6%)	16 (1.7%)	31 (2.9%)
7–7:59 a.m.	0 (0.0%)	0 (0.0%)	4 (4.1%)	25 (3.2%)	29 (3.2%)	32 (3.0%)
8–8:59 a.m.	1 (7.1%)	0 (0.0%)	0 (0.0%)	33 (4.2%)	34 (3.7%)	33 (3.1%)
9–9:59 a.m.	0 (0.0%)	0 (0.0%)	5 (5.1%)	47 (6.0%)	52 (5.7%)	47 (4.4%)
10–10:59 a.m.	1 (7.1%)	2 (14.3%)	5 (5.1%)	42 (5.3%)	50 (5.5%)	51 (4.8%)
11–11:59 a.m.	0 (0.0%)	0 (0.0)	6 6.1%)	54 (6.8%)	60 (6.6%)	51 (4.8%)
Noon–12:59 p.m.	0 (0.0%)	1 (7.1%)	14 (14.3%)	45 (5.7%)	60 (6.6%)	61 (5.7%)
1–1:59 p.m.	1 (7.1%)	0 (0.0%)	2 (2.0%)	52 (6.6%)	55 (6.0%)	45 (4.2%)
2–2:59 p.m.	1 (7.1%)	0 (0.0%)	5 (5.1%)	57 (7.2%)	63 (6.9%)	52 (4.9%)
3–3:59 p.m.	2 (14.3%)	4 (28.6%)	9 (9.2%)	67 (8.5%)	82 (9.0%)	68 (6.3%)
4–4:59 p.m.	0 (0.0%)	1 (7.1%)	7 (7.1%)	76 (9.6%)	84 (9.2%)	51 (4.8%)

Time-of-Day	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total SCEs	Baseline Epochs
5–5:59 p.m.	2 (14.3%)	2 (14.3%)	3 (3.1%)	45 (5.7%)	52 (5.7%)	52 (4.9%)
6–6:59 p.m.	1 (7.1%)	0 (0.0%)	1 (1.0%)	47 (6.0%)	49 (5.4%)	53 (4.9%)
7–7:59 p.m.	1 (7.1%)	0 (0.0%)	5 (5.1%)	22 (2.8%)	28 (3.1%)	45 (4.2%)
8–8:59 p.m.	0 (0.0%)	2 (14.3%)	2 (2.0%)	35 (4.4%)	39 (4.3%)	43 (4.0%)
9–9:59 p.m.	1 (7.1%)	0 (0.0%)	4 (4.1%)	27 (3.4%)	32 (3.5%)	59 (5.5%)
10–10:59 p.m.	0 (0.0%)	0 (0.0%)	3 (3.1%)	31 (3.9%)	34 (3.7%)	46 (4.3%)
11–11:59 p.m.	0 (0.0%)	0 (0.0%)	5 (5.1%)	16 (2.0%)	21 (2.3%)	56 (5.2%)
Total	**14 (100.0%)**	**14 (100.0%)**	**98 (100.0%)**	**789 (100.0%)**	**915 (100.0%)**	**1,072 (100.0%)**

6.4.5 Time-of-day for Single-vehicle Events

Table 47 shows the frequency and percentage of time-of-day codes for single-vehicle events. The single-vehicle SCEs were distributed much more evenly across the 24 hours than were all events. A chi-square based on (24 Time-of-day Codes for Single-vehicle Events) times (Total SCEs plus Baseline Epoch) did not show a significant difference ($x^2_{(23)} = 28.29$, $p > 0.05$).

Table 47. Frequency and percentage of time-of-day codes for single-vehicle events.

Time-of-day	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total Safety-critical Events	Baseline Epochs
Midnight–12:59 a.m.	0 (0.0%)	0 (0.0%)	2 (4.5%)	12 (5.5%)	14 (4.8%)	36 (3.4%)
1–1:59 a.m.	2 (16.7%)	0 (0.0%)	2 (4.5%)	7 (3.2%)	11 (3.8%)	29 (2.7%)
2–2:59 a.m.	0 (0.0%)	0 (0.0%)	2 (4.5%)	5 (2.3%)	7 (2.4%)	28 (2.6%)
3–3:59 a.m.	1 (8.3%)	0 (0.0%)	0 (0.0%)	8 (3.6%)	9 (3.1%)	45 (4.2%)
4–4:59 a.m.	0 (0.0%)	0 (0.0%)	4 (9.1%)	4 (1.8%)	8 (2.8%)	29 (2.7%)
5–5:59 a.m.	0 (0.0%)	1 (7.1%)	1 (2.3%)	2 (0.9%)	4 (1.4%)	29 (2.7%)
6–6:59 a.m.	0 (0.0%)	1 (7.1%)	1 (2.3%)	4 (1.8%)	6 (2.1%)	31 (2.9%)
7–7:59 a.m.	0 (0.0%)	0 (0.0%)	1 (2.3%)	7 (3.2%)	8 (2.8%)	32 (3.0%)
8–8:59 a.m.	1 (8.3%)	0 (0.0%)	0 (0.0%)	15 (6.8%)	16 (5.5%)	33 (3.1%)
9–9:59 a.m.	0 (0.0%)	0 (0.0%)	2 (4.5%)	10 (4.5%)	12 (4.1%)	47 (4.4%)
10–10:59 a.m.	0 (0.0%)	2 (14.3%)	3 (6.8%)	9 (4.1%)	14 (4.8%)	51 (4.8%)
11–11:59 a.m.	0 (0.0%)	0 (0.0%)	4 (9.1%)	17 (7.7%)	21 (7.2%)	51 (4.8%)
Noon–12:59 p.m.	0 (0.0%)	1 (7.1%)	6 (13.6%)	11 (5.0%)	18 (6.2%)	61 (5.7%)
1–1:59 p.m.	1 (8.3%)	0 (0.0%)	0 (0.0%)	9 (4.1%)	10 (3.4%)	45 (4.2%)
2–2:59 p.m.	1 (8.3%)	0 (0.0%)	1 (2.3%)	12 (5.5%)	14 (4.8%)	52 (4.9%)
3–3:59 p.m.	2 (16.7%)	4 (28.6%)	5 (11.4%)	13 (5.9%)	24 (8.3%)	68 (6.3%)
4–4:59 p.m.	0 (0.0%)	1 (7.1%)	0 (0.0%)	17 (7.7%)	18 (6.2%)	51 (4.8%)
5–5:59 p.m.	1 (8.3%)	2 (14.3%)	1 (2.3%)	6 (2.7%)	10 (3.4%)	52 (4.9%)
6–6:59 p.m.	1 (8.3%)	0 (0.0%)	2 (4.5%)	10 (4.5%)	13 (4.5%)	53 (4.9%)
7–7:59 p.m.	1 (8.3%)	0 (0.0%)	1 (2.3%)	4 (1.8%)	6 (2.1%)	45 (4.2%)
8–8:59 p.m.	0 (0.0%)	2 (14.3%)	3 (6.8%)	16 (7.3%)	21 (7.2%)	43 (4.0%)
9–9:59 p.m.	1 (8.3%)	0 (0.0%)	1 (2.3%)	6 (2.7%)	8 (2.8%)	59 (5.5%)
10–10:59 p.m.	0 (0.0%)	0 (0.0%)	2 (4.5%)	11 (5.0%)	13 (4.5%)	46 (4.3%)
11–11:59 p.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (2.3%)	5 (1.7%)	56 (5.2%)
Total	**12 (100.0%)**	**14 (100.0%)**	**44 (100.0%)**	**220 (100.0%)**	**290 (100.0%)**	**1,072 (100.0%)**

6.4.6 Time-of-day for Multivehicle Events

Table 48 shows the frequency and percentage of time-of-day codes for multivehicle events. Few of the multivehicle SCEs occurred before 7 a.m. Most occurred between 7 a.m. and 11:59 p.m., with the highest frequency between 9 a.m. and 6:59 p.m. The multivehicle SCE distribution contrasts sharply with the baseline epoch exposure distribution. A chi-square based on (24 Time-of-day Codes for Multivehicle Events) times (Total SCEs plus Baseline Epoch) showed a significant difference ($x^2_{(23)} = 131.96$, $p < 0.05$). The adjusted standardized residuals showed the observed frequency of multivehicle SCEs that occurred during the midnight–12:59 a.m., 1–1:59 a.m., 2–2:59 a.m., 3–3:59 a.m., 4–4:59 a.m., and 5–5:59 a.m. and 11–11:59 p.m. time blocks were less than expected. The frequency of multiple-vehicle SCEs that occurred during the 1–1:59 p.m., 2–2:59 p.m., 3–3:59 p.m., and 4–4:59 p.m. time blocks were more than expected.

Table 48. Frequency and percentage of time-of-day codes for multivehicle events.

Time-of-day	Crashes	Crashes: Tire Strikes	Near-crashes	Crash-relevant Conflicts	Total Safety-critical Events	Baseline Epochs
Midnight–12:59 a.m.	0 (0.0%)	0 (0.0%)	2 (3.7%)	4 (0.7%)	6 (1.0%)	36 (3.4%)
1–1:59 a.m.	0 (0.0%)	0 (0.0%)	2 (3.7%)	2 (0.4%)	4 (0.6%)	29 (2.7%)
2–2:59 a.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)	2 (0.3%)	28 (2.6%)
3–3:59 a.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	45 (4.2%)
4–4:59 a.m.	0 (0.0%)	0 (0.0%)	1 (1.9%)	4 (0.7%)	5 (0.8%)	29 (2.7%)
5–5:59 a.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (0.9%)	5 (0.8%)	29 (2.7%)
6–6:59 a.m.	0 (0.0%)	0 (0.0%)	1 (1.9%)	9 (1.6%)	10 (1.6%)	31 (2.9%)
7–7:59 a.m.	0 (0.0%)	0 (0.0%)	3 (5.6%)	18 (3.2%)	21 (3.4%)	32 (3.0%)
8–8:59 a.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	18 (3.2%)	18 (2.9%)	33 (3.1%)
9–9:59 a.m.	0 (0.0%)	0 (0.0%)	3 (5.6%)	37 (6.5%)	40 (6.4%)	47 (4.4%)
10–10:59 a.m.	1 (50.0%0)	0 (0.0%)	2 (3.7%)	33 (5.8%)	36 (5.8%)	51 (4.8%)
11–11:59 a.m.	0 (0.0%)	0 (0.0%)	2 (3.7%)	37 (6.5%)	39 (6.2%)	51 (4.8%)
Noon–12:59 p.m.	0 (0.0%)	0 (0.0%)	8 (14.8%)	34 (6.0%)	42 (6.7%)	61 (5.7%)
1–1:59 p.m.	0 (0.0%)	0 (0.0%)	2 (3.7%)	43 (7.6%)	45 (7.2%)	45 (4.2%)
2–2:59 p.m.	0 (0.0%)	0 (0.0%)	4 (7.4%)	45 (7.9%)	49 (7.8%)	52 (4.9%)
3–3:59 p.m.	0 (0.0%)	0 (0.0%)	4 (7.4%)	54 (9.5%)	58 (9.3%)	68 (6.3%)
4–4:59 p.m.	0 (0.0%)	0 (0.0%)	7 (13.0%)	59 (10.4%)	66 (10.6%)	51 (4.8%)
5–5:59 p.m.	1 (50.0%)	0 (0.0%)	3 (5.6%)	39 (6.9%)	43 (6.9%)	52 (4.9%)
6–6:59 p.m.	0 (0.0%)	0 (0.0%)	0 (0.0%)	37 (6.5%)	37 (5.9%)	53 (4.9%)
7–7:59 p.m.	0 (0.0%)	0 (0.0%)	3 (5.6%)	18 (3.2%)	21 (3.4%)	45 (4.2%)
8–8:59 p.m.	0 (0.0%)	0 (0.0%)	1 (1.9%)	19 (3.3%)	20 (3.2%)	43 (4.0%)
9–9:59 p.m.	0 (0.0%)	0 (0.0%)	1 (1.9%)	21 (3.7%)	22 (3.5%)	59 (5.5%)
10–10:59 p.m.	0 (0.0%)	0 (0.0%)	2 (3.7%)	20 (3.5%)	22 (3.5%)	46 (4.3%)
11–11:59 p.m.	0 (0.0%)	0 (0.0%)	3 (5.6%)	11 (1.9%)	14 (2.2%)	56 (5.2%)
Total	**2 (100.0%)**	**0 (0.0%)**	**54 (100.0%)**	**569 (100.0%)**	**625 (100.0%)**	**1,072 (100.0%)**

6.4.7 Summary of Results for Issue 3: Driving Patterns and Work/Rest Schedules

Chi-square analyses, and subsequent adjusted standardized residuals, showed that for multivehicle events, SCEs were more likely than baseline epochs to occur on a Friday and less likely to occur on a Monday or Tuesday. Also for multivehicle events, SCEs were more likely than baseline epochs to occur between the hours of 1–4:59 p.m. and less likely to occur between the hours of midnight–5:59 a.m. For single-vehicle events, there was no difference between SCEs and baseline epochs. Drivers were more likely to be involved in a multivehicle SCE on a Friday from 1–4:59 p.m. compared to baseline epochs during the same time. Conversely, drivers were less likely to be involved in a multivehicle SCE on a Monday or Tuesday from midnight–5:59 a.m. compared to baseline epochs during the same time.

6.5 ISSUE 4: CORRELATES OF DRIVER RISK

Many interacting factors affect CMV driver crash involvement. At any given time, CMV driver crash risk is affected by personal situational risk factors (e.g., driver hours of sleep the previous night), vehicle risk factors (e.g., condition of brakes), environmental factors (e.g., weather and roadway features), and, of course, risks created by other drivers and traffic. A fundamental question regarding CMV safety is the extent to which certain drivers are chronically at greater risk because of some relatively enduring personal trait, such as demographic factors (e.g., gender, age), personality factors (e.g., tendencies toward aggressiveness or risk-taking), performance abilities (e.g., dynamic vision), or medical conditions (e.g., sleep apnea).

The current study compared differential risk to a variety of driver characteristics. An extensive pre-study survey given to all study drivers obtained information such as driver education, marital status, personal happiness and adjustment, medical symptoms, alcohol, smoking, exercise, sleep habits, sociability, work stress, and self-reported drowsiness while driving. These driver data were entered into a study database, and responses on those variables expected to have the highest relevance to driving safety were correlated with driving incident rates. The degree of association of many of these metrics with driving safety measures are reported here. The performance of the experimental group was likely to be affected by a countermeasure. The experimental and control groups were sometimes combined, however, to increase statistical power. This was done only when both groups showed the same trends and with the caveat that the combined group included both conditions.

Of course, it should be noted that the current data are preliminary, so these correlations of risk with personal factors are preliminary. However, the statistics will be useful for identifying those personal factors (e.g., age, education, personality, sleep hygiene) most associated with risk and thus the most promising targets for fleet and industry-wide efforts to reduce risk.

6.5.1 Safety-critical Event Rates

As stated earlier, one limitation of comparing the frequency of SCEs with personal risk factors is the lack of exposure data to control for the variance in driving time and/or mileage (as increased exposure increases overall crash risk). For example, two drivers may have the same frequency of SCEs, but have vastly different exposure risk. Thus, concluding that both drivers had identical crash risk (based on raw frequencies) would be erroneous and lead to invalid conclusions. Therefore, a measure of each driver's exposure should be included in any analysis.

In the present analysis, the frequency of each driver's at-fault, not-at-fault, and high-drowsiness SCEs (events where the driver's ORD was ≥ 40) were divided by each driver's total driving hours. For example, if a driver had 15 at-fault events during 300 hours of total driving time they would have an at-fault rate/hour of 0.05 (also expressed as 0.05 at-fault events/hour). A complete list of each driver's frequency, total driving hours, and rate/hour of at-fault, not-at-fault, and high-drowsiness events can be seen in Appendices C and D. Table 49 displays the at-fault, not-at-fault, and high-drowsiness rates/hour for the control and experimental groups.

As can be seen in Table 49, the at-fault, not-at-fault, and high-drowsiness rates/hour in the control and experimental groups were very similar. In fact, t-tests did not show a significant difference between the control and experimental groups for at-fault (t = -0.989), not-at-fault (t = -0.458), and high-drowsiness (t = -0.172) rates/hour (p > 0.05). As there was no difference between groups, the data presented in the following section presents the overall dataset (i.e., all 95 drivers). This was done to increase statistical power. An odds ratio was calculated for the at-fault and not-at-fault high-drowsiness SCEs. Drivers were 1.1 times more likely to be involved in an at-fault high-drowsiness SCE than a not-at-fault high-drowsiness SCE.

Table 49. At-fault, not-at-fault, and high-drowsiness rates/hour for control and experimental groups.

Cause of SCEs	Control Group (n = 20)	Experimental Group (n = 75)
At-fault	0.0271	0.0206
Not-at-fault	0.0077	0.0067
Drowsy	0.0044	0.0040

6.5.2 Differential Risk Among Subject Drivers

As discussed in the introduction to this report, a number of studies have found strong evidence of differential risk among CMV drivers as well as non-CMV drivers. That is, risk varies dramatically from very high to nearly zero. A study of high-risk drivers and differential risk in general reviewed multiple datasets and found that, typically, 10–15 percent of drivers are associated with 30–50 percent of risk per various metrics.[(13)] In contrast, the safest 50 percent of drivers may be associated with 10–15 percent of aggregate risk.

The current study found a similar distribution of differential risk among the 95 participating drivers. For the aggregated subject pool of 95 drivers, wide variations in involvement rates were seen for at-fault, not-at-fault, and high-drowsiness events. In all three cases, rates were calculated based on hours of driving and included the combined total of crashes, near-crashes, and crash-relevant conflicts. 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 (15.8 percent of the 95 participants) drivers were compared to the middle 40 drivers and the best 40 drivers (42.1 percent). For some metrics, the worst 15 were compared to the aggregated middle and best (i.e., the remaining 80 drivers in the study). Note the "worst" and "best" drivers are defined and differentiated within each metric. There were positive correlations across the three metrics, but each was analyzed separately so a given driver could be in a different relative category for different metrics.

A summary of the differential risk rates for these three metrics follows:

- 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: 34.9 percent of driving hours; 5.1 percent of not-at-fault SCEs.
- High-drowsiness events (i.e., ORD > 40, which includes both at-fault and not-at-fault events; 127 total):
  - Worst 15 drivers: 14.6 percent of driving hours; 69.3 percent of high-drowsiness SCEs.
  - Middle 40 drivers: 49.5 percent of driving hours; 30.7 percent of high-drowsiness SCEs.
  - Best 40 drivers: 35.9 percent of driving hours; zero high-drowsiness SCEs.

Concerning high-drowsiness events, there were 52 drivers (of the 95 total) who had no observed high-drowsiness events. The 127 total high-drowsiness events were distributed among the remaining 43 drivers. There were 18 drivers who had no at-fault events; 29 drivers did not have any not-at-fault events.

6.5.3 Association of Driver Risk and Personal Factors

The above statistics demonstrate differential risk across the subject pool for the three metrics, but do not indicate factors associated with driver risk which might contribute to differential risk. This section provides statistics on how various personal driver factors correlate with driver risk per these metrics.

6.5.3.1 Gender

As there was only one female participant in the DDWS FOT, gender data are not reported.

6.5.3.2 Age

A significant inverse relationship was shown when a Pearson product moment correlation was done between each participant's age and their rate of at-fault ($r = -0.299$), not-at-fault ($r = -0.280$), and high-drowsiness ($r = -0.205$) events ($p < 0.05$). Thus, there was small inverse correlation between age and at-fault, not-at-fault, and high-drowsiness rates/hour (i.e., as the age of drivers in the dataset increased, their rates of at-fault, not-at-fault, and high-drowsiness events decreased). Figure 15, Figure 16, and Figure 17 show scatter plots of age versus drivers' at-fault, not-at-fault, and high-drowsiness rates.

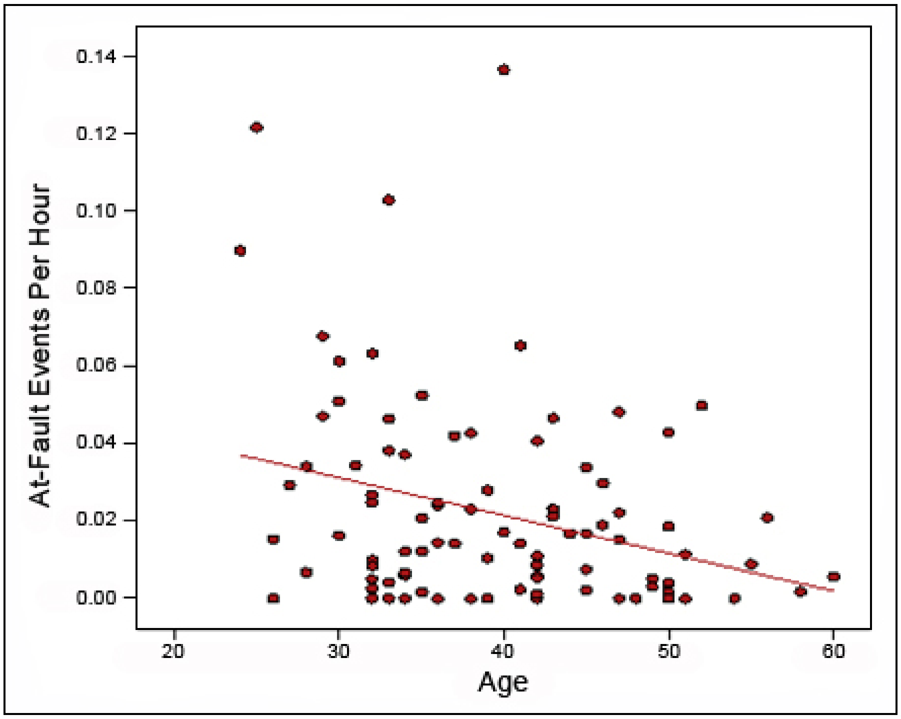

Figure 15. Chart. Scatter plot of age versus at-fault rates.

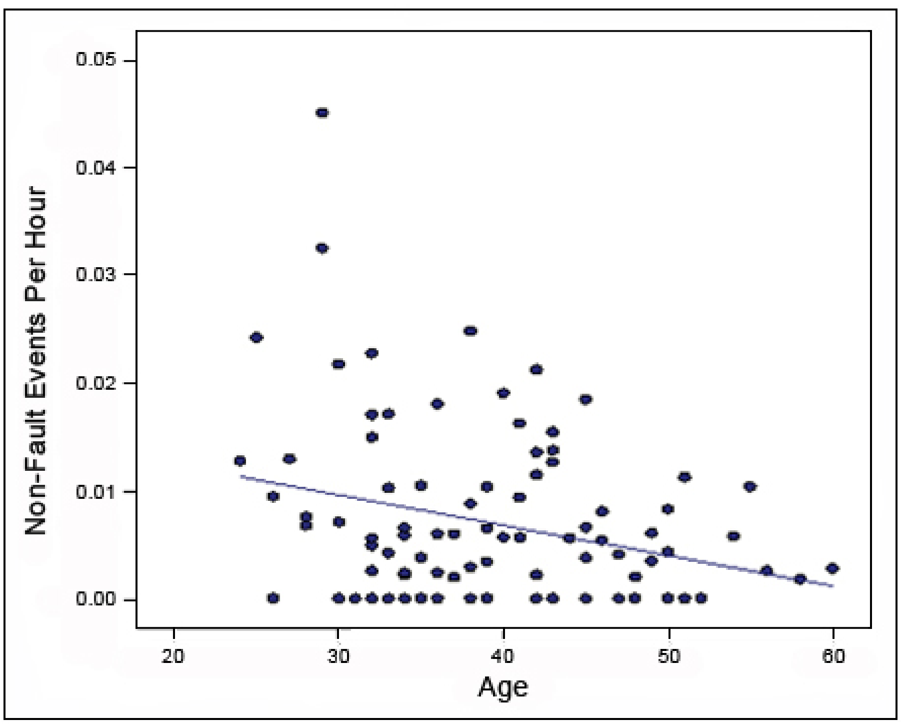

Figure 16. Chart. Scatter plot of age versus not-at-fault rates.

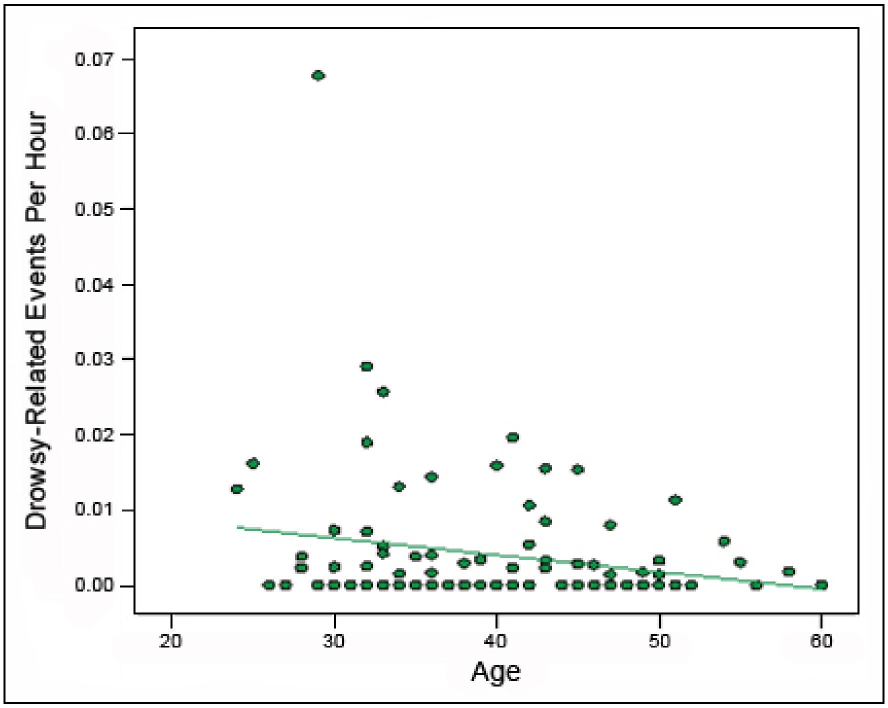

Figure 17. Chart. Scatter plot of age versus high-drowsiness rates.

6.5.3.3 Experience Driving a Commercial Motor Vehicle

A Pearson product moment correlation between each participant's experience driving a CMV (expressed in months) and their rate of at-fault events showed a significant inverse relationship ($r = -0.223$, $p < 0.05$). However, the relationship between experience driving a CMV and not-at-fault and high-drowsiness rates/hour was not significant ($p > 0.05$). There was small inverse correlation between a driver's experience driving a CMV and at-fault rate/hour (i.e., as the CMV driving experience of drivers in the dataset increased, their rates of at-fault events decreased). Figure 18 displays a scatter plot of experience driving a CMV versus drivers' at-fault rate.

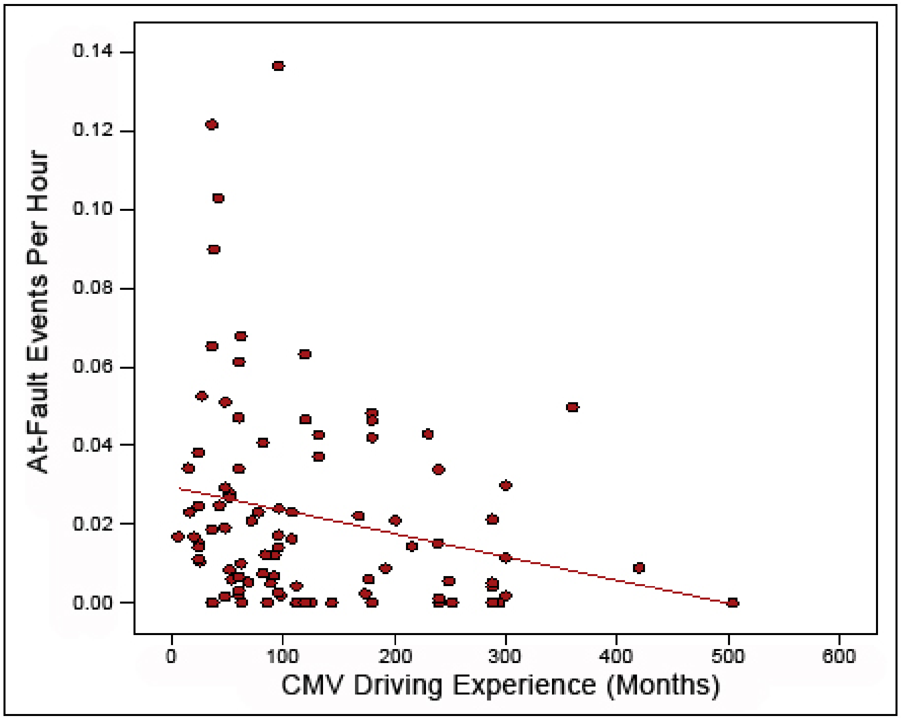

Figure 18. Chart. Scatter plot of experience driving a CMV versus at-fault rates.

6.5.3.4 Body Mass Index

Body mass index (BMI) is a tool for indicating weight status in adults.[24] The formula for obtaining BMI is: (weight/height^2) × 703. For adults more than 20 years old, BMI falls into 1 of 4 categories:

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

The average BMI for drivers in the current dataset was 30.5 (SD = 5.87) with a range of 19.37 to 51.6. These results indicated that drivers in the dataset were obese, on average, based on the BMI categories presented above. A Pearson product moment correlation between each participant's BMI and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$).

6.5.3.5 Education Level

The education levels of participants were grouped into one of three categories:

- Some high school, but did not graduate.
- Graduated from high school.

- Some post-high school experience (included technical schools, community colleges, and colleges).

Table 50 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for each education level. Only 86 drivers provided information about their education level. Most drivers in the dataset graduated from high school. Three separate one-way analyses of variance (ANOVA) did not show a significant difference between the three different education levels and at-fault ($f = 0.881$), not-at-fault ($f = 0.481$), and high-drowsiness ($f = 0.622$) rates/hour ($p > 0.05$).

Table 50. At-fault, not-at-fault, and high-drowsiness rates/hour by education level.

Education Level	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Some High School (*n* = 14)	0.0279	0.0095	0.0058
High School (*n* = 34)	0.0172	0.0064	0.0042
Some Post-High School (*n* = 38)	0.0223	0.0067	0.0040

6.5.3.6 Marital Status

Participants fell into one of six marital status categories:

- Single.
- Divorced.
- Married.
- Separated.
- Living with a partner.
- Widowed.

Table 51 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for each marital status. Most drivers in the dataset were married. Two separate one-way ANOVAs did not show a significant difference between the six different marital statuses and at-fault ($f = 1.824$) and high-drowsiness ($f = 1.787$) rates/hour ($p > 0.05$). However, the ANOVA showed a significant difference between marital status for not-at-fault events ($f = 5.487$, $p < 0.05$). Simple effects tests showed that single drivers had a higher not-at-fault rate/hour ($p = 0.0183$) than drivers who were divorced ($p = 0.0064$; $t = 2.584$), married (p=0.0056; $t = 5.018$), and living with a partner ($p = 0.0030$; $t = 2.248$).

Table 51. At-fault, not-at-fault, and high-drowsiness rates/hour for marital status.

Marital Status	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Single (*n* = 10)	0.0401	0.0183	0.0116
Divorced (*n* = 11)	0.0296	0.0064	0.0033
Married (*n* = 56)	0.0164	0.0056	0.0030

Marital Status	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Separated (*n* = 4)	0.0239	0.0060	0.0035
Living With a Partner (*n*= 4)	0.0194	0.0030	0.0021
Widowed (*n* = 1)	0.0056	0.0028	0.0000

6.5.3.7 Ethnicity

There were five different ethnicities reported by drivers:

- African American.
- Asian American.
- Caucasian American.
- Hispanic American.
- Native American.

Table 52 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for each ethnicity. Most drivers were Caucasian; three separate one-way ANOVAs did not show a significant difference between the ethnicities and at-fault (f = 0.960), not-at-fault (f = 0.438), and high-drowsiness (f = 0.545) rates/hour ($p > 0.05$).

Table 52. At-fault, not-at-fault, and high-drowsiness rates/hour for ethnicity.

Ethnicity	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
African American (*n* = 30)	0.0244	0.0088	0.0060
Asian American (*n* = 1)	0.0231	0.0000	0.0033
Caucasian American (*n* = 61)	0.0206	0.0059	0.0030
Hispanic American (*n* = 1)	0.0341	0.0076	0.0038
Native American (*n* = 2)	0.0199	0.0114	0.0095

6.5.4 Health and Well-being

6.5.4.1 Self-assessment of Health

On the pre-study survey, participating drivers were asked to provide a self-assessment on how healthy they usually felt on a scale of 0 to 100, with “0” rated as “Not Healthy at All” and “100” rated as “Very Healthy.”

The average self-assessment of health score for drivers in the dataset was 79.25 (*SD*=18.14) with a range of 30 to 100. These results indicated the drivers in the dataset considered themselves to be fairly healthy. A Pearson product moment correlation between each participant’s self-assessment of health score and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$).

6.5.4.2 Coping

Four questions in the pre-study survey asked participants about their coping ability during the previous month. They were asked to rate how often they felt or thought a certain way (e.g., "In the last month, how often have you felt confident about your ability to handle your personal problems?"). There were five possible answers for each question:

- Never.
- Almost Never.
- Sometimes.
- Fairly Often.
- Very Often.

Values were given to answers, ranging from 0 to 4. The answers for the four questions were added to obtain an overall "coping" score. Two of the four questions were reverse scored. The total coping score could range from 0 to 16 with higher scores reflecting better coping skills. The average coping score for drivers in the current dataset was 11.36 ($SD = 2.59$) with a range of 5 to 16. These results indicated the drivers in the dataset considered themselves to have above average coping skills. A Pearson product moment correlation between each participant's coping score and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$).

6.5.4.3 Smoking Tobacco

Participants were asked to indicate if they smoked tobacco products. Table 53 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for smoking tobacco. Most drivers in the dataset were smokers. Three separate independent sample *t*-tests did not show a significant difference between smoking tobacco and at-fault ($t = -0.336$), not-at-fault ($t = 0.414$), and high-drowsiness ($t = 1.198$) rates/hour ($p > 0.05$).

Table 53. At-fault, not-at-fault, and high-drowsiness rates/hour for smoking tobacco.

Smoke Tobacco	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Yes ($n = 52$)	0.0202	0.0073	0.0049
No ($n = 35$)	0.0222	0.0065	0.0025

6.5.4.4 Sociability

Participants were asked 18 different questions assessing their level of sociability (e.g., "Are you inclined to keep in the background on social occasions?"). Participants indicated their level of agreement with each question by using one of the following answers:

- Strongly Disagree.
- Disagree.
- Neutral.

- Agree.
- Strongly Agree.

These ratings were added to obtain a total sociability score. Two of the questions were reverse scored. The total sociability score could range from 18 to 90 with higher scores reflecting higher sociability. The average sociability score for drivers in the dataset was 52.8 (SD = 6.48) with a range of 31 to 64. These results indicated the drivers in the dataset considered themselves to be fairly outgoing with scores in the average range. A Pearson product moment correlation between each participant's sociability score and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$).

6.5.4.5 Major Stressful Event in the Past Year

Participants were asked to indicate if they experienced a major stressful event (e.g., death in family, divorce, bankruptcy, etc.) during the preceding 12 months. Table 54 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for the "major stressful event in the past year" question. Most drivers in the dataset had not experienced a major stressful event in the preceding 12 months. Three separate independent sample t-tests did not show a significant difference between the major stressful event in the past year question and at-fault (t = 1.552), not-at-fault (t = 0.519), and high-drowsiness (t = 0.629) rates/hour ($p > 0.05$).

Table 54. At-fault, not-at-fault, and high-drowsiness rates/hour for major stressful event in the past year.

Major Stressful Event in the Past Year	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Yes (n = 32)	0.0266	0.0076	0.0047
No (n = 55)	0.0177	0.0066	0.0035

6.5.5 Work Schedule

6.5.5.1 Fallen Asleep While Driving

Participants were asked to indicate if they had ever fallen asleep, even for a moment, while operating a CMV. Table 55 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for the "fallen asleep while driving" question. Most drivers in the dataset had not fallen asleep while driving a CMV. Three separate independent sample t-tests did not show a significant difference between the fallen asleep while driving question and at-fault (t = -0.793), not-at-fault (t = 0.302), and high-drowsiness (t = -0.312) rates/hour ($p > 0.05$).

Table 55. At-fault, not-at-fault, and high-drowsiness rates/hour for fallen asleep while driving.

Fallen Asleep While Driving	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Yes (n = 39)	0.0201	0.0077	0.0042
No (n=48)	0.0218	0.0063	0.0037

6.5.5.2 Chance of Dozing

Eight different situations were presented to participants to assess how likely they were to doze off or fall asleep (e.g., "lying down to rest in the afternoon when circumstances permit"). Drivers answered each question with one of the following answers:

- No chance of dozing.
- Slight chance of dozing.
- Moderate chance of dozing.
- High chance of dozing.

The answers to these eight questions were added to obtain an overall "chance of dozing" score. The total chance of dozing score could range from 0 to 24 with higher scores reflecting a higher chance of dozing or falling asleep. The average chance of dozing score for drivers in the dataset was 9.1 ($SD = 3.75$) with a range of 1 to 17. These results indicated the drivers in the dataset were less likely than average to doze off or fall asleep in certain situations. A Pearson product moment correlation between each participant's chance of dozing score and their rate of not-at-fault events did not show a significant relationship ($p > 0.05$). However, there was a small positive correlation between each participant's chance of dozing score and at-fault ($r = 0.264$) and high-drowsiness ($r = 0.312$) rates/hour ($p < 0.05$).

6.5.5.3 Likelihood of Fatigue Crash

Drivers were asked to provide a self-assessment of how likely they thought they were to be involved in a fatigue-related crash by marking a line on a 100-point scale (0 = Not at All; 100 = Extremely). The average "likelihood of fatigue crash" score for drivers in the dataset was 13.7 ($SD = 18.6$) with a range of 0 to 53. These results indicated the drivers in the dataset considered themselves very unlikely to be involved in a fatigue-related crash. A Pearson product moment correlation between each participant's likelihood of fatigue crash score and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$). Drivers in the experimental group were not asked this question, thus, the data presented on this question only refers to the control group.

Participants were asked if they had ever experienced a crash or incident while working that they felt was related to their sleepiness or fatigue. Table 56 displays the frequency of drivers and at-fault, not-at-fault, and high-drowsiness rates/hour for the "fatigue crash involvement at work" question. Most drivers in the dataset did indicate a crash or incident while working that they believed was related to fatigue or drowsiness. Three separate independent sample t-tests did not show a significant difference between the "fatigue crash involvement at work" question and at-fault ($t = -1.281$), not-at-fault ($t = -0.940$), and high-drowsiness ($t = 0.147$) rates/hour ($p > 0.05$).

Table 56. At-fault, not-at-fault, and high-drowsiness rates/hour for fatigue crash involvement at work.

Fatigue Crash Involvement at Work	At-fault Rate/Hour	Not-at-fault Rate/Hour	High-drowsiness Rate/Hour
Yes ($n = 77$)	0.0201	0.0066	0.0040
No ($n = 10$)	0.0283	0.0101	0.0035

6.5.5.4 Hours Working/Driving per Week

Participants were asked to estimate how many hours they worked (including driving and other work-related activities) and drove in a typical work week. The average number of hours that drivers reported driving in a typical work week was 46.7 hours (*SD* = 11.08) with a range of 25 ton70. A Pearson product moment correlation between each participant's hours driving each week and their rate of at-fault, not-at-fault, and high-drowsiness events did not show a significant relationship ($p > 0.05$). The average number of hours that drivers reported working in a typical work week was 61.3 hours (*SD* = 9.49) with a range of 42.5 to 90. A Pearson product moment correlation between each participant's hours working each week and their rate of not-at-fault and high-drowsiness events did not show a significant relationship ($p > 0.05$). However, there was a small positive correlation between hours working and at-fault rate/hour ($r = 0.354$, $p < 0.05$). Figure 19 shows a scatter plot of hours working in a typical work week versus drivers' at-fault rate.

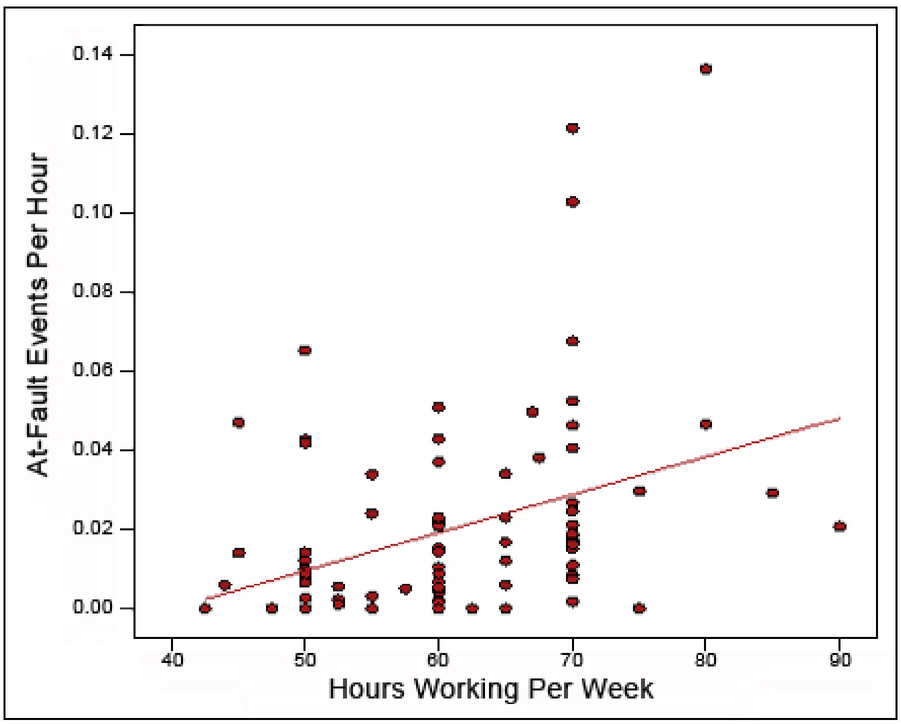

Figure 19. Chart. Scatter plot of hours working versus at-fault rates.

6.5.6 Post-hoc Analyses

Several post-hoc analyses were performed, these analyses were unrelated to the four issue areas discussed above. As many of the post-hoc analyses were not significant, only those analyses that were found to show significant results are presented below.

6.5.6.1 Self-assessment of Health and BMI

A Pearson product moment correlation between each participant's self-assessment of health score and BMI showed a small negative correlation ($r = -0.212$, $p < 0.05$). Thus, the healthier people viewed themselves, the lower their actual BMI score. Figure 20 shows a scatter plot of drivers' self-assessment of health versus their BMI.

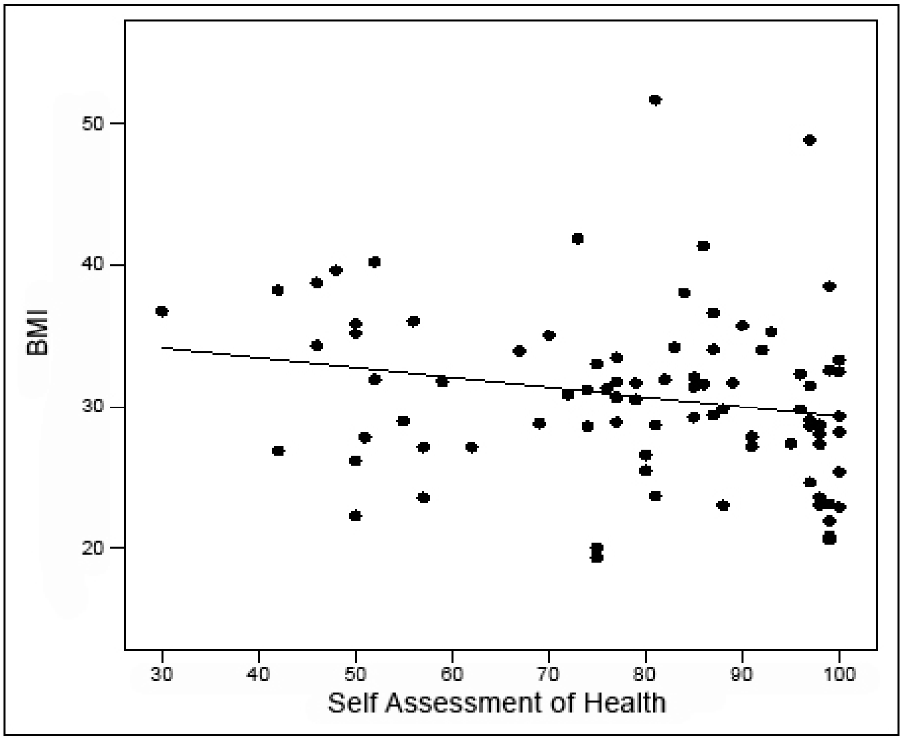

Figure 20. Chart. Scatter plot of self-assessment of health versus BMI.

6.5.6.2 Self-assessment of Health and Coping

A Pearson product moment correlation between each participant's self-assessment of health score and coping score showed a small positive correlation ($r = 0.361$, $p < 0.05$). Thus, the healthier people viewed themselves, the greater their coping skills. Figure 21 shows a scatter plot of self-assessment of health versus coping.

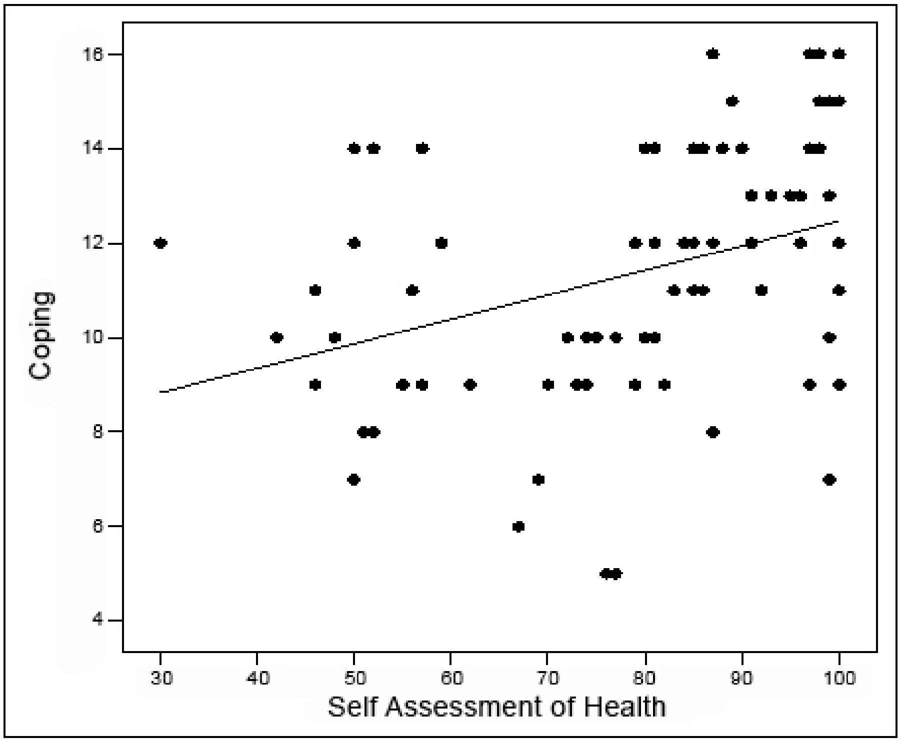

Figure 21. Chart. Scatter plot of self-assessment of health versus coping.

6.5.6.3 Hours Working and Hours Driving

A Pearson product moment correlation between each participant's self-reported hours working each week and hours driving each week showed a medium positive correlation ($r = 0.536$, $p < 0.05$). Not surprisingly, the more drivers reported working, the more hours they reported driving each week. Figure 22 displays a scatter plot of hours working versus hours driving in a typical work week.

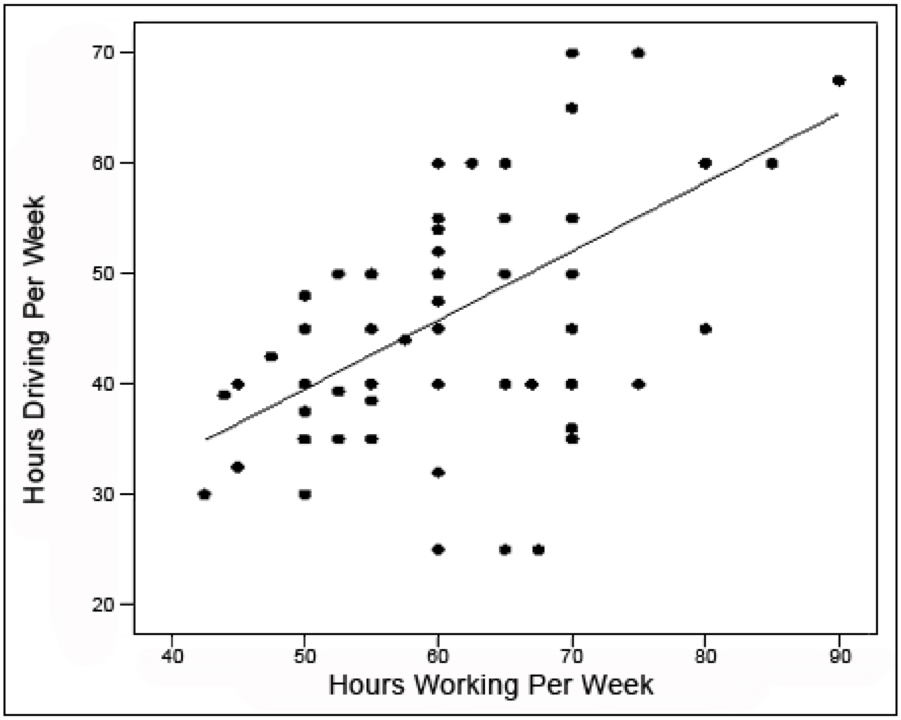

Figure 22. Chart. Scatter plot of hours working versus hours driving in a typical work week.

6.5.6.4 Age and Experience Driving a CMV

A Pearson product moment correlation between each participant's age and self-reported CMV driving experience showed a medium positive correlation ($r = 0.589$, $p < 0.05$). Older drivers reported more CMV driving experience. Figure 23 shows a scatter plot of drivers' age versus experience driving a CMV.

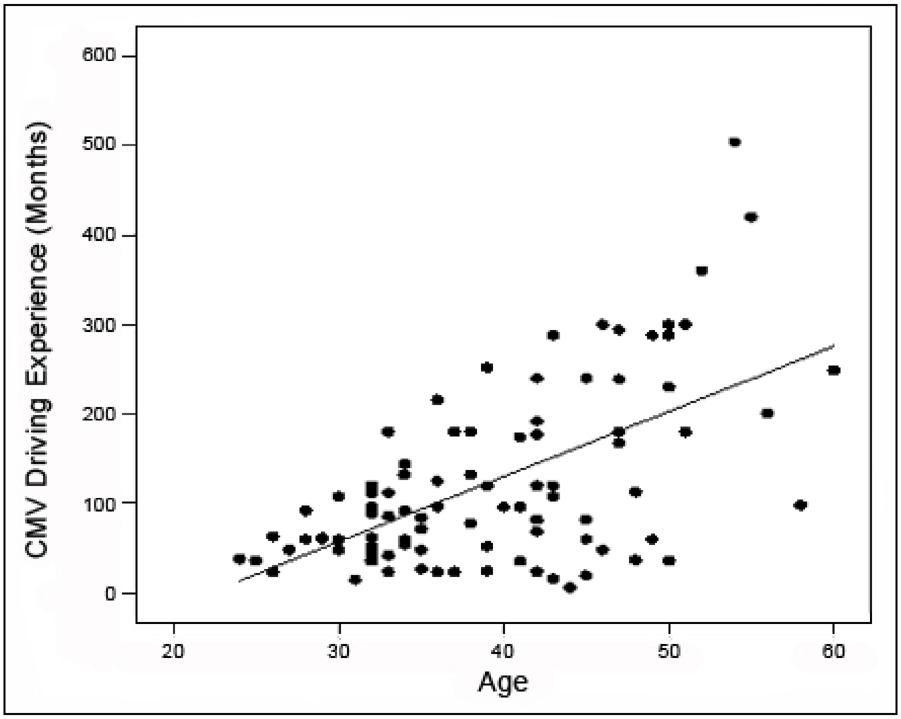

Figure 23. Chart. Scatter plot of age versus experience driving a CMV.

6.5.7 Summary of Results for Issue 4: Correlates of Driver Risk

Below is a summary of the most salient and important results. All of these statements apply to total SCEs (i.e., crashes, tire strikes, near-crashes, and crash-relevant conflicts) from both groups of drivers (i.e., experimental and control group).

- There was no difference between the experimental and control group with respect to at-fault, not-at-fault, and high-drowsiness events when controlling for exposure.
- There was a slightly increased likelihood of drivers in the dataset being involved in an at-fault, high-drowsiness event as compared to a not-at-fault, high-drowsiness event. Thus, drivers involved in at-fault events were more likely to be judged highly drowsy than drivers in not-at-fault events.
- Age was inversely related to at-fault, not-at-fault, and high-drowsiness rates.
- Age was positively related to CMV driving experience.
- CMV driving experience was inversely related to at-fault rates.
- Self-reported "chance of dozing" was positively related to at-fault and high-drowsiness rates.
- Self-reported hours working in a typical work week were positively related to at-fault crashes.
- Drivers' self-assessment of their health was inversely related to their BMI.

- Drivers' self-assessment of their health was positively related to their self-reported coping skills.
- Self-reported hours working in a typical work week were positively related to self-reported hours driving in a typical work week.

7. DISCUSSION

Before the Naturalistic Truck Driving Study, the DDWS FOT was the largest ND study ever conducted on long-haul commercial driving, and was among the first to perform systematic analyses of SCEs and to perform exposure-risk analyses to quantify risks associated with various conditions and behaviors. The analyses in this report present only a portion of the data collected. The data were collected from 95 CMV drivers between the ages of 24 and 60 for a total of 2.5 million miles over 34,230 hours in a 12-month data collection period. No experimenter was present during the data collection, and the data collection instrumentation was unobtrusive. There is every indication that drivers rapidly disregarded the presence of the instrumentation and drove as if it were not present. Thus, in addition to documenting many thousands of hours of generally safe driving, the DDWS FOT database contains many extreme cases of driving behavior and performance, including fatigue, judgment error, risk-taking, distraction and related behaviors, as well as traffic violations. This rich variety of specific safety-related behaviors and situations is generally not accessible through other empirical techniques.

The DDWS FOT had four channels of digitally compressed video and numerous electronic dynamic sensors, including radar and accelerometers. A variety of data reduction and analysis tools were created to allow efficient use of the resulting 12-TB raw database. An “event” database consisting of crashes, near-crashes, crash-relevant conflicts, and randomly selected baseline epochs was created to document and analyze the video and electronic sensor data. This database, consisting of almost 2,000 such events, could be used to answer a myriad of traffic safety problems.

A total of 915 SCEs and 1,072 baseline epochs were reported. Of these 915 SCEs, there were 28 crashes (14 tire strikes), 98 near-crashes, and 789 crash-relevant conflicts. Overall, drivers in the current dataset had the following events/hour rates:

- At-fault: 0.0198.
- Not-at-fault: 0.0068.
- High-drowsiness: 0.0037.

The event database can be used to address a multitude of additional research questions beyond those originally conceptualized. Because the data in the DDWS FOT were being continuously collected (i.e., whenever the instrumented truck was on and in motion), and many different parameters and events were captured, a variety of safety and operational issues can be investigated. Data “mining” or additional analyses may be conducted to explore various specific human factors and related issues addressable with the dataset.[1]

The DDWS FOT was originally designed to evaluate the benefits of a DDWS by comparing the alertness levels and safety performance of drivers, both with and without the device, and a control group of drivers never exposed to the active device.[9] The current project leveraged data from the DDWS FOT to investigate a set of research issues relating more fundamentally to driver performance and crash causation, and not directly related to the safety benefits of the DDWS.

The naturalistic data collection approach allows, through video, direct viewing of all of the pre-event and during-event parameters, including the pre-event driver behaviors such as distraction, fatigue, decision errors, and so forth. In addition, this technique allows the precise measurement of parameters such as vehicle speed, vehicle headway, TTC, and driver reaction time. The methodology provides much more detailed and accurate information regarding near-crash, pre-crash, and crash events than is available from post-hoc crash investigations or other traffic safety research methods. The absence of an experimenter or obtrusive observation avoids potential modification of drivers' behavior that may occur with some empirical methodologies such as the use of simulators, laboratory tests, or test track driving.

The DDWS FOT collected detailed information on a large number of near-crashes and crash-relevant conflicts. These SCEs were operationally defined for this study as having some of the elements of a crash scenario, with the exception of the presence of a successful evasive maneuver. These types of events have two important features that crash data do not. First, they occur much more frequently (e.g., there were 7 near-crashes for every crash and 56 crash-relevant conflicts for every crash). Second, near-crashes and crash-relevant conflicts are cases where 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.[(1)]

SCEs in the current dataset were apportioned as either V1 driver-initiated or V2 driver-initiated. V1 drivers in the current dataset were at-fault in 71 percent of two-vehicle SCEs; V2 drivers were assigned fault in 27.8 percent of the SCEs (1.2 percent of the SCEs were unknown or no fault was assigned). The 267 single-vehicle events were not included in the fault analysis. Most two-vehicle SCEs (n = 487) involved an interaction between an HV (V1) and an LV (V2). HV drivers were assigned fault in 57.9 percent of these LV-HV interactions; the remaining 42.1 percent were attributed to the actions of the LV driver.

These results contrast with other crash and naturalistic studies that have found that LV drivers were more likely than HV drivers to be assigned fault in LV-HV interactions. For example, in an analysis of the "Trucks Involved in Fatal Accidents" database for all two-vehicle, large-truck/passenger-vehicle fatal crashes in 1994 and 1995 (n=5,453), 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.[(25)] The passenger-vehicle drivers were cited as the only at-fault driver in 70.3 percent of the fatal crashes, while truck drivers were cited as the only at-fault driver in 16.2 percent of the fatal crashes.

In another study completed in 1999, similar results were found upon review of the FARS database.[(26)] Truck driver-related factors were cited in 29 percent of fatal truck crashes involving a passenger vehicle, while 67 percent were cited as passenger-vehicle-related. Moreover, in a separate study on crash risk, it was found that LVs were the initiators in LV-HV crashes by a ratio of approximately 3:1.[(3)]

The Light Vehicle-Heavy Vehicle Interactions Study reported results from two different ND studies where L/SH and sleeper berth trucks were instrumented with video and other data collection equipment.[(5)] A total of 142 LV-HV interactions were identified in the L/SH Study. Of these incidents, 82.4 percent were judged to have been the fault of the LV driver; 17.6 percent were judged to have been the fault of the HV driver. In the Sleeper Berth Study, a total of 68 LV-HV interactions were identified. Of these, 69.1 percent were assessed to have been the fault of the LV driver, while 38.9 percent were assessed to have been the fault of the HV driver. In the 100-Car Naturalistic Driving Study, LVs were instrumented with video and data collection equipment.(1) Of the 246 LV-HV incidents recorded in the 100-Car Naturalistic Driving Study, 56 percent were judged to have been the fault of the LV driver, while 32 percent were attributed to the HV driver. For the remaining 12 percent of incidents, it was unclear which vehicle driver was at fault.(1,27) These studies report a consistent trend for LV drivers to be assigned fault more often than HV drivers in LV-HV interactions.

In the current study, sensors were installed only on the instrumented truck's tractor, and not on the trailer. By their nature, the configuration of the instrumentation and the event detection routines limited the number of other vehicle encroachments toward subject vehicles (i.e., the instrumented trucks) that could be captured. For example, a vehicle rapidly closing toward the rear of a subject vehicle trailer could create a near-crash or other traffic conflict, but this dynamic event would not ordinarily be detected by instrumented vehicle sensors or the subsequent data analysis. The study methodology (i.e., instrumentation suite and associated data analysis procedures) differentially detected subject vehicle encroachments toward other vehicles as opposed to other vehicle encroachments toward subject vehicles. This differential detection, which signifies the apportionment of at-fault versus not-at-fault events in the current dataset, does not represent the universe of such events that occurred in actual driving.

These events are a common source of LV-HV crashes. Of the approximately 437,000 large truck crashes in 2003, 19 percent (about 81,000) were rear-end crashes.(28) Of these rear-end crashes, 39 percent (about 34,000) involved the large truck being struck. In the 100-Car Naturalistic Driving Study, 55.1 percent of the LV-HV interactions involved the LV approaching the HV from behind.(27) The lack of a rear camera on the instrumented truck was likely the reason for the HV drivers being assigned fault more often than LV drivers in the current LV-HV interactions.

ORD was used as a principal measure of driver alertness and fatigue in the current analysis. It was coded based on methodical observation of the driver's face and general vehicle control, not based on the occurrence of an error leading to the crash threat. High-drowsiness did not have to play a critical or primary factor in the event for a high ORD to be coded. Drivers were judged to be highly drowsy in about 13 percent of V1 at-fault events, but this percentage had no direct implication relating to event causation. Instead, it merely indicates that truck driver drowsiness and related performance effects were observed during the event.

In contrast, the CR variable was used to capture the principal or proximal reason for the occurrence of the event. Eleven of the 86 V1 at-fault and drowsy SCEs (12.8 percent) were assigned a CR relating to driver fatigue. These 11 cases represent less than 2 percent of cases in which the truck driver was judged to be at fault. The largest proportion of V1 at-fault and drowsy SCEs had CRs relating to subject driver recognition failures or decision errors. The finding of larger numbers of recognition and decision errors associated with fatigue is consistent with the additional lapses and judgment errors seen in laboratory studies of sleep deprivation.(16,29) These findings were consistent with the concept of fatigue playing a dual role in crash causation. That is, driver fatigue appears to be a primary cause of a relatively small percentage of crashes recognized as “asleep at the wheel,” but a contributing factor in a much larger percentage of crashes attributed to other driver errors.

If one considers only two-vehicle events where the V1 driver was at fault (i.e., assigned the CR), the driver error profile is quite similar to the preliminary LTCCS statistics reported.[6] A preliminary analysis of 87 large truck crashes from the LTCCS found the following error type classifications for two-vehicle crashes where the truck driver was assigned a CR: recognition errors (46 percent), decision errors (36 percent), performance errors (5 percent), driver non-performance errors (3 percent), and unknown driver problem (1 percent). In the current study, V1 drivers were coded with the following error type classifications in two-vehicle events: recognition errors (29.7 percent), decision errors (63.1 percent), performance errors (6.3 percent), driver non-performance errors (1 percent), and unknown (0 percent).

The current study also assessed functional countermeasures that may have prevented SCEs. Since the methodology primarily captured events with V1 avoidance maneuvers (such as hard braking), the relevant countermeasures identified were often related to improving braking response or other avoidance maneuvers to crash threats in the forward direction. The most frequent V1 functional countermeasures involved improving driver recognition of forward threats, increasing driver attention to the forward scene, and improving driver situation awareness and/or defensive driving. The single most frequent functional countermeasure for V2 was reciprocal to V1 countermeasures; that is, provide a warning to prevent rear encroachment or tailgating by the other vehicle.

In the current study there were a variety of comparisons between SCEs and baseline epochs. These comparisons allowed the study to describe and characterize “normal” driving for the study sample, as well as infer the increased or decreased risk associated with various conditions and driver behaviors and comparisons between the baseline epochs and SCEs. The current study found that more SCEs, compared to baseline epochs, occurred in the following locations:

- Intersections, intersection-related, parking lots, entrance/exit ramps, and rail grade crossings.
- Trafficways that were not physically divided or going only one way (drivers were 5.4 times more likely to be involved in a SCE, compared to a baseline epoch, on a road that was not physically divided).
- Traffic densities in which stable flow, maneuverability and speed were more restricted (drivers were 5.9 times more likely to be involved in a SCE, compared to a baseline epoch, in the traffic density described).
- Construction or construction-related zone (drivers were 8.5 times more likely to be involved in a SCE, compared to a baseline epoch, if they were traveling in a construction or construction-related zone).

One counterintuitive finding was the occurrence of SCEs associated with relatively low vehicle speeds (60 mi/h or less). Most SCEs occurred at speeds of 50 mi/h or less and, based on a comparison with baseline epochs, drivers in the current dataset were about 9 times more likely to be involved in a SCE if they were traveling at 50 mi/h or less. These results should not be interpreted as suggesting that driving slow is more dangerous than driving fast. Rather, the finding is consistent with the fact that SCEs in the current study disproportionately occurred on undivided highways and in situations of greater traffic density, both of which are associated with lower vehicle speeds.

Across the 95 drivers, a wide range of involvement rates were observed for at-fault events, not-at-fault events, and high-drowsiness events. For example, the 15 drivers with the highest at-fault event rates drove 11 percent of the driving hours but had 38.2 percent of the at-fault events. The 15 drivers with the highest not-at-fault event rates drove 14.6 percent of driving hours but had 43 percent of the not-at-fault events. One might expect not-at-fault event involvement among drivers to be largely random and therefore unpredictable and unrelated to driver factors. On the other hand, differential driver involvement in not-at-fault events could reflect individual differences in defensive driving skills or practices, or perhaps the confounding effects of differences in traffic conditions (e.g., roadway type, traffic density) among the drivers in the study. Clearly, not-at-fault events were not distributed randomly across drivers in the study. There were sharp individual differences in rates of involvement in these events and rates were correlated with driver age, experience, and work hours per shift.

Although extreme differential risk rates were observed for all three metrics, most of the personal risk factors assessed in the current study did not show a correlation with at-fault, not-at-fault, or high-drowsiness events/hour. This is most likely due to the small sample size and limited power to detect statistical significance among the categorical predictors (i.e., smoking, education, ethnicity, etc.). However, a few personal risk factors were shown to be related to at-fault, not-at-fault, or high-drowsiness events/hour. Drivers who were younger, or those with less CMV driving experience or who worked long hours per shift were more likely to doze, and were most likely to be involved in at-fault, not-at-fault, or high-drowsiness events.

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APPENDIX A: DROWSY DRIVER WARNING SYSTEM PRE-PARTICIPATION SURVEY

Thank you for taking the time to fill out this survey! It should take you about 1 minute to complete. Please leave blank any information you are not sure of or do not feel comfortable providing. We will use this information to help us determine which drivers are best suited to participate in the study. The information you provide will be kept confidential and will not be shared with any of your managers or other drivers.

Name: ___________________________________

Date: ___________

1. What is your age?: ___________ years
2. Gender (Check one): ☐ Male ☐ Female
3. What is your eye color? ______________
4. Height: _______feet _______inches
5. Weight: ___________pounds
6. Build (check one): ☐ Small frame ☐ Medium frame ☐ Large frame
7. Do you wear contact lenses? (Check one) ☐ No ☐ Yes (Lens color:________)
8. Do you wear glasses at *night* when driving? ☐ No ☐ Yes
   ☐ Metal frame ☐ Plastic frame
9. Do you use a hearing aid? ☐ No ☐ Yes, in which ears?__________
10. Which of the following groups is <u>most</u> representative of your background? (Check one)

    ☐ African/American ☐ Asian/American ☐ Caucasian/American
    ☐ Hispanic/American ☐ Native American

11. Is English your language of preference for: reading? (check one) ☐ No ☐ Yes
    speaking? (check one) ☐ No ☐ Yes
12. How long have you been driving commercial vehicles? _____years _____months
13. How long have you been working for this company? _____years _____months

14. How long did you work for your previous employer (your job before this one)?
_____years _____months

15. Are you a member of a union (Check one)? ☐ No ☐ Yes, which one?___________

16. Type of license and endorsements held:
License:________________ Endorsements: _______________

17. I would like to participate in this experiment (Check one): ☐ No ☐ Yes

If yes: What is your phone number? __________

What is the best time to reach you? __________

THANK YOU FOR COMPLETING THIS SURVEY!

APPENDIX B: DATA CODING DIRECTORY

EVENT VARIABLES

1. **Event Identifier (C-N-I-B)**

Comment: Each event will be assigned a file name that is automatically generated by the software.

2. **Analyst Identifier (C-N-I-B)**

Comment: Analysts/data reductionists will be identified by their log-ins.

3. **Trigger Type (C-N-I-B)**

00 = Not applicable (baseline epoch).
01 = Lateral acceleration.
02 = Longitudinal acceleration.
03 = CI button.
04 = Lane deviation/bust.
05 = Normalized lane position.
06 = Forward TTC.
07 = Forward range.
08 = Rear TTC.
09 = Rear range.
10 = Side object detection.
11 = Lane change cut-off.
12 = Yaw rate ("swerve").
13 = CAN.
14 = Radio frequency sensor.
15 = Glare event.
16 = Air bag.

Comment: These are taken from the 100-Car Naturalistic Driving Study coding, although a number of 100-Car triggers are not being used in the current study. Total will be somewhat greater than the total event N since some events will have more than one trigger. This variable will be automatically generated by the software.

4. **Trigger Quantitative Value (C-N-I)**

Maximum/minimum value of relevant triggers. For TTC triggers, find the closest point where the two vehicles are still in a path to collision, and enter that number.

5. **Event Classification (C-N-I-B)**

00 = Invalid trigger. These are events where sensor readings were spurious or otherwise not safety-relevant due to a transient spike or some other anomaly.

00a = No video. One or more of the quadrants of video is out/not visible. It is not possible to obtain enough information to determine the event.

01 = Baseline driving epoch (selected randomly). These are 1 minute time periods that are randomly selected from the recorded dataset. Baseline epochs will be described using many of the same variables and data elements used to describe and classify crashes, near-crashes, and incidents. Examples of such variables include ambient weather, roadway type, and driver behaviors. The creation of a baseline dataset will enable the study to describe and characterize “normal” driving for the study sample and infer the increased or decreased risk associated with various conditions and driver behaviors by comparisons between the control (baseline) dataset and the incident and/or near-crash datasets. For example, if 20 percent of incidents but only 10 percent of baseline epochs occurred during rain, one could infer that rain is associated with an increased incident rate and, therefore, increased risk.

02 = Crash. Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, cyclists or animals.

03 = Near-crash (evasive maneuver). Any circumstance requiring a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, pedalcyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities. Any event where the driver swerves off of the side of the road, and any part of the truck leaves the pavement, will automatically be coded as a near-crash.

04 = Near-crash (no evasive maneuver). Any circumstance that results in extraordinarily close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, pedalcyclists or animals, there is no avoidance maneuver or response. Extraordinarily close proximity is defined as a clear case where the absence of an avoidance maneuver or response is inappropriate for the driving circumstances (including speed, sight distance, etc.). TTCs of less than 2 seconds are reviewed to assess whether they qualify as crash-relevant conflicts (or near-crashes); those with TTCs of less than 1 second are always coded as crash-relevant conflicts or near-crashes.

05 = Crash-relevant conflict (evasive maneuver). Any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, pedalcyclist, or animal that is less severe than a rapid evasive maneuver (as defined above), but greater in severity than a “normal maneuver” to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A “normal maneuver” for the subject vehicle is defined as a control input that falls within the 99-percent confidence limit for control inputs for the initial study data sample. Examples of potential crash-relevant conflicts include hard braking by a driver because of a specific crash threat, or proximity to other vehicles. Evasive maneuvers resulting in unsafe and/or illegal maneuvers or situations should be included in this category (or as near-crashes if more severe). Longitudinal decelerations of –0.35g

or greater are reviewed to assess whether they qualify as crash-relevant conflicts (or near-crashes); those with decelerations of –0.50g or greater are always coded as crash-relevant conflicts or near-crashes.

06 = Crash-relevant conflict (no evasive maneuver). Any circumstance that results in close proximity of the subject vehicle to any other vehicle, pedestrian, pedalcyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, pedalcyclists or animals, there is no avoidance maneuver or response. Extraordinarily close proximity is defined as a clear case where the absence of an avoidance maneuver or response is inappropriate for the driving circumstances (including speed, sight distance, etc.).

07 = Non-conflict. Any incident that has an above-threshold trigger, but which does not result in a crash, near-crash, or crash-relevant conflict as defined above. There is no abrupt evasive maneuver and no signs of any other unsafe condition such as a lane break. Driver errors may be observed, but they do not result in a traffic conflict. Examples include hard braking by a driver in the absence of a specific crash threat, or high lateral acceleration on curves not resulting in any loss-of-control, lane departure, or proximity to other vehicles.

Comment: Initial coding step. Invalid triggers and non-conflicts result in no further coding. Identification of two different types of near-crashes (i.e., evasive maneuver and proximity event) permits later disaggregation if desired. Definitions of each type of event are given above.

6. Date (C-N-I-B)

Comment: Raw data from vehicle.

7. Day of Week (C-N-I-B)

Comment: Raw data from vehicle.

8. Time (C-N-I-B)

Comment: Raw data from vehicle. For C-N-I events, time of maximum/minimum trigger value is recorded. For baseline epochs, the end of the 30-second baseline period is recorded. *Format:* Integer.

9. Vehicles/Non-Motorists Involved (C-N-I)

00 = Not applicable (baseline epoch).
01 = 1 vehicle (subject vehicle only).
02 = 2 vehicles.
03 = 3 vehicles.
04 = 4 or more vehicles.
05 = Subject vehicle + pedestrian.
06 = Subject vehicle + pedalcyclist.
07 = Subject vehicle + animal.

08 = Other.

Comment: Events involving the subject vehicle and an object (i.e., struck or potentially struck) are coded 01. For some events (e.g., those involving transient encroachment into an oncoming lane), it will be difficult to decide whether the event should be considered a one- or two-vehicle event. Consider the event a two-vehicle event if the crash resulting from the incident would likely have involved two vehicles, and/or if either driver's maneuvers were influenced by the presence of the other vehicle (e.g., if V1 maneuvered to avoid V2). Consider the event a one-vehicle event if the presence of other vehicles presented no immediate threat and had no effect on V1's maneuvers or behaviors.

10. Which vehicle is considered to be at fault? (C-N-I)

00 = Not applicable (baseline epoch).
01 = Vehicle 1 (Subject vehicle).
02 = Vehicle 2 (Other vehicle, pedalcyclists, or animal).
09 = Unknown.

Comment: The "at-fault" vehicle is defined as the vehicle with the assigned CR.

11. Light Condition (C-N-I-B)

01 = Daylight.
02 = Dark.
03 = Dark but lighted.
04 = Dawn.
05 = Dusk.
09 = Unknown.

Comment: GES A19.

12. Weather (Atmospheric Condition) (C-N-I-B)

01 = No adverse conditions.
02 = Rain.
03 = Sleet.
04 = Snow.
05 = Fog.
06 = Rain and fog.
07 = Sleet and fog.
08 = Other (smog, smoke, sand/dust, crosswind, hail).
09 = Unknown.

Comment: GES A20.

13. Roadway Surface Condition (C-N-I-B)

01 = Dry.
02 = Wet.
03 = Snow or slush.
04 = Ice.
05 = Sand, oil, dirt.

08 = Other.
09 = Unknown.

Comment: GES A15.

14. Relation to Junction (C-N-I-B)

00 = Non-junction.
01 = Intersection.
02 = Intersection-related.
03 = Driveway, alley access, etc.
03a = Parking lot.
04 = Entrance/exit ramp.
05 = Rail grade crossing.
06 = On a bridge.
07 = Crossover-related.
08 = Other.
09 = Unknown.

Comment: GES variable A09. GES instructions for coding this variable will be reviewed to ensure consistency of coding approach with GES.

15. Construction-zone-related (C-N-I-B)

00 = Not construction-zone-related (or unknown).
01 = Construction zone (occurred in zone).
02 = Construction-zone-related (occurred in approach or otherwise related to zone).

Comment: Default code is 0. For the purposes of the coding, consider any area with multiple traffic cones, barrels, etc. to be a construction zone.

16. Traffic Density (C-N-I-B)

01 = LOS A: Free flow—Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.

02 = LOS B: Flow with some restrictions—In the range of stable traffic flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from LOS A, because the presence of others in the traffic stream begins to affect individual behavior.

03 = LOS C: Stable flow, maneuverability and speed are more restricted—In the range of stable traffic flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by the interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level.

04 = LOS D: Unstable flow: temporary restrictions substantially slow driver—Represents high-density, but stable traffic flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems at this level.

05 = LOS E: Flow is unstable; vehicles are unable to pass, temporary stoppages, etc.—Represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to "give way" to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because small increases in flow or minor perturbations within the traffic stream will cause breakdowns.

06 = LOS F: Forced traffic flow condition with low speeds and traffic volumes that are above capacity. Queues' forming in particular locations—This condition exists whenever the amount of traffic approaching a point exceeds the amount which can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go waves, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, then be required to stop in a cyclic fashion. LOS F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge slow which causes the queue to form, and LOS F is an appropriate designation for such points.

09 = Unknown/unable to determine

DRIVER/VEHICLE 1 VARIABLES

Note: Driver/Vehicle 1 (DV-1) is always the study subject driver/vehicle (i.e., the truck or truck driver).

17. Subject Vehicle Number (C-N-I-B)

Format: Integer. Automatically generated.

18. Subject Driver Number (C-N-I-B)

Format: Integer. Automatically generated.

19. Trafficway Flow (C-N-I-B)

00 = Not physically divided (center two-way left turn lane).
01 = Not physically divided (two-way trafficway).
02 = Divided (median strip or barrier).
03 = One-way trafficway.

09 = Unknown.
Comment: GES variable V A11. Coded in relation to subject vehicle.

20. Number of Travel Lanes (C-N-I-B)

01 = 1.
02 = 2.
03 = 3.
04 = 4.
05 = 5.
06 = 6.
07 = 7+.
09 = Unknown.

Comment: GES V A12. Per GES, if road is divided, only lanes in travel direction are counted. If undivided, all lanes are counted. Coded in relation to subject vehicle. Count all contiguous lanes at the time and location of the incident; e.g., include entrance or exit lanes if contiguous.

21. Truck Pre-event Speed (C-N-I-B)

Format: Integer.

Comment: For C-N-I events, coded for the period just prior to the occurrence of the critical event and/or just prior to any avoidance maneuver. For example, when braking is involved, the pre-event speed is the speed just prior to the beginning of braking. For baseline events, coded for the end of the 30-second baseline interval. Note that roadway "Speed Limit" cannot currently be determined because most speed limit signs are not legible on the videos. Future efforts (in Phase 2, in particular) will consider automated ways to obtain this variable such as the use of the global positioning and roadway geographic information systems.

22. Roadway Alignment (C-N-I-B)

01 = Straight.
02a = Curve right.
02b = Curve left.
09 = Unknown.

Comment: GES V A13, with expansion of curve choices. Coded in relation to subject vehicle.

23. Roadway Profile (C-N-I-B)

01 = Level (or unknown).
02a = Grade up.
02b = Grade down.
03 = Hillcrest.
04 = Sag.

Comment: GES V A14, with expansion of grade choices. Coded in relation to subject vehicle.

24. Driver Safety Belt Worn? (C-N-I-B)

01 = Yes.
02 = No.
09 = Unknown.

Comment: This issue is of current interest to FMCSA and its capture would permit comparisons of driver behavior between drivers wearing and not wearing safety belts. Judged based on whether a shoulder strap is visible; lap belt typically cannot be seen.

25. Does the Driver Cover the Camera/Is the Camera Covered? (C-N-I-B)

00 = Yes.
01 = No/not observed.
02 = Attempts, but fails.

26. Alcohol Use (C-N-I-B)

00 = None apparent.
01 = Suspected use observed in vehicle without overt effects on driving.
02 = Suspected use observed in vehicle with overt effects on driving.
03 = Reported by police (applicable only to crashes).
04 = Use not observed or reported, but suspected based on driver behavior.
09 = Unknown.

Comment: Use indicated only if apparent from event review.

Note: The remaining DV-1 variables are pre-crash and event causation variables. Table 57 lists these variables, indicates sources, and shows the corresponding variable for DV-2.

Table 57. Coded pre-crash and causation variables.

Variable Name	Principal Source(s) (e.g., Other Databases/Studies)	Subject Vehicle (V1) Variable #	Other Vehicle (V2) Variable #
Vehicle Pre-event Movement	GES, LTCCS	27	44
“Accident” Type [Scenario Role]	GES, LTCCS	28	45
Incident Types	Two recent Virginia Technical Transportation Institute (VTTI) studies	29	46
Critical Pre-crash Event	LTCCS	30	47
CR for the Critical Event	LTCCS	31	48*
Attempted Avoidance Maneuver	GES, LTCCS	32	49

Variable Name	Principal Source(s) (e.g., Other Databases/Studies)	Subject Vehicle (V1) Variable #	Other Vehicle (V2) Variable #
Driver Vision Obscured By	GES	34	Not coded
Average PERCLOS Value (1, 3, 5 Minutes)	VTTI and other fatigue research	35–37	Not coded
Observer Rating of Drowsiness (1 Minute)	Previous VTTI research	38	Not coded
Potentially Distracting Driver Behaviors	GES	39	Not coded
Driver Actions/Factors Relating to Event	100-Car Study	40	*50
Applicable Functional Countermeasures	Various	41	51

*****Abridged due to inability to observe specific Driver 2 behaviors and states.

27. Vehicle Pre-event Movement (C-N-I-B)

00 = No driver present.
01 = Going straight.
02 = Decelerating in traffic lane.
03 = Accelerating in traffic lane.
04 = Starting in traffic lane.
05 = Stopped in traffic lane.
06 = Passing or overtaking another vehicle.
07 = Disabled or parked in travel lane.
08a = Leaving a parking position, moving forward.
08b = Leaving a parking position, backing.
09a = Entering a parking position, moving forward.
09b = Entering a parking position, backing.
10 = Turning right.
11 = Turning left.
12 = Making a U-turn.
13 = Backing up (other than parking).
14 = Negotiating a curve.
15 = Changing lanes.
16 = Merging.
17 = Successful avoidance maneuver to a previous critical event.
98 = Other.
99 = Unknown.

Comment: This is LTCCS Variable #4 with expanded choices for 8 and 9. For baseline epochs, the primary movement of the vehicle during the epoch is coded.

28. "Accident" Type [Scenario Role] (C-N-I)

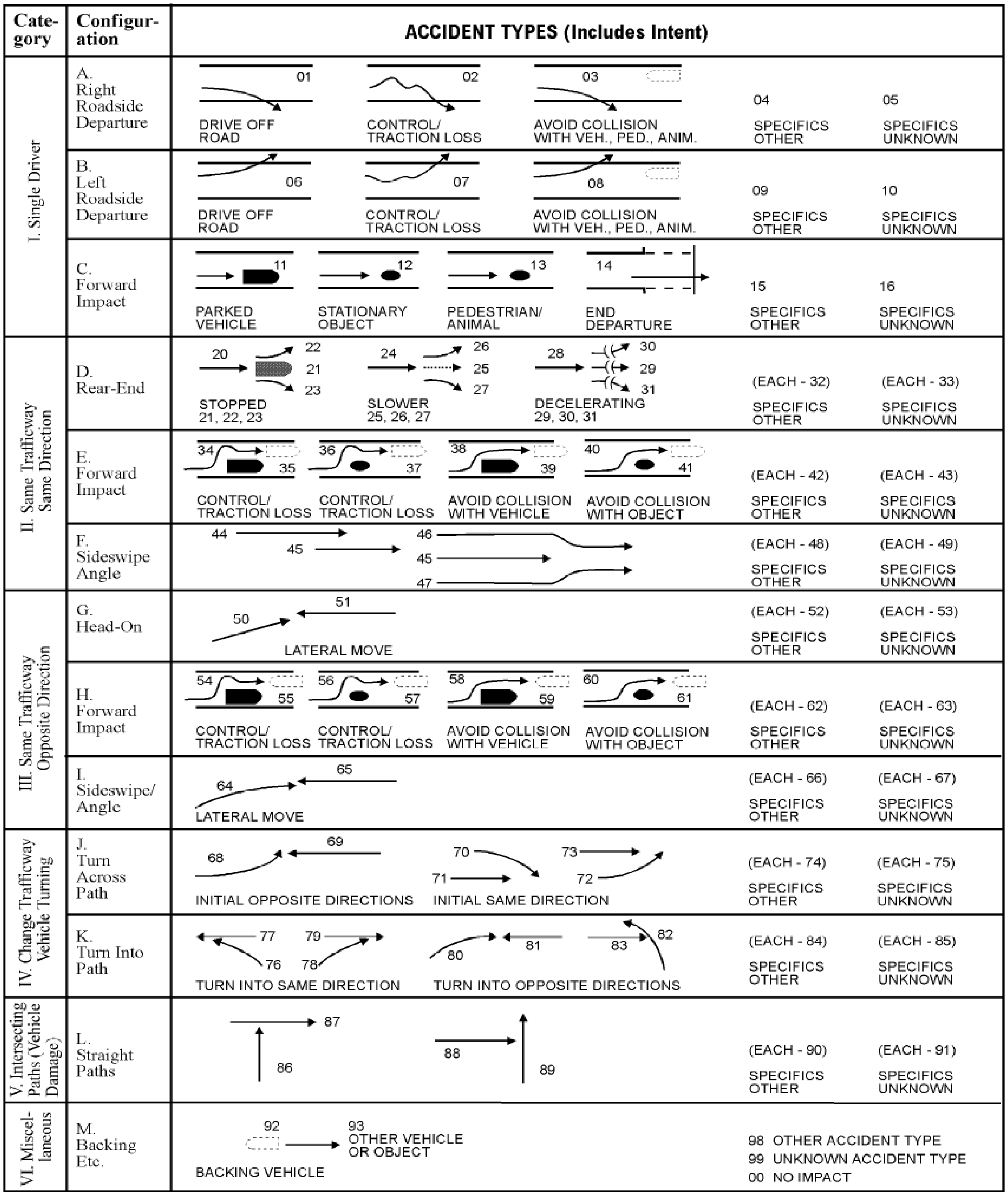
00 = Not applicable (baseline epoch).

Other codes: See diagram, next page.

Comment: LTCCS Variable #10 and GES Variable V23. Since this variable "includes intent," analysts should project likely scenario roles for incidents where outcomes are not definite. In other words, if the trigger-related event had resulted in a crash, what would the crash scenario be? When specific scenarios cannot be projected, use the "Specifics Unknown" choices (e.g., 5, 10, 16, 33, etc.). Figure 24 illustrates the Accident Types.

Additional clarifications:

- Drive off road codes (e.g., 01 and 06) are used when a vehicle has crossed, or is projected to cross, a roadside delineation such as a lane edge line (going onto the shoulder or median), curb, or the edge of the pavement. This includes scenarios involving parked vehicles and stationary objects if those objects are outside of the roadway delineation (e.g., on an unpaved shoulder).
- Forward impact codes (e.g., 11, 12) are used when the objects are in the travel lane or when there is no lane edge delineation as described above. Thus, a scenario involving a parked vehicle on the pavement where there is no lane edge delineation is coded 12.
- For left-side lane departures into the oncoming traffic lane, code 64/65 if the lateral encroachment is less than a few feet. Code 50/51 only if the lateral encroachment was sufficient to create a significant risk of a head-on crash.
- Hard braking events at intersections in the absence of a specific crash or crash threat are coded 91 (intersecting straight paths, specifics unknown).



Source: Thieriez, Radja, and Toth (2002)

Figure 24. Diagram. Description of the accident types.

29. Incident Types (C-N-I)

00	= Not applicable (baseline epoch).
01/02	= Aborted lane change.
03/04	= Approaches traffic quickly (not used).
05/06/07/08	= Backing in roadway.
09/10	= Clear path for emergency vehicle.
11/12	= Conflict between merging and existing traffic.
13/14	= Conflict with oncoming traffic.
15/16	= Exit then re-entrance onto roadway.
17/18	= Following too closely.
19/20/21	= Improper lane change.
22/23	= Improper passing.
24/25	= Improper U-turn.
26/27	= Lane change without sufficient gap.
28/29	= Lane drift.
30/31	= Late braking for stopped/stopping traffic.
32/33	= Lateral deviation of through vehicle.
34/35	= Left turn without clearance.
36/37	= Merge out of turn (before lead vehicle).
38/39/40	= Merge without sufficient gap.
41/42	= Obstruction in roadway.
43/44	= Proceeding through red traffic signal.
45/46	= Roadway entrance without clearance.
47/48	= Slow speed.
49/50	= Slow upon passing.
51/52/53	= Sudden braking in roadway.
54/55	= Through traffic does not allow lane change.
56/57/58	= Through traffic does not allow merge.
59/60	= Turn without sufficient warning.
61/62	= Turn/exit from incorrect lane.
63/64	= Wide turn into adjacent lane.
65	= Conflict with object/animal/pedalcyclist in roadway.
66	= Conflict with object/animal/bicyclist on side of road.
67	= Other single-vehicle event.
68/69	= Close proximity to turning vehicle.
99	= Unknown.

Comment: This scenario classification has been used in other studies.[4,25] Coding this variable will enable comparisons with those studies. Diagrams of these scenarios are provided below.

Table 58. Description of incident types.

Incident Type	Description
Aborted Lane Change	A driver tries to make a lane change into a lane where there is already a vehicle (driver doesn't see vehicle). The driver has to brake and move back into the original lane.
Approaches Traffic Quickly (Not Used)	A driver approaches stopped/slowing traffic too quickly and has to brake hard/suddenly to avoid hitting the lead vehicle.
Backing in Roadway	A driver backs the vehicle while on a roadway in order to maneuver around an obstacle ahead on the roadway
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.
Conflict between Merging and/or Exiting Traffic	Drivers entering and/or exiting a roadway, using a shared weaving section, conflict.
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.
Exit Then Re-entrance Onto Roadway	A driver exits a roadway then crosses a solid white line to re-enter.
Following Too Closely	A driver does not allow adequate spacing between the driver's vehicle and the lead vehicle (e.g., tailgating).
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.)
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).
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.
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.
Lane Drift	A driver drifts into an adjacent lane without intention to make a lane change.
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.
Lateral Deviation of Through Vehicle	A driver has substantial lateral deviation of a through vehicle. Vehicle may or may not deviate from the lane.
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.
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.

Incident Type	Description
Merge without Sufficient Gap	A driver merges into traffic without a sufficient gap to either the front or back of one or more vehicles.
Obstruction in Roadway	A stationary object blocks through traffic, such as traffic that is backed up or an animal in the roadway.
Proceeding through Red Traffic Signal	A driver fails to respond to a red traffic signal, conflicting with a vehicle proceeding through the intersection legally.
Roadway Entrance without Clearance	A driver turns onto a roadway without adequate clearance from through traffic.
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.
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.
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.
Through Traffic Does Not Allow Lane Change	A driver is trying to make a lane change (with turn signal on) but traffic in the adjacent lane will not allow the lane change to be completed.
Through Traffic Does Not Allow Merge	Through traffic obstructs a driver from entering the roadway.
Turn without Sufficient Warning	A driver slows and turns without using a turn signal or without using a turn signal in advance.
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).
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.
Conflict with Object/Animal/Pedalcyclist in Roadway	A vehicle approaches an object/animal/bicyclist in the roadway and either makes contact with it, or performs an evasive maneuver in order to avoid it.
Conflict with Object/Animal/Pedalcyclist on Side of Roadway	A vehicle approaches an object/animal/bicyclist on the side of the road and either makes contact with it, or performs an evasive maneuver in order to avoid it.
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.
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.
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.

30. Critical Pre-crash Event for Vehicle 1 (C-N-I)

00 = Not applicable (baseline epoch).

THIS VEHICLE (V1) LOSS OF CONTROL DUE TO:

01 = Blow out or flat tire.
02 = Stalled engine.
03 = Disabling vehicle failure (e.g., wheel fell off).

04 = Non-disabling vehicle problem (e.g., hood flew up).
05 = Poor road conditions (*wet road*, puddle, pothole, ice, etc.).
06 = Traveling too fast for conditions.
07 = Jack-knife event.
08 = Cargo shift.
09 = Braking.
10 = Steering.
18 = Other cause of control loss.
19 = Unknown cause of control loss.

THIS VEHICLE (V1) TRAVELING

20 = Toward or over the lane line on left side of travel lane.
21 = Toward or over the lane line on right side of travel lane.
22 = Toward or off the edge of the road on the left side.
23 = Toward or off the edge of the road on the right side.
24 = End departure.
25 = Turning left at intersection.
26 = Turning right at intersection.
27 = Crossing over (passing through) intersection.
28 = This vehicle decelerating.
29 = Unknown travel direction.

OTHER MOTOR VEHICLE (V2) IN LANE

50 = Other vehicle stopped.
51 = Traveling in same direction with lower steady speed.
52 = Traveling in same direction while decelerating.
53 = Traveling in same direction with higher speed.
54 = Traveling in opposite direction.
55 = In crossover.
56 = Backing.
59 = Unknown travel direction of other motor vehicle in lane.

OTHER MOTOR VEHICLE (V2) ENCROACHING INTO LANE

60 = From adjacent lane (same direction)—toward or over left lane line.
61 = From adjacent lane (same direction)—toward or over right lane line.
62 = From opposite direction—toward or over left lane line.
63 = From opposite direction—toward or over right lane line.
64 = From parking lane.
65 = From crossing street, turning into same direction.
66 = From crossing street, across path.
67 = From crossing street, turning into opposite direction.
68 = From crossing street, intended path not known.
70 = From driveway, turning into same direction.
71 = From driveway, across path.

72 = From driveway, turning into opposite direction.
73 = From driveway, intended path not known.
74 = From entrance to limited access highway.
78 = Encroachment by other vehicle—details unknown.

PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST

80 = Pedestrian in roadway.
81 = Pedestrian approaching roadway.
82 = Pedestrian - unknown location.
83 = Pedalcyclist or other non-motorist in roadway.
84 = Pedalcyclist or other non-motorist approaching roadway.
85 = Pedalcyclist or other non-motorist—unknown location.

OBJECT OR ANIMAL

87 = Animal in roadway.
88 = Animal approaching roadway.
89 = Animal - unknown location.
90 = Object in roadway.
91 = Object approaching roadway.
92 = Object - unknown location.

OTHER

93 = This vehicle not involved in first harmful event.
98 = Other critical pre-crash event.
99 = Unknown.

Comment: This is LTCCS Variable #5. This variable is coded for both vehicles in a two-vehicle incident. However, the CR (see below), is coded for only one vehicle. For consistency with the Accident Type variable (28), lane edges between travel lanes and non-travel lanes (e.g., shoulders) are considered road edges; e.g., events involving V1 crossing of these edges are coded 22 or 23. Unlike the Accident Type variable, however, the analyst should code the actual precipitating event and should not project or extrapolate the event. In the above list, note addition of 09 = loss of control due to braking and 10 = steering.

31. DV1 Critical Reason for the Critical Event (C-N-I)
000a = Not applicable (baseline epoch).
000b = CR not coded to this vehicle.

DRIVER-RELATED FACTOR

Critical Non-performance Errors:

100 = Asleep.
101 = Heart attack or other physical impairment of the ability to act.

107 = Drowsiness, fatigue, or other reduced alertness (not asleep).
108 = Other critical non-performance.
109 = Unknown critical non-performance.

DRIVER-RELATED FACTOR

Recognition Errors:

110 = Inattention (i.e., daydreaming).
111 = Internal distraction.
112 = External distraction.
113 = Inadequate surveillance (e.g., failed to look, looked but did not see).
118 = Other recognition error.
119 = Unknown recognition error.

Decision Errors:

120 = Too fast for conditions (e.g., for safe vehicle control or to be able to respond to unexpected actions of other road users).
121 = Too slow for traffic stream.
122 = Misjudgment of gap or other's speed.
123 = Following too closely to respond to unexpected actions (close proximity for 2 or more seconds).
124 = False assumption of other road user's actions.
125 = Illegal maneuver.
125a = Apparently intentional sign/signal violation.
125b = Illegal U-turn.
125c = Other illegal maneuver.
126 = Failure to turn on head lamps.
127 = Inadequate evasive action (e.g., braking only not braking and steering; release accelerator only instead of braking).
128a = Aggressive driving behavior—intimidation: any behavior emitted by a driver while driving that is intended to cause physical or psychological harm to another person.
128b = Aggressive driving behavior—wanton, neglectful or reckless behavior: excessive risky driving behaviors performed without intent to harm others, such as weaving through traffic, maneuvering without signaling, running red lights, frequent lane changing, and tailgating.
138 = Other decision error.
139 = Unknown decision error.
140 = Apparent recognition or decision error (unknown which).

Performance Errors:

141 = Panic/freezing.
142 = Overcompensation.
143 = Poor directional control, e.g., failing to control vehicle with skill ordinarily expected.

148 = Other performance error.
149 = Unknown performance error.
199 = Type of driver error unknown.

VEHICLE-RELATED FACTOR

200 = Tires/wheels failed.
201 = Brakes failed.
202 = Steering failed.
203 = Cargo shifted.
204 = Trailer attachment failed.
205 = Suspension failed.
206 = Lights failed.
207 = Vehicle-related vision obstructions.
208 = Body, doors, hood failed.
209 = Jack-knifed.
298 = Other vehicle failure.
299 = Unknown vehicle failure.

ENVIRONMENT-RELATED FACTOR

Highway-related:

500 = Signs/signals missing.
501 = Signs/signals erroneous/defective.
502 = Signs/signals inadequate.
503 = View obstructions by roadway design.
504 = View obstructed by other vehicles crash circumstance.
505 = Road design—roadway geometry (e.g., ramp curvature).
506 = Road design—sight distance.
507 = Road design—other.
508 = Maintenance problems (potholes, deteriorated road edges, etc.).
509 = Slick roads (low-friction road surface due to ice, loose debris, any other cause).
518 = Other highway-related condition.

Weather-related:

521 = Rain, snow [Note: code loss-of-control as 509].
522 = Fog.
523 = Wind gust.
528 = Other weather-related condition.

Other:

530 = Glare.
531 = Blowing debris.
532 = Animal in roadway (no driver error).
533 = Pedestrian or bicyclist in roadway (no driver error).

538 = Other sudden change in ambience.
999 = Unknown reason for critical event.
Comment: LTCCS Variable #6 with revisions. "This vehicle" will always be used for the vehicle being coded. Note that vehicle-related factors will rarely be apparent to data reductionists.

Vehicle 1 Attempted Avoidance Maneuver (C-N-I):

00 = No driver present.
0a = Not applicable (baseline epoch).
01 = No avoidance maneuver.
02 = Braking (no lockup or lockup unknown).
03 = Braking (lockup).
04 = Braking (lockup unknown).
05 = Releasing brakes.
06 = Steered to left.
07 = Steered to right.
08 = Braked and steered to left.
08a = Braked and steered to left (no lockup or lockup unknown).
08b = Braked and steered to left (lockup).
09 = Braked and steered to right.
09a = Braked and steered to right (no lockup or lockup unknown).
09b = Braked and steered to right (lockup).
10 = Accelerated.
11 = Accelerated and steered to left.
12 = Accelerated and steered to right.
13 = Released gas pedal without braking.
14 = Released gas pedal (without braking) and steered to left.
15 = Released gas pedal (without braking) and steered to left.
98 = Other actions.
99 = Unknown if driver attempted any corrective action.

Comment: LTCCS Variable #7 and also GES V27, Corrective Action Attempted. "Released gas pedal" elements added because this evasive maneuver by subject drivers is sometimes observed.

32. Relevant Object (C-N-I)

Analyst chooses the most relevant object; i.e., one that was struck in a crash or which constituted a crash threat for near-crashes and crash-relevant conflicts.

00a = Not applicable (baseline epoch).
00b = Not applicable (single-vehicle event but no critical object; e.g., shoulder only).
00c = Not applicable (two-vehicle event, pedestrian, animal, etc.).
01 = Parked motor vehicle.

Fixed objects:

02 = Building.
03 = Impact attenuator/crash cushion.
04 = Bridge structure (e.g., abutment).
05 = Guardrail.
06 = Concrete traffic barrier or other longitudinal barrier (e.g., Jersey barrier).
07 = Post, pole, or support (e.g., sign, light).
08 = Culvert or ditch.
09 = Curb.
10 = Embankment.
11 = Fence.
12 = Wall.
13 = Fire hydrant.
14 = Shrubbery or bush.
15 = Tree (not overhang—see below).
16 = Boulder.
17 = Loading dock.
18 = Loading equipment (e.g., fork lift, pallets).
19 = Cargo.

Overhanging objects (code only if struck or potentially struck by top of truck/trailer):

20 = Tree branch.
21 = Overhanging part of sign or post.
22 = Bridge/overpass.
23 = Building.
24 = Telephone wires.

Non-fixed objects:

25 = Vehicle parts, including tire parts.
26 = Spilled cargo.
27 = Dead animal in roadway.
28 = Broken tree limbs or other tree/shrub parts.
29 = Trash/debris.
30 = Construction barrel.
31 = Construction cone.
98 = Other.
99 = Unknown object hit.

Comment: Most objects are the same as those used in GES A06, first harmful event.

33. Driver 1 Vision-obscured-by (C-N-I)
00 = No obstruction.
01 = Rain, snow, fog, smoke, sand, dust.

02 = Reflected glare, sunlight, headlights.
03 = Curve or hill.
04 = Building, billboard, or other design features (includes signs, embankment).
05 = Trees, crops, vegetation.
06 = Moving vehicle (including load).
07 = Parked vehicle.
08 = Splash or spray of passing vehicle (any other vehicle).
09 = Inadequate defrost or defog system.
10 = Inadequate lighting system (includes vehicle/object in dark area).
11 = Obstruction interior to vehicle.
12 = Mirrors.
13 = Head restraints.
14 = Broken or improperly-cleaned windshield.
15 = Fog.
16 = Other vehicle or object in blindspot.
50 = Hit-and-run vehicle.
95 = No driver present.
96 = Not reported.
97 = Vision obscured—no details.
98 = Other obstruction.
99 = Unknown whether vision was obstructed.

Comment: GES Variable D4. Element 16 added because of relevance to large trucks. Elements 50, 95, and 96 are not applicable.

34. DFM Operating Mode (C-N-I-B)
01 = Auto-manual.
02 = Manual.
03 = Auto (if operating mode = auto, DFM is automatically non-operative).

35. DFM Sensitivity Level (C-N-I-B)
01 = Low.
02 = Medium.
03 = High.

Rules to follow when trying to determine if DFM is in standby:

- When speed is below 30 mi/h (48.28 km/h) and ambient brightness is above 100, the DFM is in standby.
- When the speed is above 35 mi/h (56.32 km/h) and ambient brightness is less than 50, the DFM is active.
- Ambient brightness (0 = dark; 255 = bright):
    - Special note: There will be times when the DFM should be functioning according to the above two rules, but often during dawn and dusk it still does not operate correctly. If it looks light in the video, but the ambient brightness values are within the correct range, you may need to make a

judgment call to determine if it is working or not. Please ask if you have any questions.

36. Average PERCLOS more than 1 Minute (C-N-I-B)

Comment: Recorded parameter from DFM, averaged over a 1-minute period prior to initiating event. Coded when available for time epoch.

Format: Percent; 999 = DFM not operative.

37. Average PERCLOS over 3 Minutes (C-N-I-B)

Comment: Recorded parameter from DFM, averaged over a 3-minute period prior to initiating event. Coded when available for time epoch.

Format: Percent; 999 = DFM not operative.

38. Average PERCLOS over 5 Minutes (C-N-I-B)

Comment: Recorded parameter from DFM, averaged over a 5-minute period prior to initiating event. Coded when available for time epoch.

Format: Percent; 999 = DFM not operative.

39. Observer Rating of Driver Drowsiness (ORD) (C-N-I-B)

Note: Analysts will use a 100-point scale to code ORD. The analysts can choose any value (i.e., 35, 62, 87) on the following scale (Figure 25). The five given points are to be used as guidelines.

If ORD is 25 or greater, mark "drowsy, sleepy, asleep, fatigued, other reduced alertness" under Driver 1 behaviors.

999 = Driver is wearing sunglasses or eyes are otherwise blocked from view.

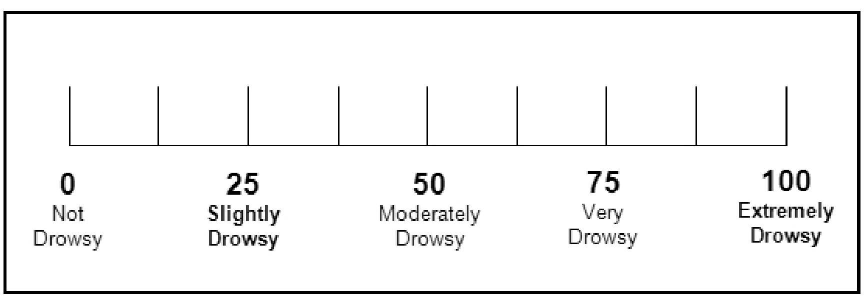


Figure 25. Scale. Drowsiness scale.

00 = Not Drowsy—No signs of being drowsy.

25 = Slightly Drowsy—Driver shows minor signs of being drowsy (single yawn, single stretch, droopy eyes for a short period of time); quickly recovers; does not have any apparent impact on vehicle control.

50 = Moderately Drowsy—Driver shows signs of being drowsy (yawns, stretches, moves around in seat, droopy eyes for a slightly longer period of time; minor blinking); takes slightly longer to recover; does not have any apparent impact on vehicle control.

75 = Very Drowsy—Driver shows signs of being drowsy (yawns often, has very heavy/droopy eyes, frequent blinking); duration lasts much longer; does not have any apparent impact on vehicle control.

100 = Extremely Drowsy—Driver shows extreme signs of being drowsy (yawns often, has very heavy/droopy eyes, has trouble keeping eyes open, very frequent blinking); duration lasts much longer; has apparent impact on vehicle control.

Comment: An observer rating of drowsiness will be assigned for the 1 minute prior to the event based on review of driver videos. Three, six, and twenty-minute ORDs will not be obtained because of the labor required and difficulties in averaging reliably over these periods.

40. Driver 1 Potentially Distracting Driver Behaviors (C-N-I-B)

Analyst codes up to four behaviors observed during 10 seconds prior to maximum/minimum trigger value or during final 10 seconds of 30-second baseline epoch. Code observed behaviors regardless of their apparent relevance to the incident. Similar to GES, but significantly modified. If there are more than four, select the ones occurring closest in time to the trigger.

00 = None observed.
01 = Looked but did not see (e.g., driver looked in direction of crash threat but apparently did not recognize threat; not applicable to baseline epochs.).
02a = Interact with or look at other occupant(s).
02b = Interact with or look at pet in vehicle.
03a = Look at, or for, object in vehicle.
03b = Reach for object in vehicle (including hand-held cell phone, hands-free cell phone, PDA, Citizen's Band (CB) microphone/other communications device, or other object).
04a = Talk or listen to hand-held phone.
04b = Talk or listen to hands-free phone.
04c = Talk or listen to CB microphone or other communications device.
05a = Dial hand-held phone.
05b = Dial hands-free phone.
05c = Operate PDA (inputting or reading).
06 = Adjust instrument panel (including climate control, radio, or cassette/CD).
07a = Look at left-side mirror/out left-side window.
07b = Look at right-side mirror/out right-side window.
07c = Look back in sleeper berth.

07d = Shift gears.
07e = Looks down (at lap, or at something on the floor).
08 = Use or reach for other devices.
09 = Appears drowsy, sleepy, asleep, fatigued.
10a = Look at previous crash or highway incident.
10b = Look at construction zone signs, barriers, flag person, etc.
10c = Look at outside person.
10d = Look at outside animal, object, store, etc.
10e = Look at undetermined outside event, person, or object.
11a = Eat with utensil.
11b = Eat without utensil (includes chewing, other than gum; e.g., toothpick).
11c = Drink from covered container (e.g., with straw).
11d = Drink from open container.
11e = Chewing gum.
12a = Smoking-related behavior—reaching, lighting, extinguishing.
12b = Smoking-related behavior—other (e.g., cigarette in hand or mouth).
13a = Read book, newspaper, etc.
13b = Read or look at map.
14 = Talk/sing/"dance" with no indication of passenger.
15a = Handle or interact with dispatching, electronic recording, or navigational device.
15b = Read or look at dispatching, electronic recording, or navigational device.
16a = Comb/brush/fix hair.
16b = Apply make-up.
16c = Shave.
16d = Brush/floss teeth.
16e = Bite nails/cuticles.
16f = Remove/adjust jewelry.
16g = Remove/insert contact lenses.
16h = Other personal hygiene.
17 = Look at or handle DFM.
18 = Look at or handle DAS (e.g., in-vehicle camera).
19 = Appears inattentive or lost in thought.
20 = Other potentially distracting behavior.

Comment: Similar to GES Variable D7 (Driver Distracted By), with expansions of many elements to capture direct observations. All observed behaviors or conditions occurring within 10 seconds prior to the maximum trigger, without regard to apparent relevance to the conflict. For baseline epochs, coded only for activities occurring within the last 10 seconds of the 30-second baseline epoch. Hand-held and hands-free phone data coded separately to permit comparisons.

41. Driver 1 Actions/Factors/Behaviors Relating to Event (C-N-I)

Note: Analyst codes up to four factors believed to have relevance to the occurrence of the incident; e.g., as contributing factors. If there are more than four, select the four most important.
00a = Not applicable—baseline epoch.

00b = None coded.
01 = Apparent excessive speed for conditions or location (regardless of speed limit; does not include tailgating, unless above speed limit).
02 = Drowsy, sleepy, asleep, fatigued, other reduced alertness.
03 = Angry.
04 = Other emotional state.
05 = Inattentive or distracted.
06 = Apparent impairment (e.g., drowsy, drunk, distracted)—specific type unknown.
07 = Driving slowly; below speed limit or in relation to other traffic.
08 = Illegal passing (i.e., across double line).
09 = Passing on right.
10 = Other improper or unsafe passing.
11a = Cutting in too close in front of other vehicle.
11b = Cutting in at safe distance, but then decelerated, causing conflict.
12 = Cutting in too close behind other vehicle.
13 = Making turn from wrong lane (e.g., across lanes).
14 = Did not see other vehicle during lane change or merge.
15 = Driving in other vehicle's blind zone.
16 = Aggressive driving, specific, directed menacing actions.
17 = Aggressive driving, other; i.e., reckless driving without directed menacing actions.
18 = Wrong side of road, not overtaking (includes partial or full drift into oncoming lane).
19 = Following too close.
19a = Inadequate evasive action.
20 = Failed to signal, or improper signal.
21 = Improper turn—wide right turn.
22 = Improper turn—cut corner on left turn.
23 = Other improper turning.
24 = Improper backing, did not see.
25 = Improper backing, other.
26 = Improper start from parked position.
27 = Disregarded officer or watchman.
28 = Signal violation, apparently did not see signal.
29 = Signal violation, intentionally ran red light.
30 = Signal violation, tried to beat signal change.
31 = Stop sign violation, apparently did not see stop sign.
32 = Stop sign violation, intentionally ran stop sign at speed.
33 = Stop sign violation, "rolling stop."
34 = Other sign (e.g., yield) violation, apparently did not see sign.
35 = Other sign (e.g., yield) violation, intentionally disregarded.
36 = Other sign violation.
37 = Non-signed crossing violation (e.g., driveway entering roadway).
38 = Right-of-way error in relation to other vehicle or person, apparent recognition failure (e.g., did not see other vehicle).
39 = Right-of-way error in relation to other vehicle or person, apparent decision failure (i.e., did see other vehicle prior to action, but misjudged gap).

40 = Right-of-way error in relation to other vehicle or person, other or unknown cause.
41 = Sudden or improper stopping on roadway.
42 = Parking in improper or dangerous location; e.g., shoulder of interstate.
43 = Speeding or other unsafe actions in workzone.
44 = Failure to dim headlights.
45 = Driving without lights or insufficient lights.
46 = Avoiding pedestrian.
47 = Avoiding other vehicle.
48 = Avoiding animal.
48a = Avoiding object.
49 = Apparent unfamiliarity with roadway.
50 = Apparent unfamiliarity with vehicle (e.g., displays and controls).
52 = Excessive braking/deceleration creating potential hazard.
53 = Loss of control on slippery road surface.
54 = Loss of control on dry (or unknown) surface.
55 = Apparent vehicle failure (e.g., brakes).
56 = Other.

Comment: This variable was used in the 100-Car Naturalistic Driving Study, although some new elements have been added. Also, the coding rule is different; in the 100-Car Study, the analyst coded up to three factors for each driver, in descending order of judged importance. In the current study, analysts will code all that apply and in no order of importance. Thus, the data from the two studies are not directly comparable. Note that Element 6 is not relevant to Driver 1 since analysts will be able to identify impairment type.

42. Applicable Countermeasures for DV1 (C-N-I)

Based on the above variables relating to the event scenario, pre-event actions and states, and event causation, a senior analyst will identify applicable functional countermeasures. For crashes, an applicable DV1 functional countermeasure is one that would likely have prevented the crash, either by preventing the genesis of the unsafe condition or by improving the driver response to the unsafe condition. Near-crashes and crash-relevant conflicts are analyzed “as if” a crash had occurred. Below is a table of functional countermeasures and coding rules for them. The coding of functional countermeasures is based both on algorithmic determination from previous coded variables and on analyst judgment. In many cases, particular Accident Type, CR, or other causation-related codes algorithmically determine applicable functional countermeasures. Some countermeasure choices, however, are coded based on senior analyst judgment.

Table 59. Coding of functional countermeasures.

#	Functional Countermeasure	Scenario/Driver Error Source(s)	Code DV2?	Comments
0a	Not Applicable (Baseline Epoch)	N/A	Yes	
0b	No Countermeasure Applicable to This Driver/Vehicle (No Driver Error and/or Coded to Other Vehicle Only)	N/A	Yes	
0c	No Obvious/Plausible Countermeasure Applicable to This Driver/Vehicle (e.g., Insufficient Information, Due to Random Occurrence)	N/A	Yes	
0d	Not Applicable: Single-vehicle Event	Vehicle/Non-motorists Involved = 01, 05-07	Yes	Never coded for V1.
1	Increase Driver Alertness (Reduce Drowsiness)	CR = 100 or 107 **OR** Analyst Judgment considering PERCLOS, ORD, Driver Behavior	No	
2	Improve Commercial Driver HOS Compliance (i.e., Reflective of Alertness-related Incident During HOS Violation Period)		No	Not coded during Phase I; potential for Phase II.
3	Prevent "Drift" Lane Departures (e.g., Due to Fatigue, Inattention, Misjudgment of Lines)	AT = 01 or 06	Yes	No evidence of intention; e.g., lane change.
4	Improve Vehicle Control/Stability on Curves	Trigger Type = 1 **AND** PEM = 14 **AND** AT = 02, 07, 46, 47, or 50	Yes	Assumes potential rollover or other LOC event; no triggers for V2.
5	Improve Vehicle Control/Stability on Slippery Road Surfaces	Road surface = 2-5 **AND** CPE = 05	Yes	
6	Improve Vehicle Control/Stability During Braking	CPE = 09 **OR** Avoidance Maneuver = 3	Yes	
7	Improve Vehicle Control/Stability During Evasive Steering	CPE = 10 **OR** Avoidance Maneuver = 6-9 with LOC	Yes	
8	Increase Driver Attention to Forward Visual Scene (e.g., Eyes on Road)	Analyst Judgment, considering potential distractions coded (V39) and CR (e.g., 110-119, 140)	No	
9	Increase/Improve Driver Use of Mirrors or Provide Better Information From Mirrors (or from Other Indirect Visibility Systems)	AT = 46, 47, 70, 73, 76, 78, or others TBD **AND** Vision Obscured = 12 or 16	No	
10	Improve General Driver Situation Awareness and/or Proactive/Defensive Driving	Analyst judgment	No	Not coded if 1 and/or 8 are coded.

#	Functional Countermeasure	Scenario/Driver Error Source(s)	Code DV2?	Comments
12	Reduce Road/Highway Travel Speed	CR = 120 **OR** Driver Behavior = 1, 43	Yes	Includes all road configurations and thus is inclusive of 14-16. However, does not include all speeds above speed limit; must be significant factor.
13	Reduce Speed on Downgrades	CR = 120 **AND** Profile = 2b **OR** Driver B = 1, 43 **AND** Profile = 2b	No	
14	Reduce Speed on Curves or Turns	CR = 120 **AND** Alignment = 2a, 2b **OR** Driver B = 1, 43 **AND** Alignment = 2a, 2b	No	
15	Reduce Speed at or on Exits (Including Ramps)	CR = 120 **AND** Profile = 2b **OR** Driver B = 1, 43 **AND** Profile = 2b	No	
16	Limit Top Speed to 70 mi/h (Except on Downgrades)	Prevented speed >70 mi/h; Analyst judgment Evidence: CR = 120; Driver A/F/B = 1	No	
17	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Stopped Vehicle(s) in Lane Ahead, Traveling in Same Direction	AT = 11, 20 **AND** CR = 107-119	Yes	
18	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Moving/Decelerating Vehicle(s) in Lane Ahead, Traveling in Same Direction	AT = 24, 28 **AND** CR = 107-119	Yes	
19	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane on Highway	AT = 47 **AND** CR = 107-119	Yes	
20	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane on Highway	AT = 46 **AND** CR = 107-114	Yes	
21	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Left Adjacent Lane During Merging Maneuver	AT = 47, 78 **AND** PEM = 16 **AND** CR = 107-119	Yes	

#	Functional Countermeasure	Scenario/Driver Error Source(s)	Code DV2?	Comments
22	Increase Driver Recognition/Appreciation of Specific Highway Crash Threats: Vehicle in Right Adjacent Lane During Merging Maneuver	AT = 46, 76 **AND** PEM = 16 **AND** CR = 107-119	Yes	
23	Increase Driver Recognition of Crossing or Oncoming Traffic at Intersections	AT = 76, 78, 80, 82-91 **AND** CR = 107-119	Yes	
24	Improve Driver Gap Judgment re: Crossing or Oncoming Traffic at Intersections	AT = 76, 78, 80, 82-91 **AND** CR = 122	Yes	
25	Improve Driver Response Execution of Crossing or Turning Maneuver at Intersections (Performance Failure)	AT = 76, 78, 80, 82-91 **AND** CR = 141-199	Yes	
26	Improve Driver Recognition/Gap Judgment/Response Execution at Intersection, (Specific Cause Not Determined)	AT = 76, 78, 80, 82-91 **AND** CR = 140 or 199	Yes	
27	Improve Driver Compliance with Intersection Traffic Signal (e.g., Red Light) Controls (Includes Both Intentional and Unintentional Intersection Control Violations).	Driver A/F/B = 28-30	Yes	
28	Improve Driver Compliance with Intersection Traffic Sign (e.g., Stop or Yield Sign) Controls (Includes Both Intentional and Unintentional Intersection Control Violations).	Driver A/F/B = 31-33	Yes	
29	Increase Forward Headway During Vehicle Following	AT = 24, 28 **AND** CR = 123	Yes	Applies to tailgating scenarios, not rapid closing scenarios.
30	Improve Driver Night Vision in the Forward Field	Light = 2, 3 **AND** AT = 1-14, 20, 34, 36, 38, 40 **AND** Analyst judgment	Yes	CM would provide earlier driver recognition of distant object (e.g., pedestrian waling in roadway).
32	Provide Warning to Prevent Rear Encroachment or Tailgating by Other Vehicle (i.e., This Vehicle is Lead Vehicle, Other Vehicle is Following)	AT = 21, 22, 23, 25, 26, 27, 29, 30, 31	Yes	Reciprocal relation between 17/18 and 32; i.e., if one vehicle is coded 17 or 18, other vehicle is coded 32.
33	Provide Advisory to Driver Regarding Reduced Road-tire Friction (i.e., Associated with Slippery Roads)	Roadway surface condition = 2-5 **AND** LOC **AND** Analyst judgment	No	
34	Prevent Vehicle Mechanical Failure (e.g., Brakes, Steering, Tire Blowout)	CR = 200-209, 298-299	Yes	Likely undercounted in instrumented vehicle studies.

#	Functional Countermeasure	Scenario/Driver Error Source(s)	Code DV2?	Comments
35	Other, Specify	Analyst judgment	Yes	When possible, analyst will specify associated pre-crash/causation algorithm and add to list of CMs.
36	Prevent Splash and Spray from This Vehicle Affecting Other Vehicle(s)	AT = 25-26, 35-41, 45-47 **AND** Analyst judgment **AND** Roadway surface condition = 2-3	Yes	
37	Improve Driver Recognition/Gap Judgment Relating to Oncoming Vehicle During Passing Maneuver	PEM = 06 **AND** AT = 50 or 64 **AND** CR = 110-119, 120-122, or 128-140	Yes	
38	Prevent Animals from Crossing Roadways	Vehicle/Person 2 Type = 13 or 14	No	Applicable to all animal-related events.
39	Navigation System/Routing Aid	Driver A/F/B = 49	No	
40	Aid to Vertical Clearance Estimation	Object = overhanging object	No	Used when truck hits or has the potential to hit overhanging object (e.g., tree limb).
98	Driver Error and/or Vehicle Failure Apparent for This Vehicle, But Countermeasure(s) to Address It Unknown.	Vehicle has CR, but no other CM specified.	Yes	Not coded if other CMs coded.
99	Unknown		Yes	Not coded if other CMs coded.

KEY: AT = Accident Type / CR = Critical Reason / CM = Countermeasure / PEM = Pre-event Movement CPE = Critical Pre-crash Event / A = Actions / B = Behaviors / F = Factors / TBD = To Be Determined / LOC = Loss of Control

DRIVER/VEHICLE 2 VARIABLES

43. Vehicle/Person 2 Type (C-N-I)

00a = Not applicable (baseline epoch).
00b = Not applicable (single-vehicle event; includes single vehicle plus object).
01 = Automobile.
02 = Van (minivan or standard van).
03 = Pickup truck.
03a = SUV (includes Jeep).
04 = Bus (transit or motorcoach).
05 = School bus.
06 = Single-unit straight truck (includes panel truck, U-Haul truck).
07 = Tractor-trailer.
08 = Motorcycle or moped.
09 = Emergency vehicle (police, fire, EMS = in service).
10 = Vehicle pulling trailer (other than tractor-trailer).
11 = Other vehicle type.

12 = Pedestrian.
13 = Pedalcyclist.
14 = Deer.
15 = Other animal.
99 = Unknown vehicle type.

Comment: Highly abridged version of GES V5, Body Type. If Driver/Vehicle 2 is a pedestrian, cyclist, animal, or object, most other DV1 file variables will be coded "not applicable."

44. Vehicle 2 Position (in Relation to V1) (C-N-I)

00 = Not applicable (baseline epoch).
00a = Not applicable (single-vehicle event).
K = Top of vehicle.

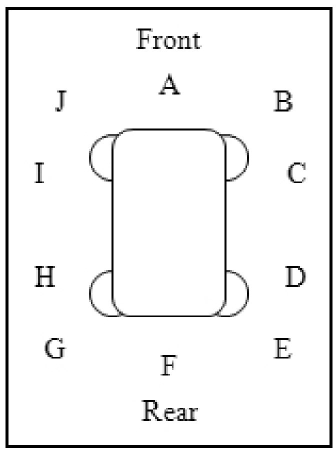


Figure 26. Diagram. Position of truck in relation to second vehicle.

Comment: The vehicle in the diagram (Figure 26) represents the subject vehicle (V1, the truck). The relative position of Vehicle 2 (in relation to Vehicle 1) is coded for the time in which the Critical Event occurs; i.e., the event creating the crash risk. Vehicles in adjacent left lane are coded J, I, H, or G depending on position. Vehicles in adjacent right lane are coded B, C, D, or E depending on position. Baseline epochs will be coded "0."

45. Vehicle 2 Pre-event Movement (C-N-I)

00 = No driver present.
00a = Not applicable (single-vehicle event).
01 = Going straight.
02 = Decelerating in traffic lane.
03 = Accelerating in traffic lane.
04 = Starting in traffic lane.
05 = Stopped in traffic lane.
06 = Passing or overtaking another vehicle.
07 = Disabled or parked in travel lane.
08a = Leaving a parking position, moving forward.
08b = Leaving a parking position, backing.

09a = Entering a parking position, moving forward.
09b = Entering a parking position, backing.
10 = Turning right.
11 = Turning left.
12 = Making a U-turn.
13 = Backing up (other than parking).
14 = Negotiating a curve.
15 = Changing lanes.
16 = Merging.
17 = Successful avoidance maneuver to a previous critical event.
98 = Other.
99 = Unknown.

Comment: This is LTCCS Variable #4 with expanded choices for 8 and 9. For baseline epochs, the primary movement of the vehicle during the epoch is coded.

46. Vehicle 2 "Accident" Type [Scenario Role] (C-N-I)
00 = Not applicable (baseline epoch).
00a = Not applicable (single-vehicle event).
Other Codes: See diagram shown earlier for Variable 28.

47. Vehicle 2 Incident Type (C-N-I)

00a	= Not applicable (baseline epoch).
00b	= Not applicable (single-vehicle event; includes those with pedestrian, animal).
01/02	= Aborted lane change.
03/04	= Approaches traffic quickly.
05/06/07/08	= Backing in roadway.
09/10	= Clear path for emergency vehicle.
11/12	= Conflict between merging and existing traffic.
13/14	= Conflict with oncoming traffic.
15/16	= Exit then re-entrance onto roadway.
17/18	= Following too closely.
19/20/21	= Improper lane change.
22/23	= Improper passing.
24/25	= Improper U-turn.
26/27	= Lane change without sufficient gap.
28/29	= Lane drift.
30/31	= Late braking for stopped/stopping traffic.
32/33	= Lateral deviation of through vehicle.
34/35	= Left turn without clearance.
36/37	= Merge out of turn (before lead vehicle).
38/39/40	= Merge without sufficient gap.
41/42	= Obstruction in roadway.
43/44	= Proceeding through red traffic signal.
45/46	= Roadway entrance without clearance.
47/48	= Slow speed.

49/50	= Slow upon passing.
51/52/53	= Sudden braking in roadway.
54/55	= Through traffic does not allow lane change.
56/57/58	= Through traffic does not allow merge.
59/60	= Turn without sufficient warning.
61/62	= Turn/exit from incorrect lane.
63/64	= Wide turn into adjacent lane.
68/69	= Close proximity to turning vehicle.
99	= Unknown.

Comment: This scenario classification has been used in other studies.[4,25] Coding this variable will enable comparisons with that study. See Variable 29 for diagrams of these scenarios.

48. Vehicle 2 Critical Pre-crash Event (C-N-I)

00 = Not applicable (baseline epoch).
00a = Not applicable (single-vehicle event).

THIS VEHICLE (V2) LOSS OF CONTROL DUE TO:

01 = Blowout or flat tire.
02 = Stalled engine.
03 = Disabling vehicle failure (e.g., wheel fell off).
04 = Non-disabling vehicle problem (e.g., hood flew up).
05 = Poor road conditions (wet road, puddle, pothole, ice, etc.).
06 = Traveling too fast for conditions.
07 = Jack-knife event.
08 = Cargo shift.
09 = Braking.
10 = Steering.
18 = Other cause of control loss.
19 = Unknown cause of control loss.

THIS VEHICLE (V1) TRAVELING

20 = Toward or over the lane line on left side of travel lane.
21 = Toward or over the lane line on right side of travel lane.
22 = Toward or off the edge of the road on the left side.
23 = Toward or off the edge of the road on the right side.
24 = End departure.
25 = Turning left at intersection.
26 = Turning right at intersection.
27 = Crossing over (passing through) intersection.
28 = This vehicle decelerating.
29 = Unknown travel direction.

OTHER MOTOR VEHICLE (V2) IN LANE

50 = Other vehicle stopped.
51 = Traveling in same direction with lower steady speed.
52 = Traveling in same direction while decelerating.
53 = Traveling in same direction with higher speed.
54 = Traveling in opposite direction.
55 = In crossover.
56 = Backing.
59 = Unknown travel direction of other motor vehicle in lane.

OTHER MOTOR VEHICLE (V2) ENCROACHING INTO LANE

60 = From adjacent lane (same direction)—toward or over left lane line.
61 = From adjacent lane (same direction)—toward or over right lane line.
62 = From opposite direction—toward or over left lane line.
63 = From opposite direction—toward or over right lane line.
64 = From parking lane.
65 = From crossing street, turning into same direction.
66 = From crossing street, across path.
67 = From crossing street, turning into opposite direction.
68 = From crossing street, intended path not known.
70 = From driveway, turning into same direction.
71 = From driveway, across path.
72 = From driveway, turning into opposite direction.
73 = From driveway, intended path not known.
74 = From entrance to limited access highway.
78 = Encroachment by other vehicle—details unknown.

PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST

80 = Pedestrian in roadway.
81 = Pedestrian approaching roadway.
82 = Pedestrian—unknown location.
83 = Pedalcyclist or other nonmotorist in roadway.
84 = Pedalcyclist or other nonmotorist approaching roadway.
85 = Pedalcyclist or other nonmotorist—unknown location.

OBJECT OR ANIMAL

87 = Animal in roadway.
88 = Animal approaching roadway.
89 = Animal—unknown location.
90 = Object in roadway.
91 = Object approaching roadway.
92 = Object—unknown location.

OTHER

93 = This vehicle not involved in first harmful event.

98 = Other critical pre-crash event.
99 = Unknown.

Comment: This is LTCCS Variable #5. This variable is coded for both vehicles in a two-vehicle incident. However, the CR (see below), is coded for only one vehicle. In the above list, note addition of 09 = loss of control due to braking and 10 = steering.

DV2 CR for the Critical Event (C-N-I)

000a = Not applicable (baseline epoch).
000b = Not applicable (single-vehicle event).
000c = CR not coded to this vehicle.

DRIVER RELATED FACTOR

Critical Non-performance Errors:
100 = Sleep, that is, actually asleep.
101 = Heart attack or other physical impairment of the ability to act.
107 = Drowsiness, fatigue, or other reduced alertness (not asleep).
108 = Other critical non-performance.
109 = Apparent critical non-performance (includes any apparent driver impairment).

DRIVER-RELATED FACTOR
Recognition Errors:

110 = Inattention (i.e., daydreaming).
111 = Internal distraction.
112 = External distraction.
113 = Inadequate surveillance (e.g., failed to look, looked but did not see).
118 = Other recognition error.
119 = Apparent recognition error.

Decision Errors:

120 = Too fast for conditions (e.g., for safe vehicle control or to be able to respond to unexpected actions of other road users).
121 = Too slow for traffic stream.
122 = Misjudgment of gap or other's speed.
123 = Following too closely to respond to unexpected actions (close proximity for 2 or more seconds).
124 = False assumption of other road user's actions.
125 = Illegal maneuver.
125a = Apparently intentional sign/signal violation.
125b = Illegal U-turn.
125c = Other illegal maneuver.
126 = Failure to turn on head lamps.
127 = Inadequate evasive action (e.g., braking only not braking and steering; release accelerator only instead of braking).

128a = Aggressive driving behavior— intimidation: any behavior emitted by a driver while driving that is intended to cause physical or psychological harm to another person.
128b = Aggressive driving behavior—wanton, neglectful or reckless behavior: excessive risky driving behaviors performed without intent to harm others, such as weaving through traffic, maneuvering without signaling, running red lights, frequent lane changing, and tailgating.
138 = Other decision error.
139 = Apparent, unknown decision error.
140 = Apparent recognition or decision error (unknown which).

Performance Errors:

141 = Panic/freezing.
142 = Overcompensation.
143 = Poor directional control (e.g., failing to control vehicle with skill ordinarily expected).
148 = Other performance error.
149 = Apparent performance error.
199 = Type of driver error unknown.

VEHICLE-RELATED FACTOR

200 = Tires/wheels failed.
201 = Brakes failed.
202 = Steering failed.
203 = Cargo shifted.
204 = Trailer attachment failed.
205 = Suspension failed.
206 = Lights failed.
207 = Vehicle-related vision obstructions.
208 = Body, doors, hood failed.
209 = Jack-knifed.
298 = Apparent other vehicle failure.
299 = Unknown vehicle failure.

ENVIRONMENT-RELATED FACTOR
Highway-related:

500 = Signs/signals missing.
501 = Signs/signals erroneous/defective.
502 = Signs/signals inadequate.
503 = View obstructions by roadway design.
504 = View obstructed by other vehicles crash circumstance.
505 = Road design—roadway geometry (e.g., ramp curvature).
506 = Road design—sight distance.
507 = Road design—other.
508 = Maintenance problems (potholes, deteriorated road edges, etc.).

509 = Slick roads (low-friction road surface due to ice, loose debris, any other cause).
518 = Other highway-related condition.

Weather Related:

521 = Rain, snow [Note: code loss-of-control as 509].
522 = Fog.
523 = Wind gust.
528 = Other weather-related condition.

Other:

530 = Glare.
531 = Blowing debris.
532 = Animal in roadway (no driver error).
538 = Other sudden change in ambience.
999 = Unknown reason for critical event.

Comment: LTCCS Variable #6, with revisions reflecting lack of information about Driver 2. Many CR elements available for DV1 are not allowed for DV2 because they require observation of pre-crash driver behavior. The remaining elements for DV2 are either maneuvers or conditions visible from outside the vehicle (e.g., most of the decision error choices) or reasonable general inferences (e.g., Codes 109, 119, 139, 140, 149).

49. Attempted Avoidance Maneuver (C-N-I)

00 = No driver present.
00a = Not applicable (baseline epoch).
00b = Not applicable (single-vehicle event).
01 = No avoidance maneuver.
02 = Braking (no lockup or lockup unknown).
03 = Braking (lockup).
04 = Braking (lockup unknown).
05 = Releasing brakes.
06 = Steered to left.
07 = Steered to right.
08 = Braked and steered to left.
08a = Braked and steered to left (no lockup or lockup unknown).
08b = Braked and steered to left (lockup).
09 = Braked and steered to right.
09a = Braked and steered to right (no lockup or lockup unknown).
09b = Braked and steered to right (lockup).
10 = Accelerated.
11 = Accelerated and steered to left.
12 = Accelerated and steered to right.
98 = Other actions.
99 = Unknown if driver attempted any corrective action.

Comment: LTCCS Variable #7 and also GES V27, Corrective Action Attempted. The "released gas pedal" elements available for DV1 are not available for DV2 since they would not be observable from outside the vehicle.

50. Driver Behavior: Driver 2 Actions/Factors Relating to Event (C-N-I)

Note: Analyst codes up to four factors believed to have relevance to the occurrence of the incident; e.g., as contributing factors. If there are more than four, select the four most important.

00a = Not applicable (baseline epoch).
00b = Not applicable (single-vehicle event).
00 = None coded.
01 = Apparent excessive speed for conditions or location (regardless of speed limit; does not include tailgating, unless above speed limit).
02 = Drowsy, sleepy, asleep, fatigued, other reduced alertness.
03 = Angry.
04 = Other emotional state.
05 = Alert but inattentive or distracted.
06a = Vehicle "drift" or "slow weave" consistent with possible drowsy/distracted driving.
06b = Erratic steering, weaving, lane break, or other vehicle motion consistent with possible alcohol-impaired driving.
07 = Driving slowly; below speed limit or in relation to other traffic.
08 = Illegal passing (i.e., across double line).
09 = Passing on right.
10 = Other improper or unsafe passing.
11a = Cutting in too close in front of other vehicle.
11b = Cutting in at safe distance, but then decelerated, causing conflict.
12 = Cutting in too close behind other vehicle.
13 = Making turn from wrong lane (e.g., across lanes).
14 = Did not see other vehicle during lane change or merge.
15 = Driving in other vehicle's blind zone.
16 = Aggressive driving, specific, directed menacing actions.
17 = Aggressive driving, other (i.e., reckless driving without directed menacing actions).
18 = Wrong side of road, not overtaking (includes partial or full drift into oncoming lane).
19 = Following too close.
19a = Inadequate evasive action.
20 = Failed to signal, or improper signal.
21 = Improper turn: wide right turn.
22 = Improper turn: cut corner on left turn.
23 = Other improper turning.
24 = Improper backing, (apparently) did not see.
25 = Improper backing, other.
26 = Improper start from parked position.
27 = Disregarded officer or watchman.
28 = Signal violation.

29 = Not used.
30 = Signal violation, tried to beat signal change.
31 = Stop sign violation.
32 = Not used.
33 = Stop sign violation, “rolling stop.”
34 = Other sign (e.g., yield) violation.
35 = Not used.
36 = Other sign violation.
37 = Non-signed crossing violation (e.g., driveway entering roadway).
38 = Right-of-way error in relation to other vehicle or person.
39 = Not used.
40 = Not used.
41 = Sudden or improper stopping on roadway.
42 = Parking in improper or dangerous location (e.g., shoulder of interstate).
43 = Speeding or other unsafe actions in work zone.
44 = Failure to dim headlights.
45 = Driving without lights or insufficient lights.
46 = Avoiding pedestrian.
47 = Avoiding other vehicle.
48 = Avoiding animal.
48a = Avoiding object.
49 = Apparent unfamiliarity with roadway.
50 = Apparent unfamiliarity with vehicle; e.g., displays and controls.
51 = Use of cruise control contributed to late braking.
52 = Excessive braking/deceleration creating potential hazard.
53 = Loss of control on slippery road surface.
54 = Loss of control on dry (or unknown) surface.
55 = Apparent vehicle failure (e.g., brakes).
56 = Other.
57 = Unknown.

Comment: Parallel variable to #40. Note, however, that a number of element choices relating to specific driver behaviors or impairments are disallowed because these will not be observable for Driver 2. Also, for signal, sign, and right-of-way violations, analysts code the violation but do not attempt to ascertain whether the violation was intention or due to recognition failure. Thus, several elements are not used. As noted under #40, this variable was used in the 100-Car Naturalistic Driving Study, although some new elements have been added. Also, the coding rule is different; in the 100-Car Study, the analyst coded up to three factors for each driver, in descending order of judged importance. In the current study, analysts will code all that apply and in no order of importance. Thus, the data from the two studies are not directly comparable.

51. Applicable Functional Countermeasures for DV2 (C-N-I)

Based on the above variables relating to the event scenario, pre-event actions and states, and event causation, a senior analyst will identify applicable functional countermeasures. For crashes, an applicable DV2 functional countermeasure is one that would likely have prevented the crash, either by preventing the genesis of the unsafe condition or by improving the driver response to the unsafe condition. Near-crashes and crash-relevant conflicts are analyzed "as if" a crash had occurred. Variable 41 provides a table of functional countermeasures and shows coding rules for them. The coding of functional countermeasures is based both on algorithmic determination from previous coded variables and on analyst judgment. In many cases, particular "Accident" Type, CR, or other causation-related codes algorithmically determine applicable functional countermeasures. Some countermeasure choices, however, are coded based on senior analyst judgment. Note that most potential functional countermeasures are coded for DV2, but that some are not due to the fact that little information is available to analysts on the specific Driver 2 behaviors and states.

GENERAL

52. Event Comments (C-N-I-B)

Comment: This text variable will permit analysts to provide any comments on the event, including information not captured by data variables, assumptions made about the event affecting coding, and coding issues that arose. Ordinarily this will not contain information that is captured by the coded variables.

APPENDIX C: FREQUENCY AND RATES OF AT-FAULT AND NOT-AT-FAULT EVENTS

Table 60. Frequency and rates of at-fault and not-at-fault events.

Driver	Group	At-fault Events Frequency	At-fault Events Percentage	At-fault Events Rate	Not at-fault Events Frequency	Not at-fault Events Percentage	Not at-fault Events Rate	Total Drive Time
1	Ex	0	0.0%	0.0000	3	1.6%	0.0113	265.27
2	Ex	6	1.2%	0.0144	1	0.5%	0.0024	418.05
3	Ex	7	1.4%	0.0899	1	0.5%	0.0128	77.89
4	Ex	6	1.2%	0.0678	4	2.2%	0.0452	88.49
5	Ex	7	1.4%	0.0231	0	0.0%	0.0000	302.56
7	Ex	12	2.3%	0.1030	2	1.1%	0.0172	116.54
8	Ex	9	1.8%	0.0382	1	0.5%	0.0042	235.49
9	Ex	3	0.6%	0.0042	0	0.0%	0.0000	715.98
10	Ex	1	0.2%	0.0498	0	0.0%	0.0000	20.09
13	Ex	7	1.4%	0.0510	3	1.6%	0.0218	137.37
15	Ex	6	1.2%	0.0168	0	0.0%	0.0000	357.99
16	Ex	43	8.4%	0.1366	6	3.3%	0.0191	314.69
17	Ex	25	4.9%	0.0280	3	1.6%	0.0034	892.15
18	Ex	6	1.2%	0.0089	7	3.8%	0.0104	671.07
19	Ex	17	3.3%	0.0372	1	0.5%	0.0022	456.75
21	Ex	1	0.2%	0.0022	3	1.6%	0.0066	455.68
22	Ex	2	0.4%	0.0050	6	3.3%	0.0150	400.68
24	Ex	19	3.7%	0.0268	4	2.2%	0.0056	708.49
26	Ex	12	2.3%	0.0240	3	1.6%	0.0060	501.04
27	Ex	16	3.1%	0.0221	3	1.6%	0.0041	725.13
29	Ex	7	1.4%	0.0142	1	0.5%	0.0020	492.66
30	Ex	0	0.0%	0.0000	1	0.5%	0.0020	490.64
32	Ex	13	2.5%	0.0247	12	6.6%	0.0228	526.69
33	Ex	12	2.3%	0.0172	4	2.2%	0.0057	697.67
34	Ex	5	1.0%	0.0429	0	0.0%	0.0000	116.45
35	Ex	0	0.0%	0.0000	2	1.1%	0.0088	228.31
37	Ex	0	0.0%	0.0000	0	0.0%	0.0000	68.47
38	Ex	0	0.0%	0.0000	1	0.5%	0.0065	154.50
39	Ex	11	2.1%	0.0298	2	1.1%	0.0054	368.95
101	Ex	8	1.6%	0.0209	1	0.5%	0.0026	383.26
102	Ex	1	0.2%	0.0023	4	2.2%	0.0094	427.08
103	Ex	15	2.9%	0.0247	11	6.0%	0.0181	608.36
104	Ex	4	0.8%	0.0084	0	0.0%	0.0000	473.76
106	Ex	1	0.2%	0.0017	5	2.7%	0.0083	601.43
107	Ex	20	3.9%	0.0653	5	2.7%	0.0163	306.12
108	Ex	6	1.2%	0.0075	3	1.6%	0.0038	799.79
109	Ex	0	0.0%	0.0000	0	0.0%	0.0000	196.58
110	Ex	37	7.2%	0.0633	10	5.5%	0.0171	584.15
113	Ex	1	0.2%	0.0041	0	0.0%	0.0000	242.30
115	Ex	2	0.4%	0.0060	0	0.0%	0.0000	330.93

Driver	Group	At-fault Events Frequency	At-fault Events Percentage	At-fault Events Rate	Not at-fault Events Frequency	Not at-fault Events Percentage	Not at-fault Events Rate	Total Drive Time
116	Ex	4	0.8%	0.0059	4	2.2%	0.0059	676.46
118	Ex	1	0.2%	0.0018	1	0.5%	0.0018	551.10
119	Ex	13	2.5%	0.0471	9	4.9%	0.0326	275.76
122	Ex	1	0.2%	0.0026	1	0.5%	0.0026	387.36
123	Ex	10	2.0%	0.0230	6	3.3%	0.0138	434.48
125	Ex	25	4.9%	0.0525	5	2.7%	0.0105	476.05
126	Ex	3	0.6%	0.0087	4	2.2%	0.0115	346.64
127	Ex	5	1.0%	0.0141	2	1.1%	0.0057	353.80
128	Ex	5	1.0%	0.0121	1	0.5%	0.0024	413.30
129	Ex	1	0.2%	0.0011	0	0.0%	0.0000	920.10
130	Ex	1	0.2%	0.0016	0	0.0%	0.0000	621.12
131	Ex	11	2.1%	0.0208	2	1.1%	0.0038	528.68
132	Ex	3	0.6%	0.0052	2	1.1%	0.0035	579.25
134	Ex	0	0.0%	0.0000	0	0.0%	0.0000	14.01
135	Ex	1	0.2%	0.0066	1	0.5%	0.0066	150.38
136	Ex	0	0.0%	0.0000	1	0.5%	0.0058	171.05
151	Ex	0	0.0%	0.0000	0	0.0%	0.0000	64.00
152	Ex	1	0.2%	0.0122	0	0.0%	0.0000	81.78
153	Ex	0	0.0%	0.0000	0	0.0%	0.0000	99.17
202	Ex	0	0.0%	0.0000	0	0.0%	0.0000	236.80
203	Ex	12	2.3%	0.0168	4	2.2%	0.0056	715.93
204	Ex	12	2.3%	0.0427	7	3.8%	0.0249	281.20
206	Ex	1	0.2%	0.0163	0	0.0%	0.0000	61.21
212	Ex	0	0.0%	0.0000	0	0.0%	0.0000	19.00
213	Ex	10	2.0%	0.0212	6	3.3%	0.0127	471.30
215	Ex	5	1.0%	0.0110	1	0.5%	0.0022	453.72
216	Ex	4	0.8%	0.0056	2	1.1%	0.0028	717.10
217	Ex	2	0.4%	0.0053	0	0.0%	0.0000	374.07
218	Ex	1	0.2%	0.0114	0	0.0%	0.0000	87.54
219	Ex	7	1.4%	0.0190	3	1.6%	0.0081	369.30
221	Ex	8	1.6%	0.0230	1	0.5%	0.0029	348.43
234	Ex	1	0.2%	0.0031	2	1.1%	0.0061	327.39
236	Ex	0	0.0%	0.0000	0	0.0%	0.0000	34.80
249	Ex	7	1.4%	0.0420	1	0.5%	0.0060	166.80
250	Ex	9	1.8%	0.0293	4	2.2%	0.0130	307.08
11	Con	3	1.8%	0.0001	0	0.0%	0.0000	87.41
12	Con	9	5.4%	0.1030	0	0.0%	0.0000	87.41
14	Con	8	4.8%	0.0303	2	3.8%	0.0076	264.19
20	Con	0	0.0%	0.0000	5	9.6%	0.0095	524.00
23	Con	22	13.1%	0.0485	0	0.0%	0.0000	453.72
25	Con	1	0.6%	0.0015	12	23.1%	0.0185	649.04
28	Con	26	15.5%	0.2708	1	1.9%	0.0104	96.03
31	Con	13	7.7%	0.0307	3	5.8%	0.0071	423.83
105	Con	6	3.6%	0.0086	3	5.8%	0.0043	700.37
111	Con	3	1.8%	0.0241	0	0.0%	0.0000	124.55

Driver	Group	At-fault Events Frequency	At-fault Events Percentage	At-fault Events Rate	Not at-fault Events Frequency	Not at-fault Events Percentage	Not at-fault Events Rate	Total Drive Time
112	Con	30	17.9%	0.0680	3	5.8%	0.0068	441.30
114	Con	18	10.7%	0.0730	6	11.5%	0.0243	246.45
121	Con	4	2.4%	0.0104	6	11.5%	0.0155	386.09
124	Con	9	5.4%	0.0222	2	3.8%	0.0049	405.75
137	Con	0	0.0%	0.0000	2	3.8%	0.0103	194.15
138	Con	0	0.0%	0.0000	0	0.0%	0.0000	166.14
201	Con	0	0.0%	0.0000	2	3.8%	0.0213	94.00
205	Con	15	8.9%	0.0386	0	0.0%	0.0000	389.02
210	Con	0	0.0%	0.0000	5	9.6%	0.0136	368.72
242	Con	1	0.6%	0.0070	0	0.0%	0.0000	142.63

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APPENDIX D: FREQUENCY AND RATES OF DROWSY-RELATED EVENTS

Table 61.Frequency and rates of drowsy-related events.

Driver	Group	Drowsy-related Events Frequency	Drowsy-related Events Percentage	Drowsy-related Events Rate	Total Drive Time
1	Ex	3	3.1%	0.0113	265.27
2	Ex	6	6.2%	0.0144	418.05
3	Ex	1	1.0%	0.0128	77.89
4	Ex	6	6.2%	0.0678	88.49
5	Ex	1	1.0%	0.0033	302.56
7	Ex	3	3.1%	0.0257	116.54
8	Ex	1	1.0%	0.0042	235.49
9	Ex	0	0.0%	0.0000	715.98
10	Ex	0	0.0%	0.0000	20.09
13	Ex	1	1.0%	0.0073	137.37
15	Ex	1	1.0%	0.0028	357.99
16	Ex	5	5.2%	0.0159	314.69
17	Ex	3	3.1%	0.0034	892.15
18	Ex	2	2.1%	0.0030	671.07
19	Ex	6	6.2%	0.0131	456.75
21	Ex	0	0.0%	0.0000	455.68
22	Ex	0	0.0%	0.0000	400.68
24	Ex	5	5.2%	0.0071	708.49
26	Ex	2	2.1%	0.0040	501.04
27	Ex	1	1.0%	0.0014	725.13
29	Ex	0	0.0%	0.0000	492.66
30	Ex	0	0.0%	0.0000	490.64
32	Ex	10	10.3%	0.0190	526.69
33	Ex	0	0.0%	0.0000	697.67
34	Ex	0	0.0%	0.0000	116.45
35	Ex	0	0.0%	0.0000	228.31
37	Ex	0	0.0%	0.0000	68.47
38	Ex	0	0.0%	0.0000	154.50
39	Ex	1	1.0%	0.0027	368.95
101	Ex	0	0.0%	0.0000	383.26
102	Ex	1	1.0%	0.0023	427.08
103	Ex	1	1.0%	0.0016	608.36
104	Ex	0	0.0%	0.0000	473.76
106	Ex	2	2.1%	0.0033	601.43
107	Ex	6	6.2%	0.0196	306.12
108	Ex	0	0.0%	0.0000	799.79
109	Ex	0	0.0%	0.0000	196.58
110	Ex	17	17.5%	0.0291	584.15
113	Ex	0	0.0%	0.0000	242.30
115	Ex	0	0.0%	0.0000	330.93
116	Ex	1	1.0%	0.0015	676.46
118	Ex	1	1.0%	0.0018	551.10

Driver	Group	Drowsy-related Events Frequency	Drowsy-related Events Percentage	Drowsy-related Events Rate	Total Drive Time
119	Ex	0	0.0%	0.0000	275.76
122	Ex	0	0.0%	0.0000	387.36
123	Ex	1	1.0%	0.0023	434.48
125	Ex	0	0.0%	0.0000	476.05
126	Ex	0	0.0%	0.0000	346.64
127	Ex	0	0.0%	0.0000	353.80
128	Ex	0	0.0%	0.0000	413.30
129	Ex	0	0.0%	0.0000	920.10
130	Ex	0	0.0%	0.0000	621.12
131	Ex	2	2.1%	0.0038	528.68
132	Ex	1	1.0%	0.0017	579.25
134	Ex	0	0.0%	0.0000	14.01
135	Ex	0	0.0%	0.0000	150.38
136	Ex	1	1.0%	0.0058	171.05
151	Ex	0	0.0%	0.0000	64.00
152	Ex	0	0.0%	0.0000	81.78
153	Ex	0	0.0%	0.0000	99.17
202	Ex	0	0.0%	0.0000	236.80
203	Ex	0	0.0%	0.0000	715.93
204	Ex	0	0.0%	0.0000	281.20
206	Ex	0	0.0%	0.0000	61.21
212	Ex	0	0.0%	0.0000	19.00
213	Ex	4	4.1%	0.0085	471.30
215	Ex	0	0.0%	0.0000	453.72
216	Ex	0	0.0%	0.0000	717.10
217	Ex	0	0.0%	0.0000	374.07
218	Ex	0	0.0%	0.0000	87.54
219	Ex	0	0.0%	0.0000	369.30
221	Ex	1	1.0%	0.0029	348.43
234	Ex	0	0.0%	0.0000	327.39
236	Ex	0	0.0%	0.0000	34.80
249	Ex	0	0.0%	0.0000	166.80
250	Ex	0	0.0%	0.0000	307.08
11	Con	0	0.0%	0.0000	87.41
12	Con	0	0.0%	0.0000	87.41
14	Con	1	3.3%	0.0038	264.19
20	Con	0	0.0%	0.0000	524.00
23	Con	0	0.0%	0.0000	453.72
25	Con	10	33.3%	0.0154	649.04
28	Con	0	0.0%	0.0000	96.03
31	Con	1	3.3%	0.0024	423.83
105	Con	1	3.3%	0.0014	700.37
111	Con	1	3.3%	0.0080	124.55
112	Con	1	3.3%	0.0023	441.30
114	Con	4	13.3%	0.0162	246.45
121	Con	6	20.0%	0.0155	386.09
124	Con	1	3.3%	0.0025	405.75

Driver	Group	Drowsy-related Events Frequency	Drowsy-related Events Percentage	Drowsy-related Events Rate	Total Drive Time
137	Con	1	3.3%	0.0052	194.15
138	Con	0	0.0%	0.0000	166.14
201	Con	1	3.3%	0.0106	94.00
205	Con	0	0.0%	0.0000	389.02
210	Con	2	6.7%	0.0054	368.72
242	Con	0	0.0%	0.0000	142.63

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