

IDAHO TRANSPORTATION DEPARTMENT

Final Report

Breaking Down Commercial Motor Vehicle Crashes: What are the Main Causes?

RP 318

By

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Prepared for

Idaho Transportation Department

ITD Research Program, Planning and Development Services

Highways Division

November 2025



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Technical Report Documentation Page

1. Report No. FHWA-ID-25-318	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Breaking Down Commercial Motor Vehicle Crashes: What are the Main Causes?		5. Report Date November 2025	
		6. Performing Organization Code	
7. Author(s) Christie Ridgeway, https://orcid.org/0009-0000-8876-108X Susan Soccolich, https://orcid.org/0000-0001-9060-4358 Matthew C. Camden, https://orcid.org/0000-0002-1879-0560		8. Performing Organization Report No.	
9. Performing Organization Name and Address The Virginia Tech Transportation Institute 3500 Transportation Research Plaza Blacksburg, VA 24061		10. Work Unit No. (TRAVIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Idaho Transportation Department (SPR) Highways Division, Planning and Development Services, Research Program PO Box 7129 Boise, ID 83707-7129		13. Type of Report and Period Covered Final Report 12/20/2024 – 11/25/2025	
		14. Sponsoring Agency Code RP-318	
15. Supplementary Notes Project performed in cooperation with the Idaho Transportation Department and Federal Highway Administration.			
16. Abstract This study examines commercial motor vehicle (CMV) crash severity in Idaho state from 2014–2023 by linking several state and federal databases to create an integrated analysis dataset. After filtering for completeness, 13,701 CMV-involved crashes were modeled using binary logistic regression to estimate the association between temporal, roadway, environmental, work-zone, vehicle, and driver factors and the odds of high-severity outcomes. Key findings include elevated fatal-crash odds in specific weather, during time of day, in certain roadway conditions, and in particular lighting conditions. The study translates these results into actionable mitigation strategies for Idaho, including infrastructure changes, technologies, public campaigns, and educational efforts. A dedicated section outlines a continuous data quality framework to support ongoing evaluation.			
17. Key Words Commercial Motor Vehicles, Crash Severity, Distraction		18. Distribution Statement Copies available from the ITD Research Program	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 113	22. Price

Acknowledgments

The authors thank the Idaho Transportation Department (ITD) team for continuous support throughout the project and access to critical crash datasets. This collaboration made possible the data linkage, modeling, and practical recommendations presented in this report.

Technical Advisory Committee

Each research project is overseen by a Technical Advisory Committee (TAC), which is led by an ITD project sponsor and project manager. The TAC is responsible for monitoring project progress, reviewing deliverables, ensuring that study objectives are met, and facilitating implementation of research recommendations, as appropriate. ITD's Research Program Manager appreciates the work of the following TAC members in guiding this research study.

- Project Sponsor: The Idaho Transportation Department
- Project Manager: Kelly Campbell
- TAC Members: Craig Roberts, Mona Hunt, Amanda Laib, Caleb Forrey, Luke Hajda
- FMCSA-Idaho Advisor: Richard York

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List of Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
BrAC	Breath Alcohol Content
CMV	Commercial Motor Vehicles
CVSA	Commercial Vehicle Safety Alliance
DMS	Driver Monitoring System
DOT	Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Association
GVWR	Gross Vehicle Weight Rating
HFST	High-friction Surface Treatments
HOS	Hours-of-service
ITD	Idaho Transportation Department
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
NDMCA	North Dakota's Motor Carriers Association
NIOSH	National Institute for Occupational Safety and Health
OOS	Out of Service
OR	Odds Ratio
PDO	Property Damage Only
TAC	Technical Advisory Committee
VMT	Vehicle Miles Traveled
VTTI	Virginia Tech Transportation Institute
WEBCARS	Web Crash Analysis Reporting System

Executive Summary

Introduction

Commercial motor vehicle (CMV) safety has become a growing concern across the United States. National data from the Federal Motor Carrier Safety Administration (FMCSA) shows that large trucks are disproportionately involved in fatal crashes compared to other vehicle types (FMCSA, 2024). Beyond the human toll, the economic costs are substantial—FMCSA estimated in 2005 that each fatal tractor-trailer crash cost an average of \$3.6 million in damages and losses, a figure that would be significantly higher today when adjusted for inflation (CRC Group, 2025).

In Idaho, CMVs play an essential role in supporting commerce and agricultural production, but they also represent a significant share of highway traffic exposure and crash risk. As of 2023, CMVs accounted for nearly 69% of all registered vehicles in Idaho as estimated by FHWA (Federal Highway Administration [FHWA], 2023). Many of the state's CMV-involved crashes occur along major freight corridors, including I-84, I-86, and I-90. Idaho's unique geography, rural roadway network, and mix of industry shape its CMV safety challenges and make it an important case study for understanding risk patterns.

Given these trends, targeted research and evidence-based mitigation strategies are critical for improving safety outcomes for both CMV operators and the travelling public. This report aims to identify the most influential factors contributing to CMV crash severity in Idaho and to propose actionable strategies that may reduce fatalities, prevent injuries, and support the safe movement of goods throughout the state.

Methods

This study analyzed trends in CMV crashes on Idaho's public roadways by examining how crash severity varies across key contributing factors. To support this analysis, data from multiple state and federal sources were integrated to create a comprehensive crash database. An interactive geodatabase tool was created to visualize crash patterns and support ongoing analysis. The tool integrates state and federal data sources to provide a reference dataset of reportable CMV crashes that occurred in Idaho between 2014 and 2023.

Key Analysis Results

The analysis produced several key findings highlighting the primary factors influencing crash severity among CMVs in Idaho. These findings summarize the most significant trends observed across driver, vehicle, roadway, environmental, and temporal factors.

Temporal Factors

- Summer and fall seasons showed significantly higher likelihoods of fatal crashes compared to winter (OR = 1.67 and 1.54, respectively). Spring, summer, and fall had significantly increased odds of an injury crash compared to winter (OR = 1.17, 1.24, and 1.14, respectively).
- Crashes that occurred on Saturday had twice the odds of a fatal crash compared to crashes on Monday (OR = 2.05).
- Years 2019, 2020, 2022, and 2023 all showed significantly lower odds of injury crashes compared to the year 2014.
- The likelihood of an injury crash increased for the afternoon rush hour period of 3:00 p.m.–5:59 p.m. compared to 9:00 a.m.–11:59 a.m.

Roadway Factors

- On roads with speed limits less than or equal to 30 mph or 31–45 mph, crashes were much less likely to be fatal compared to crashes on roads with speed limits of 56–65 mph (OR = 0.06 and 0.34, respectively).
- Crashes on roads with winter conditions (ice, snow, slush) showed significantly lower odds of a fatal outcome compared to crashes on roads with dry conditions (OR = 0.50).
- Roads with loose gravel or seal coat were associated with significantly higher odds of a fatal crash compared to roads with no other reported road conditions (OR = 3.88).
- Roads that were upgrade or downgrade were associated with higher odds of a fatal crash compared to level roads (OR = 1.44).
- Curved roads were also associated with higher odds of a fatal outcome compared to straight roads (OR = 1.68).
- Compared to crashes on local roads, crashes on principal arterial (freeways) roads were more likely to be fatal (OR = 2.62).

Environmental Factors

- Crashes in the dark on unlit roads showed a significant increase in odds of a fatal outcome compared to crashes during daylight (OR = 1.90).
- Crashes during dawn or dusk conditions also showed an increase in fatal outcomes compared to crashes during daylight (OR = 1.87).

- Most weather conditions did not show any significant association with fatal or non-fatal crash outcomes. However, snow and blowing snow did show lower odds of a fatal outcome compared to clear weather conditions (OR = 0.51 and 0.29, respectively).

Vehicle Factors

- Crashes involving CMVs with brake issues had significantly higher odds of a fatal outcome compared to crashes involving CMVs without brake issues (OR = 2.74).
- Lower odds of a fatal outcome were observed in crashes involving CMVs registered with an interstate carrier compared to CMVs registered to an intrastate carrier (OR = 0.76) and involving CMVs with one trailer compared to CMVs with two trailers (OR = 0.63).

Driver Factors

- Driving behaviors and maneuvers associated with increased odds of a fatal outcome included driving left of center (OR = 2.85), exceeding the posted speed limit (OR = 3.80), and driving the wrong way or on the wrong side (OR = 4.38).
- Previous crashes as a contributing circumstance were also associated with increased odds of a fatal crash (OR = 3.79).
- A few factors were associated with reduced odds of a fatal outcome: female driver compared to male driver (OR = 0.46) and wearing a seat belt (OR = 0.22). Driver maneuvers found to be associated with reduced odds of a fatal outcome included following too closely (OR = 0.27) and making an improper turn (OR = 0.06).

Mobilizations

- Overall, 398 crashes occurred during distraction mobilization periods and 2.76% of these crashes resulted in an inattention or distraction citation. Outside of the distraction mobilization periods, 3.48% of a total of 10,104 crashes resulted in an inattention or distraction citation. Although a Chi-Square test comparing the distribution of distraction-related crashes by time period showed no statistically significant difference ($df = 1$, $\chi^2 = 0.5948$, p -value = 0.4406), additional research is needed to fully assess the impacts of mobilizations on CMV driving behavior.

Potential Mitigation Strategies

Based on the analysis findings, the study proposes a series of targeted mitigation strategies for Idaho. Potential actions include enhancing fleet safety through inspection incentives and continued participation in the Commercial Vehicle Safety Alliance's Brake Safety Week, piloting automated infrared brake screening technologies, and restricting double and triple trailer

operation on particular terrain. Behavioral countermeasures focus on promoting driver-monitoring systems, distraction-awareness training, and targeted enforcement for speeding and load-securement compliance. Infrastructure and environmental strategies include high-friction surface treatments, improved curve delineation, adaptive lighting, and dust detection or suppression systems in agricultural regions. For temporal factors, coordinated high-visibility enforcement and seasonal awareness campaigns could help reduce risk during known high-crash periods. Finally, strengthening Idaho’s crash data system through better geospatial integration, standardized fields, and linkage with complementary databases (such as vehicle registration, weather, and inspection data) would enhance the ability to identify trends and evaluate program effectiveness over time. Collectively, these efforts would provide Idaho with a more data-driven and proactive approach to reducing CMV crash severity statewide.

1. Introduction

In recent years, research into crashes involving commercial motor vehicles (CMVs) has become an increasingly important topic in the United States. According to data from the Federal Motor Carrier Safety Administration (FMCSA), CMVs, particularly large trucks, are disproportionately involved in fatal crashes compared to other vehicle types. From 2010 to 2021, the number of fatal crashes involving large trucks increased by over 50%, even when controlling for the number of vehicle miles traveled (VMT) (FMCSA, 2024). The upward trend does not appear to be slowing; between 2020 and 2022 alone, fatal crashes involving large trucks rose by 6.7% (FMCSA, 2024). The severity of these crashes is particularly concerning. Crashes involving large trucks—defined as having a gross vehicle weight rating (GVWR) of over 10,000 lb—are more likely to result in a fatality (FMCSA, 2023a). In addition to the cost of human life, large truck crashes impose significant economic burdens, including property damage and disruptions to the broader economy (Zaloshnja, 2004). In 2005, FMCSA estimated the average cost of a tractor-trailer crash involving a fatality to be \$3.6 million. Given that this figure has not been adjusted for inflation, it is likely that the true cost today is considerably higher (CRC Group, 2025).

Given the critical role that CMVs play in interstate and intrastate commerce, combined with the increasing rates of fatalities involving heavy vehicles, there is a pressing need for targeted research aimed at reducing these incidents and improving road safety. While CMVs are federally regulated by the FMCSA, individual states experience varying impacts from large truck traffic density and subsequent crashes. In Idaho, for example, CMVs made up 68.7% of all registered vehicles as of 2023 (FHWA, 2023). These vehicles are critical to maintaining a strong supply chain. The number of interstate VMT by CMVs represents approximately 27% of total VMT on the state’s rural interstate system and approximately 14% of the state’s urban interstate system (FHWA, 2021). Meanwhile, the safety of CMVs on highways is also essential to ensure safe and

efficient highways for the overall motoring public. Many of the crashes in Idaho occurred along major interstate systems, specifically I-84, I-86, and I-90 (FHWA, 2021). Geographic, demographic, and traffic-related factors, as well as local law enforcement practice, contribute to differing needs and challenges across states. Factors such as these also influence which countermeasures are most effective in reducing fatalities and improving safety outcomes for CMVs.

2. Brief Background and Prior Research

The Virginia Tech Transportation Institute (VTTI) conducted a literature review to examine the primary factors influencing CMV crashes. The factors included driver behavior, vehicle characteristics, and environmental conditions, as well as countermeasures aimed at reducing crash risk and severity. The review of current research indicates that fatal CMV crashes have risen slightly in recent years, emphasizing the need for targeted safety interventions (FMCSA, 2024). The size and weight of CMVs significantly contribute to crash severity, often disproportionately affecting passenger vehicle occupants (Milton et al., 2008; Qin et al., 2013; Stein and Jones, 1988; Teoh et al., 2017). Driver behavior remains the leading contributor to CMV crashes, with fatigue, distraction, impairment, and prior driving violations identified as key risk factors (FMCSA, 2007). High-risk drivers, particularly those with poor safety histories, are responsible for a disproportionate number of crashes, highlighting driver history as a strong predictor of future involvement (Knipling et al., 2004; Socolich et al., 2011). Speeding among CMV drivers is also a major factor, contributing to higher crash severity, especially in rollover and loss-of-control events (FMCSA, 2023a; Imprialou & Quddus, 2019).

Vehicle related issues – particularly brake and tire defects further increase crash likelihood and severity (FMCSA, 2023a). Although older vehicles may be more prone to mechanical failures, the correlation between vehicle age and crash risk is still uncertain (National Highway Traffic Safety Administration, 2013; Christoforou & Wolff, 2010; Yuan, et al., 2021). Cargo type also influences crash dynamics, with hazardous materials, liquid loads, and unstructured cargo presenting unique safety challenges (Carson et al., 2007; Feng et al., 2021; Calabrese et al., 2017). Environmental and roadway factors such as rural highways, limited infrastructure, narrow shoulders, steep grades, and curves all contribute to elevated crash rates (FMCSA, 2023a; Governors Highway Safety Association, 2022; Zhao et al., 2018; Flintsch et al., 2021; Layton, 2022; Aarts & Van Schagen, 2006). Adverse weather conditions, including snow, ice, and high winds, increase crash frequency, while nighttime driving is associated with greater crash severity (FHWA, 2024; Chen et al., 2016; Hernandez et al., 2020; Abdel-Aty et al., 2010; Rossetti & Johnsen, 2011).

A range of countermeasures has demonstrated effectiveness in reducing CMV crashes. Technology-based solutions, such as automatic emergency braking, lane departure warnings, and speed limiters, have been shown to prevent collisions and mitigate severity (Willstrand et al., 2024; Thiffault, 2011; Hanowski et al., 2012; Jonah et al., 2009). Infrastructure improvements, including rumble strips, enhanced pavement markings, curve signage, and variable speed limit systems, further support safety by improving driver awareness and roadway feedback (Datta et al., 2012; Gan et al., 2005; Davis, 2015; Knodler, 2008; Gan et al., 2005; FHWA, 2011). Law enforcement strategies, particularly high-visibility enforcement and targeted

inspections, effectively deter unsafe driving behaviors (Thiffault, 2011; Hans et al., 2014; Dougherty et al., 1999; Fontaine et al., 2009; Alrejjal et al., 2021; Craft, 2008). Policy interventions, including stricter hours-of-service (HOS) regulations, lane restrictions, and safety incentive programs for carriers, promote compliance and accountability within the industry (Fontaine et al., 2009; Kirley et al., 2023). Education and outreach programs targeting drivers of both CMVs and passenger vehicle are also essential for fostering awareness and promoting safety roadway interactions (Thiffault, 2011; Gander et al., 2005; Chen et al., 2024; Zhao et al., 2018; Hanowski et al., 2007). Finally, ongoing research and improved data quality are critical to refining safety strategies and evaluating the long-term effectiveness of interventions (U.S. Department of Transportation, 2022; Olson et al., 2009; Cho et al., 2025). Enhanced crash data accuracy and consistency will enable more precise analyses of contributing factors, while continued research on human factors—such as driver fatigue management, decision-making, and risk perception—will support the development of targeted behavioral countermeasures (Blower, 2017). Overall, the findings of this review provide a framework for identifying and prioritizing key factors to analyze within Idaho’s crash data and ensuring that future research does not overlook critical variables influencing CMV safety outcomes.

A detailed version of this literature review is provided in Appendix A.

3. Methods

The current study investigated trends in CMV crashes occurring on public roadways in Idaho across key factors under several factor categories. To achieve this objective, the study linked data from multiple sources to create a comprehensive crash database and assessed the data for differences in crash severity by factor level. In addition, the study sought to develop a framework for measuring the impacts of traffic enforcement mobilization. These results are included in Chapter 4. The comprehensive crash database was then used in the development of an interactive geodatabase, as detailed in Chapter 5.

Data Sources

The study assessed crashes that occurred on all public roadways in Idaho in years 2014 through 2023 and involving at least one CMV weighing 10,000 lb or more for patterns in temporal-, roadway-, environmental-, work zone-, vehicle-, and driver-related factors and crash severity. The analysis utilized crash data from the Idaho Crash database through the Idaho Web Crash Analysis Reporting System (WEBCARS) and the American Association of State Highway and Transportation Officials (AASHTO) Safety tools. Carrier information from the Motor Carrier Management Information System (MCMIS) Census database and Idaho traffic enforcement mobilization information were also accessed. These datasets were linked by date (crash date, mobilization dates), unique numerical IDs assigned to crash (to link crash information stored in multiple crash databases), and carrier Department of Transportation (DOT) number (to match MCMIS Census data to crash data). The Census data was used to determine carrier location and carrier freight types hauled, as the crash data did not include detailed information on the vehicle freight at the time of the crash.

The linked and filtered dataset included 15,876 crashes, which contained crashes with full and partial data (due to missing information). Analysis of the key factors for crash severity patterns focused on 13,701 crashes with more complete data available. MCMIS census data was available for 10,715 crashes.

Analysis Approach

VTTI used the linked data sets to investigate contributing factors and trends associated with CMV crashes. For each factor of interest, the frequency and proportion of crashes was calculated per factor level and crash severity level. The analysis approach utilized a series of binary logistic regression models used to quantify the effects of roadway, environmental,

temporal, vehicle, and driver-related factors on crash injury severity. The analysis was performed for all CMV crash data and repeated in analysis of CMVs over 26,000 lb.

Crashes were labeled in the data by highest severity where the scale was as follows (Idaho Transportation Department, 2023; FHWA, n.d.b):

- Fatal
- A- Suspected serious
- B- Suspected minor
- C- Possible injury
- O- No injury or fatality evident (property damage only)
- Unknown or missing (excluded from analyses)

Each crash was re-classified for severity in order to compare Fatal crashes to Non-Fatal crashes (which included A, B, and C injury crashes and property damage only crashes) and Injury crashes (including A, B, and C injury crashes) to Property Damage Only crashes. Crash severity as labeled in these binary classifications served as the model dependent variable, such that the outcomes of each crash y_i can be described as:

$$Y_i = \begin{cases} 1 & \text{Higher severity crash} \\ 0 & \text{Lower severity crash} \end{cases}$$

The logistic regression model assumes that the crash severity dependent variable follows a Bernoulli distribution:

$$Y_i \sim \text{Bernoulli}(p_i)$$

Where p_i is the probability a crash will be a higher severity crash.

The model was structured as:

$$\text{logit}(p_i) = \log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i1} + \dots + \beta_k x_{ik} = X_i \beta$$

Where β represents the coefficients of the explanatory variables included in the model. Individual models were built to assess specific roadway, environmental, temporal, vehicle, and driver-related conditions, and crash year was included in each model as a covariate.

The model outcome was expressed as an odds ratio (OR) to describe how the odds of a crash with a specific severity change with the explanatory variables. ORs greater than 1 and found statistically significant indicate increased odds of higher crash severity for the comparison value listed first in the Results tables, whereas ORs less than 1 and found statistically significant indicate decreased odds of higher crash severity for the comparison value listed first. The ORs and corresponding confidence intervals (listed in the Results section tables as LCL for lower confidence limit and UCL for upper confidence limit) do not indicate that a particular crash outcome is more likely than another but rather measure how the likelihood of a crash outcome changes across levels of a factor. For example, if during dry conditions, fatal outcomes occurred in 1% of crashes, crashes are more likely to be non-fatal than fatal (99% non-fatal crashes vs. 1% fatal). If during rainy conditions, fatal outcomes occurred in 5% of crashes, crashes are still more likely to be non-fatal than fatal (95% non-fatal crashes vs. 5% fatal). However, the odds of a fatal crash are higher during rainy conditions compared to dry conditions. In cases where multiple comparisons were made within a factor, due to more than two factor levels with sufficient data, the alpha was adjusted using a Bonferroni correction to control the Type I error rate.

Idaho utilizes law enforcement mobilizations to target specific risky driving behaviors at different times of the calendar year. These mobilizations may be specific to commercial vehicles or more general to all vehicles on Idaho roadways. To develop an analysis framework for assessing the impact of mobilizations on driver behaviors and crash outcomes, the analysis focused on distraction and inattention, an issue targeted through annual mobilizations and with sufficient counts in the crash data for further analysis. This mobilization focus area targeted all vehicles and was not limited to commercial vehicles. The dates of distraction-related mobilizations are included in Table 3-1 below. Future analyses of mobilizations could investigate all mobilizations, mobilizations targeting commercial vehicles, or other saturation activities. The analysis tabulated the number of crashes occurring within and outside of the mobilization time periods per year and the number of these crashes that had inattentive-related citations or distraction or inattention-related contributing circumstances. The distributions of distraction-related crashes were compared in the two periods using a Chi-Square test of homogeneity.

Table 3-1. Distraction-related Mobilizations with Dates of Mobilization Period

Year	Mobilization Focus Area	Dates
2016	Distracted Driving	April 1-11, 2016
2017	Distracted/Aggressive	June 15-25, July 14-24, Aug 11-21
2018	Distracted (School Zone)	Aug 15-Sept 4, 2018

Year	Mobilization Focus Area	Dates
2019	School Zone Safety- Distracted	Sept 16-20, 2019
2021	Distracted	April 19-30, 2021
2022	Distracted	April 19-29, 2022
2023	Distracted Driving–April	April 5-19, 2023

4. Results

Temporal Factors

Temporal factors assessed for association with crash severity included calendar year, season, day of the week, and time of day. Table 4-1 presents for each temporal factor and level the frequency counts and percentage of observations by crash severity. For each factor, the level with the highest number of CMV-related crashes was year 2023, winter season, Tuesday, and time of day 12:00 p.m.–2:59 p.m.

Table 4-1. Temporal-related Factors: Frequency of Factor Levels in Fatal, Injury, and PDO CMV-Related Crashes

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
Calendar Year	2014	1,244	21 (1.69%)	426 (34.25%)	797 (64.07%)
	2015	1,297	26 (2.00%)	446 (34.39%)	825 (63.61%)
	2016	1,403	30 (2.14%)	454 (32.36%)	919 (65.50%)
	2017	1,405	38 (2.70%)	435 (30.96%)	932 (66.33%)
	2018	1,392	40 (2.87%)	426 (30.60%)	926 (66.52%)
	2019	1,405	27 (1.92%)	410 (29.18%)	968 (68.90%)
	2020	1,242	35 (2.82%)	332 (26.74%)	875 (70.45%)
	2021	1,364	33 (2.42%)	396 (29.03%)	935 (68.55%)
	2022	1,472	19 (1.29%)	373 (25.34%)	1,080 (73.37%)
	2023	1,477	39 (2.64%)	358 (24.24%)	1,080 (73.12%)
Season	Spring	2,861	67 (2.34%)	863 (30.17%)	1,931 (67.49%)
	Summer	3,436	91 (2.65%)	1,076 (31.31%)	2,269 (66.04%)
	Fall	3,669	90 (2.45%)	1,094 (29.82%)	2,485 (67.73%)
	Winter	3,735	60 (1.61%)	1,023 (27.39%)	2,652 (71.00%)
Day of the Week	Monday	2,347	42 (1.79%)	693 (29.52%)	1,612 (68.68%)
	Tuesday	2,493	54 (2.17%)	739 (29.64%)	1,700 (68.19%)
	Wednesday	2,438	52 (2.13%)	696 (28.54%)	1,690 (69.32%)
	Thursday	2,363	53 (2.24%)	704 (29.8%)	1,606 (67.96%)
	Friday	2,381	52 (2.18%)	729 (30.62%)	1,600 (67.2%)
	Saturday	970	35 (3.61%)	275 (28.36%)	660 (68.04%)
	Sunday	709	20 (2.82%)	220 (31.03%)	469 (66.15%)
Time of Day	12:00 a.m.–2:59 a.m.	439	17 (3.87%)	135 (30.75%)	287 (65.38%)
	3:00 a.m.–5:59 a.m.	605	21 (3.47%)	176 (29.08%)	408 (67.44%)
	6:00 a.m.–8:59 a.m.	2,286	52 (2.27%)	678 (29.66%)	1,556 (68.07%)
	9:00 a.m.–11:59 a.m.	2,780	55 (1.98%)	774 (27.85%)	1,951 (70.18%)
	12:00 p.m.–2:59 p.m.	2,901	54 (1.86%)	875 (30.16%)	1,972 (67.98%)

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
	3:00 p.m.–5:59 p.m.	2,658	55 (2.07%)	847 (31.86%)	1,756 (66.06%)
	6:00 p.m.–8:59 p.m.	1,130	33 (2.92%)	337 (29.83%)	760 (67.26%)
	9:00 p.m.–11:59 p.m.	619	16 (2.58%)	177 (28.59%)	426 (68.82%)

Model Results: Fatal Crashes

Results of the logistic regression model analysis of temporal factors for association with fatal and less severe, non-fatal crashes (injury and PDO) are presented in Table 4-2. Summer and fall seasons showed significantly higher likelihoods of fatal crashes compared to winter (OR = 1.67 and 1.54, respectively). Crashes that occurred on Saturday had twice the odds of a fatal crash compared to crashes on Monday (OR = 2.05). In crashes involving CMVs 26,000 lb or heavier, summer was associated with an increased odds of a fatal crash (OR = 1.68). All other comparisons within the temporal factors were either insignificant or limited by low observation counts.

Table 4-2. Temporal-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Season	Summer vs. Winter	1.67*	1.11	2.49	1.68*	1.09	2.58
	Fall vs. Winter	1.54*	1.03	2.31	1.50	0.97	2.31
Day of the Week	Saturday vs. Monday	2.05*	1.11	3.79	1.85	0.95	3.61

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury Crashes

Results of the logistic regression model analysis of temporal factors for association with injury and less severe PDO crashes are presented in Table 4-3. Years 2019, 2020, 2022, and 2023 all showed significantly lower odds of injury crashes compared to year 2014. Spring, summer, and fall had significantly increased odds of an injury crash compared to winter (OR = 1.17, 1.24, and 1.14, respectively). Likelihood of an injury crash increased for the afternoon rush hour period of 3:00 p.m.–5:59 p.m. compared to 9:00 a.m.–11:59 a.m. Analysis of crashes involving a CMV 26k+ lb revealed similar patterns in significant findings. Differences included 2021 also showing significantly lower odds of an injury crash compared to year 2014 and no significant difference in crash outcome for fall season versus winter season. Other comparisons within the temporal factors were either insignificant or limited by low observation counts.

Table 4-3. Temporal Related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Calendar Year	2019 vs. 2014	0.79*	0.63	1.00	0.79	0.59	1.04
	2020 vs. 2014	0.71*	0.56	0.91	0.67*	0.51	0.89
	2021 vs. 2014	1.44	0.66	3.16	0.74*	0.56	0.98
	2022 vs. 2014	0.65*	0.51	0.82	0.62*	0.47	0.81
	2023 vs. 2014	0.62*	0.49	0.79	0.60*	0.46	0.79
Season	Spring vs. Winter	1.17*	1.02	1.33	1.20*	1.03	1.39
	Summer vs. Winter	1.24*	1.09	1.40	1.20*	1.04	1.39
	Fall vs. Winter	1.14*	1.01	1.29	1.11	0.97	1.29
Time of Day	3:00 p.m.–5:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.21*	1.03	1.43	1.24*	1.02	1.50

* Indicates statistically significant result at alpha = 0.05

Roadway-related Factors

Roadway related factors investigated in the current study included roadway speed limit, road surface condition, road surface type, vertical and horizontal geometry of the roadway, roadway classification, and presence of specific roadway conditions like the presence of loose gravel. Table 4-4 presents the frequency count and percentage of observations for each roadway-related factor level.

Table 4-4. Roadway related Factors: Frequency of Work Zone Factor Levels in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
Speed Limit	≤ 30 MPH	1,871	4 (0.21%)	296 (15.83%)	1,571 (83.97%)
	31–45 MPH	3,397	43 (1.27%)	934 (27.50%)	2,420 (71.24%)
	46–55 MPH	2,857	84 (2.94%)	987 (34.55%)	1,786 (62.51%)
	56–65 MPH	3,107	114 (3.67%)	1,045 (33.64%)	1,948 (62.70%)
	66–75 MPH	871	20 (2.30%)	255 (29.27%)	596 (68.43%)
	76+ MPH	1,598	43 (2.69%)	539 (33.73%)	1,016 (63.58%)
Road Surface Condition	Dry	10,250	253 (2.47%)	3,136 (30.60%)	6,861 (66.94%)
	Winter Conditions (Ice, Snow, Slush)	2,166	27 (1.25%)	530 (24.47%)	1,609 (74.28%)

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
	Wet (Wet, Water-standing/moving, Oil)	1,179	25 (2.12%)	368 (31.21%)	786 (66.67%)
	Particulate (Mud, Dirt, Gravel, Sand)	48	1 (2.08%)	14 (29.17%)	33 (68.75%)
	Other	12	1 (8.33%)	6 (50%)	5 (41.67%)
	Unknown	46	1 (2.17%)	2 (4.34%)	43 (93.48%)
Road Surface Type	Paved (Asphalt)	12,345	284 (2.3%)	3,574 (28.95%)	8487 (68.75%)
	Concrete	1,070	16 (1.5%)	409 (38.22%)	645 (60.28%)
	Dirt	87	1 (1.15%)	24 (27.59%)	62 (71.26%)
	Gravel/Stone	166	7 (4.22%)	48 (28.91%)	111 (66.87%)
	Other	2	0 (0%)	0 (0%)	2 (100%)
Roadway Condition	High/Low Shoulder	268	8 (2.99%)	85 (31.71%)	175 (65.30%)
	Lane Closed	95	1 (1.05%)	32 (33.68%)	62 (65.26%)
	Loose Gravel/Seal Coat	37	3 (8.11%)	13 (35.14%)	21 (56.76%)
	None	13,081	293 (2.24%)	3872 (29.6%)	8916 (68.16%)
	Other	68	0 (0%)	19 (27.94%)	49 (72.06%)
	Poor Pavement Markings	31	1 (3.23%)	10 (32.26%)	20 (64.52%)
	Ruts/Bumps/Holes	45	0 (0%)	9 (20.01%)	36 (80.00%)
	Slick Asphalt (Bleeding)	16	0 (0%)	5 (31.25%)	11 (68.75%)
	Washboard	13	1 (7.69%)	5 (38.46%)	7 (53.85%)
Vertical Geometry	Hillcrest	117	1 (0.85%)	35 (29.92%)	81 (69.23%)
	Level	10,750	224 (2.08%)	3152 (29.32%)	7374 (68.60%)
	Upgrade/Downgrade	2,796	83 (2.97%)	866 (30.97%)	1847 (66.06%)
Horizontal Geometry	Curve	2,523	84 (3.33%)	801 (31.75%)	1,638 (64.92%)
	Straight	11,140	224 (2.01%)	3,252 (29.19%)	7,664 (68.80%)
Roadway Classification	Interstate	3,596	77 (2.14%)	1,065 (29.62%)	2,454 (68.24%)
	Local	1,499	20 (1.33%)	306 (20.42%)	1,173 (78.25%)
	Major Collector	1,803	37 (2.05%)	545 (30.23%)	1,221 (67.72%)
	Minor Arterial	1,975	40 (2.03%)	538 (27.24%)	1,397 (70.73%)
	Minor Collector	183	3 (1.64%)	57 (31.15%)	123 (67.21%)
	Principal Arterial (Freeways)	1,793	59 (3.29%)	683 (38.09%)	1,051 (58.62%)
	Principal Arterial (Other)	2,852	72 (2.52%)	862 (30.23%)	1,918 (67.25%)

Model Results: Fatal Crashes

Table 4-5 lists the results of the logistic regression model analysis for fatal and less severe, non-fatal crashes (injury and PDO). On roads with speed limits less than or equal to 30 mph or

between 31–45 mph, crashes were much less likely to be fatal compared to crashes on roads with speed limits of 56–65 mph (OR = 0.06 and 0.34, respectively). Crashes on roads with winter conditions (ice, snow, slush) showed significantly lower odds of a fatal outcome compared to crashes on roads with dry conditions (OR = 0.50). Roads with loose gravel or seal coat were associated with significantly higher odds of a fatal crash compared to roads with no other reported road conditions (OR = 3.88). Roads that were upgrade or downgrade were associated with higher odds of a fatal crash compared to level roads (OR = 1.44). Curved roads were also associated with higher odds of a fatal outcome compared to straight roads (1.68). Compared to crashes on local roads, crashes on principal arterial (freeways) roads were more likely to be fatal (OR = 2.62). Analysis of CMVs weighing 26k+ lb showed similar findings in significance and magnitude of OR. Exceptions included insignificant findings for loose gravel or seal coat and roadway classification of principal arterial (freeways).

Table 4-5. Roadway-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Speed Limit	≤ 30 MPH vs. 56–65 MPH	0.06*	0.02	0.21	0.70*	0.02	0.32
	31–45 MPH vs. 56–65 MPH	0.34*	0.21	0.54	0.32*	0.19	0.56
Road Surface Condition	Winter Conditions (Ice, Snow, Slush) vs. Dry	0.50*	0.30	0.83	0.56*	0.33	0.95
Roadway Condition	Loose Gravel/Seal Coat vs. None	3.88*	1.18	12.70	2.99	0.70	12.70
Vertical Geometry	Upgrade/Downgrade vs. Level	1.44*	1.07	1.93	1.47*	1.08	2.01
Horizontal Geometry	Curve vs. Straight	1.68*	1.30	2.17	1.53*	1.16	2.02
Roadway Classification	Principal Arterial (Freeways) vs. Local	2.62*	1.31	5.24	2.09	0.97	4.53

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury Crashes

Table 4-6 lists the results of the logistic regression model analysis for injury and less severe PDO crashes. Many findings echoed those of the analysis of fatal crashes, indicating several factors are associated with increased risk of general higher severity crash outcomes. On roads with speed limits less than or equal to 30 mph or 31–45 mph, crashes were much less likely to result in injuries compared to crashes on roads with speed limits of 56–65 mph (OR = 0.34 and 0.70, respectively). Road surface conditions of ice, snow, slush showed significantly lower odds of an injury outcome compared to crashes on roads with dry conditions (OR = 0.72). Concrete roadways showed higher likelihoods of an injury crash compared to asphalt roadways (OR = 1.56). Curved roads were associated with slightly higher odds of an injury crash compared to

straight roads (1.15). When compared to local roads, all other roadway classifications showed increased risk of an injury crash. The highest increase in risk of an injury crash was on principal arterial (freeways) roads (OR = 2.32). These findings were echoed in the analysis of CMVs 26k+ lb counts.

Table 4-6. Roadway-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Speed Limit	≤ 30 MPH vs. 56–65 MPH	0.34*	0.28	0.41	0.32*	0.25	0.41
	31–45 MPH vs. 56–65 MPH	0.70*	0.61	0.81	0.66*	0.56	0.78
Road Surface Condition	Winter Conditions (Ice, Snow, Slush) vs. Dry	0.72*	0.63	0.82	0.75*	0.64	0.88
Road Surface Type	Concrete vs. Paved (Asphalt)	1.56*	1.32	1.84	1.46*	1.21	1.76
Horizontal Geometry	Curve vs. Straight	1.15*	1.05	1.26	1.17*	1.05	1.30
Roadway Classification	Interstate vs. Local	1.83*	1.50	2.23	1.80*	1.41	2.29
	Major Collector vs. Local	1.77*	1.42	2.20	1.67*	1.27	2.20
	Minor Arterial vs. Local	1.52*	1.23	1.89	1.51*	1.15	1.99
	Minor Collector vs. Local	1.93*	1.22	3.05	2.01*	1.18	3.44
	Principal Arterial (Freeways) vs. Local	2.32*	1.87	2.88	2.22*	1.70	2.89
	Principal Arterial (Other) vs. Local	1.84*	1.50	2.26	1.85*	1.43	2.39

* Indicates statistically significant result at alpha = 0.05

Environment-related Factors

The environment-related factors assessed in the current analysis included lighting and weather. The lighting variable was condensed to include “dark, no street lights” and “dark, street lights off” under the level “dark, not lighted” to describe the lighting conditions at the time of the crash. For each crash, up to two weather conditions could be listed. If the weather was clear or cloudy, with no other conditions listed, the weather was considered to have “no adverse conditions.” Because crashes could have one or multiple conditions listed, the total crashes occurring across all weather conditions is greater than the total number of unique crashes. Table 4-7 presents the frequency counts and percentage of observations by crash severity across all levels of lighting and weather.

Table 4-7. Environment-related factors: Frequency of Weather and Lighting Levels in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
Lighting	Dark, Not Lighted	2,078	76 (3.66%)	612 (29.46%)	1,390 (66.89%)
	Dark, Lighted	661	9 (1.36%)	175 (26.47%)	477 (72.16%)
	Dawn or Dusk	528	19 (3.60%)	181 (34.28%)	328 (62.12%)
	Daylight	10,431	204 (1.96%)	3,088 (29.60%)	7,139 (68.44%)
Weather	No Adverse Conditions	11,106	269 (2.42%)	3338 (30.06%)	7499 (67.52%)
	Blowing Dust/Sand	52	2 (3.85%)	33 (63.46%)	17 (32.69%)
	Blowing Snow	432	3 (0.69%)	112 (25.93%)	317 (73.38%)
	Cloudy	3,149	85 (2.70%)	925 (29.38%)	2139 (67.93%)
	Fog	226	9 (3.98%)	72 (31.85%)	145 (64.16%)
	Rain	701	13 (1.85%)	212 (30.24%)	476 (67.90%)
	Severe Cross Winds	178	3 (1.69%)	62 (34.83%)	113 (63.48%)
	Sleet/Hail	57	0 (0%)	19 (33.34%)	38 (66.67%)
	Smoke/Smog	76	1 (1.32%)	23 (30.26%)	52 (68.42%)
	Snow	1,231	15 (1.22%)	297 (24.13%)	919 (74.65%)

Model Results: Fatal Crashes

Results of the logistic regression model analysis of lighting and weather factors for association with fatal and less severe, non-fatal crashes (injury and PDO) are presented in Table 4-8. Crashes in the dark on roads that were not lit showed a significant increase in odds of a fatal outcome compared to crashes during daylight (OR = 1.90). Crashes during dawn or dusk conditions also showed an increase in fatal outcomes compared to crashes during daylight (OR = 1.87). Most weather conditions did not show any significant association with fatal or non-fatal crash outcomes. However, snow and blowing snow did show lower odds of a fatal outcome compared to clear weather conditions (OR = 0.51 and 0.29, respectively). CMVs weighing at least 26,000 lb showed similar patterns in crash outcome by environment-related variables, except a non-significant result for blowing snow, for this vehicle subset.

Table 4-8. Environment-related Factors: Logistic Regression Model Results for Weather and Lighting in Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Lighting	Dark, Not Lighted vs. Daylight	1.90*	1.35	2.68	1.88*	1.31	2.70
	Dawn or Dusk vs. Daylight	1.87*	1.02	3.44	1.98*	1.04	3.80
Weather	Adverse Conditions vs. No Adverse Conditions	1.62*	1.16	2.28	1.51*	1.07	2.15

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
	Blowing Snow vs. No Adverse Conditions	0.29*	0.09	0.92	0.32	0.10	1.01
	Snow vs. No Adverse Conditions	0.51*	0.30	0.86	0.57*	0.34	0.96

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury Crashes

Table 4-9 presents the results of the logistic regression model analysis of lighting and weather factors for association with injury and less severe PDO crash outcomes. For this crash subset, crashes during dawn or dusk conditions showed an increase in injury outcomes compared to crashes during daylight (OR = 1.28). Generally, adverse conditions were shown to slightly increase likelihood of an injury crash compared to non-adverse conditions (OR = 1.14). Compared to clear conditions, blowing dust or sand increased the likelihood of an injury crash by over four times (OR = 4.77). Snowy conditions did show lower odds of an injury outcome compared to clear weather conditions (OR = 0.72). CMVs weighing at least 26,000 lb showed similar patterns of crash outcomes by these variables. However, blowing dust or sand was associated with an even stronger change in likelihood of an injury outcome (OR = 5.82) in these vehicles.

Table 4-9. Environment-related Factors: Logistic Regression Model Results for Weather and Lighting in Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Lighting	Dawn or Dusk vs. Daylight	1.28*	1.01	1.62	1.45*	1.11	1.90
Weather	Adverse Conditions vs. No Adverse Conditions	1.14*	1.04	1.25	1.10	0.99	1.23
	Blowing Dust/Sand vs. No Adverse Conditions	4.77*	2.65	8.58	5.82*	3.03	11.15
	Snow vs. No Adverse Conditions	0.72*	0.63	0.83	0.75*	0.64	0.87

* Indicates statistically significant result at alpha = 0.05

Work Zone-related Factors

Work zone factors assessed for association with crash severity included work zone related crash, work zone type, whether work zone workers were present at the site, and whether law enforcement was present at the work zone site. Table 4-10 presents, for each work zone factor and level, the frequency counts and percentage of observations by crash severity. From 2014 to 2023, there were 867 CMV-related crashes that were marked as related to a work zone.

Table 4-10. Work Zone-related Factors: Frequency of Work Zone Factor Levels in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	# (%) Fatal	# (%) Injury	# (%) PDO
Work Zone Related Crash	Yes	867	16 (1.85%)	259 (29.87%)	592 (68.68%)
	No	12,765	292 (2.29%)	3,781 (29.62%)	8,692 (68.09%)
	Unknown	68	0 (0%)	16 (23.53%)	52 (76.46%)
Work Zone Crash Location	Activity Area (Work incident area)	514	7 (1.36%)	156 (30.35%)	351 (68.29%)
	Advance Warning Area	101	3 (2.97%)	36 (35.64%)	62 (61.39%)
	Before the First Work Zone Warning Sign	36	1 (2.78%)	19 (52.78%)	16 (44.44%)
	Termination Area	28	0 (0%)	7 (25.00%)	21 (75.00%)
	Transition Area	187	5 (2.67%)	41 (21.92%)	141 (75.40%)
Work Zone Type	Intermittent or Moving Work	90	2 (2.22%)	21 (23.34%)	67 (74.44%)
	Lane Closure	304	7 (2.30%)	92 (30.27%)	205 (67.43%)
	Lane Shift / Crossover	183	5 (2.73%)	56 (30.61%)	133 (66.67%)
	Other	37	0 (0%)	13 (35.14%)	24 (64.86%)
	Work on Shoulder or Median	252	2 (0.79%)	77 (30.55%)	173 (68.65%)
Workers Present	Yes	467	5 (1.07%)	138 (29.55%)	324 (69.38%)
	No	316	10 (3.16%)	93 (29.43%)	213 (67.41%)
	Unknown	84	1 (1.19%)	28 (33.33%)	55 (65.48%)
Law Enforcement Present	Officer Present	48	0 (0%)	17 (35.42%)	31 (64.58%)
	No	818	16 (1.96%)	242 (29.58%)	560 (68.46%)

Model Results: Fatal Crashes

Results of the logistic regression model analysis of work zone factors for association with fatal and less severe, non-fatal crashes (injury and PDO) are presented in Table 4-11. The absence of work zone workers was associated with a higher likelihood of a fatal crash (OR = 2.98). All other comparisons within the work zone factors were either insignificant or limited by low observation counts. CMVs weighing at least 26,000 lb showed a slightly higher OR for a fatal outcome when workers were not present compared to when workers were present (OR = 3.36).

Table 4-11. Work Zone-related Factors: Logistic Regression Model Results for Work Zone Factors in Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
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Workers Present	No vs. Yes	2.98*	1.01	8.83	3.36*	1.02	11.06
* Indicates statistically significant result at alpha = 0.05							

Model Results: Injury Crashes

Results of the logistic regression model analysis of work zone factors for association with injury and less severe PDO crashes are presented in Table 4-12. Significant differences in injury crash likelihood were found for work zone location in analyses of both vehicle weight groupings. Crashes before the first warning sign were associated with higher likelihood of injuries compared to the activity area (OR = 2.66 in all CMVs, 2.93 in CMVs weighing 26k+ lb).

Table 4-12. Work Zone-related Factors: Logistic Regression Model Results for Work Zone Factors in Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ lb Veh	LCL 26k+ lb Veh	UCL 26k+ lb Veh
Work Zone Crash Location	Before the First Work Zone Warning Sign vs. Activity Area (Work incident area)	2.66*	1.08	6.52	2.93*	1.04	8.23
* Indicates statistically significant result at alpha = 0.05							

Vehicle-related Factors

Vehicle-related factors assessed in the current study included carrier type (interstate or intrastate), state of the vehicle license plate (Idaho or out of state), cargo body, whether the vehicle was insured, number of trailers, vehicle maintenance-related contributing circumstances, and carrier freight type (as noted in the FMCSA MCMIS census data). Table 4-13 and Table 4-14 present the frequency count and percentage of observations for each vehicle-related factor level.

Table 4-13. Vehicle-related Factors: Frequency of Vehicle-related Factor Levels in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	#!/% Fatal	#!/% Injury	#!/% PDO
Carrier Type	Interstate	7,225	205 (2.84%)	2,160 (29.89%)	4,860 (67.27%)
	Intrastate	3,418	115 (3.36%)	1,066 (31.19%)	2,237 (65.45%)
	Other	4,036	42 (1.04%)	1,151 (28.52%)	2,843 (70.44%)
Carrier Type (more than 26,000 lb)	Interstate	6,396	187 (2.92%)	1,947 (30.44%)	4,262 (66.64%)
	Intrastate	2,587	99 (3.83%)	805 (31.12%)	1,683 (65.06%)
	Other	1,853	22 (1.19%)	491 (26.49%)	1,340 (72.32%)
License Plate State	Idaho	8,632	205 (2.37%)	2,563 (29.69%)	5,864 (67.93%)

Factor	Level	N total	#!/% Fatal	#!/% Injury	#!/% PDO
	Out of State	6,047	157 (2.60%)	1,814 (30.00%)	4,076 (67.41%)
Interstate or Intrastate Plate	Interstate	3,063	84 (2.74%)	888 (28.99%)	2,091 (68.27%)
	Intrastate	2,933	86 (2.93%)	852 (29.05%)	1,995 (68.02%)
Cargo Body	Auto Transporter	182	4 (2.20%)	63 (34.61%)	115 (63.19%)
	Belly Dump/Hopper	1,244	42 (3.38%)	393 (31.60%)	809 (65.03%)
	Bus	537	1 (0.19%)	156 (29.06%)	380 (70.76%)
	Cargo Tank	780	23 (2.95%)	220 (28.21%)	537 (68.85%)
	Concrete Mixer	138	2 (1.45%)	56 (40.58%)	80 (57.97%)
	Dump	1,050	32 (3.05%)	312 (29.72%)	706 (67.24%)
	Flatbed	1,952	57 (2.92%)	534 (27.35%)	1,361 (69.72%)
	Garbage/Refuse	258	6 (2.33%)	72 (27.91%)	180 (69.77%)
	Intermodal Container Chassis	343	8 (2.33%)	87 (25.36%)	248 (72.30%)
	Log	372	16 (4.30%)	132 (35.48%)	224 (60.22%)
	None	708	24 (3.39%)	183 (25.84%)	501 (70.76%)
	Other	1,297	16 (1.23%)	406 (31.30%)	875 (67.46%)
	Pick-up Bed	472	5 (1.06%)	171 (36.22%)	296 (62.71%)
	Pole Trailer	61	1 (1.64%)	18 (29.51%)	42 (68.85%)
	Van/Enclosed Box	4,816	121 (2.51%)	1,464 (30.39%)	3,231 (67.09%)
	Vehicle Towing Another Vehicle	67	1 (1.49%)	20 (29.85%)	46 (68.66%)
Vehicle Insured	Yes	13,751	329 (2.39%)	4,033 (29.33%)	9,389 (68.28%)
	No	160	6 (3.75%)	63 (39.38%)	91 (56.88%)
	Unknown	768	27 (3.52%)	281 (36.59%)	460 (59.90%)
Trailer Count	0	255	3 (1.18%)	79 (30.98%)	173 (67.84%)
	1	7,883	222 (2.82%)	2,293 (29.08%)	5,368 (68.10%)
	2	1,005	44 (4.38%)	283 (28.17%)	678 (67.46%)
	3	134	7 (5.22%)	32 (23.88%)	95 (70.90%)
Contributing Circumstance	Brakes	141	9 (6.38%)	48 (34.04%)	84 (59.57%)
	Light Defect	21	0 (0%)	10 (47.62%)	11 (52.38%)
	Other Vehicle Defect	228	3 (1.32%)	34 (14.91%)	191 (83.77%)
	Tire Defect	172	2 (1.16%)	40 (23.25%)	130 (75.58%)
	Truck Coupling, Trailer Hitch, Safety Chains	70	1 (1.43%)	7 (10%)	62 (88.57%)
	Wheel Defect	63	0 (0%)	14 (22.22%)	49 (77.78%)

Table 4-14. Freight Types: Frequency of Freight Types in Fatal, Injury, and PDO CMV-related Crashes

Freight Type	N total	#!/% Fatal	#!/% Injury	#!/% PDO
General Freight	5,108	150 (2.94%)	1,472 (28.82%)	3,486 (68.25%)
Metal: Sheets, Coils, Rolls	1,395	43 (3.08%)	398 (28.53%)	954 (68.39%)
Motor Vehicles	820	30 (3.66%)	234 (28.54%)	556 (67.80%)
Driveaway/Towaway	411	13 (3.16%)	114 (27.73%)	284 (69.10%)
Logs, Poles, Beams, Lumber	1,907	61 (3.20%)	569 (29.83%)	1,277 (66.96%)
Building Materials	2,290	64 (2.79%)	654 (28.55%)	1,572 (68.65%)
Mobile Homes	74	2 (2.70%)	14 (18.92%)	58 (78.38%)
Machinery, Large Objects	2,278	69 (3.03%)	647 (28.40%)	1,562 (68.57%)
Fresh Produce	2,229	72 (3.23%)	631 (28.30%)	1,526 (68.46%)
Liquids/Gases	1,229	38 (3.09%)	340 (27.66%)	851 (69.24%)
Intermodal Containers	853	23 (2.70%)	238 (27.90%)	592 (69.40%)
Passengers	242	5 (2.07%)	73 (30.16%)	164 (67.77%)
Oilfield Equipment	304	8 (2.63%)	87 (28.62%)	209 (68.75%)
Livestock	435	8 (1.84%)	139 (31.96%)	288 (66.21%)
Grain, Feed, Hay	1,990	68 (3.42%)	612 (30.75%)	1,310 (65.83%)
Coal/Coke	184	5 (2.72%)	61 (33.15%)	118 (64.13%)
Meat	1,389	38 (2.74%)	375 (27.00%)	976 (70.27%)
Garbage, Refuse, Trash	306	12 (3.92%)	88 (28.75%)	206 (67.32%)
U.S. Mail	306	12 (3.92%)	85 (27.78%)	209 (68.30%)
Chemicals	1,015	28 (2.76%)	286 (28.17%)	701 (69.06%)
Commodities Dry Bulk	1,884	57 (3.03%)	544 (28.87%)	1,283 (68.10%)
Refrigerated Food	2,123	61 (2.87%)	614 (28.92%)	1,448 (68.21%)
Beverages	1,889	60 (3.18%)	533 (28.21%)	1,296 (68.61%)
Paper Products	1,984	56 (2.82%)	558 (28.12%)	1,370 (69.05%)
Utility	321	8 (2.49%)	98 (30.53%)	215 (66.98%)
Farm Supplies	1,072	31 (2.89%)	296 (27.61%)	745 (69.50%)
Construction	1,664	48 (2.88%)	461 (27.71%)	1,155 (69.41%)
Water – Well	82	0 (0%)	18 (21.96%)	64 (78.05%)
Cargo – Other	2,215	52 (2.35%)	661 (29.84%)	1,502 (67.81%)

Model Results: Fatal Crashes

Table 4-15 presents logistic regression model analysis results for vehicle-related factors and associations with fatal and less severe, non-fatal crashes (injury and PDO). Crashes involving CMVs with brake issues (listed in the contributing factors), had significantly higher odds of a fatal outcome compared to crashes involving CMVs without brake issues (OR = 2.74). Lower odds of a fatal outcome were observed in crashes involving CMVs registered with an interstate carrier compared to CMVs registered to an intrastate carrier (OR = 0.76) and involving CMVs with one trailer compared to CMVs with two trailers (OR = 0.63). For CMVs weighing at least

26,000 lb, interstate carrier type and out of state license plates were associated with a lower likelihood of an injury outcome (OR = 0.76 and 0.75, respectively). Trailer count showed a strong relationship with crash outcome for this vehicle weight group, with three trailers greatly increasing the odds of a fatal outcome (OR for three trailers versus no trailers = 5.90, versus one trailer = 3.29, and versus two trailers = 2.57). All other comparisons within the vehicle-related factors were either insignificant or limited by low observation counts.

Table 4-15. Vehicle-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Carrier Type	Interstate vs. Intrastate	0.84	0.64	1.09	0.76*	0.59	0.97
License Plate State	Out of State vs. Idaho	1.08	0.88	1.34	0.75*	0.63	0.90
Trailer Count	1 vs. 2	0.63*	0.40	0.98	0.78	0.59	1.03
	3 vs. 0	4.60	0.73	29.08	5.90*	1.68	20.76
	3 vs. 1	1.90	0.88	4.12	3.29*	2.05	5.29
	3 vs. 2	1.17	0.51	2.66	2.57*	1.51	4.38
Contributing Circumstance	Brakes Listed vs Brakes Not Listed	2.74*	1.38	5.42	1.41	0.62	3.25
	Other Vehicle Defect vs. Other Vehicle Defect Not Listed	0.52	0.17	1.62	0.22*	0.05	0.87

* Indicates statistically significant result at alpha = 0.05

Table 4-16 presents logistic regression model analysis results for freight types and associations with fatal and less severe, non-fatal crashes (injury and PDO). The analysis of all CMVs showed no associations between freight type and fatal crash outcome. For vehicles weighing at least 26,000 lb, the highest likelihood of a fatal outcome was observed for vehicles operating for a carrier who hauls grain, feed, or hay (OR = 1.97). Lower likelihoods of a fatal crash outcome were observed for vehicles operating for carriers hauling coal/coke (OR = 0.29), livestock (OR = 0.36), oilfield equipment (OR = 0.46), farm supplies (OR = 0.60), and other cargo freight (OR = 0.74).

Table 4-16. Freight Types: Logistic Regression Model Results for Freight Types in Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Chemicals	Yes vs. No	0.96	0.64	1.42	1.20*	1.03	1.40

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Coal/Coke	Yes vs. No	0.94	0.38	2.30	0.29*	0.15	0.57
Commodities Dry Bulk	Yes vs. No	1.07	0.80	1.45	1.83*	1.61	2.07
Farm Supplies	Yes vs. No	1.02	0.69	1.49	0.60*	0.47	0.76
Grain, Feed, Hay	Yes vs. No	0.63	0.31	1.28	1.97*	1.73	2.24
Intermodal	Yes vs. No	0.93	0.60	1.44	1.19*	1.02	1.38
Liquids/Gases	Yes vs. No	0.93	0.60	1.44	1.48*	1.29	1.69
Livestock	Yes vs. No	0.91	0.45	1.86	0.36*	0.21	0.63
Logs, Poles, Beams, Lumber	Yes vs. No	1.16	0.86	1.55	1.39*	1.22	1.59
Machinery, Large Objects	Yes vs. No	1.08	0.82	1.43	1.24*	1.09	1.41
Motor Vehicles	Yes vs. No	1.33	0.90	1.95	1.27*	1.08	1.50
Oilfield Equipment	Yes vs. No	0.91	0.45	1.86	0.46*	0.27	0.78
Other Cargo Freight	Yes vs. No	0.77	0.57	1.05	0.74*	0.64	0.86
Paper Products	Yes vs. No	0.98	0.73	1.32	1.25*	1.09	1.42
Passengers	Yes vs. No	0.71	0.29	1.74	1.63*	1.34	1.98
Produce	Yes vs. No	1.18	0.90	1.56	1.38*	1.21	1.58

** Indicates statistically significant result at alpha = 0.05*

Model Results: Injury Crashes

Table 4-17 and Table 4-18 present results of the logistic regression model analysis of vehicle-related factors for association with injury and less severe PDO crashes. Factors associated with lower odds of an injury crash include truck coupling, trailer hitch, or safety chain issues (OR = 0.26), tire defects (OR = 0.70), and other vehicle defects (OR = 0.41) compared to CMVs without these issues. These findings were closely mirrored for CMVs weighing at least 26,000 lb Crashes involving CMVs with a carrier type of “other” compared to intrastate and with mobile homes as a freight type showed lower odds of an injury outcome (OR = 0.80 and OR = 0.55, respectively). Operating an uninsured vehicle was associated with 1.55 to 2.79 times higher odds of an injury outcome for all CMVs and CMVs weighing at least 26,000 lb respectively. Out of state plates were associated with slightly higher odds of an injury crash compared to Idaho plates for vehicles weighing at least 26,000 lb (OR = 1.18). All other comparisons within the vehicle-related factors were either insignificant or limited by low observation counts.

Table 4-17. Vehicle-related Factors: Logistic Regression Model Results for Work Zone Factors in Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Carrier Type	Other vs. Intrastate	0.80*	0.72	0.90	0.80*	0.71	0.89
License Plate State	Out of State vs. Idaho	1.04	0.97	1.12	1.18*	1.09	1.27
Cargo Body	Auto Transporter vs. Van/Enclosed Box	1.22	0.78	1.91	2.07*	1.37	3.12
	Flatbed vs. Van/Enclosed Box	0.87	0.73	1.03	0.84*	0.71	1.00
Vehicle Insured	No vs. Yes	1.55*	1.12	2.14	2.79*	1.98	3.94
Contributing Factors	Brakes listed as a "Contributing Factor" vs. Not listed	1.32	0.92	1.88	1.61*	1.08	2.38
	Other Vehicle Defect listed as a "Contributing Factor" vs. Not listed	0.41*	0.28	0.59	0.37*	0.25	0.53
	Tire Defect listed as a "Contributing Factor" vs. Not listed	0.70*	0.49	1.00	0.56*	0.37	0.85
	Truck Coupling, Trailer Hitch, Safety Chains listed as a "Contributing Factor" vs. Not listed	0.26*	0.12	0.56	0.30*	0.14	0.67

** Indicates statistically significant result at alpha = 0.05*

Table 4-18. Freight Types: Logistic Regression Model Results for Freight Types in Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Commodities Dry Bulk	Yes vs. No	0.98	0.88	1.10	1.09*	1.02	1.15
General Freight	Yes vs. No	0.99	0.90	1.08	0.93*	0.88	0.99
Grain, Feed, Hay	Yes vs. No	1.11	1.00	1.24	1.16*	1.09	1.24
Livestock	Yes vs. No	1.15	0.94	1.42	1.30*	1.10	1.54
Logs, Poles, Beams, Lumber	Yes vs. No	1.03	0.93	1.16	1.08*	1.02	1.16
Mobile Homes	Yes vs. No	0.55*	0.31	0.99	0.15*	0.08	0.28
Metal: Sheets, Coils, Rolls	Yes vs. No	0.97	0.85	1.10	1.10*	1.03	1.18
Motor Vehicles	Yes vs. No	0.98	0.84	1.16	1.21*	1.12	1.30
Passengers	Yes vs. No	1.04	0.78	1.37	1.12*	1.01	1.25
Construction	Yes vs. No	0.93	0.82	1.05	0.83*	0.77	0.90

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Other Cargo Freight	Yes vs. No	1.03	0.93	1.15	1.07*	1.00	1.14
<i>* Indicates statistically significant result at alpha = 0.05</i>							

Driver-related Factors

Driver-related factors assessed for association with crash severity included driver sex, age, seat belt use, alcohol or drug involvement, state of driver's license, and driver behavior-related contributing circumstances. The analysis also included reasons for driver citations. Driver-related factors are presented in Table 4-19. Table 4-20 and Table 4-21 present driver citations by broad and specific categories.

Table 4-19. Driver-related factors: Frequency of Driver-related Factor Levels in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	#!/% Fatal	#!/% Injury	#!/% PDO
Sex	Male	13,417	345 (2.57%)	3,969 (29.58%)	9,103 (67.85%)
	Female	841	10 (1.19%)	281 (33.42%)	550 (65.40%)
	Unknown	206	1 (0.49%)	58 (28.15%)	147 (71.36%)
State of Driver's License	Idaho	9,044	213 (2.36%)	2702 (29.88%)	6129 (67.77%)
	Out of State	5,144	140 (2.72%)	1525 (29.65%)	3479 (67.63%)
	Unknown	276	3 (1.09%)	81 (29.35%)	192 (69.57%)
Alcohol or Drug Involvement	Alcohol	47	6 (12.77%)	15 (31.92%)	26 (55.32%)
	Drug	28	12 (42.86%)	14 (50%)	2 (7.14%)
	Both	4	2 (50.00%)	1 (25.00%)	1 (25.00%)
	Neither	14,306	329 (2.30%)	4250 (29.71%)	9,727 (67.99%)
Seat Belt Use	Yes, lap, shoulder, or both	12,375	261 (2.11%)	3649 (29.48%)	8,465 (68.40%)
	None	680	61 (8.97%)	295 (43.39%)	324 (47.65%)
	Other protection device	6	0 (0%)	0 (0%)	6 (100%)
	Unknown	1,403	34 (2.42%)	364 (25.95%)	1,005 (71.63%)
Contributing Circumstances	Alcohol Impaired	48	5 (10.42%)	16 (33.34%)	27 (56.25%)
	Asleep, Drowsy, Fatigued	243	3 (1.23%)	100 (41.15%)	140 (57.61%)
	Distracted IN or ON Vehicle or Inattention	1,486	23 (1.55%)	556 (37.41%)	907 (61.04%)
	Drove Left of Center	198	13 (6.57%)	69 (34.85%)	116 (58.59%)
	Exceeded Posted Speed	34	3 (8.82%)	13 (38.23%)	18 (52.94%)

Factor	Level	N total	#!/% Fatal	#!/% Injury	#!/% PDO
	Failed to Maintain Lane	1,422	34 (2.39%)	428 (30.09%)	960 (67.51%)
	Failed to Obey Signal	89	3 (3.37%)	39 (43.82%)	47 (52.81%)
	Failed to Obey Stop Sign	127	6 (4.72%)	63 (49.61%)	58 (45.67%)
	Failed to Signal	29	0 (0%)	5 (17.24%)	24 (82.76%)
	Failed to Yield	673	9 (1.34%)	243 (36.10%)	421 (62.56%)
	Following Too Close	852	6 (0.7%)	372 (43.66%)	474 (55.63%)
	Foot Slipped Off or Caught On Pedal	36	0 (0%)	8 (22.22%)	28 (77.78%)
	Improper Backing	353	0 (0%)	33 (9.35%)	320 (90.65%)
	Improper Lane Change	515	0 (0%)	127 (24.66%)	388 (75.34%)
	Improper Overtaking	100	1 (1.00%)	30 (30.00%)	69 (69.00%)
	Improper Turn	684	1 (0.15%)	92 (13.45%)	591 (86.4%)
	Improper Use of Turn Lane	36	0 (0%)	5 (13.89%)	31 (86.11%)
	Improperly Parked	43	1 (2.33%)	13 (30.24%)	29 (67.44%)
	Overcorrected	210	4 (1.90%)	98 (46.67%)	108 (51.43%)
	Physical Impairment or Sick	54	1 (1.85%)	38 (70.37%)	15 (27.78%)
	Previous Accident	92	8 (8.70%)	31 (33.70%)	53 (57.61%)
	Too Slow for Traffic	26	1 (3.85%)	11 (42.30%)	14 (53.85%)
	Vision Obstruction	231	13 (5.63%)	81 (35.06%)	137 (59.31%)
	Wrong Side or Wrong Way	20	2 (10.00%)	7 (35.00%)	11 (55.00%)
Age	Under 21	300	8 (2.67%)	99 (33%)	193 (64.33%)
	21–24	808	27 (3.34%)	246 (30.44%)	535 (66.21%)
	25–34	2,703	58 (2.15%)	805 (29.79%)	1,840 (68.07%)
	35–54	6,060	145 (2.39%)	1,787 (29.49%)	4,128 (68.12%)
	55–64	3,066	84 (2.74%)	913 (29.78%)	2,069 (67.48%)
	65–74	1,064	26 (2.44%)	332 (31.21%)	706 (66.35%)
	74+	463	8 (1.73%)	126 (27.21%)	329 (71.06%)

Table 4-20. Driver Citations (Broad Categories): Frequency of Driver Citations in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	#!/% Fatal	#!/% Injury	#!/% PDO
Driver Citations (Broad)	Accident	105	0 (0%)	12 (11.43%)	93 (88.57%)
	Brakes	17	0 (0%)	8 (47.05%)	9 (52.94%)
	License	139	1 (0.72%)	56 (40.28%)	82 (58.99%)
	Driving	2,385	2 (0.08%)	956 (40.08%)	1,427 (59.83%)
	DUI	25	4 (16.00%)	10 (40.00%)	11 (44.00%)

Factor	Level	N total	#/% Fatal	#/% Injury	#/% PDO
	Equipment	48	0 (0%)	18 (37.50%)	30 (62.50%)
	Logbook	4	0 (0%)	0 (0%)	4 (100%)
	Insurance	109	0 (0%)	47 (43.12%)	62 (56.88%)
	License Plate	2	0 (0%)	1 (50.00%)	1 (50%)
	Lights	3	0 (0%)	0 (0%)	3 (100%)
	Liquor	3	0 (0%)	2 (66.66%)	1 (33.33%)
	Litter	36	0 (0%)	7 (19.45%)	29 (80.56%)
	Loads	3	0 (0%)	1 (33.33%)	2 (66.67%)
	Mudflaps	2	0 (0%)	0 (0%)	2 (100%)
	Non-English Speaking	1	0 (0%)	1 (100%)	0 (0%)
	One-Way	3	0 (0%)	3 (99.99%)	0 (0%)
	Parked	5	0 (0%)	0 (0%)	5 (100%)
	Passing	18	0 (0%)	4 (22.23%)	14 (77.78%)
	Permits	13	0 (0%)	2 (15.38%)	11 (84.62%)
	Railroad Crossing	11	0 (0%)	5 (45.45%)	6 (54.55%)
	Register	33	1 (3.03%)	15 (45.45%)	17 (51.52%)
	Safety Restraint/Seat Belt	23	1 (4.35%)	17 (73.92%)	5 (21.74%)
	Safety Seat	1	0 (0%)	1 (100%)	0 (0%)
	Speed	314	2 (0.64%)	113 (35.98%)	199 (63.38%)
	Tires	5	0 (0%)	0 (0%)	5 (100%)
	Turning	309	0 (0%)	52 (16.82%)	257 (83.17%)
	Windshield	1	0 (0%)	0 (0%)	1 (100%)
	Yield	260	1 (0.38%)	93 (35.76%)	166 (63.85%)

Table 4-21. Driver Citations (Specific Categories): Frequency of Specific Driver Citations in Fatal, Injury, and PDO CMV-related Crashes

Factor	Level	N total	#/% Fatal	#/% Injury	#/% PDO
Driver Citations (Specific)	(Accident) Leaving scene - damage	62	0 (0%)	8 (12.91%)	54 (87.1%)
	(Accident) Striking fixtures adjacent to highway	28	0 (0%)	2 (7.14%)	26 (92.86%)
	(Driver's license) Driving without privileges	50	1 (2.00%)	22 (44.00%)	27 (54.00%)
	(Driver's license) Failure to have current and valid	73	0 (0%)	29 (39.73%)	44 (60.27%)
	(Driving) Following too close	602	0 (0%)	273 (45.35%)	329 (54.65%)
	(Driving) Improper, unsafe backing	169	0 (0%)	18 (10.65%)	151 (89.35%)
	(Driving) Inattentive or careless	571	1 (0.18%)	275 (48.16%)	295 (51.66%)
	(Driving) Left of center on curve or hillcrest	22	0 (0%)	12 (54.54%)	10 (45.45%)
	(Driving) Observe & obey traffic control light	71	1 (1.41%)	28 (39.43%)	42 (59.15%)

Factor	Level	N total	#/% Fatal	#/% Injury	#/% PDO
	(Driving) Reckless	55	0 (0%)	29 (52.73%)	26 (47.27%)
	(Driving) Start- pull out safely	37	0 (0%)	10 (27.02%)	27 (72.97%)
	(Driving) Stop for stop sign	245	0 (0%)	103 (42.03%)	142 (57.96%)
	(Insurance) Display to police officer	97	0 (0%)	42 (43.29%)	55 (56.70%)
	(Litter) Placing glass, etc. - prohibited	29	0 (0%)	6 (20.69%)	23 (79.31%)
	(Speed) Reasonable and prudent – conditions/hazard	306	2 (0.65%)	110 (35.94%)	194 (63.40%)
	(Turning) Improper left turn	82	0 (0%)	13 (15.86%)	69 (84.15%)
	(Turning) Improper right turn	84	0 (0%)	13 (15.47%)	71 (84.52%)
	(Turning) Signal and with reasonable safety	126	0 (0%)	23 (18.26%)	103 (81.75%)
	(Yield) From alley, driveway, other	89	1 (1.12%)	26 (29.21%)	62 (69.66%)
	(Yield) From yield sign	21	0 (0%)	6 (28.57%)	15 (71.43%)
	(Yield) Intersections	36	0 (0%)	13 (36.12%)	23 (63.89%)

Model Results: Fatal Crashes

Results of the logistic regression model analysis of driver related factors for association with fatal and less severe, non-fatal crashes (injury and PDO) are presented in Table 4-22. Odds of a fatal outcomes increased for drivers who showed alcohol (OR = 6.17) or drug (OR = 32.74) involvement or the use of both alcohol and drugs (OR = 41.39) compared to drivers who did not use alcohol or drugs. Driving behaviors and maneuvers associated with increased odds of a fatal outcome included driving left of center (OR = 2.85), exceeding the posted speed limit (OR = 3.80), driving the wrong way or on the wrong side (OR = 4.38). “Previous accidents” as a contributing circumstance were also associated with increased odds of a fatal crash (OR = 3.79). A few factors were associated with reduced odds of a fatal outcome: female driver compared to male driver (OR = 0.46) and wearing a seat belt (OR = 0.22). Driver maneuvers found to be associated with reduced odds of a fatal outcome included following too closely (OR = 0.27) and making an improper turn (OR = 0.06). In crashes involving CMVs weighing at 26k+ lb, increased odds of a fatal outcome were observed for alcohol and drug use (OR = 6.57 for alcohol, 45.37 for drugs, and 36.58 for use of both), driving left of center (OR = 2.51), in situations where a previous crash was present (OR = 7.87), where the driver’s vision was obstructed (OR = 4.54), and when the driver was on the wrong side or going the wrong way (OR = 3.68). Driver-related factor comparisons not shown within the table were either insignificant or limited by low observation counts.

Table 4-22. Driver-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Sex	Female vs Male	0.46*	0.25	0.87	0.60	0.31	1.17
Alcohol or Drug Involvement	Alcohol vs. Neither	6.17*	2.15	17.72	6.57*	2.04	21.21
	Drug vs. Neither	32.74*	12.97	82.66	36.58*	3.32	402.8
	Both vs. Neither	41.39*	3.75	457.22	45.37*	15.3	134.5
Seat Belt Use	Yes, Lap, Shoulder, or Both vs. None	0.22*	0.15	0.30	0.24*	0.16	0.34
Contributing Circumstances	Alcohol Impaired	7.14*	2.79	18.33	5.79*	2.64	12.69
	Distracted IN or ON Vehicle or Inattention	0.74	0.23	2.34	0.53*	0.36	0.78
	Drove Left of Center	2.85*	1.61	5.06	2.51*	1.55	4.06
	Exceeded Posted Speed	3.80*	1.16	12.51	2.38	0.72	7.91
	Failed to Maintain Lane	0.95	0.67	1.36	0.68*	0.48	0.95
	Failed to Yield	0.53	0.27	1.03	0.51*	0.29	0.91
	Following Too Close	0.27*	0.12	0.60	1.28	0.92	1.79
	Improper Turn	0.06*	0.01	0.40	0.04*	0.01	0.29
	Previous Accident	3.79*	1.82	7.89	7.87*	5.41	11.44
	Vision Obstruction	2.40*	1.36	4.24	4.54*	3.18	6.48
	Wrong Side or Wrong Way	4.38*	1.01	18.97	3.68*	1.07	12.66

* Indicates statistically significant result at alpha = 0.05

Results of the logistic regression model analysis of driver citations for association with fatal and less severe, non-fatal crashes (injury and PDO) are presented in Table 4-23 and Table 4-24. Crashes where the driver received a DUI-related citation showed increased risk of a fatal crash (OR = 6.45). Broad citation categories related to driving behaviors, speeding, and yielding were associated with lower odds of a fatal outcome (OR = 0.03, 0.21, and 0.14, respectively). Citations for inattentive or careless driving and for issues related to reasonable and prudent speed due to conditions or a hazard were also associated with a lower odds of a fatal outcome

(OR = 0.06 and 0.21, respectively). CMVs weighing at least 26,000 lb showed nearly identical results.

Table 4-23. Driver Citations (Broad Categories): Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Broad)	Driving vs. Not Cited	0.03*	0.01	0.11	0.02*	0.00	0.11
	DUI vs. Not Cited	6.45*	2.20	18.94	8.21*	2.68	25.14
	Speed vs. Not Cited	0.21*	0.05	0.84	0.22*	0.05	0.88
	Yield vs. Not Cited	0.13*	0.02	0.92	0.16	0.02	1.17
* Indicates statistically significant result at alpha = 0.05							

Table 4-24. Driver Citations (Specific Categories): Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Level	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Specific)	(Driving) Inattentive or Careless vs. Not Cited	0.06*	0.01	0.42	-	-	-
	(Speed) Reasonable and Prudent – Conditions/Hazard vs. Not Cited	0.21*	0.05	0.86	0.22*	0.05	0.90
* Indicates statistically significant result at alpha = 0.05							

Model Results: Injury Crashes

Results of the logistic regression model analysis of driver-related factors for association with injury and less severe PDO crashes are presented in Table 4-25. Driver state was associated with significant differences in injury crash likelihood. Injury crash likelihood increased for drivers with drug use noted compared to no alcohol or drug use (OR = 15.11 for all CMVs; OR = 16.47 for CMVs at least 26,000 lb), those who were asleep, drowsy or fatigued (OR = 1.66 for all CMVs; OR = 1.46 for CMVs at least 26,000 lb), when distracted or inattentive (OR = 1.43 and OR = 1.37 for all CMVs and those weighing at 26k+ lb, respectively), and when the driver was physically impaired or sick (OR = 6.04 and OR = 5.10 for all CMVs and those weighing 26k+ lb, respectively). Driving behaviors and maneuvers associated with increased injury outcome included driving left of center (OR = 1.36), failing to obey signal (OR = 1.92) or stop sign (OR = 2.43), failing to yield (OR = 1.32), following too closely (OR = 1.87), and overcorrecting (OR = 2.12). Similar results were found for CMVs weighing 26k+ lb. Obstructed vision was also associated with increased injury outcome (OR = 1.37 for all CMVs, OR = 1.68 for CMVs 26k+ lb).

Drivers who wore a seat belt lowered their risk of an injury outcome by at least half (OR = 0.48 for all CMVs; OR = 0.44 for CMVs 26k+ lb). Several driving maneuvers were associated with lower severity crash outcomes (improper backing, improper turn, improper use of turn lane, improper lane change).

Table 4-25. Driver-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Sex	Female vs Male	1.15	0.99	1.34	1.23*	1.01	1.48
Alcohol or Drug Involvement	Drug vs. Neither	15.11*	2.46	92.67	16.47*	1.29	209.80
Seat Belt Use	Yes, Lap, Shoulder, Or Both vs. None	0.48*	0.40	0.58	0.44*	0.35	0.55
Contributing Circumstances	Asleep, Drowsy, Fatigued	1.66*	1.28	2.15	1.46*	1.09	1.95
	Distracted IN or ON Vehicle or Inattention	1.43*	1.28	1.60	1.37*	1.22	1.54
	Drove Left of Center	1.36*	1.00	1.83	1.34*	1.00	1.79
	Failed to Obey Signal	1.92*	1.26	2.95	1.84*	1.11	3.04
	Failed to Obey Stop Sign	2.43*	1.69	3.48	1.98*	1.30	3.02
	Failed to Yield	1.32*	1.12	1.55	1.17	0.97	1.40
	Following Too Close	1.87*	1.62	2.15	1.82*	1.57	2.11
	Improper Backing	0.22*	0.15	0.32	0.18*	0.12	0.30
	Improper Lane Change	0.76*	0.62	0.93	0.72	0.59	0.89
	Improper Turn	0.33*	0.27	0.42	0.33*	0.26	0.42
	Improper Use of Turn Lane	0.35*	0.14	0.91	0.35*	0.15	0.84
	Overcorrected	2.12*	1.61	2.79	1.83*	1.34	2.49
	Physical Impairment or Sick	6.04*	3.13	11.01	5.10*	2.59	10.03
	Previous Accident	1.36	0.87	2.12	1.53*	1.06	2.22
	Vision Obstruction	1.37*	1.04	1.81	1.68*	1.28	2.20

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Wrong Side or Wrong Way	1.43	0.55	3.69	2.74*	1.09	6.85
* Indicates statistically significant result at alpha = 0.05							

Results of the logistic regression model analysis of driver citations for association with injury and PDO crashes are presented in Table 4-26 and Table 4-27. Crashes where the driver received a DUI-related citation showed increased risk of a fatal crash (OR = 6.45). Broad citation categories related to driving behaviors, speeding, and yielding were associated with higher risks of an injury or PDO crash (OR = 0.03, 0.21, and 0.14, respectively). Crashes with citations for driving recklessly or left of center on curve or hillcrest had the highest OR for increased risk of an injury outcome (OR = 2.83 for each citation). Other specific citations associated with increasing the odds of an injury outcome by two or more included driving without privileges (OR = 2.03), following too closely (OR = 2.05), and being inattentive or careless (OR = 2.27). These results were largely mirrored for CMVs weighing 26k+ lb.

Table 4-26. Driver Citations (Broad Categories): Logistic Regression Model Results for Injury And PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Broad)	Accident vs. Not Cited	0.32*	0.18	0.59	0.31*	0.16	0.60
	License vs. Not Cited	1.71*	1.22	2.42	1.71*	1.12	2.61
	Driving vs. Not Cited	1.65*	1.50	1.81	1.62*	1.46	1.80
	Insurance vs. Not Cited	1.79*	1.22	2.62	1.74*	1.06	2.86
	Register vs. Not Cited	2.18*	1.09	4.39	2.98*	1.23	7.21
	Safety Restraint/Seat Belt vs. Not Cited	8.35*	3.07	22.67	7.98*	2.19	29.08
	Speed vs. Not Cited	1.44*	1.14	1.82	1.38*	1.07	1.79
	Turning vs. Not Cited	0.50*	0.37	0.67	0.53*	0.38	0.73
	Yield vs. Not Cited	1.37*	1.06	1.77	1.48*	1.08	2.01
* Indicates statistically significant result at alpha = 0.05							

Table 4-27. Driver Citations (Specific Categories): Logistic Regression Model Results for Injury and PDO CMV-related Crashes

Factor	Level	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Specific)	(Accident) Leaving Scene – Damage vs. Not Cited	0.37*	0.18	0.79	0.38*	0.17	0.84
	(Accident) Striking Fixtures Adjacent to Highway vs. Not Cited	0.19*	0.04	0.78	0.22*	0.05	0.95
	(Driver’s License) Driving without Privileges vs. Not Cited	2.03*	1.15	3.57	1.58	0.78	3.18
	(Driver’s License) Failure to have Current and Valid vs. Not Cited	1.65*	1.03	2.64	1.90*	1.07	3.38
	(Driving) Following Too Close vs. Not Cited	2.05*	1.74	2.42	2.15*	1.76	2.64
	(Driving) Improper, Unsafe Backing vs. Not Cited	0.29*	0.18	0.47	0.26*	0.13	0.52
	(Driving) Inattentive or Careless vs. Not Cited	2.27*	1.91	2.69*	2.21*	1.82	2.67
	(Driving) Left of Center on Curve or Hillcrest vs. Not Cited	2.83*	1.22	6.58	3.95*	1.43	10.91
	(Driving) Observe & Obey Traffic Control Light vs. Not Cited	1.66*	1.03	2.69	1.22	0.67	2.23
	(Driving) Reckless vs. Not Cited	2.83*	1.66	4.81	3.70*	1.96	6.98
	(Driving) Stop for Stop Sign vs. Not Cited	1.79*	1.38	2.31	1.51*	1.09	2.08
	(Insurance) Display to Police Officer vs. Not Cited	1.78*	1.19	2.67	1.71*	1.00	2.92
	(Speed) Reasonable and Prudent – Conditions/Hazard vs. Not Cited	1.44*	1.13	1.82	1.39*	1.07	1.80
	(Turning) Improper Left Turn vs. Not Cited	0.46*	0.25	0.83	0.41*	0.21	0.80
	(Turning) Improper Right Turn vs. Not Cited	0.46*	0.25	0.83	0.49*	0.25	0.93
	(Turning) Signal and with Reasonable Safety vs. Not Cited	0.54*	0.34	0.85	0.60*	0.36	0.99
* Indicates statistically significant result at alpha = 0.05							

Other Contributing Factors

The data included coded indicators of several other key crash factors that may have contributed to the crash occurrence. The factors include notes of whether the crash was related to a wild animal, youth driver, stop controlled intersection, bicycle, pedalcycle, pedestrian, motorcycle, intersection, fixed object, distracted driver, alcohol, or impairment. These variables were recorded in the Idaho Crash Database data. Table 4-28 presents frequency counts and percentage of observations by crash severity for each of these other contributing factors.

Table 4-28. Other Contributing Factors: Frequency of Factor Levels in Fatal, Injury, and PDO CMV-Related Crashes

Factor	N total	#!/% Fatal	#!/% Injury	#!/% PDO
Wild animal-related	305	0 (0%)	13 (4.26%)	292 (95.74%)
Youth driver-related	1,212	29 (2.39%)	409 (33.75%)	774 (63.86%)
Stop-controlled intersection-related	2,165	51 (2.36%)	677 (31.27%)	1,437 (66.37%)
Bicycle-related	18	3 (16.67%)	15 (83.33%)	0 (0%)
Pedalcycle-related	18	3 (16.67%)	15 (83.33%)	0 (0%)
Pedestrian-related	48	16 (33.33%)	32 (66.67%)	0 (0%)
Motorcycle-related	70	10 (14.29%)	51 (72.86%)	9 (12.86%)
Intersection-related	4,453	77 (1.73%)	1,282 (28.79%)	3,094 (69.48%)
Fixed object-related	2,782	99 (3.56%)	921 (33.11%)	1762 (63.34%)
Distracted driver-related	2,605	64 (2.46%)	1026 (39.38%)	1515 (58.16%)
Alcohol-related	258	29 (11.24%)	124 (48.07%)	105 (40.70%)
Impairment-related	374	74 (19.79%)	177 (47.32%)	123 (32.89%)

Model Results: Fatal Crashes

Model results investigating other contributing factors in fatal and less severe injury and PDO crashes are shown in Table 4-29. The odds of a fatal crash increased for crashes related to a bicycle (OR = 8.81), a pedalcycle (OR = 8.81), a pedestrian (OR = 13.04), a motorcycle (OR = 7.48), a fixed object (OR = 1.89), alcohol (OR = 5.97), and impairment (OR = 13.79). Intersection-related crashes showed a decrease in odds of a fatal crash (OR = 0.69). Crashes related to a youth driver, a stop-controlled intersection, or distraction did not show any change in odds of fatal outcomes. For CMVs weighing 26k+ lb, the odds of a fatal crash outcome increased significantly when the crash involved a pedestrian (OR = 30.33), impairment (OR = 14.15), a motorcycle (OR = 8.58), alcohol (OR = 6.57), a fixed object (OR = 1.92), or a youth driver in any vehicle (OR = 1.73). Intersection-related crashes were associated with a lower odds of a fatal crash outcome for CMVs weighing 26k+ lb.

Table 4-29. Other Contributing Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Bicycle-related	Yes vs. No	8.81*	2.54	30.59	-	-	-
Youth driver-related	Yes vs. No	1.73	1.22	2.45	1.73*	1.22	2.45
Unbelted person-related	Yes vs. No	8.61*	6.66	11.11	8.66*	6.64	11.30
Pedalcycle-related	Yes vs. No	8.81*	2.54	30.59	5.71	0.69	47.59

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Pedestrian-related	Yes vs. No	13.04*	6.41	26.55	30.33*	13.47	68.29
Motorcycle-related	Yes vs. No	7.48*	3.79	14.75	8.58*	4.10	17.93
Intersection-related	Yes vs. No	0.69*	0.53	0.89	0.66*	0.50	0.86
Fixed object-related	Yes vs. No	1.89*	1.48	2.41	1.92*	1.51	2.45
Alcohol-related	Yes vs. No	5.97*	3.98	8.94	6.57*	4.38	9.86
Impairment-related	Yes vs. No	13.79*	10.37	18.35	14.15*	10.55	18.98

** Indicates statistically significant result at alpha = 0.05*

Model Results: Injury Crashes

Model results investigating other contributing factors in injury and PDO crashes are shown in Table 4-30. Several factors were associated with an increased risk of injury outcomes: youth driver (OR = 1.24), pedestrian (OR = 23.14), motorcycle (OR = 13.04), fixed object (OR = 1.27), distracted driver (OR = 1.72), alcohol (OR = 2.81), and impairment (OR = 3.45). The likelihood of an injury crash was lower in crashes related to a wild animal (OR = 0.10) or an intersection (OR = 0.92). For CMVs weighing 26k+ lb, the odds of an injury crash outcome increased significantly when the crash involved a motorcycle (OR = 9.68), an unbelted person in any vehicle (OR = 3.99), impairment (OR = 3.56), alcohol (OR = 2.80), distraction (OR = 1.82), a youth driver in any vehicle (OR = 1.39), or a fixed object (OR = 1.36). Wild animal-related crashes (OR = 0.11) and intersection-related crashes (OR = 0.84) were associated with a lower odds of an injury crash outcome for CMVs weighing 26k+ lb. There were no PDO bicycle-related crashes.

Table 4-30. Other Contributing Factors: Logistic Regression Model Results for Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Wild animal-related	Yes vs. No	0.10*	0.06	0.17	0.11*	0.06	0.20
Youth driver-related	Yes vs. No	1.24*	1.09	1.40	1.39*	1.20	1.62
Unbelted person-related	Yes vs. No	3.40*	2.89	4.00	3.99*	3.28	4.86
Pedestrian-related	Yes vs. No	23.14*	12.55	42.69	-	-	-
Motorcycle-related	Yes vs. No	13.04*	6.41	26.55	9.68*	4.24	22.12
Intersection-related	Yes vs. No	0.92*	0.85	0.99	0.84*	0.77	0.92
Fixed object-related	Yes vs. No	1.27*	1.16	1.39	1.36*	1.23	1.50

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Distracted driver-related	Yes vs. No	1.72*	1.58	1.89	1.82*	1.65	2.01
Alcohol-related	Yes vs. No	2.81*	2.16	3.66	2.80*	2.07	3.80
Impairment-related	Yes vs. No	3.45*	2.73	4.35	3.56*	2.72	4.67

** Indicates statistically significant result at alpha = 0.05*

Mobilizations

Table 4-31 presents the total number of crashes during the distraction mobilization periods and outside of the distraction mobilization periods. The table also presents the proportion of crashes with distraction, within and outside of the mobilization periods, based on inattentive-related citation data and distraction and inattention contributing circumstance data. Data from the years 2015 and 2016 is excluded from the table as these years did not feature a distraction-related mobilization effort. Year 2020 is excluded from the table due to impacts of COVID-19 on mobilizations. Overall, 398 crashes occurred during distraction mobilization periods—2.76% of these crashes resulted in an inattentive citation and 10.18% had distraction listed as contributing circumstance. Outside of the distraction mobilization periods, 3.48% of a total of 10,104 crashes resulted in an inattentive citation and 8.42% of these crashes had distraction listed as a contributing circumstance.

Table 4-31. Counts of All Crashes and Proportion with Inattentive Citations During Distraction-related Mobilization Periods and Outside of these Mobilization Periods

Year	Number of Crashes during Distraction Mobilization Period	Proportion of Crashes with Inattentive Citations during Mobilization Period	Number of Crashes Outside of Distraction Mobilization Period	Proportion of Crashes with Inattentive Citations Outside of Mobilization Period
2016	29	0.00%	1,440	4.17%
2017	129	2.33%	1,336	4.19%
2018	77	5.19%	1,395	3.01%
2019	29	3.45%	1,450	4.14%
2021	44	4.55%	1,410	3.83%
2022	34	2.94%	1,545	2.98%
2023	56	0.00%	1,528	2.23%
All	398	2.76%	10,104	3.48%

Table 4-32. Counts of and Proportion with Distraction or Inattention Contributing Circumstances During Distraction-Related Mobilization Periods and Outside of These Mobilization Periods

Year	Number of Crashes During Distraction Mobilization Period	Proportion of Crashes with Distraction Circumstances during Mobilization Period	Number of Crashes Outside of Distraction Mobilization Period	Proportion of Crashes with Distraction Circumstances Outside of Mobilization Period
2016	29	3.23%	1,440	10.39%
2017	129	9.30%	1,336	9.73%
2018	77	6.25%	1,395	10.32%
2019	29	10.00%	1,450	9.99%
2021	44	8.82%	1,410	13.64%
2022	34	9.28%	1,545	8.82%
2023	56	9.29%	1,528	7.14%
All	398	10.18%	10,104	8.42%

Although Chi-Square tests comparing the distribution of distraction-related crashes by time period showed no statistically significant difference (for citation-based distraction definition: $df = 1, \chi^2 = 0.5948, p\text{-value} = 0.4406$; for contributing circumstance data: $df = 1, \chi^2 = 0.7396, p\text{-value} = 0.3898$), distraction or inattention contributing circumstances were noted at a slightly higher rate during mobilization periods. Additional research is needed to fully assess the impacts of mobilizations on CMV driving behavior. Analysis of time periods following the mobilization effort are needed to understand the change in behavior a mobilization effort can have on drivers. Future work should investigate non-crash-related violations for differences in behavior within and following a mobilization period. Future analyses of crash behavior could also control for time of year of the mobilization, for specific mobilization efforts are typically done at regular times across multiple years. Further, analyses may investigate CMV-specific saturation activities by using within- and between-district comparisons to determine how driver behavior changes during saturation periods and to determine if districts with saturations show differences in driver behavior compared to districts without saturations during the same time period (to control for extraneous variables related to the time of the saturation).

5. Geodatabase

VTTI developed this tool in partnership with the Idaho Transportation Department (ITD) as part of a study of CMV crash causation for Idaho crashes. The objective of this tool was to create a unified location for the ITD team to analyze CMV crashes in Idaho by using an interactive tool that visualizes the crash trend data. The geodatabase developed for this project serves as an interactive crash visualization and analysis tool. The tool integrates state and federal data sources to provide a reference dataset of reportable CMV crashes that occurred in Idaho between 2014 and 2023.

Crash data was obtained from two primary sources: ITD crash database and the FMCSA MCMIS. The Idaho database and MCMIS datasets were linked using unique identifiers associated with individual crashes and motor carriers to ensure that each record corresponds to the correct crash event and vehicle. Reportable crashes are defined by ITD as incidents that occurred on a public street, were not the result of an intentional act, and involved damage exceeding \$1,500 to any one property. Only crashes reported to the Idaho Crash Database and met reportable crash criteria are included in the geodatabase.

The resulting geodatabase includes coordinates for each crash along with crash attributes, including roadway, environmental, vehicle, and driver-related factors. Each record corresponds to a CMV-involved crash meeting the reportable criteria. Within the geodatabase, a user can filter the data using a multi-level filtering tool and visualize the filtered data onto the state map (Figure 5-1). This enables users to investigate spatial and temporal crash distributions, contributing conditions, and relationships among variables. The geodatabase also includes a bivariate analysis tool that visualizes data in bar plots and summary tables so users may observe interactions between variables.

The data contained in the geodatabase does not represent exposure measures such as the total number of CMVs traveling, CMV vehicle miles traveled, or frequency of conditions during all driving time. Instead, the data illustrates occurrence but not risk. All interpretations of tool outputs should be made with this limitation in mind.

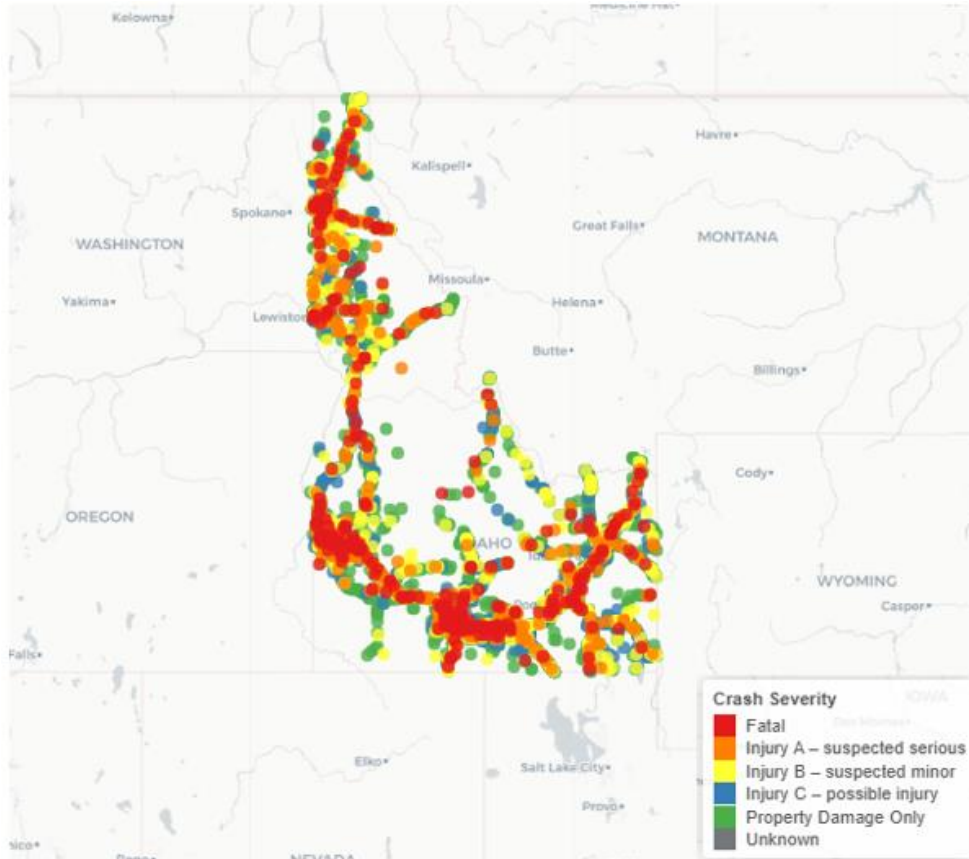


Figure 5-1. The Idaho geodatabase interactive tool

6. Potential Mitigation Strategies

According to the crash data analysis conducted using data from ITD, several areas of improvement have been identified related to CMV crashes in Idaho. The following section summarizes the significant results and presents potential mitigation strategies for Idaho to consider, organized by key contributing factors. The key contributing factors discussed in this section are vehicle-related factors, driver-related factors, work zone characteristics, environmental conditions, temporal factors, and data quality considerations. Each factor includes an overview summarizing relevant findings, an explanation of problem mechanics describing underlying causes, and a set of mitigation strategies with corresponding performance metrics to support implementation and evaluation.

Vehicle-related Factors

Vehicle-related factors include variables such as carrier type (interstate vs. intrastate), state of license plate registration, cargo body type, number of trailers, vehicle-related contributing circumstances, and carrier freight type. Between 2014 and 2023, the majority of crashes in Idaho involved interstate carrier vehicles with Idaho plates, a van or box cargo body type, and general freight registration. Trucks hauling a single trailer were associated with lower crash severity than those pulling two trailers, while vehicles with brake defects showed a greater likelihood of severe crash outcomes. Although the frequency of brake-related crashes could not be determined, this pattern is consistent with national findings—FMCSA data (2023a) identifies brake and tire defects as the most common vehicle-related factors in fatal large-truck crashes. Such defects increase stopping distance, reduce maneuverability, and elevate loss-of-control risk, particularly on Idaho’s graded or curved roadways.

Similarly, log trucks and grain/feed/hay carriers exhibited a disproportionate, though not statistically significant, association with crash severity, likely due to their high centers of gravity, non-uniform mass distribution, and potential for load shift—conditions closely linked to rollover crashes, the most fatal crash type for truck drivers (McKnight & Bahouth, 2008; Moonesinghe et al., 2003; Calabrese et al., 2017). Overall, the vehicle-related factors most relevant to crash severity in Idaho were brake and tire defects, trailer configuration, and load type, aligning prior literature on mechanical and configuration influences on heavy-vehicle safety (The Multimodal Transportation and Infrastructure Consortium, 2009; Carson, 2007). The recommended mitigation strategies are listed by relevant crash factors in the following sections.

Mitigation Strategies for Brake and Tire Defects

Fleet Incentive and Recognition Programs

North Dakota's Motor Carriers Association (NDMCA) operates a fleet safety incentive program where participating carriers voluntarily submit annual safety records for committee review. A small committee reviews the applicants and awards the overall "safest" fleet. NDMCA recognizes fleets with a metal truck trophy donated by an insurance partner. However, when speaking with a representative of the organization, the committee chair lamented that they often have the same 15–20 applicants each year and are looking to change their application process to an online version to promote greater participation. The Idaho Trucking Association has a similar program through their Safety Awards initiative. However, these awards are given by nomination instead of application.

Although the NDMCA did not comment as to whether fleet safety scores improved over time due to the incentive program, Idaho may consider developing a similar recognition framework to encourage fleets to improve their safety record. Additionally, Idaho can incorporate lessons learned from NDMCA by expanding reach via an electronic submission form and considering modest financial or operational incentives (e.g., inspection bypass credits or insurance discounts). Idaho may also consider tracking measurable performance thresholds such as out-of-service (OOS) rate reductions or zero brake violations over a defined period.

Brake Safety Campaigns

The Commercial Vehicle Safety Association (CVSA) hosts annual Brake Safety Weeks that are announced and a one-day brake safety enforcement initiative, which may be held at any time. CVSA tracks the results of the campaign. Based on plotting the announced brake safety week and unannounced brake safety day, there seems to be a decrease over time in the percentage of vehicles with an OOS violation based on brake condition. It appears that Idaho does participate in these brake safety week initiatives.

Therefore, the continuation of these programs seems beneficial for ITD. However, ITD may want to consider tracking more detailed results of these initiatives to consider if their enforcement campaigns match the downward trend of CVSA's results. An additional benefit of this program is providing fleets with maintenance resources, technical guidance, and post-inspection feedback, even if they are not an OOS vehicle.

Automated Brake Condition Screening

The "Thermal Imaging Safety Screening System" fact sheet describes infrared brake screening as a "proven, cost-effective method for detecting CMVs with defective brakes (AASHTO, n.d.)."

Several locations, including Washington, Virginia, Minnesota, and Canada, have implemented infrared imaging and machine-vision systems that assess brake temperature symmetry as trucks pass roadside sensors (Emitted Energy, 2017; Virginia Department of Motor Vehicles, 2025; Minnesota Department of Transportation, 2024; ProScan Inspections, n.d.). Thermal anomalies flag potential brake malfunctions without requiring manual inspections.

Although some states use these imaging systems to flag specific vehicles, privacy laws in Idaho may prevent this particular application. Therefore, it may be beneficial for Idaho to consider this technology paired with a dynamic message sign that warns drivers of the issue as they near steep downhill grades. Benefits of this solution include minimizing the need for enforcement personnel and aligning with FMCSA's interest in roadside technologies (U.S. Department of Transportation, n.d.; FMCSA, n.d.)

Mitigation Strategies for Configuration/Load Type

Strategic Route Restrictions for Multi-trailer Combinations

Configuration-related instability, particularly with double and triple trailers—can be dampened through route designations and restrictions that ensure vehicle configuration aligns with roadway conditions and weather exposure. For example, Oregon limits long combination vehicles to designated corridors and issues route-specific advisories directing doubles away from steep or sharply curved routes (Oregon Secretary of State, 2025). Colorado uses a similar restriction by publishing GIS routes where doubles are restricted by both size and weight only to certain corridors (Colorado General Assembly, n.d.). Wyoming utilizes these restrictions for all light, high-profile vehicles during high winds or extremely poor weather periods only (Wyoming Department of Transportation, 2024).

Although the overall number of crashes involving double and triple trailers was low in Idaho, ITD may consider implementing route restrictions based on size and weight parameters during specific roadway and weather conditions to impact configuration-based crash severity.

Targeted Enforcement for Load Type

Crash patterns in Idaho showed a disproportional number of crashes for log trucks and grain/hay carriers, possibly due to load-shift potential, higher center of gravity, cargo securement, vehicle condition, or driver experience.

As targeted enforcement can focus on a number of things, Idaho may consider conducting targeted inspection focusing on load securement and brake condition for vehicles carrying these specific load types. This enforcement effort, even if just considered a pilot program, may give more specific insight to ITD as to why these load types are disproportionately involved in

crashes. Further intervention may include mandatory refresher training on the identified failure point or continued enforcement with these vehicles and fleets.

Driver-related Factors

Driver factors include variables such as driver demographics, driver's licensed state, seat belt use, alcohol and drug involvement, driver-related contributing circumstances, and driver citations. The majority of CMV drivers involved in crashes in Idaho between 2014–2023 were males between 35 and 54 years of age. Driver distraction or inattention were the most commonly noted contributing factors in the dataset, followed by failure to maintain lane position. This finding is consistent with national research identifying distraction or inattention (FMCSA, 2023a). Distraction impairs situational awareness and reaction time, which often results in degraded performance, such as lane deviations. Lane deviation can reflect fatigue, cognitive overload, or secondary task engagement.

Drug and alcohol use were very rarely (< 1%) involved in CMV crashes in Idaho but had a highly significant impact on fatal crash outcomes when they were present. Substances that substantially degraded decision-making and vehicle control such as drugs and alcohol are rarely shown in crash data; however, they are tied to increased crash severity (Ichikawa et al., 2023; Toma et al., 2014; Compton & Berning, 2015). Seatbelt use was high (> 80%) and was associated with significantly lower risks of a fatal or injury crash outcome. This is consistent with established evidence that restraint use significantly reduces driver ejection and impact injury risk. Higher occurrence of injury crashes occurred where drivers were cited for speed, failure to yield, following too closely, and not following road signage— all behaviors that reduce available reaction time and/or increase kinetic energy at impact. An interesting finding in the Idaho data was that the involvement of youth drivers in the CMV crash was a common contributing factor in higher severity crash outcomes. This finding is likely related to novice driving research linking teen and novice drivers to limited hazard recognition and overcorrection tendencies (Klauer et al. 2014). Additionally, this issue may be amplified by the state's rural and agricultural culture, where it is common for young people to operate farm vehicles or equipment at an early age. Early informal driving experience can improve vehicle handling familiarity but often occurs without structured training, formal hazard perception instruction, or supervised exposure to public-road conditions, potentially contributing to risk when these young drivers transition to higher-speed or mixed-traffic environments. All other comparisons within driver-related factors were either insignificant or limited by low observation counts.

Overall, the driver-related factors most relevant to crash severity in Idaho included distraction and inattention, lane deviation, excessive speed, and limited driver experience. The recommended mitigation strategies are listed by relevant crash factors below:

Mitigation Strategies for Distraction and Inattention

Supporting Driver Monitoring System Use

Camera-based driver monitoring systems (DMSs) track eye movement, head pose, and gaze duration, with some even issuing in-cab alerts when a driver's eyes are off the forward roadway for more than 2 seconds. FMCSA's Naturalistic Truck Driving Study found inattention from the forward roadway for greater than 2 seconds increased crash risk by up to 23 times (Klauer et al., 2014; Hickman et al., 2015). Another study found that fleets using DMSs with real-time coaching saw up to a 60% reduction in distraction-related critical events (Hickman et al., 2010).

Based on these results, ITD may consider methods for supporting the implementation of these devices in CMVs travelling through their state. ITD may incentivize DMS adoption among high-risk carriers through fleet-safety grants or insurance premium reductions.

Attention Maintenance Training

Many driver education programs fail to emphasize active scanning and attention maintenance skills. Evidence from Don Fisher's research at the University of Massachusetts Amherst (2024) shows that targeted hazard anticipation and attention maintenance training significantly reduces crash risk by improving gaze behavior and situational awareness.

Although this is a fairly broad mitigation strategy, Idaho may consider partnering with both CMV and novice driver education programs to deliver refresher courses including attention maintenance training. Don Fisher often offers free versions of the training program online to aid in the dissemination of this information. Considering the threat of distraction to all drivers, Idaho may consider implementing this strategy into driver licensing systems state-wide.

Roadway Design and Feedback

Roadway design can aid in momentary lapses in driver attention through haptic and visual feedback. Rumble strips offer both haptic and auditory warnings during lane departures, which aid in regaining a driver's attention. Work from the FHWA (2011) shows that rumble strips reduce single-vehicle run-off-road crashes by approximately 36%. Along the same lines, high contrast markings offer improved lane visibility for drivers to quickly correct poor driving.

For Idaho, implementation may include regular maintenance of already implemented rumble strips and lane lines or the addition of new rumble strips in areas identified as lane-departure prone crash locations. The rumble strips may be center-line rumble strips for two-lane roads or roadway edge/shoulder rumble strips for multi-lane locations.

Dynamic Message Signs

A pilot program in Tennessee uses infrared cameras and a dynamic message sign to identify distracted drivers. The cameras identify a driver using a cellphone and display a message on the sign stating various messages such as “Phone Down” or “Phone Detected – Fines Apply” to deter drivers in the moment (Bell, 2024).

Considering Idaho’s privacy laws, this may be a good option for anonymously providing feedback to drivers who are identified as using an electronic device while driving. Idaho may consider deploying deterrent messaging on high-crash corridors where handheld device use has been documented.

Mitigation Strategies for Excessive Speed

Variable Speed Limit Signs

Variable speed limit (VSL) signs adjust posted speeds dynamically based on grade, weather, and traffic flow, reducing speed variance based on conditions. Multiple states have adopted VSL systems and use them for speed control across various terrain types and road types (U.S. Department of Transportation, 2021).

Idaho’s implementation may include piloting VSL systems on corridors such as I-84 and US-95 where frequent downgrade or weather-related crashes occur. Integration with Idaho’s existing road weather information system could enable automated operation during snow, ice, or blowing dust conditions.

High-friction Surface Treatments

High-friction surface treatments (HFSTs) increase pavement grip on steep or curved segments, particularly under wet or icy conditions. FHWA field evaluations show HFSTs can reduce crashes by 50–60% on treated segments (FHWA, n.d.a). The treatments are shown to improve braking performance and reduce loss-of-control events in both dry and wet environments.

Prioritizing HFSTs on high-grade corridors, downhill ramps, and curves identified as high-severity areas may benefit ITD through the reduction of CMV loss-of-control crashes. Coordination with ITD’s pavement management system may ensure targeted application when maintenance is due.

Mitigation Strategies for Novice Drivers

Education About Sharing the Road with Large Trucks

Education programs that teach light-vehicle drivers how to interact safely with large trucks may improve crash risk in mixed-traffic environments. Programs such as Walmart's Sharing the Road with Trucks, the American Trucking Association's Share the Road campaign, and the VTTI's CMV Sharing the Road with Trucks Program teach drivers about trucks' blind spots, stopping distances, and turning radius. These complementary programs have shown measurable improvements in driver behavior and awareness (CMV Road Sharing, 2025).

For Idaho, implementation may include integrating CMV-awareness modules into driver's education curricula statewide. Classroom instruction can be bolstered by hands-on training offered by these programs.

Education About Youth CMV Operators

To address youth drivers in agriculture-heavy states, programs exist in Wisconsin, Oregon, Kansas, and Minnesota, where certified youth can operate farm equipment under defined conditions such as limited routes, daylight hours, and supervision (University of Wisconsin-Madison Division of Extension, 2025). These programs balance agricultural needs with roadway safety by introducing even a minimum level of training to otherwise naïve operators. Minnesota even offers a youth training certificate for drivers under age 16 to operate a vehicle (Minnesota Department of Public Safety, 2025).

Giving farm-operating families an option for youth to operate machinery on public roads to obtain certification through a short safety course focused on traffic interaction and visibility may be an option for ITD to address youth-related crashes. However, the safety impacts of these provisional certificates and licenses have yet to be determined.

Work Zone Characteristics

Work zone characteristics included variables such as whether a crash occurred at the location of a work zone, type of work zone, location of the crash relative to the work zone, whether the work zone had workers present or not, and whether there was a law enforcement officer present in the work zone. Overall, the number of work zone related crashes was low relative to other crash types. The majority of work zone crashes took place in a lane closure or shoulder/median work zone type and were concentrated in the transition or activity areas of the work zone layout. These locations are characterized by lane shifts, tapering, and speed adjustments that create temporary geometric and visual complexity. Crashes taking place

before the first warning sign in the advanced warning area were associated with higher likelihood of injuries compared to the activity area, likely reflecting insufficient driver awareness or inadequate reaction time to changing roadway conditions or potentially stopped vehicles. Conversely, crashes in the transition area were associated with lower likelihood of injuries compared to the activity areas possibly due to reduced speeds once drivers recognized the work zone environment. It may be expected that work zones with workers present would result in a higher number of fatal crashes due to the presence of vulnerable road users; however, unexpectedly, the *absence* of work zone workers within the work zone was associated with a higher likelihood of a fatal crash outcome. This pattern may indicate reduced driver caution when visible cues such as workers or moving equipment are absent, leading to higher approach speeds and delayed braking. All other comparisons within work zone characteristics were either insignificant or limited by low observation counts. Overall, the driver-related factors most relevant to crash severity in Idaho included injury crashes before the first sign in a work zone and inactive work zone fatalities. The recommended mitigation strategies for work zones are listed in the following sections.

Mitigation Strategies for Work Zone Crashes

Increase Distance of Work Zone Awareness

Early warning and enhanced visibility at the approach to a work zone allow drivers more time to perceive, decide, and react safely. Therefore, methods for extending the distance of the first warning sign and increasing the saliency of signs may reduce surprise at downstream effects of stopped traffic. The recommended distance of a first warning sign is variable based on the roadway design (Occupational Safety and Health Administration, 2002). Two methods for improving saliency of the first warning sign include transverse rumble strips, which are placed across traffic lanes to provide auditory and haptic signals to the driver of an upcoming work zone, and optical speed lines, which perceptually create the sensation of moving quickly, which can encourage drivers to slow down on their own volition.

Although Idaho experienced a low number of work-zone related crashes overall between the years 2014 and 2023, there are still checks ITD can do to ensure these numbers remain low. Idaho may choose to utilize transverse rumble strips or optical speed lines to increase driver awareness of an upcoming work zone. Additionally, ITD may verify that construction zones are following the recommended taper lengths, signage, and barriers on high-traffic sites. Driver messaging may also play a crucial role considering the most severe crashes occurred in inactive work zones. Public outreach explaining why speed reductions remain necessary—due to narrowed lanes, barriers, uneven pavement, or residual debris—may improve understanding of reducing speed even in an inactive work zone. Overall, Idaho can enhance work zone safety

through combination of early-warning improvements and communication about the ongoing hazards present in inactive work zones.

Environmental Conditions

Environmental conditions included variables like weather, roadway characteristics, and lighting conditions. In terms of the impact of weather in Idaho, the majority of crashes occurred over winter periods, yet crashes on roads with winter conditions (ice, snow, slush) showed significantly lower odds of a fatal outcome compared to crashes on roads with dry conditions (OR = 0.50). This pattern is consistent with behavioral adaptation—drivers typically reduce speed and increase following distance in visible adverse weather, mitigating crash severity even as crash frequency rises. Roads with loose gravel or seal coat saw significantly higher odds of a fatal crash compared to roads with no other reported characteristics (OR = 3.88), likely due to reduced traction and longer braking distances. Generally, adverse conditions were shown to only slightly increase the likelihood of an injury outcome compared to non-adverse conditions. However, compared to clear conditions, blowing dust or sand increased the likelihood of an injury crash by five times. This is likely due to sudden and severe visibility loss that limits reaction time and lane maintenance capability. These conditions may be exacerbated by Idaho's agricultural landscape, where harvest operations and field tilling generate localized dust events, particularly in late summer and fall. Such activity increases airborne particulate matter along rural routes and may heighten crash risk during peak harvesting periods.

Time of day and lighting were also critical environmental factors. Most CMV crashes occurred during weekdays and in daylight hours, consistent with commercial traffic volumes. Crashes during nighttime on roads that were not lit showed a significant increase in odds of a fatal outcome compared to crashes during daylight hours. Reduced luminance and limited contrast make object detection and hazard recognition more difficult, particularly in rural conditions. Similarly, crashes during dawn or dusk also showed an increase in fatal outcomes compared to crashes during daylight. Transitional light conditions may challenge both visibility and depth perception. Roadway geometry and design further influenced crash severity. Roads with an upgrade or a downgrade were associated with higher odds of a fatal crash compared to level roads (OR = 1.44). Curved roads were also associated with higher odds of a fatal outcome compared to straight roads. This is consistent with the influence of increased kinetic energy downhill combined with braking demands on grades that can increase susceptibility to loss-of-control events. Curved roads increase lateral acceleration and rollover potential for heavy vehicles as well. The speeds of the roads were also significant. On roads with speed limits of less than 45 mph, crashes were much less likely to be fatal compared to crashes on roads with speed limits above 55 mph. Similarly, crashes on principal arterial (freeways) roads were more likely to

be fatal (OR = 2.62). Condition of the roads was significant as well. All other comparisons within environmental conditions were either insignificant or limited by low observation counts.

Overall, the environment-related factors most relevant to crash severity in Idaho included the influence of poor roadway conditions, visibility, lighting, and roadway geometry. The recommended mitigation strategies for environmental conditions are listed by condition in the following sections.

Mitigation Strategies for Poor Roadway Conditions

Roadway Treatments

As discussed previously, HFST applied on downgrade curves, rural intersections, and ramp terminals can reduce skid resistance during poor weather conditions on already complex roadway geometry. Additionally, a roadway treatment called the “SafetyEdge” can reduce roadway departure and edge drop-off crashes on rural two-lane highways. FHWA empirical-Bayes evaluations show total crash reductions of 5–15% and a high cost-benefit analysis (U.S. Department of Transportation, 2017).

For Idaho, implementation may include requiring the SafetyEdge design on all future rural resurfacing projects where unpaved shoulders exist. This can be incorporated into standard resurfacing specifications to reduce additional costs.

Mitigation Strategies for Low-visibility Conditions

Dust Suppression Systems

Dust suppression and real-time detection systems can mitigate crashes caused by sudden visibility loss. Scheduling field tilling and harvest activities during low wind periods and applying water or polymer-based dust controls on adjacent roads can reduce dust generation. Additionally, installing CCTV or radar sensors in known dust corridors allows automated relay of information to nearby drivers. Roadside vegetative buffers can also serve as natural dust and wind barriers, reducing both the frequency and severity of low-visibility events. Vegetative windbreaks, such as hedgerows or shelterbelts, stabilize roadside soil and capture airborne particles before they reach the roadway.

For Idaho, implementation may include establishing dust-suppression partnerships with agricultural operators and deploying automated detection systems on known dust corridors, particularly during harvest months in southern Idaho. Additionally, Idaho may choose to coordinate with local conservation districts to plant vegetative buffers along rural corridors prone to agricultural dust or crosswinds, particularly in the open plains region of the Snake River

Plain/Basin. Seasonal advisories during harvest months may also help drivers anticipate low-visibility events. Giving drivers guidance on what to do when a dust storm strikes may also reduce panic or overreaction during these events.

Mitigation Strategies for Low Lighting Conditions

Increased Quantity or Quality of Lighting Installation

Improved roadway illumination can address Idaho's elevated nighttime crash risk, particularly at rural intersections, ramps, and curved segments. Idaho may choose to select additional key locations for low-lighting installations or assess whether current lighting fixtures need updated maintenance.

Mitigation Strategies for Complex Roadway Geometry

Complex Roadway Warning Systems

Mitigation strategies for complex roadway geometry focus on improving curve safety, enhancing delineation, and managing speeds through technology and design. Dynamic curve speed warning systems—radar-activated feedback signs that display advisory speeds or flashing warnings—may reduce lane-departure and rollover crashes by alerting drivers who approach curves too quickly. Another solution is to enhance delineation of horizontal curves through reflective chevron signage and flashing beacons. These engineering measures can be reinforced through driver education programs addressing the human factors that contribute to loss-of-control events on complex roadway geometry.

For Idaho, implementing these strategies would involve a coordinated blend of infrastructure upgrades, technology deployment, and driver outreach. The ITD team could complete a curve audit to identify high-risk locations that would benefit most from these added technologies. Additionally, ITD could develop specific signage for out-of-state drivers explaining how to safely operate in mountainous terrain.

Temporal Factors

Temporal factors included variables such as crash year, season, day of the week, and time of day. Seasonal and time-of-day patterns further contributed to crash severity. Summer and fall seasons showed a significantly higher likelihood of fatal crashes compared to winter, and the likelihood of an injury crash increased across spring, summer, and fall months relative to winter. These patterns likely reflect higher exposure during agricultural and freight peak periods, increased recreational traffic, and elevated travel speeds on dry pavements. Injury crashes were also more frequent during the afternoon rush period (3:00 p.m.–5:59 p.m.) compared to mid-

morning (9:00 a.m.–11:59 a.m.), when traffic density and time pressure elevate the probability of conflicts and close following events. Additionally, crashes occurring on Saturdays had twice the odds of a fatal outcome compared to those on Mondays (OR = 2.05), which may correspond to higher proportions of mixed traffic involving both recreational and commercial vehicles, along with increased discretionary speeding on less congested weekend roads. In general, though, there has been a consistent decrease in the likelihood of injury crash outcomes in recent years compared to 2014. All other comparisons within temporal characteristics were either insignificant or limited by low observation counts. Overall, the temporal-related factors most relevant to crash severity in Idaho included seasonal factors and time-of-day influences. The recommended mitigation strategies for temporal factors are listed in the following section.

Mitigation Strategies for Temporal-related Crashes

High-visibility Seasonal Enforcement Campaigns & Management

Missouri and Iowa departments of transportation demonstrated reductions in rural fatalities through coordinated high-visibility enforcement operations timed with national safety campaigns for maximum visibility (National High Traffic Safety Administration, n.d.). Wisconsin and Minnesota use agricultural movement windows and public advisories during harvest months to reduce conflicts between farm machinery and commuter or freight traffic (Paczuski & LeCloux, 2019). Other approaches such as FHWA’s Rural Road Safety Awareness Week, may contribute to increased seasonal driver awareness and compliance (U.S. Department of Transportation, 2025b). Oregon’s off-peak freight incentives and Utah’s weekend enforcement initiatives may further reduce crash risk tied to specific temporal patterns, particularly on rural freight corridors (Oregon Department of Transportation, 2023).

Idaho may choose to tailor these time-sensitive strategies to state-specific seasonal and geographic conditions. Coordinated enforcement surges could be scheduled during summer and fall, particularly along high-volume rural arterials and agricultural corridors. An agricultural calendar could also help schedule slow-mover advisories and temporary route adjustments during harvest periods. Seasonal outreach campaigns are another option and could be delivered through dynamic message signs, radio, and/or social media.

Data Quality Considerations

A formal analysis of the data quality for ITD was not conducted; however, several observations made during the analysis highlight potential areas for improvement. One identified weakness in the Idaho data was a lack of data for points of interest. For example, the ITD team expressed interest in English speaking versus non-English speaking crashes, HOS violations, exposure data, and specific cargo types; however, datasets complete with this data were unavailable for

inclusion in the analysis. If these variables are of interest, ITD may want to seek opportunities to supplement current data or begin collecting additional data. In a brief review of the crash narrative fields, several officers noted whether the driver was a native English speaker or not; however, this was not captured in easily accessible data fields. One option for ITD is to use natural language processing algorithms to comb through their crash narratives to link missing or supplementary data to the crash entry in the database. Another option is to link data accessible to the ITD team to the Idaho Crash database data. For example, daily traffic flow, state inspection numbers, commodity codes, and daily weather could be tied to the crash data for additional analysis.

The ITD team gave feedback that they currently use logic tracking and lock-out techniques in the data entry system to prevent missing data. However, the VTTI team identified missing data fields in the Idaho Crash Database data, including crash location, vehicle type, etc. Therefore, further investigation into the root cause would be needed to recommend a potential mitigation strategy. Overall, the ITD team could track annual key performance indicators such as completion rates, geolocation accuracy, and reporting timeliness using dashboards. Collectively, these improvements would create a more complete, interoperable, and actionable crash data system. Investment in data quality analysis would position Idaho to identify risk factors more precisely, evaluate countermeasure effectiveness, and align with national best practices in roadway safety analytics.

7. Conclusion

This study examined the key factors influencing CMV crash severity in Idaho between 2014 and 2023. The analysis integrated data from state and federal datasets to identify how roadway, vehicle, environmental, and driver factors contribute to crash outcomes. The findings show that CMV crash severity in Idaho is shaped by both predictable patterns, such as time of year and road type, and by the interaction between roadway design, operating conditions, and driver behavior.

Driver-related factors were significantly linked with crash severity. Speeding, distraction, and following too closely were among the most common behavioral contributors, while impairment, though rare, was strongly associated with fatal outcomes. These results highlight the ongoing importance of behavioral safety initiatives, including high-visibility enforcement, distraction-prevention campaigns, and hazard anticipation training for both CMV and passenger-vehicle drivers.

Vehicle-related factors also played a central role. Brake and tire defects were strongly linked to severe outcomes, consistent with national research showing that these defects remain the most common mechanical contributors in fatal truck crashes. Trucks operating with double or triple trailers experienced higher crash severity than single-trailer configurations. Certain load types, particularly log and grain or hay, were overrepresented in severe crashes, likely due to higher centers of gravity and potential for load shift. These findings underscore the value of proactive maintenance and inspection programs, automated roadside brake-screening technologies, and configuration-based route restrictions to minimize instability risks.

Environmental and roadway factors further influenced crash severity. Crashes on curved or graded segments, high-speed arterials, and unlit rural corridors were significantly more likely to result in fatalities. Loose gravel, seal coat, and blowing dust also contributed to higher severity by reducing traction or visibility. However, crashes under winter conditions, while more frequent, tended to be less severe, likely due to drivers' reduced speeds and increased caution in adverse weather. These results support infrastructure strategies such as high-friction surface treatments, enhanced curve delineation, adaptive lighting on rural roadways, and dust-suppression partnerships with agricultural operators in southern Idaho.

Temporal patterns revealed increased crash severity during summer and fall months, especially on weekends, and during afternoon peak hours. These trends correspond with Idaho's agricultural, freight, and recreational traffic cycles. Coordinated seasonal enforcement campaigns, targeted weekend patrols on mixed-use corridors, and public outreach during harvest and travel seasons can help mitigate these predictable risk periods.

Working with the datasets also highlighted the importance of high-quality crash data. Gaps in exposure data, incomplete vehicle classification records, and inconsistent linkage with roadway geometry limited the precision of the findings. Future efforts should focus on adopting national crash data standards and implementing automated data validation checks. Linking crash records to traffic volume, weather, and carrier databases would further strengthen Idaho's ability to identify and monitor safety trends over time. Additionally, utilizing algorithms to analyze crash narratives from officers on the scene may produce fruitful data for new information or validating available data.

Overall, this study demonstrates that CMV crash severity in Idaho is influenced by multiple interrelated factors that vary across time, location, and operating conditions. Improving safety outcomes will require coordinated actions across several domains: targeted infrastructure improvements on high-risk corridors, expanded inspection and maintenance initiatives, consistent behavioral enforcement, and ongoing investment in data integration and quality monitoring. Together, these measures can help Idaho reduce the frequency and severity of CMV crashes while improving the safety of the state's freight and highway systems.

8. Cited Works

- Aarts, L., and I. van Schagen. 2006. *The Relation Between Speed and Crashes*. SWOV Institute for Road Safety Research.
https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwas1304/Resources3/08%20-%20The%20Relation%20Between%20Speed%20and%20Crashes.pdf.
- Abdel-Aty, M., A. Ekram, and H. Huang. 2010. *A Study on Visibility Obstruction Related Crashes Due to Fog and Smoke*. Department of Civil, Environmental & Construction Engineering, University of Central Florida.
- Abdel-Rahim, A., and M. Khan. 2012. *Potential Crash Reduction Benefits of Safety Improvement Projects – Part A: Shoulder Rumble Strips*. Report No. FHWA-ID-12-191A. National Institute for Advanced Transportation Technology.
- Ackaah, W., and M. Salifu. 2021. "Risk Factors Associated with Crash Injury Severity Involving Trucks." Report No. 20-01. Mineta Transportation Institute.
<https://rosap.nhtl.bts.gov/view/dot/62686>.
- Adanu, E. K., A. Lidbe, E. Tedla, and S. Jones. 2021. "Injury-Severity Analysis of Lane Change Crashes Involving Commercial Motor Vehicles on Interstate Highways." *Journal of Safety Research* 76: 30–35.
- Ahmed, S. T., M. A. Rahman, E. Mitran, and X. Sun. 2024. "Investigating Safety and Cost-Effectiveness of Cable Median Barriers in Louisiana." *Traffic Injury Prevention* 25, no. 3: 544–552. <https://doi.org/10.1080/15389588.2024.2314596>.
- Al-Kaisy, A., D. Veneziano, L. Ewan, and F. Hossain. 2015. *Risk Factors Associated with High Potential for Serious Crashes: Final Report*. SPR Report No. 771. Western Transportation Institute, Montana State University; Oregon Department of Transportation & Federal Highway Administration.
- Alrejfal, A., and K. Ksaibati. 2022. "Impact of Mountainous Interstate Alignments and Truck Configurations on Rollover Propensity." *Journal of Safety Research* 80: 160–174.
<https://doi.org/10.1016/j.jsr.2021.07.005>.
- Alrejfal, A., M. Moomen, and K. Ksaibati. 2021. "Evaluating the Effectiveness of Law Enforcement in Reducing Truck Crashes for a Rural Mountainous Freeway in Wyoming." *Transportation Letters* 14, no. 9: 807–817.
<https://doi.org/10.1080/19427867.2021.1949089>.
- American Association of State Highway and Transportation Officials. 2010. *Highway Safety Manual First Edition*.
- . n.d. "Thermal Imaging Safety Screening System: Priority, Market-Ready Technologies and Innovations." Fact sheet. Accessed October 25, 2025.
<https://aai.transportation.org/Documents/TISSFactSheet.pdf>.

- Anderson, J. C., and S. Hernandez. 2017. "Roadway Classifications and the Accident Injury Severities of Heavy-Vehicle Drivers." *Journal of Safety Research* 61: 119–126. <https://doi.org/10.1016/j.jsr.2017.02.002>.
- Apostolopoulos, Y., S. Sönmez, M. M. Shattell, and M. Belzer. 2010. "Worksite-Induced Morbidities Among Truck Drivers in the United States." *AAOHN Journal* 58, no. 7: 285–296. <https://doi.org/10.3928/08910162-20100625-01>.
- Azimi, G., A. Rahimi, H. Asgari, and X. Jin. 2020. "Severity Analysis for Large Truck Rollover Crashes Using a Random Parameter Ordered Logit Model." *Accident Analysis & Prevention* 144: 105594. <https://doi.org/10.1016/j.aap.2020.105594>.
- Barr, L., and L. Boyle. 2010. *Sleep Apnea Crash Risk Study* (Brief). Federal Motor Carrier Safety Administration, March. <https://rosap.ntl.bts.gov/view/dot/144>.
- Bearpark, H. 1994. "Road Safety and Pathological Sleepiness: The Role of Sleep Apnea Syndrome and Narcolepsy in Traffic Accidents." *Sleep* 17, no. 7 (Suppl.): S93–S96. https://doi.org/10.1093/sleep/17.suppl_7.s93.
- Bell, S. 2024. "Smart Traffic Signs Spot Phone Usage, Tell You to Put It Down." Carscoops. <https://www.carscoops.com/2024/04/new-infrared-traffic-signs-will-detect-when-youre-driving-distracted-or-speeding-and-tell-you-to-behave-properly/>.
- Berning, A., and D. D. Smither. 2014. *Understanding the Limitations of Drug Test Information, Reporting, and Testing Practices in Fatal Crashes*. Traffic Safety Facts Research Note. Report No. DOT HS 812 072. National Highway Traffic Safety Administration. <https://rosap.ntl.bts.gov/view/dot/40777>.
- Bill, A., F. Serrano, and D. A. Noyce. 2011. *Wisconsin Large Truck Safety and Enforcement Study*. Report No. CFIRE 04-24. National Center for Freight and Infrastructure Research and Education. <https://rosap.ntl.bts.gov/view/dot/25354>.
- Blanco, M., J. S. Hickman, R. L. Olson, J. L. Bocanegra, R. J. Hanowski, A. Nakata, M. Greening, P. Madison, G. T. Holbrook, and D. S. Bowman. 2016. *Investigating Critical Incidents, Driver Restart Period, Sleep Quantity, and Crash Countermeasures in Commercial Vehicle Operations Using Naturalistic Data Collection*. Report No. FMCSA-RRR-13-017. Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/31518>.
- Blower, D., and A. Matteson. 2010. *Evaluation of 2008 Mississippi Crash Data Reported to the MCMIS Crash File*. Report No. UMTRI-2010-1. University of Michigan Transportation Research Institute; U.S. Department of Transportation, Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/574>.
- Blower, D. 2017. *Estimating Motor Carrier Management Information System Crash File Underreporting from Carrier Records*. Report No. FMCSA-RRR-16-025. University of Michigan Transportation Research Institute; Federal Motor Carrier Safety Administration. <https://doi.org/10.21949/1502548>.

- Braver, E. R., D. F. Preusser, A. F. Williams, and H. B. Weinstein. 1996. "Major Types of Fatal Crashes Between Large Trucks and Cars." In *Proceedings of the 40th Annual Conference of the Association for the Advancement of Automotive Medicine*.
<https://www.iihs.org/topics/bibliography/ref/1037>.
- Bunn, T. L., S. Slavova, T. W. Struttman, and S. R. Browning. 2005. "Sleepiness/Fatigue and Distraction/Inattention as Factors for Fatal versus Nonfatal Commercial Motor Vehicle Driver Injuries." *Accident Analysis & Prevention* 37, no. 5: 862–869.
<https://doi.org/10.1016/j.aap.2005.04.004>.
- Byrnes, D. 2022. *FTA Standards Development Program: Over-the-Counter and Prescription Drug Use in the Public Transit Industry, Final Report*. No. FTA Report No. 0217. United States. Department of Transportation. Federal Transit Administration.
- Calabrese, C., I. Bartinique, A. Bisch, M. Raney, and R. Markunas. 2017. *Cargo Tank Incident Study (CTIS): Rollover Data and Risk Framework*. Report No. DOT-VNTSC-PHMSA-17-01. John A. Volpe National Transportation Systems Center (U.S.), Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation.
<https://rosap.ntl.bts.gov/view/dot/12479>.
- Camden, M. C., J. S. Hickman, and R. J. Hanowski. 2015. *Effective Use of Commercially Available Onboard Safety Monitoring Technologies: Guidance for Commercial Motor Vehicle Carriers*. National Surface Transportation Safety Center for Excellence.
<https://vtechworks.lib.vt.edu/handle/10919/51586>.
- Camden, M. C., S. A. Soccolich, J. S. Hickman, M. Walker, and R. J. Hanowski. 2020. *Examining the Relationship Between CMV Driver Retention and Safety*. National Surface Transportation Safety Center for Excellence. <http://hdl.handle.net/10919/99714>.
- Cantor, D. 2015. *A Firm Size and Safety Performance Profile of the U.S. Motor Carrier Industry: Executive Summary*. Report No. 42309. Iowa State University, Institute for Transportation; Midwest Transportation Center.
<https://rosap.ntl.bts.gov/view/dot/29566>.
- Carson, J. L. 2007. *Large Truck Crashes in Texas: A Predictive Approach for Identifying Those at Higher Risk*. Technical Report No. SWUTC/07/473700-00089-1. Southwest Region University Transportation Center, Texas Transportation Institute, Texas A&M University System. <https://rosap.ntl.bts.gov/view/dot/16332>.
- Chen, C., G. Zhang, Z. Qian, R. A. Tarefder, and Z. Tian. 2016. "A Comprehensive Analysis of Factors Contributing to Driver Injury Severity on Rural Two-Lane Highways." *Accident Analysis & Prevention* 92: 43–57. <https://doi.org/10.1016/j.aap.2016.03.012>.
- Chen, G. X., Y. Fang, F. Guo, and R. J. Hanowski. 2016. "The Influence of Daily Sleep Patterns of Commercial Truck Drivers on Driving Performance." *Accident Analysis & Prevention* 91: 55–63. <https://doi.org/10.1016/j.aap.2016.02.027>.

- Chen, J., and Y. Wang. 2024. "Effects of Transition Curves and Superelevation on the Critical States of Truck Rollovers on Sharp Curves." *The Baltic Journal of Road and Bridge Engineering* 19, no. 1: 53–70. <https://doi.org/10.7250/bjrbe.2024-19.627>.
- Chen, Z., Z. Ma, and F. Chen. 2022. "Impact of Mountainous Interstate Alignments and Truck Configurations on Rollover Propensity." *Journal of Safety Research* 80: 160–174. <https://doi.org/10.1016/j.jsr.2021.07.005>.
- Cho, H. W., E. M. Robartes, and M. D. Fontaine. 2025. *Operational and Safety Effects of the I–95 Variable Speed Limit System in Fredericksburg, Virginia*. Report No. VTRC 22-R9. Virginia Transportation Research Council; Virginia Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/79371>.
- Christoforou, Z., and H. Wolff. 2010. "Heavy Vehicle Age and Road Safety." *Proceedings of the Institution of Civil Engineers – Transport* 163, no. 1: 41–47. <https://doi.org/10.1680/tran.2010.163.1.41>.
- CMV Road Sharing. n.d. "About – Safety Tips." Accessed October 25, 2025. <https://cmvroadsharing.org/about.html#safety-tips>.
- Colorado General Assembly. n.d. "Size and Weight Limitations (Sections 42-4-502 through 42-4-509, C.R.S.)." Accessed October 21, 2025. <https://leg.colorado.gov/content/size-and-weight-limitations>.
- Commercial Vehicle Safety Alliance. 2006. *Cutting It Close: A Guide to Understanding and Preventing Close Calls in Commercial Vehicle Operations*. <https://cvsa.org/wp-content/uploads/Cutting-It-Close-Brochure.pdf>.
- Compton, R. P., and A. Berning. 2015. "Drug and Alcohol Crash Risk." Traffic Safety Facts Research Note. DOT HS 812 117. National Highway Traffic Safety Administration, February. https://www.nhtsa.gov/sites/nhtsa.gov/files/812117-drug_and_alcohol_crash_risk.pdf.
- Craft. 2008. "Why Trucks and Buses Collide with Cars – TRB Conference." Conference presentation at the Transportation Research Board (TRB) Annual Meeting, Washington, DC.
- CRC Group. 2025. "Truck Accident Frequency and Claims Severity on the Rise." CRC Group. <https://www.crcgroup.com/Tools-Intel/post/truck-accident-frequency-and-claims-severity-on-the-rise>.
- Datta, T., T. Gates, and P. Savolainen. 2012. *Impacts of Non-Freeway Rumble Strips Phase 1*. Publication RC-1575. Michigan Department of Transportation.
- Davis, P.G. 2015. Correspondence, May. FDOT State Estimates Engineer.
- Dingus, T. A., R. J. Hanowski, and S. G. Klauer. 2011. "Estimating Crash Risk." *Ergonomics in Design: The Quarterly of Human Factors Applications* 19, no. 4: 8–12. <https://doi.org/10.1177/1064804611423736>.

- Dingus, T., V. Neale, S. Garness, R. Hanowski, A. Keisler, S. Lee, M. Perez, G. Robinson, S. Belz, J. Casali, E. Pace-Schott, R. Stickgold, and J. A. Hobson. 2002. *Impact of Sleeper Berth Usage on Driver Fatigue* (Final Project Report). Virginia Tech Transportation Institute. <https://vtechworks.lib.vt.edu/bitstreams/f6bab820-7584-4b74-a7a5-5510e2dc36fc/download>.
- Dougherty, K. H., R. R. Plate, R. M. Stuefen, and S. L. Tracy. 1999. *Truck Crash Analysis in South Dakota*. Final Report No. SD99-05. Business Research Bureau, University of South Dakota; South Dakota Department of Transportation.
- Dunn, N. J., S. A. Soccolich, and J. S. Hickman. 2020. *Commercial Motor Vehicle Driver Risk Based on Age and Driving Experience*. National Surface Transportation Safety Center for Excellence. <https://vtechworks.lib.vt.edu/items/a73eaf6a-03fa-4f7f-b34c-deb67a33a4aa>.
- ECRI Institute. 2008. *Psychiatric Disorders and Commercial Motor Vehicle Driver Safety* (Evidence Report). Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/16528>.
- Elshamly, A. F., R. A. El-Hakim, and H. A. Afify. 2017. "Factors Affecting Accidents Risks among Truck Drivers in Egypt." *MATEC Web of Conferences* 124: 04009. <https://doi.org/10.1051/mateconf/201712404009>.
- Emitted Energy. 2017. "Automated Thermal Imaging Improves Highway Safety: Washington's Automated Infrared Roadside Screening System Uses Machine Vision to Check Truck Brakes." Application story. https://www.emittedenergy.com/wp-content/uploads/2025/07/improving_highway_safety.pdf.
- European Parliament and Council of the European Union. 2019. "Regulation (EU) 2019/2144 on Type-Approval Requirements for Motor Vehicles and Their Trailers, and Systems, Components and Separate Technical Units Intended for Such Vehicles, as Regards Their General Safety and the Protection of Vehicle Occupants and Vulnerable Road Users." *Official Journal of the European Union*, November 27. <https://eur-lex.europa.eu/eli/reg/2019/2144/oj/eng>.
- European Transport Safety Council. 2021. *15th Road Safety Performance Index Report*. <https://etsc.eu/wp-content/uploads/15-PIN-annual-report-FINAL.pdf>.
- Federal Highway Administration (FHWA). 1996. *Commercial Driver Rest and Parking Requirements: Making Space for Safety*. Report No. FHWA-MC-96-0010. U.S. Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/24062>.
- . 2011. "Technical Advisory T 5040.39, Revision 1: Shoulder and Edge Line Rumble Strips." Technical advisory. U.S. Department of Transportation. <https://highways.dot.gov/safety/rwd/keep-vehicles-road/rumble-strips/technical-advisory-shoulder-and-edge-line-rumble-strips>.

- . 2021. "Highway Statistics 2021: Table VM-4 – Annual Vehicle Distance Traveled in Miles and Related Data." U.S. Department of Transportation.
<https://www.fhwa.dot.gov/policyinformation/statistics/2021/vm4.cfm>.
 - . 2023. *Highway Statistics 2023*. U.S. Department of Transportation.
<https://www.fhwa.dot.gov/policyinformation/statistics/2023/>.
 - . 2024. "How Do Weather Events Impact Roads?" U.S. Department of Transportation.
https://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.
 - . n.d.a "High Friction Surface Treatments (HFST)." Accessed October 25, 2025.
<https://highways.dot.gov/safety/rwd/keep-vehicles-road/pavement-friction/hfst>.
 - . n.d.b "KABCO Injury Classification Scale and Definitions." Accessed October 25, 2025.
<https://highways.dot.gov/media/20141>.
- Federal Motor Carrier Safety Administration. 2000. *Stress and Fatigue Effects of Driving Longer Combination Vehicles*. Tech Brief No. FMCSA-MCRT-00-012. U.S. Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/14282>.
- . 2007. *Large Truck Crash Causation Study: Analysis Brief*. U.S. Department of Transportation. <https://www.fmcsa.dot.gov/safety/research-and-analysis/large-truck-crash-causation-study-analysis-brief>.
 - . 2013. "Distracted Driving." U.S. Department of Transportation.
<https://www.fmcsa.dot.gov/driver-safety/distracted-driving>.
 - . 2014. *National Survey of Long-Haul Truck Driver Health and Injury*. U.S. Department of Transportation.
<https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/National%20Survey%20of%20Long-Haul%20Truck%20Driver%20Health%20and%20Injury.pdf>.
 - . 2016. "Size Differences." U.S. Department of Transportation.
<https://www.fmcsa.dot.gov/ourroads/cmvsafetychallenges>.
 - . 2017. *Our Roads, Our Safety: Partnership for Responsible Driving* (Brochure). U.S. Department of Transportation.
<https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Our%20Roads%20Our%20Safety%20Brochure.pdf>.
 - . 2018. *Commercial Motor Vehicle Driver Risk Factors: A Synthesis of the Literature*. Report No. FMCSA-RRT-13-011. U.S. Department of Transportation.
<https://rosap.ntl.bts.gov/view/dot/39407>.
 - . 2023a. *Large Truck and Bus Crash Facts 2021*. Report No. FMCSA-RRA-23-002. U.S. Department of Transportation.
https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/2023-12/LTBCF%202021-FINAL%20508_0.pdf.

- . 2023b. *Effects of Hours-of-Service Regulations: Report to Congress*. U.S. Department of Transportation. <https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/2023-05/Effects%20of%20HOS%20Regulations%202021-Report-Final%20May%202023.pdf>.
- . 2023c. *Demographics of the CMV Workforce* (Presentation to the Women of Trucking Advisory Board). U.S. Department of Transportation. <https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/2023-08/Demographics%20of%20CMV%20Workforce%20WOTAB%208.14.23.pdf>.
- . 2023d. "Medical Requirements for Commercial Driver's License." U.S. Department of Transportation. <https://www.fmcsa.dot.gov/registration/commercial-drivers-license/medical>.
- . 2024. *2024 Pocket Guide to Large Truck and Bus Statistics*. U.S. Department of Transportation. <https://www.fmcsa.dot.gov>.
- . n.d. "Core Compliance – Innovative Technology Deployment (ITD) Program." Accessed October 21, 2025. <https://itd.fmcsa.dot.gov/ProgramManagement/CoreCompliance>
- . n.d. "Smart Roadside Initiative." U.S. Department of Transportation. Accessed October 21, 2025. <https://www.fmcsa.dot.gov/research-and-analysis/technology/smart-roadside-initiative>.
- Feng, J., G. Tan, M. Ye, K. Chen, and X. Huang. 2021. "Safety and Speed Warning System for Tank Truck Rollover." SAE Technical Paper No. 2021-01-0978. SAE International. <https://saemobilus.sae.org/papers/safety-speed-warning-system-tank-truck-rollover-2021-01-0978>.
- Fitch, G. M., S. A. Soccolich, F. Guo, J. A. McClafferty, Y. Fang, R. L. Olson, M. A. Perez, and R. J. Hanowski. 2013. *The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk*. Report No. FMCSA-RRR-13-017. Federal Motor Carrier Safety Administration.
- Flintsch, A. M., F. Guo, S. Han, K. Hancock, B. Williams, Y. Li, and R. Gibbons. 2021. *Impact of Access Spacing Standards on Crash Risk*. Report No. FHWA/VTRC 21-R7. Virginia Transportation Research Council. http://www.virginiadot.org/vtrc/main/online_reports/pdf/21-r7.pdf.
- Fontaine, M. D., L. E. Dougald, and C. S. Bhamidipati. 2009. *Evaluation of Truck Lane Restrictions in Virginia: Phase II*. Virginia Transportation Research Council.
- Gan, A., P. Shen, and A. Rodriguez. 2005. *Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects*. Lehman Center for Transportation Research, Florida International University.
- Gander, P. H., N. S. Marshall, W. Bolger, and I. Girling. 2005. "An Evaluation of Driver Training as a Fatigue Countermeasure." *Transportation Research Forum, Traffic Psychology Behavior* 8, no. 1: 47–58.

- Giroto, E., S. M. de Andrade, A. D. González, and A. E. Mesas. 2016. "Professional Experience and Traffic Accidents/Near-Miss Accidents Among Truck Drivers." *Accident Analysis & Prevention* 95: 299–304.
- Governors Highway Safety Association. 2022. "America's Rural Roads: Beautiful and Deadly," September. <https://www.ghsa.org/resources/GHSA/Rural-Road-Safety22>.
- Granlund, J., R. di Cristoforo, R. Mellum, and M. H. Raddum. 2016. "Investigating Heavy Vehicle Rollover Crashes and the Influence of Road Design by Use of Vehicle Simulations." In *Proceedings of the 14th International Symposium on Heavy Vehicle Transport Technology*. <https://hvtforum.org/wp-content/uploads/2019/11/Granlund-Investigating-heavy-vehicle-rollover-crashes-and-the-influence-of-road-design-by-use-of-vehicle-simulations.pdf>.
- Hanowski, R. J., M. A. Perez, and T. A. Dingus. 2005. "Driver Distraction in Long-Haul Truck Drivers." *Transportation Research Part F: Traffic Psychology and Behaviour* 8, no. 6: 441–458.
- Hanowski, R. J., G. Bergoffen, J. S. Hickman, F. Guo, D. Murray, R. Bishop, S. Johnson, and M. Camden. 2012. *Research on the Safety Impacts of Speed Limiter Device Installations on Commercial Motor Vehicles: Phase II*. Report No. FMCSA-RRR-12-006. Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/105>.
- Hans, Z., K. Gkritza, D. Cerwick, Y. Huang, and I. Nlenanya. 2014. *Statewide Heavy-Truck Crash Assessment*. Report No. InTrans Project 12-437. Center for Transportation Research and Education, Iowa State University, September. https://publications.iowa.gov/17823/1/CTRE_MATC_Hans_Statewide_Heavy-Truck_Crash_Assessment_2014_r.pdf.
- Hansotia, P., and S. K. Broste. 1991. "The Effect of Epilepsy or Diabetes Mellitus on the Risk of Automobile Accidents." *New England Journal of Medicine* 324, no. 1: 22–26. <https://doi.org/10.1056/NEJM199101033240105>.
- Hernandez, S., J. C. Anderson, J. Claveria, and A. Olsen. 2020. *A Framework to Evaluate Causes and Effects of Truck Driver At-Fault Crashes*. Report No. FHWA-OR-RD-21-05; SPR-810. Oregon Department of Transportation, Research Section; Portland State University, December. <https://rosap.ntl.bts.gov/view/dot/57465>.
- Hickman, J. S., R. J. Hanowski, and J. Bocanegra. 2010. *Evaluating the Safety Benefits of a Low-Cost Driving Behavior Management System in Commercial Vehicle Operations*. Report No. FMCSA-RRR-10-033. Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/61>.
- . 2011. "A Preliminary Investigation Into the Safety-Critical Event Risk of Younger Commercial Motor Vehicle Drivers." Virginia Tech Transportation Institute. <https://vtechworks.lib.vt.edu/items/1e23e9ba-f396-46ca-b885-0025a1f91e6a>.

- Hickman, J. S., S. A. Soccolich, and R. J. Hanowski. 2015. "Evaluating the Impact of Driver Distraction in Commercial Motor Vehicle Operations." *Journal of Safety Research* 54: 17–28. [suspicious link removed].
- Hickman, J., J. E. Mabry, L. Marburg, F. Guo, H. Mao, R. Hanowski, J. Whiteman, and W. Herbert. 2020. *Commercial Driver Safety Risk Factors (CDSRF)*. Report No. FMCSA-RRR-17-014. Federal Motor Carrier Safety Administration. <https://rosap.ntl.bts.gov/view/dot/49620>.
- Houser, A., D. Murray, and V. Dick. 2007. *Onboard Safety Technology Survey Synthesis Final Report*. Report No. FMCSA-MCRR-07-028. Federal Motor Carrier Safety Administration, December. https://rosap.ntl.bts.gov/view/dot/87/dot_87_DS1.pdf.
- Ichikawa, M., H. Inada, K. Katanoda, and S. Nakahara. 2023. "Trend in Alcohol-Related Crashes Before and After the Introduction of Mandatory Breath Testing Among Commercial Truck Drivers." *Journal of Epidemiology* 33, no. 11: 556–561. <https://doi.org/10.2188/jea.JE20220054>.
- Idaho Transportation Department, Office of Highway Safety. 2023. *Idaho Traffic Crashes 2023*. <https://apps.itd.idaho.gov/Apps/OHS/Crash/23/Analysis.pdf>.
- Imprialou, M., and M. Quddus. 2019. "Crash Data Quality for Road Safety Research: Current State and Future Directions." *Accident Analysis & Prevention* 130: 84–90.
- Insurance Institute for Highway Safety (IIHS). 2016. *Status Report, Vol. 51, No. 10*, December 8. <https://www.iihs.org/api/datastoredocument/status-report/pdf/51/10>.
- Jonah, B. A., D. R. Mayhew, S. W. Brown, W. G. M. Vanlaar, K. D. Marcoux, and British Columbia Trucking Safety Council. 2009. *Best Practices in Truck Safety*. Traffic Injury Research Foundation.
- Kim, J., N. S. S. Al-Bdairi, and S. Hernandez. 2024. "Lane Number and Its Impact on Commercial Motor Vehicle Crash Safety: An Econometric Perspective." *International Journal of Transportation Science and Technology* 13, no. 1: 119–133. <https://doi.org/10.1016/j.ijtst.2024.01.002>.
- Kirley, B. B., K. L. Robison, A. H. Goodwin, K. J. Harmon, N. P. O'Brien, A. West, S. S. Harrell, L. Thomas, and K. Brookshire. 2023. *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*. 11th ed. Report No. DOT HS 813 490. National Highway Traffic Safety Administration.
- Klauer, S. G., T. A. Dingus, V. L. Neale, J. Sudweeks, and D. J. Ramsey. 2006. *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*. Report No. DOT HS 810 594. National Highway Traffic Safety Administration.
- Klauer, S. G., F. Guo, B. G. Simons-Morton, M.-C. Ouimet, S. E. Lee, and T. A. Dingus. 2014. "The Prevalence and Risk of Secondary Task Engagement with Novice Drivers: Distracted Driving and Risk of Road Crashes Among Novice and Experienced Drivers." Presentation at the Fourth International Symposium on Naturalistic Driving Research, Blacksburg, VA. <http://hdl.handle.net/10919/53970>.

- Klena, T., II, D. Blower, K. Fischer, and J. Woodrooffe. 2011. "Characterization of Commercial Vehicle Crashes and Driver Injury." SAE Technical Paper No. 2011-01-2294. SAE International.
- Knipling, R. R., L. N. Boyle, J. S. Hickman, J. S. York, C. Daecher, E. C. B. Olsen, and T. D. Prailey. 2004. *Synthesis Report on Individual Differences & the "High-Risk" Commercial Driver: Implications for Carrier Human Resource Management*. Transportation Research Board Commercial Truck & Bus Synthesis Program Project MC-04. Transportation Research Board.
- Knodler, M. A. 2008. *Massachusetts Traffic Safety Toolbox Final Report*. No. SPR11. 03.07. 12. Massachusetts. Executive Office of Transportation and Public Works. https://rosap.nhtl.bts.gov/view/dot/29468/dot_29468_DS1.pdf.
- Layton, R. 2022. "Road Safety Management of Uncontrolled Access Points: Design Criteria and Insights Into Risk Factors." *Journal of Transportation Safety & Security*. Advance online publication. <https://doi.org/10.1080/19439962.2022.2151234>.
- Lemke, M. K., A. Hege, Y. Apostolopoulos, and S. Sönmez. 2021. "Hours-of-Service Compliance and Safety Outcomes Among Long-Haul Truck Drivers." *Transportation Research Part F: Traffic Psychology and Behaviour* 76: 297–308.
- Mabry, J. E., M. Camden, A. Miller, A. Sarkar, A. Manke, C. Ridgeway, H. Iridiastadi, T. Crowder, M. Islam, S. Soccolich, and R. J. Hanowski. 2022. "Unravelling the Complexity of Irregular Shiftwork, Fatigue and Sleep Health for Commercial Drivers and the Associated Implications for Roadway Safety." *International Journal of Environmental Research and Public Health* 19, no. 22: 14780. <https://doi.org/10.3390/ijerph192214780>.
- Mahajan, K., N. R. Velaga, A. Kumar, A. Choudhary, and P. Choudhary. 2019a. "Effects of Driver Work-Rest Patterns, Lifestyle and Payment Incentives on Long-Haul Truck Driver Sleepiness." *Transportation Research Part F: Traffic Psychology and Behaviour* 60: 366–382.
- Mahajan, K., N. R. Velaga, A. Kumar, and P. Choudhary. 2019b. "Effects of Driver Sleepiness and Fatigue on Violations Among Truck Drivers in India." *International Journal of Injury Control and Safety Promotion* 26, no. 4: 412–422.
- McCartt, A. T., J. W. Rohrbaugh, M. C. Hammer, and S. Z. Fuller. 2000. "Factors Associated with Falling Asleep at the Wheel Among Long-Distance Truck Drivers." *Accident Analysis & Prevention* 32, no. 4: 493–504. [https://doi.org/10.1016/S0001-4575\(99\)00067-6](https://doi.org/10.1016/S0001-4575(99)00067-6).
- McGee, H., and F. Hanscom. 2006. *Low-Cost Treatments for Horizontal Curve Safety*. Report No. FHWA-SA-07-002. U.S. Department of Transportation, Federal Highway Administration.
- McKnight, A. J., and G. T. Bahouth. 2008. "Analysis of Large Truck Rollover Crashes." In *Annals of Advances in Automotive Medicine/Annual Scientific Conference* 52: 281.

- Mejza, M. C., R. E. Barnard, T. M. Corsi, and T. Keane. 2003. "Driver Management Practices of Motor Carriers with High Compliance and Safety Performance." *Transportation Journal* 42: 16–29.
- Milton, J. C., V. N. Shankar, and F. L. Mannering. 2008. "Highway Accident Severities and the Mixed Logit Model: An Exploratory Empirical Analysis." *Accident Analysis & Prevention* 40, no. 1: 260–266.
- Minnesota Department of Public Safety. n.d. "Restricted Provisional License for New Driver Under Age 16." Accessed October 25, 2025. <https://dps.mn.gov/divisions/dvs/license-and-id/class-d-regular-dl/restricted-provisional-license-new-driver-under-age-16>.
- Minnesota Department of Transportation. 2024. "Thermal Imaging." PDF. <http://dot.minnesota.gov/aero/documents/aviationbusinesses/thermalimaging.pdf>.
- Moonesinghe, R. L. 2003. *An Analysis of Fatal Large Truck Crashes*. DOT HS 809 596. National Center for Statistics and Analysis, National Highway Traffic Safety Administration.
- Multimodal Transportation and Infrastructure Consortium. 2009. *An Analysis of Truck Size and Weight: Phase I – Safety*. Tech Report No. PRESS-040914-TSW.
- Murray, D., B. Lantz, and S. Keppler. 2022. "Predicting Truck Crash Involvement: 2022 Update." American Transportation Research Institute. <https://truckingresearch.org/2022/10/predicting-truck-crash-involvement-2022-update/>.
- . 2005. "Predicting Truck Crash Involvement: Developing a Commercial Driver Behavior-Based Model and Recommended Countermeasures." American Transportation Research Institute.
- Nafukho, F. M., B. E. Hinton, and C. M. Graham. 2007. "A Study of Truck Drivers and Their Job Performance Regarding Highway Safety." *Performance Improvement Quarterly* 20, no. 1: 61–74. <https://doi.org/10.1111/j.1937-8327.2007.tb00432.x>.
- National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. *Commercial Motor Vehicle Driver Fatigue, Long-Term Health, and Highway Safety: Research Needs*. The National Academies Press. <https://doi.org/10.17226/21921>.
- National Highway Traffic Safety Administration (NHTSA). 2009. *Driver Fitness Medical Guidelines*. Report No. DOT HS 811 210. U.S. Department of Transportation. <https://www.nhtsa.gov/sites/nhtsa.gov/files/811210.pdf>.
- . 2013. *How Vehicle Age and Model Year Relate to Driver Injury Severity in Fatal Crashes*. Report No. DOT HS 811 825. U.S. Department of Transportation. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811825>.
- . 2014. *Heavy Truck Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications*. Report No. DOT-VNTSC-NHTSA-11-14; DOT HS 812 023. U.S. Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/12067>.

- . 2022. *Traffic Safety Facts: Distracted Driving 2020*. Research Note, Report No. DOT HS 813 309. U.S. Department of Transportation. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813309>.
- . n.d. "High-Visibility Enforcement: Countermeasures That Work – Speeding and Speed Management." U.S. Department of Transportation. Accessed October 25, 2025. <https://www.nhtsa.gov/book/countermeasures-that-work/speeding-and-speed-management/countermeasures/enforcement/high>.
- National Institute for Occupational Safety and Health (NIOSH). 2020. "Impairments Due to Sleep Deprivation Are Similar to Impairments Due to Alcohol Intoxication!" Centers for Disease Control and Prevention. <https://www.cdc.gov/niosh/work-hour-training-for-nurses/longhours/mod3/08.html>.
- National Safety Council (NSC). 2013. *Undercounted Is Underinvested: How Incomplete Crash Reports Impact Efforts to Save Lives*. U.S. Department of Transportation. <https://www.nsc.org/getmedia/2e33083e-5bfb-4f21-98b7-0706bdc3af4d/nsc-under-reporting-white-paper.pdf.aspx>.
- National Work Zone Safety Information Clearinghouse. 2022. "Commercial Motor Vehicle Safety." American Road & Transportation Builders Association. <https://workzonesafety.org/topics-of-interest/large-truck-safety/>.
- Occupational Safety and Health Administration. 2002. "Safety Standards for Signs, Signals, and Barricades; Final Rule (29 CFR Pt. 1926; 67 Fed. Reg. 57722-57736)." *Federal Register*, September 12. U.S. Department of Labor. <http://www.osha.gov/laws-regs/federalregister/2002-09-12.pdf>.
- Olson, R. L., R. J. Hanowski, J. S. Hickman, and J. Bocanegra. 2009. *Driver Distraction in Commercial Vehicle Operations*. Report No. FMCSA-RRR-09-042. Federal Motor Carrier Safety Administration.
- Oregon Secretary of State. 2025. "OAR 734-082-0040: Combination of Vehicles (Dept. of Transp., Highway Division)." Accessed October 21, 2025. <https://secure.sos.state.or.us/oard/view.action?ruleNumber=734-082-0040>.
- Owner-Operator Independent Drivers Association Foundation (OOIDA). 2024. *2024 Owner-Operator Member Profile Survey Report*. <https://www.ooida.com/wp-content/uploads/2024/12/2024-OOMP-Survey-Report.pdf>.
- Paczuski, K., and R. LeCloux. 2019. "The Right-to-Farm Law in Wisconsin." *Wisconsin Policy Project 2*, no. 5. Wisconsin Legislative Reference Bureau. https://docs.legis.wisconsin.gov/misc/lrb/wisconsin_policy_project/wisconsin_policy_project_2_5.pdf.
- Palmer, K. T., E. C. Harris, and D. Coggon. 2008. "Chronic Health Problems and Risk of Accidental Injury in the Workplace: A Systematic Literature Review." *Occupational and*

Environmental Medicine 65, no. 11: 757–764.
<https://doi.org/10.1136/oem.2007.037440>.

Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health, Committee on National Statistics, Board on Human-Systems Integration, Division of Behavioral and Social Sciences and Education, Transportation Research Board, and National Academies of Sciences, Engineering, and Medicine. 2016. *Commercial Motor Vehicle Driver Fatigue, Long-Term Health, and Highway Safety: Research Needs*. National Academies Press.
<https://www.ncbi.nlm.nih.gov/books/NBK384974/>.

Pearlman, J., and N. R. Meltzer. 2012. *Risk of Commercial Truck Fires in the United States: An Exploratory Data Analysis*. Report No. FMCSA-RRA-12-033. John A. Volpe National Transportation Systems Center, Federal Motor Carrier Safety Administration, U.S. Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/9671>.

ProScan Inspections. n.d. "ProScan Inspections." Accessed October 15, 2025.
<https://www.proscaninspections.ca/>.

Pulugurtha, S. S., S. Duvvuri, and S. Mathew. 2022. *Risk Factors Associated with Crash Injury Severity Involving Trucks*. Report No. 22-23. Mineta Transportation Institute.
<https://rosap.ntl.bts.gov/view/dot/62686>.

Qin, X., K. Wang, and C. E. Cutler. 2013. "Logistic Regression Models of the Safety of Large Trucks." *Transportation Research Record* 2392, no. 1: 1–10.

Rashmi, B. S., and S. Marisamynathan. 2023. "Factors Affecting Truck Driver Behavior on a Road Safety Context: A Critical Systematic Review of the Evidence." *Journal of Traffic and Transportation Engineering (English Edition)* 10, no. 5: 835–865.
<https://doi.org/10.1016/j.jtte.2023.04.006>.

Ray, R. M., B. E. Ketcham, S.-W. Huang, and C. Kelly. 2008. "Fire in Large Truck Crashes: Comparing Results from the Large Truck Crash Causation Study, FARS, and NASS GES Data." SAE Technical Paper No. 2008-01-0255. SAE International.
<https://saemobilus.sae.org/articles/fire-large-truck-crashes-comparing-results-large-truck-crash-causation-study-fars-nass-ges-data-2008-01-0255>.

Research and Special Programs Administration (RSPA). 2003. *The Role of Hazardous Material Placards in Transportation Safety and Security*. Office of Hazardous Materials Safety and Volpe National Transportation Systems Center.

Roberts, G. L., and C. W. Lynn. 2003. *Passenger Vehicle Crashes into Stationary Large Trucks: Incidence and Possible Countermeasures*. Report No. VTRC 03-CR17. Virginia Transportation Research Council. <https://rosap.ntl.bts.gov/view/dot/19577>.

Rodríguez, D. A., M. Rocha, A. J. Khattak, and M. H. Belzer. 2003. "Effects of Truck Driver Wages and Working Conditions on Highway Safety: Case Study." *Transportation Research*

- Record: Journal of the Transportation Research Board* 1833: 95–102.
<https://doi.org/10.3141/1833-13>.
- Rodríguez, D. A., M. Rocha, and M. H. Belzer. 2004. "The Effects of Trucking Firm Financial Performance on Driver Safety." *Research in Transportation Economics* 10, no. 1: 35–55.
[https://doi.org/10.1016/S0739-8859\(04\)10003-6](https://doi.org/10.1016/S0739-8859(04)10003-6).
- Rossetti, M. A., and M. Johnsen. 2011. *Weather and Climate Impacts on Commercial Motor Vehicle Safety*. Report No. FMCSA-RRA-11-013. Federal Motor Carrier Safety Administration. https://rosap.ntl.bts.gov/view/dot/11531/dot_11531_DS1.pdf.
- Rosso, G. L., C. Montomoli, and S. M. Candura. 2016. "Poor Weight Control, Alcoholic Beverage Consumption and Sudden Sleep Onset at the Wheel Among Italian Truck Drivers: A Preliminary Pilot Study." *International Journal of Occupational Medicine and Environmental Health* 29, no. 3: 405–416. <https://doi.org/10.13075/ijomeh.1896.00638>.
- Russell, S., and M. Rys. 2009. *Mitigating Wind Induced Truck Crashes*. Kansas Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/34359>.
- Safari, M., M. Effati, and M. Arabani. 2024. "Spatial Analysis of Daytime and Nighttime Crash Severity on Horizontal Curves of Mountainous Rural Highways: A Case Study in Northern Iran." *Results in Engineering* 103344. <https://doi.org/10.1016/j.rineng.2024.103344>.
- Saha, P., M. M. Rezapour Mashhadi, and K. Ksaibati. 2018. "Impact of Traffic Citations to Reduce Truck Crashes on Challenging Roadway Geometry." *International Journal of Injury Control and Safety Promotion* 25, no. 4: 403–410.
<https://doi.org/10.1080/17457300.2018.1476386>.
- Sepulveda, J. A., J. M. Wood, A. J. Anderson, and A. M. McKendrick. 2022. "The Effects of Glare on the Perception of Visual Motion as a Function of Age." *Translational Vision Science & Technology* 11, no. 9: 11. <https://doi.org/10.1167/tvst.11.9.11>.
- Shipp, E., L. Wu, D. Perkinson, and E. Martin. 2023. "Data in the Driver's Seat: A Look into CMV Driver Behaviors on Texas Roadways" (Law Enforcement Officer Factsheet). Texas A&M Transportation Institute, Center for Transportation Safety, August.
https://cts.tti.tamu.edu/files/2023/09/7.-CMV_Driver-Behaviors_v2.pdf.
- Smiley, A. 2008. "Session Three – Countermeasures." Report on symposium proceedings, symposium of the Highway Safety Roundtable.
- Socolich, S. A., J. S. Hickman, and R. J. Hanowski. 2011. *Identifying High-Risk Commercial Truck Drivers Using a Naturalistic Approach*. National Surface Transportation Safety Center for Excellence. <http://hdl.handle.net/10919/23321>.
- Soro, W., N. Haworth, J. Edwards, A. K. Debnath, D. Wishart, and M. Stevenson. 2020. "Associations of Heavy Vehicle Driver Employment Type and Payment Methods with Crash Involvement in Australia." *Safety Science* 127: 104706.
<https://doi.org/10.1016/j.ssci.2020.104706>.

- Souleyrette, R., M. Caputcu, T. McDonald, R. Speery, Z. Hans, and D. Cook. 2010. *Safety Analysis of Low-Volume Rural Roads in Iowa*. Report No. 07-309. Iowa Department of Transportation.
- Sperry, R., J. Latterell, and T. McDonald. 2008. *Best Practices for Low-Cost Safety Improvements on Iowa's Local Roads*. Report No. CTRE-08-338. Iowa Department of Transportation.
- Staplin, L., K. W. Gish, and E. K. Wagner. 2003. "MaryPODS Revisited: Updated Crash Analysis and Implications for Screening Program Implementation." *Journal of Safety Research* 34, no. 4: 389–397. <https://doi.org/10.1016/j.jsr.2003.09.002>.
- Stein, H. S., and I. S. Jones. 1988. "Crash Involvement of Large Trucks by Configuration: A Case-Control Study." *American Journal of Public Health* 78, no. 5: 491–498.
- Teoh, E. R., D. L. Carter, S. Smith, and A. T. McCartt. 2017. "Crash Risk Factors for Interstate Large Trucks in North Carolina." *Journal of Safety Research* 62: 13–21.
- Thiese, M. S., U. Ott, R. Robbins, A. Effiong, M. Murtaugh, M. R. Lemke, and K. T. Hegmann. 2015. "Factors Associated with Truck Crashes in a Large Cross Section of Commercial Motor Vehicle Drivers." *Journal of Occupational and Environmental Medicine* 57, no. 10: 1098–1106.
- Thiese, M. S., R. J. Hanowski, S. N. Kales, R. J. Porter, G. Moffitt, N. Hu, and K. T. Hegmann. 2017. "Multiple Conditions Increase Preventable Crash Risks Among Truck Drivers in a Cohort Study." *Journal of Occupational and Environmental Medicine* 59, no. 2: 205–211. <https://doi.org/10.1097/JOM.0000000000000940>.
- Thiffault, P. 2011. *Addressing Human Factors in the Motor Carrier Industry in Canada*. Ottawa: Canadian Council of Motor Transport Administrators (CCMTA).
- Toma, S., E. D. Swanson, J. D. Smith, and W. G. Najm. 2014. *Heavy Truck Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications*. Report No. DOT HS 812 023. National Highway Traffic Safety Administration. <https://rosap.nhtsa.gov/view/dot/12067>.
- Tseng, C. M., M. S. Yeh, L. Y. Tseng, H. H. Liu, and M. C. Lee. 2016. "A Comprehensive Analysis of Factors Leading to Speeding Offenses Among Large-Truck Drivers." *Transportation Research Part F: Traffic Psychology and Behaviour* 38: 171–181.
- U.S. Department of Transportation. 2017. *Safety Effects of the SafetyEdgeSM: Technical Summary of Crash Modification Factors*. Report No. FHWA-SA-17-044. <https://rosap.nhtsa.gov/view/dot/49564>.
- . 2021. *Effectiveness of Dynamic Speed Feedback Signs*. Report No. DOT HS 813 164. NHTSA BSR Traffic Tech. <https://doi.org/10.21949/1526027>.
- . 2022. *National Roadway Safety Strategy*. <https://www.transit.dot.gov/sites/dot.gov/files/2022-02/USDOT-National-Roadway-Safety-Strategy.pdf>.

- . n.d. "Rural Roadway Safety." <https://www.transportation.gov/rural/safety>.
- United States General Accounting Office (GAO). 2003. *Highway Safety: Research Continues on a Variety of Factors That Contribute to Motor Vehicle Crashes*. Report No. GAO-03-436. U.S. Department of Transportation. <https://rosap.ntl.bts.gov/view/dot/15709>.
- University of Massachusetts Amherst. 2024. "Risk Anticipation Isn't Covered in Drivers' Ed – Researchers Collaborate with Toyota to Fill in the Gap," July 30. <https://www.umass.edu/news/article/risk-anticipation-isnt-covered-drivers-ed-umass-amherst-researchers-collaborate-toyota>.
- University of Wisconsin–Madison Division of Extension. 2025. *Youth Tractor Safety – Student Curriculum*. <https://farms.extension.wisc.edu/programs/youth-tractor-safety/youth-tractor-safety-student/>.
- Uttley, J., and S. Fotios. 2017. "The Effect of Ambient Light Condition on Road Traffic Collisions Involving Pedestrians on Pedestrian Crossings." *Accident Analysis & Prevention* 108: 189–200. <https://doi.org/10.1016/j.aap.2017.09.005>.
- Virginia Department of Motor Vehicles. 2025. "Infrared Inspection System (IRIS)." <https://www.dmv.virginia.gov/businesses/motor-carriers/weigh/iris>.
- Walton, J. R., M. L. Barrett, and J. D. Crabtree. 2001. *Management and Effective Use of Changeable Message Signs*. Tech. Rep. KTC-01-14/SPR233-00-1F. University of Kentucky Transportation Center & Kentucky Transportation Cabinet. <https://rosap.ntl.bts.gov/view/dot/15856>.
- Wen, H., Z. Ma, Z. Chen, and C. Luo. 2023. "Analyzing the Impact of Curve and Slope on Multi-Vehicle Truck Crash Severity on Mountainous Freeways." *Accident Analysis & Prevention* 181: 106951.
- Wiegand, D. M., R. J. Hanowski, and S. E. McDonald. 2020. "Medical Conditions and Crash Risk in Commercial Motor Vehicle Drivers." *Journal of Occupational and Environmental Medicine* 62, no. 8: 595–600. <https://doi.org/10.1097/JOM.0000000000001912>.
- . 2017. "Factors Associated with Health and Safety Outcomes in Long-Haul Truck Drivers." *Journal of Occupational and Environmental Medicine* 59, no. 2: 177–184. <https://doi.org/10.1097/JOM.0000000000000938>.
- Williams, E., and K. Monaco. 2001. "Accidents and Hours-of-Service Violations Among Over-the-Road Drivers." *Journal of the Transportation Research Forum* 40, no. 1: 105–115. <https://doi.org/10.22004/ag.econ.317583>.
- Willstrand, T. D., K. Holmquist, R. Fredriksson, and M. Rizzi. 2024. "Potential of Heavy Goods Vehicle Countermeasures to Reduce the Number of Fatalities in Crashes with Vulnerable Road Users in Sweden." *Traffic Safety Research* 6: e000053-e000053. <https://tsr.international/TSR/article/view/26283>.

- Wyoming Department of Transportation. 2024. "Wyoming Wind – Weight-Based Wind Closures (WBWC)." Accessed October 23, 2025. <https://dot.state.wy.us/home/travel/wyoming-wind.html#:~:text=WYDOT%20has%20been%20closing%20sections%20of%20highway%20to,to%20strong%20crosswinds%20and%20extreme%20blow%20over%20risk>.
- Yuan, Y., M. Yang, Y. Guo, S. Rasouli, Z. Gan, and Y. Ren. 2021. "Risk Factors Associated with Truck-Involved Fatal Crash Severity: Analyzing Their Impact for Different Groups of Truck Drivers." *Journal of Safety Research* 76: 154–165. <https://doi.org/10.1016/j.jsr.2020.12.019>.
- Zaloshnja, E., and T. R. Miller. 2004. "Costs of Large Truck-Involved Crashes in the United States." *Accident Analysis & Prevention* 36, no. 5: 801–808.
- Zhao, Q., T. Goodman, M. Azimi, and Y. Qi. 2018. "Roadway-Related Truck Crash Risk Analysis: Case Studies in Texas." *Transportation Research Record* 2672, no. 34: 20–28. <https://doi.org/10.1177/0361198118794055>.
- Zhao, S., and A. J. Khattak. 2020. "Motor Vehicle Driver Injury Severity in Single-Vehicle Crashes Involving Large Trucks and Passenger Vehicles on Rural and Urban Roadways." *Journal of Safety Research* 75: 155–168. <https://doi.org/10.1016/j.jsr.2020.09.009>.
- Zheng, Z., P. Lu, and B. Lantz. 2018. "Commercial Truck Crash Injury Severity Analysis Using Gradient Boosting Data Mining Model." *Journal of Safety Research* 65: 115–124.

Appendix A. Detailed Literature Review

Characterizing CMV Crashes

This literature review was conducted as part of a study commissioned by the Idaho Transportation Department (ITD). The review's aim is to explore research characterizing CMV crashes in the United States, primary contributing factors to CMV crashes, crash severity, and evidence-based countermeasures for reducing CMV-involved crashes. To understand how to reduce the number of CMV crashes, it is important to understand the trends in circumstances surrounding and leading to collisions. This literature review summarizes factors such as crash characteristics, driver characteristics, vehicle traits, operational characteristics, and environmental qualities impacting CMV safety. Researchers considered both CMV crash frequency (most often expressed as a rate or risk of occurrence) and CMV crash severity. This review considers specific pre-crash events impacting a crash, when possible; however, limited data was available about the cause of CMV crashes. During the review, several sources were identified pertaining to CMV crashes based on the factors of interest, though few studies have investigated the effect of these factors in combination. A synopsis of key characteristics contributing to CMV safety and available countermeasures is provided below. The insights gained from this review will support ITD in creating a picture of CMV crashes in Idaho and identifying specific countermeasures relevant to Idaho's unique needs.

Crash Characteristics

Characteristics of CMV crashes differ from non-CMV crashes. Annually, FMCSA publishes the most recent analyses of large truck and bus crashes in the United States. In 2023, FMCSA published data indicating that, in 2021, 90% of the fatal crashes where at least one large truck was involved resulted in only one fatality. Further, of those reported crashes, 83% of the fatalities were not occupants of the large truck. This statistic is likely due to the physical size and weight disparity between large trucks and other road users. The most common first harmful event across all crash severities involving *two or more* vehicles with one being a large truck is a collision with a vehicle in transport (FMCSA, 2023a). However, when investigating *single* vehicle large truck crashes, the first harmful event varies across crash severity level. For fatal, single vehicle crashes, the first harmful event is striking a vulnerable road user 44.9% of the time. For injury and property damage only (PDO) crashes, the first harmful event is striking a fixed object in 45.2% of crashes. Other leading crash events for single and multi-vehicle crashes involving a large truck across crash severities include rollover crashes, striking a parked car, fire, and collision with an animal or other object.

Note that this review focuses on factors available in police crash reports. Some literature considers personality or risk-taking behavior as a factor in crashes; however, those factors are not noted in police reports and are thus excluded from this review.

Driver-related Factors

According to an analysis from the Large Truck Crash Causation Study (LTCCS; FMCSA, 2007), driver error was cited as the critical reason for 87% of large truck crashes. This statistic makes sense considering the critical role the driver plays in providing input to the vehicle. There are many sub-categories of driver error; this review primarily focuses on driver-related factors with a significant relationship to crash risk and prevalence. The bulk of the literature focuses on investigations into fatigue, distraction, and other impairments. Some literature talks about driving history, experience, age, longevity with company, previous crashes and violations, and safety belt usage.

Distraction

In 2021, driver distraction/inattention was the second most frequently cited critical factor in large truck crashes (FMCSA, 2023a). The risks of distracted driving are well documented in the literature. Although distraction can be caused by many types of tasks, the root issue with distraction is when it takes the driver's eyes away from the driving task for more than 2 seconds. Drivers who glance from the forward roadway for more than 2 seconds are at significantly higher risk of crashes and near crashes (Klauer et al, 2006; Olson et al., 2009; Fitch et al., 2013; National Highway Traffic Safety Administration [NHTSA], 2014). Hanowski et al. (2005) investigated driver distraction among long-haul truck drivers by analyzing critical incidents from naturalistic driving data. The results showed that visual-manual distraction tasks dramatically increase crash and near-crash risk (Dingus et al., 2011). Data from (Olson et al., 2009) showed that crash risks related to distraction in a heavy vehicle are somewhat higher than in light vehicles. Hanowski et al. (2005) argues this difference may be attributable to the additional demand required by a CMV driver to control a large truck. FMCSA banned hand-held cellphone use in 2012 based on the findings that the odds of being involved in a safety-critical event are 6 times greater for CMV drivers who dial a mobile phone while driving and 23.2 times greater for CMV drivers who text while driving (FMCSA, 2013). Additional tasks found to increase crash risk were reaching for an object, adjusting in-cab devices, and smoking.

The previously mentioned studies analyzed naturalistic driving data where video of a driver was captured prior to near-crash or crash events. This type of footage is rarely available outside of intentional data collection efforts. Several studies and reports have highlighted challenges in accurately identifying driver distraction in police-reported crashes. Kirley et al., (2023) note that pre-crash distractions often leave no evidence for law enforcement officers or crash

investigators to observe, making it difficult to ascertain the role of distraction in crashes. The National Safety Council (2013) advises that crashes involving cell phone use are often underreported, as the involvement of a cell phone may not be recorded on police crash reports. The National Highway Transportation Safety Administration (NHTSA; 2022) expands this problem by acknowledging that even if distraction is noted in a police report, there may be inconsistencies across different reporting systems.

Fatigue

Converging literature indicates that fatigue is a contributing factor in a substantial number of CMV crashes. Long hours on the road, irregular sleep patterns, and the demands of freight schedules create conditions that can severely impact driver alertness and performance (Mabry et al., 2022). According to data from the LTCCS, approximately 13% of truck drivers involved in crashes were considered to be fatigued at the time of the reported crash (FMCSA, 2007). However, due to challenges in detecting fatigue post-crash, experts believe this number is likely underestimated. Toma et al. (2014) found that drivers with higher fatigue rates were involved in different crash types than drivers without fatigue. They noted that fatigued drivers were more represented in opposite direction crashes (63%), running stop sign crashes (47%), and rear-end/lead vehicle moving crashes (13%). In addition to crash type, fatigue has been found to influence the severity of crashes. Pulugurtha et al. (2022) determined that fatigue-related crashes tended to result in higher severity than other types of crashes because fatigued drivers are less likely to take corrective action, such as braking or steering, before impact. Similar results (Zhao et al., 2020; Bunn et al., 2005) found that crashes with fatigue were more likely to result in serious or fatal injury. One study by the National Institute for Occupational Safety and Health (NIOSH) found that drowsy driving can be as dangerous as driving with a blood alcohol concentration of 0.08%—the legal limit for intoxication in most states (NIOSH, 2020).

The impact of sleep on fatigue and its impact on crash risk is complex. A study by Chen et al. (2016) found that when sleep takes place, sleep duration, and sleep location all impact fatigue in truck drivers. The results showed that the sleep pattern with the highest safety-critical event (SCE; a crash or near-crash) rate was characterized by shorter sleep length closer to the early state of a non-work period and less sleep between the hours of 1:00 a.m. and 5:00 a.m. Additionally, the analysis of SCE risk suggested that longer sleep duration in the hours prior to a following shift reduces the SCE risk. These results are supported by previous findings from other authors (Rashimi et al., 2023 & Elshamly et al., 2017).

A study assessing the impact of sleeper berth usage for team and single drivers found that solo drivers had many more critical incidents across all levels of severity compared to team drivers (Dingus et al., 2002). The study points to fatigue as a crucial factor in these findings based on analysis showing that team drivers generally acquired more sleep over a 24-hour period than

solo drivers. Additionally, team drivers maintained a relatively constant level of alertness throughout a 24-hour period, whereas solo drivers tended to be more alert during the start of a shift and become fatigued throughout the day. To encourage rest for CMV drivers, the FMCSA mandates hours of service (HOS) regulations for CMV drivers. The regulation impacts consecutive driving hours, on-duty time, driving breaks, and restart periods.

The FMCSA mandated the use of electronic logging devices (ELDs) in December 2017 to enhance compliance with HOS regulations. This mandate has led to a significant decline in HOS violations. According to FMCSA data, the number of inspections with at least one HOS violation decreased by approximately 33% between January 2018 and September 2021 (FMCSA, 2023b). However, some drivers report increased pressure to continue driving even when fatigued, due to the inflexibility of ELDs compared to paper logbooks. A survey indicated that 78% of drivers felt more pressure to drive when they preferred to stop, and 71% felt pressured to drive in unsafe conditions since the ELD mandate took effect (Owner-Operator Independent Drivers Association Foundation, 2024). These findings suggest that while ELDs have improved compliance with HOS regulations, they may also contribute to unintended consequences, such as increased pressure on drivers to operate while fatigued. Chen et al. (2016) suggest that longer sleep duration has a measurable safety benefit, whereby more sleep reduces the SCE risk in the following shift; however, more research is needed to understand the direct safety benefit of the multiple regulations involved in the HOS rules.

Blanco et al. (2016) found slightly different results suggesting that the available time period for a driver to restart or rest did not have a significant relationship to SCEs, indicating that given more available time to sleep, drivers may not necessarily use the time for that purpose. An interesting result showed that the number of SCEs was highest during the first day after a restart period. However, the authors point out that when an SCE occurred, the driver had fewer hours of sleep than their average night before returning to work, which may be more of a factor than available time to sleep. This is consistent with results from previous research (Dingus et al., 2002). Several other studies confirm these findings, suggesting that longer driving duration, unfulfilled rest requirements, and seated posture behind the wheel significantly cause drowsiness among truck drivers (Elshamly et al., 2017; Lemke et al., 2021; Mahajan et al., 2019; Tseng et al., 2016). A report by the Insurance Institute for Highway Safety (IIHS; 2016) showed that truckers who reported driving after at least 12 hours since an extended sleep period were 86% more likely to crash than drivers who had been awake for less than 8 hours. Truckers who reported driving more than 5 hours without stopping were more than twice as likely to crash as those who drove between 1 and 5 hours. While converging literature points to truck driver sleep as a leading factor in crash risk, it seems that though drivers may be aware of this, they still do not get sufficient sleep. Thiffault (2011) highlighted that even though truck

drivers have good knowledge about fatigue countermeasures and risk, they tend to resist and keep fighting with fatigue, thereby increasing their crash risk.

Medical Conditions

Truck drivers have higher prevalence for several health conditions when compared to the national working population (FMCSA, 2014). A self-report study conducted by FMCSA in 2010 found that truck drivers had over twice the prevalence of obesity, morbid obesity, smoking, and diabetes than other occupations. A review conducted by Wiegand et al. (2020) confirmed the self-reported findings through converging sources, citing that CMV drivers have high rates of chronic disease. For example, several sources found that prevalence rates of diabetes range from 6% to 14%, cardiovascular disease from 3.4% to 4.4%, hypertension from 22% and 23.9%, and sleep apnea from 2.3% to 18%. Summarized literature also suggests that many drivers experience mental health problems, including depression and loneliness, with one cited study finding that 14% of CMV drivers drank daily (Apostolopoulos et al., 2010). However, the author emphasizes how little research exists analyzing the association between chronic disease and crash risk in CMV drivers.

The FMCSA requires all commercial drivers traveling interstate with a GVWR over 10,000 pounds to undergo a medical exam from a licensed medical examiner (FMCSA, 2023c). The FMCSA disqualifies drivers who do not meet specific standards in the following categories due to their impact on driving safety:

- Vision (NHTSA, 2009); (Apostolopoulos et al., 2010)
- Hearing (Palmer et al., 2008)
- Epilepsy and Seizure Conditions (Hansotia & Broste, 1991)
- Insulin Use (Hansotia & Broste, 1991; FHWA, 1996)

These are known factors related to increased crash risk. Few other health risk factors were associated with increased crash risk despite numerous investigations. Staplin et al. (2003) found that crash risk increased 2–5 times when specific physical and cognitive abilities were impaired due to varying disease, trauma, or aging. However, relevant abilities to crash risk include vision, attention, and reaction time, which are interrelated with vision and hearing related deficiencies. This suggests that the reason diabetes mellitus is a disqualifying factor is due to the disease being characterized by fatigue, blurred vision, and numbness in extremities.

Multiple studies attempt to link sleep apnea, a commonly occurring sleep disorder in the truck driver population, with increased crash risk. However, with the exception of a significant positive relationship between severe sleep apnea and severe crashes, no compelling statistical

evidence exists for the predictive value of sleep apnea in large truck crashes (Barr & Boyle, 2010 & Bearpark, 1994). Perhaps a more strongly associated metric with crash risk is excessive daytime sleepiness. A report by the National Academies of Sciences, Engineering, and Medicine (2016) found that excessive daytime sleepiness was the most significant predictor of falling asleep at the wheel for CMV drivers. In addition, (McCartt et al., 2000) found that sleep apnea was predictive of self-reported excessive daytime sleepiness.

In terms of comorbidities, contrary to previous work by Wiegand et al. (2017), Thiese et al. (2017) found that having three or more medical conditions was not related to crashes. The authors suggest more investigations into specific comorbidities, as specific diseases do increase crash risk. For example, although diabetes is manageable, the combination of diabetes with obesity and depression may substantially increase crash risk in CMV drivers (ECRI Institute, 2008). As noted, truck drivers face disproportionately high rates of chronic disease, including obesity, diabetes, cardiovascular disease, hypertension, and sleep apnea. While certain medical conditions are linked to increased crash risk, the severity and symptom history of a condition appear to be more critical factors than the mere presence of the disease itself.

Alcohol and Drugs

The FMCSA has strict rules governing controlled substance use in CMV drivers. Drivers are prohibited from consuming alcohol while on duty, 4 hours prior to on-duty time, and up to 8 hours following a crash. Additionally, FMCSA requires that controlled substances and alcohol tests be given in specific circumstances, including post-crash and randomly. A driver with a blood alcohol concentration of 0.02 to 0.04 is considered alcohol positive and should not drive until 24 hours after the test. The prevalence of intoxicated or drug positive cases for CMV drivers is low. Ichikawa et al. (2023) found that during the 26-year period between 1995 and 2020, truck drivers caused over 1.8 million at-fault crashes, only 0.4% of which crashes involved intoxicated driving. Similarly, Toma et al. (2014) found that alcohol was involved in just over 1% of all CMV drivers of interest and drugs were implicated in less than 1% of all CMV drivers of interest. These extremely low prevalence rates suggest that substance use in CMV drivers is not a major factor in crashes and/or prevalence of drug and alcohol in CMV drivers is misrepresented due to alternative factors. Data from FMCSA (2023a) classifies alcohol, drugs, and medication together. When combining these influences, the percentage of drivers involved in fatal crashes in 2021 with impairment was 2.1% (118 drivers). Although the prevalence rate of alcohol impaired driving is low, Compton and Berning (2015) found a significant association between driver alcohol level and crash risk, as crash risk grows exponentially with increasing breath alcohol content (BrAC). Alcohol levels at 0.05 BrAC increased risk by two times that of sober drivers. BrAC of 0.10 increased the risk five and a half times. Additionally, an extensive

review of the literature by Ackaah et al. (2021) found alcohol use significantly influences truck crash injury severity.

It is important to note that there are several police-reported crash limitations in relation to drug use. Compton and Berning (2015) stress that it is not possible to make inferences about impairment, crash causation or comparisons to alcohol across differing datasets due to variations in testing and reporting. Considering this limitation, only select studies pertaining to drug use are mentioned in this review. Berning and Smither (2014) analyzed drug use across drivers of both light and heavy vehicles. When analysis models were adjusted for age, gender, ethnicity, and alcohol concentration, there was no significant increase found in levels of crash risk associated with the presence of drugs. This finding indicates that these variables were highly correlated with drug use and account for much of the increased risk associated with the use of illegal drugs and with THC. An extensive review by Byrnes (2022) found limited conclusive research and industry guidance about the impacts of prescription and over the counter medication use by CMV drivers. Additionally, many potentially dangerous prescription drugs are not included in the Department of Health and Human Services drug testing panels.

Speeding

Speeding is a leading factor in CMV crashes, contributing to both higher crash risk and increased severity when a collision occurs. Excessive speed reduces a driver's ability to react to hazards, increases stopping distances, and amplifies the impact force in a crash, making it a critical concern in CMV safety. CMVs require significantly longer stopping distances than passenger vehicles, meaning that even small increases in speed can lead to disproportionately higher crash risks (FMCSA, 2017).

Speeding is cited as a contributing factor in a substantial proportion of CMV crashes. According to FMCSA's 2021 crash data, speeding was a factor in 6.5% of fatal large truck crashes and speeding of any kind was the number one most cited driver related factor in fatal crashes (7.0%)—a significant percentage considering the overall number of CMV-involved crashes (FMCSA, 2023a) Speeding was also the leading driver-related factor in fatal crashes for passenger vehicles, except the percentage was much higher, with 18.2% of fatal crashes involving speed. Some studies suggest that this figure may even be an underestimation, as police crash reports do not always capture speed-related contributing factors accurately (Imprialou & Quddus, 2019). In naturalistic driving studies, speeding-related behaviors—such as exceeding posted limits, driving too fast for conditions, and inappropriate acceleration—have been associated with higher crash and near-crash rates (FMCSA, 2007). CMV drivers who habitually speed have also been found to engage in other risky driving behaviors, such as following too closely and aggressive lane changes, further compounding crash risk (Soccolich et al., 2011). The relationship between speed and crash severity is well-documented in the

literature. Higher speeds increase both kinetic energy and impact forces, leading to greater injury severity and higher fatality rates in the event of a crash (Teoh et al., 2017). Crashes occurring at higher speeds are more likely to result in rollovers, underride crashes, and jackknife incidents, all of which have high fatality rates (McKnights & Bahouth, 2008) An FMCSA study (2024), found that in 2022 there were a total of 1,094,979 driver violations, 139,266 (36.7%) of which involved speeding between 1–15+ miles per hour over the speed limit. A study by Shipp et al. (2023) found that when a CMV is traveling 15 mph or more over the speed limit, the likelihood of a fatal crash increases by over 50% compared to a CMV traveling within posted limits. Additionally, the severity of a crash involving a speeding CMV is often greater than that of a speeding passenger vehicle crash due to differences in mass and momentum. Research suggests that even moderate-speed CMV crashes (40–55 mph) often result in higher fatality rates compared to high-speed crashes (70+ mph) involving passenger vehicles (Braver et al., 1996).

Different types of CMV crashes are associated with speeding-related risk factors, including rollovers, rear-end collisions, jackknife crashes, and loss-of-control incidents. Speeding is a primary contributor to rollover crashes, particularly when excessive speed is combined with curves, abrupt lane changes (Adanu et al., 2021), or improperly distributed cargo (FMCSA, 2007). Research indicates that speeding around curves is the leading cause of CMV rollovers, as excessive speed increases centrifugal force, making the vehicle more prone to tipping (Wen et al., 2023). An FMCSA study (2007) found that speeding CMVs were 89% more likely to be the striking vehicle in a rear-end crash compared to CMVs obeying speed limits. Speeding also contributes to loss-of-control crashes, where drivers are unable to stabilize the vehicle after a sudden maneuver, brake application, or traction loss. Loss-of-control crashes are particularly common when speeding occurs in work zones or congested areas, where quick reactions are necessary (National Work Zone Safety Information Clearinghouse, 2022).

Driving History

In 2023, FMCSA reported the demographics of the CMV workforce (FMCSA, 2023d). The majority of truck drivers (74%) were between the ages of 36 and 65, older than the average for the US labor force. Age and driving experience were considered factors in many reviewed studies and reports. In general, it is clear that large truck safety levels were observed to improve with increased age and experience until over the age of 65; however, age and experience play different roles depending on the topic of discussion (Mahajan et al., 2019b).

FMCSA (2023a) 2021 data showed that of the 5,634 drivers of large trucks involved in fatal crashes in 2021, 417 (7%) were 25 or younger, and 419 (7%) were 66 or older. In comparison, none of the 204 bus drivers in fatal crashes were 25 or younger, and 30 (15%) were 66 or older. These et al. (2015) found age and experience to be predictors of CMV crashes as well. These

and other authors determined that age also plays a role in several other factors related to CMV crashes. Age was found as a factor in fatigue, impact of medical conditions, substance abuse, and likelihood that a crash leads to a fatality for the driver (Rosso et al., 2016; FMCSA, 2018 ; Thiese et al., 2015; Compton & Berning, 2015; FMCSA, 2007).

Crash characteristics also differ between younger and older drivers. The US General Accounting Office (2003) reported that younger drivers are the most likely to be involved in a speed-related fatality and that the incidence of speeding drivers in fatal crashes decreases with age. Additionally, across all vehicle types, more drivers aged 16 to 20 were found to be inattentive than any other age group. In terms of crash types, Toma et al. (2014) found higher rates of involvement by younger drivers in drifting/same direction, rear-end/lead vehicle accelerating, and rear-end/lead vehicle moving pre-crash scenarios as compared to other scenarios. For older drivers, higher rates of involvement showed up in opposite direction/maneuver, rear-end/striking maneuver, and left-turn across path/opposite direction at non signal (non-left-turning) pre-crash scenarios as compared to other scenarios. Based on the importance of age, it makes sense that Mejza et al. (2003) found that 59% of high-safety fleets and nearly 66% of large fleets considered age 25+ to be an important or very important selection factor in driver employee hiring decisions.

However, several studies assert that the crash differences between younger and older drivers are related to experience as opposed to age. Giroto et al. (2016) showed an evident relationship between longer professional driving experience and a reduction in reporting involvement in crashes and near crashes, regardless of age, substance use, working conditions, and behavior in traffic. Hickman et al. (2011) indicated that no-fault SCE, at-fault SCE, near-crash, and crash-relevant conflict rates did not differ significantly between the younger, older, and oldest CMV driver groups. Wang et al. (2021) support this argument, indicating that drivers with less than 3 years of truck driving experience are more likely to be involved in a crash than those with more than 15 years of driving experience. Dunn et al. (2020) showed results that drivers over the age of 55 with less than 1 year of CMV driving experience had higher crash rates and odds of being involved in a crash than their younger, inexperienced counterparts. These authors assert that, generally speaking, the first year of CMV driving is riskier in terms of crash rates, crash involvement, and moving violations, regardless of age. Results from Zheng et al. (2018) affirm this, showing that newly registered drivers were found to have a higher risk of being involved in a truck crash, regardless of age.

A study by Knipling et al. (2004) introduced the idea of high-risk CMV drivers, proposing that the worst 10% of drivers were responsible for over 50% of fleet crashes. This principle has been reinforced by more recent studies. For instance, research by Soccolich et al. (2011) analyzing naturalistic driving data found that a small subset of drivers, representing only 7.1% of total

VMT, accounted for 50.3% of SCEs. These findings underscore the significance of driver history as a predictor of crash risk and suggest that focusing on previous violations and crash involvement could improve safety interventions.

Murray et al. (2005) further supported this, reporting that drivers with a prior crash were 87% more likely to have a future crash. This suggests that crash involvement may be indicative of an underlying risk profile that persists over time. An updated study by Murray et al. (2022) found that specific prior violations significantly increased the likelihood of future crashes. For example, drivers convicted of failing to obey traffic signals were 23.7% more likely to be involved in a future crash. Additionally, the Commercial Vehicle Safety Alliance (2006) highlights that certain driver violations are strongly correlated with increased crash risk; for example, convictions for following too closely and failure to yield the right of way are associated with higher likelihood of future crashes. Another possible indicator of high-risk drivers is seat belt use. Hickman et al. (2015) showed that drivers who do not wear seatbelts are more likely to engage in behaviors such as speeding and aggressive driving.

More broadly, Hickman et al. (2020) showed that any prior moving violation convictions in the last 3 years were associated with increased crash and future moving violation risk. In contrast to focusing on demographic factors such as age or years of experience, some researchers argue that crash history and moving violation records are more reliable indicators of future safety performance. A study by the California Department of Motor Vehicles (2017) concluded that driver history data, including prior violations and crashes, were significant predictors of future crash involvement, whereas demographic factors had a less pronounced effect.

Vehicle-related factors

Vehicle-related factors were coded for 4% of the large trucks involved in fatal crashes and 2% of the passenger vehicles involved in fatal crashes in an FMCSA report (2023a). "Tires" and "Brake System" were the most common vehicle-related factors for large trucks in fatal crashes, at approximately 1% each. "Tires" was the most frequently coded vehicle-related factor for passenger vehicles in fatal crashes, at approximately 1% (FMCSA, 2023a). The physical characteristics of CMVs, including their size, configuration, and age, play a substantial role in crash dynamics as well. Larger and heavier trucks typically have longer stopping distances, which may increase their crash risk in time-critical situations. Additionally, different truck configurations (e.g., articulated trucks, straight trucks) have different maneuverability profiles, which may influence crash outcomes.

Configuration

There are various configurations of CMVs which impact the maneuverability of the vehicle, subsequently impacting the driver's experience. Singles (truck tractors pulling a single semi-trailer) accounted for 54% of the large trucks involved in fatal crashes according to FMCSA data (2023a). However, Klena et al. (2011) found only a slight difference between straight truck and tractor/trailer configuration relative to fatal injury levels. The FMCSA (2000) also suggests that configurations affect performance in a CMV, though that source provides no analysis of crash risk. The Multimodal Transportation and Infrastructure Consortium (2009) showed a 13% higher crash severity for double-trailer configurations than for single-trailer configurations, though it is unclear whether configuration also impacts crash risk. Carson (2007), in a review commissioned by Texas, summarized historical papers from the 1980s and 1990s, finding higher crash rates for two-axle trucks, local service activities, and tanker and flatbed trailers; however, more recent studies have not been conducted to confirm this relationship. The researchers conducted an analysis of CMV crashes in Texas and found that single-unit, three-axle, and bobtail vehicle configurations increased the severity of a crash.

Size and Weight

While the size and weight of CMVs inherently contribute to the severity of crashes (Milton et al., 2008; Qin et al., 2013; Stein and Jones, 1988; Teoh et al., 2017), the direct correlation between these factors and overall crash risk is still not fully understood. FMCSA data from 2021 (FMCSA, 2023a) indicates the majority of fatal crashes, injuries, and towaway crashes involved a class 8 CMV with a GVWR greater than 33,000 lb., though it remains unclear exactly what role weight plays in the crashes. Moonesinghe et al. (2003) suggest that the heavier the truck and cargo, the more prone the truck is to rollover, but speed, cargo shift, weather, and road curvature were confounding factors in the analysis. A study by the NIH conducted by the Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health and others (2016) discusses the complexities of higher weight vehicles being related to longer stopping distances, difficulty in making quick maneuvers, and a higher center of gravity. To address these factors, drivers with a CDL are trained specifically on these topics and FMCSA encourages the dissemination of this information to other road users who may not be aware (FMCSA, 2016). A paper by Calabrese et al. (2017) asserts that instead of focusing on overall weight and size as a predictor in crash risk, weight distribution and predictability of the load may be better indicators of crash risk.

Model Year of the Truck

Although light-vehicle research has shown an increase in the probability of a fatal crash given an increase in vehicle age and earlier model year (NHTSA, 2013), few studies discuss the same

impacts for CMVs. One study in Greece (Christoforou & Wolff, 2010) suggests that older vehicles have a 4.5 times higher crash involvement probability in comparison with newer vehicles, and that crashes involving older vehicles have a four times higher probability of resulting in a fatality. Another study investigating high risk drivers noted vehicle age as a factor, though the effects are somewhat unintuitive (Yuan, et al., 2021). The study shows that drivers in the average and safe groups were less likely to be involved in a crash when the vehicle's age was less than 5 years. If the vehicle's age was between 5 and 10 years, there was a decrease in crash severities only in the safe group. This suggests that vehicle age does not have an understood impact on crash severity or prevalence across drivers.

Cargo Characteristics

The type of cargo transported by CMVs may be associated with crash severity and crash risk. Carson (2007) conducted an analysis of CMV crashes in Texas and found that tank cargo types and grain/feed/hay cargo types increased crash severity. Mobile homes, livestock, and beverage cargo types had a decreased severity of crash in Texas. The FMCSA provides regulations mandating cargo securement to prevent shifting or falling during transit, while commodities in bulk that lack structure or fixed shape such as grain, liquid, sand, and gravel are exempt from these securement rules when transported in tankers or hopper-type cargo bays. The impact of this difference has not been considered in research; however, it may have an impact on crash risk considering the results from the Texas study. Liquid cargo types may have additional safety concerns. Feng et al. (2021) point out that liquid tank trucks are often only partially filled due to weight regulations, which allows liquid sloshing that can unpredictably shift the center of gravity of the truck. In 2021, cargo shift was cited as the first harmful event in 3,000 PDO crashes, 1,000 injury crashes, and 8 fatal crashes (FMCSA, 2023a). However, it is unknown what type of cargo shifted in these events. Calabrese et al. (2017) found that the dynamic qualities of tank-style cargo may contribute to poor directional control and overcompensation found in rollover crashes.

Other cargo considerations are vehicles carrying hazardous materials, also referred to as hazmat. In 2022, 548 of 3,244 crashes involving large trucks with hazmat placards involved a cargo release, and in 346 crashes it was unknown whether the cargo was released. Together, gasoline, other flammable liquids, and corrosives accounted for 57% of serious incidents according to the Research and Special Programs Administration (2003), a subagency of the United States Department of Transportation (U.S. Department of Transportation). Ray et al. (2008) found that 1/3 of truck fires originated in the cargo area. Pearlman and Meltzer (2012) found that CMV fires are most common among GVWR Class 8 trucks, with the frequency of truck fire fatalities six times greater than that of other motor vehicles. Additionally, this study indicates that truck fires occur more often in the days following a crash, that trucks with

compliance issues are much more susceptible to fires, and that the truck is the striking vehicle in most fatal fires.

Carrier-related Factors

Of the 178,931 crashes involving a large truck in 2022, 124,994 were known interstate and 24,173 were known intrastate carriers (29,764 were either unknown or did not have a department of transportation number). Research conducted by the Texas Transportation Institute (Carson, 2007) completed an analysis of CMV crashes in Texas and found that carrier's home state had a significant impact on crash severity for two states with interstate routes in Texas. Carriers being physically based in Arizona and Oklahoma decreased crash severity and carriers being physically based in Illinois increased crash severity. Although the analysis did not look at interstate versus intrastate carriers, it suggests that other factors may contribute to crash severity amongst interstate carriers.

When assessing firms of different sizes across all drivers, Cantor (2015) found that larger firms were involved in fewer driver and vehicle out-of-service violations than smaller firms, yet as firm size increases, crash rates increase until a certain level. This study also found an inverse relationship between firm size and HOS, vehicle maintenance, and seven BASIC measure scores. Another interesting finding was that as fleet ownership by the firm percentage increased, safety performance decreased. However, no recent studies were found to support these findings, so further research is needed.

Klauer et al. (2006) considered the extent to which large truck crashes can be linked to turnover. Researchers found that drivers with frequent job changes (i.e., three or more different carriers per year for 2 years or more) were more than twice as likely to be involved in a crash as an at-fault driver with less frequent job changes. It is uncertain whether job changes increase a driver's risk, or whether poor driving results in dismissal or other management actions resulting in job changes. Camden et al. (2020) furthered this result, finding that, overall, drivers who had continuous employment were significantly less likely to be involved in a future FMCSA-reportable crash or receive a violation compared to drivers who left the carrier at any time. Furthermore, drivers who left the carrier without a recent crash were significantly less likely to be involved in an FMCSA-reportable injury crash compared to drivers who left the carrier following a recent crash. Several studies also discuss the impact of driver compensation on safety performance (Rodríguez et al., 2004; Rodríguez et al., 2003; Rodríguez et al., 2006; Williams & Monaco, 2001; Nafukho et al., 2007); however, these results are largely based on self-report measures and are difficult to assess with police-reported data. In general, it is believed that increases in compensation improve drivers' safety performance. Similar results were found for carriers in Australia (Soro et al., 2020).

Environment-related Factors

Environmental factors may play a significant role in CMV crash risk, severity, and prevalence. Research suggests that elements such as roadway design, traffic characteristics, weather conditions, and lighting could influence crash outcomes. However, the extent of their impact likely depends on various interacting factors, including driver behavior, vehicle condition, and traffic conditions.

Roadway Factors

The geographic setting of a roadway—whether rural or urban—has been shown to influence CMV crash risk. FMCSA data from 2021 indicates that 54% of fatal CMV crashes occurred in rural areas, of which 26% took place on interstate highways. Additionally, 12% of fatal crashes occurred on rural interstates, suggesting that rural roadways experience a disproportionate share of CMV-related fatalities (FMCSA, 2023a). One explanation for this trend is that rural roads often lack key safety infrastructure, such as divided highways, lighting, and access to immediate emergency medical care. A report by the Governors Highway Safety Association (2022) found that crashes on rural roads were more likely to be severe due to higher average travel speeds, fewer safety barriers, and longer emergency response times. Additionally, the study found that seat belt use is often lower in rural crashes, contributing to increased fatality risk. Conversely, urban CMV crashes analyzed were more frequently PDO crashes due to congested traffic conditions and lower speeds. Rear-end crashes, intersection collisions, and sideswipe crashes are more prevalent in urban environments where frequent stopping, merging and lane changes increase risk (Zhao et al., 2018).

Roadway access design also influences CMV crash risk. High-access roadways such as commercial corridors with numerous intersections, driveways, and entry points, have been associated with higher crash rates due to increased traffic conflicts (Flintsch et al., 2021). One study found that adding an additional access point per kilometer increased crash rates by 1.5% on two-lane roads (Layton, 2022). Conversely, limited-access highways and interstates generally exhibit lower CMV crash rates due to controlled entry points and consistent traffic flow. However, when crashes do occur on high-speed interstates, they are often more severe due to the physics of high-speed CMV collisions. Aarts and van Schagen (2006) found that fatal/severe crashes tend to occur on trafficways that are divided without a barrier or non-divided. Additionally, when traffic is non-divided, injury severity increases.

Some studies suggest that roadway geometry and infrastructure could also be associated with crash risk, particularly in relation to roadway curvature and grade for rollovers and loss of control crashes. One study found that medium-radius curves with moderate slopes significantly increase crash severity compared to high-radius, flat-slope roadways (Wen et al., 2023).

Additionally, steep downgrades amplify the impact of vehicle weight, making braking and maneuvering more challenging for CMVs (Alrejjal & Ksaibati, 2022). A case study in Norway found that access ramps with sharp curves immediately before acceleration zones led to increased rollover rates, as drivers often misjudged appropriate speeds (Granlund et al., 2016). The same study found that the tightest curvature of some access ramps occurs right before the start of the acceleration field. Bill et al. (2011) found that negotiating a curve was highly correlated with crash risk. Several studies confirm the finding that horizontal and vertical roadway curvature increases crash risk and injury severity significantly. (Anderson & Hernandez, 2017; Saha et al., 2018). One reason for this may be related to truck dynamics and speed. Chen et al. (2022) modeled that complying with the assigned speed limits of curved and sloped roadways is not enough to navigate a curve in a heavy truck without experiencing a rollover under some circumstances. Steeper downgrades amplify the impact of the gross weight of a truck and tighter curves raise the significance in differences between truck configurations.

The presence and condition of road shoulders can also impact CMV crashes. Some studies indicate that narrow or poorly maintained shoulders increase the risk of rollovers, particularly when drivers attempt to recover from a lane departure (Azimi et al., 2020). A safety analysis of rural low-volume roads found that CMV crashes occurred more frequently at locations with narrow lanes and limited shoulder space while presence of fixed objects increased crash severity (Souleyrette et al., 2010; Sperry et al., 2008) An extensive review by Al-Kaisy et al. (2015) confirmed findings that several factors contribute varying risk to CMV drivers, including fixed roadside features, drop-off, lane width, and shoulder width.

Work zones present unique safety challenges for CMV drivers due to lane restrictions, abrupt speed limit changes, and unpredictable traffic patterns. In 2021, CMVs were involved in 33% of all fatal work zone crashes and 15% of work zone injury crashes (FMCSA, 2023a). Studies suggest that narrow lane configurations, temporary barriers, and poorly marked detours increase the likelihood of CMV crashes in work zones. Additionally, lane reductions and sudden slowdowns at work zones have been linked to rear-end crashes, particularly when passenger vehicles make unexpected stops in front of heavy trucks (Chen et al., 2016).

Other Environmental Factors

Adverse weather conditions significantly impact roadway friction, visibility, and vehicle handling, making CMV crashes more likely. Approximately 70% of weather-related crashes occur on wet pavement, and 46% take place during rainfall (FHWA, 2024). Snow and ice conditions are frequently associated with loss of control crashes such as jackknife crashes and rollovers, particularly on roadways with steep grades or tight curves (Chen et al., 2016). Studies examining the relationship between weather conditions and CMV crash risk have found that rain and wet pavement increase braking distances, reducing driver reaction time and increasing crash

likelihood (Hernandez et al., 2020); fog significantly impacts injury severity, with reduced visibility leading to chain-reaction crashes in low-speed environments (Abdel-Aty et al., 2010); and high winds can lead to vehicle destabilization, loss of control, and therefore is associated with slightly increased crash risk when considering large wind gusts as opposed to consistent speed (Rossetti & Johnsen, 2011).

Lighting conditions, whether daytime, nighttime, or transitional periods, have been linked to CMV crash frequency and severity. Studies indicate that 37% of fatal CMV crashes, 24% of injury crashes, and 21% of PDO crashes occurred between the hours of 6:00 p.m. and 6:00 a.m. (FMCSA, 2023a). Uttley and Fotios (2017) support this finding by showing that CMV crashes occurring in dark, unlit conditions are more likely to be fatal than those occurring during daylight. Additionally, headlight glare from oncoming traffic may contribute to momentary vision impairment, increasing crash risk on two-lane roads (Sepulveda et al., 2022).

CMV crashes rarely occur due to a single environmental factor; rather, multiple risk elements often interact. For example, nighttime crashes on rural roads with poor visibility and inclement weather have the highest fatality risk (Safari et al., 2024). Additionally, traffic density is shown to impact the prevalence of crashes across severity types when considering time of day and number of lanes as a factor (Kim et al., 2024).

Available Countermeasures

CMV safety remains a critical concern for transportation agencies. CMV safety requires a multifaceted approach to mitigate risks and enhance roadway safety. This section outlines a set of countermeasures categorized by intervention type. The literature supports claims linking these countermeasures to reduction in both CMV crash risk and severity and the safety of other road users. The following sections explore evidence-based countermeasures that have been shown to enhance CMV driver performance and reduce crash severity.

Technology-based Countermeasures

Technological advancements in CMV safety systems can potentially reduce crash risk and severity. Successful adoption of these countermeasures depends on support at multiple levels, including regulatory agencies, transportation departments, fleet operators, and individual drivers (Houser et al., 2007). State transportation agencies play a crucial role in promoting, incentivizing, and facilitating the adoption of proven safety technologies.

Driver Impairment

The use of technologies designed to detect and prevent driver impairment is strongly supported by national and international transportation safety initiatives.

Alcohol Ignition Interlocks: These systems require a driver to pass a breathalyzer test before operating a vehicle, preventing alcohol-impaired driving. The U.S. Department of Transportation (2022) recommends ignition interlocks as an effective engineering control for reducing alcohol-related crashes. Studies indicate that these devices significantly reduce recidivism among previously convicted impaired drivers (Jonah et al., 2009). European regulations have already mandated that new CMVs be equipped to accommodate aftermarket alcohol interlock devices, promoting wider adoption (European Parliament and Council of the European Union, 2019).

Driver Monitoring and Event Data Recorders: In-vehicle event recorders with driver-facing and road-facing cameras have been shown to effectively reduce risky driving behaviors, particularly when coupled with managerial coaching programs (Camden et al., 2015). Studies on effectiveness indicate implementing these systems led to significant reductions in safety-critical events per 10,000 VMT (Hickman et al., 2010). Additionally, Jonah et al. (2009) found event data recorders to be best practice in truck safety due to their role in identifying impaired driving incidents and establishing liability in crash investigations.

Technologies designed to detect drowsiness and inattention, including eye-tracking, steering pattern analysis, and lane deviation detection, are increasingly recognized as critical tools for reducing distraction and drowsy driving crashes. A naturalistic driving study on CMV fatigue found increasing driver attention to the forward roadway plays a significant role in fatigue-related crashes (Blanco et al., 2016). In the European Union, regulations now mandate in-cab driver warnings for drowsiness, distraction, and inattention, as well as event data recorders to track safety violations (European Parliament and Council of the European Union, 2019). The National Roadway Safety Strategy similarly advocates the adoption of advanced impairment detection systems in new vehicles (U.S. Department of Transportation, 2022).

Speeding

Speed management technologies have emerged as highly effective tools in reducing CMV crash risk and severity.

Speed Limiter Devices: Empirical studies confirm that speed limiters significantly reduce the likelihood of speed-related crashes, particularly in highway environments (Hanowski et al., 2012). While some concerns have been raised regarding potential speed differentials between CMVs and passenger vehicles, research suggests that the overall safety benefits of speed limiters significantly outweigh these drawbacks (Jonah et al., 2009).

Collision Avoidance

Adaptive Cruise Control and Automatic Emergency Braking (AEB): These technologies reduce the risk of rear-end collisions by automatically adjusting vehicle speed and applying brakes

when necessary. AEB has been found to prevent a significant percentage of crashes caused by following too closely or due to driver inattention (Roberts & Lynn, 2003; Thiffault, 2011).

Lane Departure Warning and Blind Spot Monitoring: Lane departure warning systems mitigate roadway departure crashes, while blind-spot monitoring reduces the risk of sideswipe and lane-change collisions. Studies indicate that trucks equipped with blind-spot monitoring experience fewer lane-change crashes, particularly in urban environments (Thiffault, 2011). Research in Sweden found that front-blind spot warning systems significantly reduce fatal pedestrian and cyclist crashes caused by CMV front-end impacts (Willstrand et al., 2024).

Underride Prevention Technologies: Side and rear underride guards are designed to reduce fatality risk in crashes involving passenger vehicles striking CMVs. Research suggests that stronger underride guards and improved rear-lighting systems can significantly reduce the severity of these incidents (Roberts & Lynn, 2003).

Intersection Collision Avoidance Systems: These systems assist in preventing intersection crashes, particularly those involving unseen pedestrians or small vehicles. Advanced intersection collision avoidance technology has shown promise in mitigating urban CMV crashes (Thiffault, 2011).

Other Technology

Additional innovations have been proposed, but their effectiveness is less documented.

Emergency Response Notification Systems: Technologies that automatically alert emergency responders in the event of a crash may help reduce fatalities by improving response times (U.S. Department of Transportation, 2022).

Tire Under-inflation Warning Systems: Tire blowouts are a leading cause of CMV crashes, and under-inflation detection systems have the potential to reduce these incidents by providing real-time alerts (Jonah et al., 2009).

Automated License and Driver Credential Verification: In-vehicle technology that allows law enforcement to remotely verify driver credentials and vehicle compliance status could improve enforcement efficiency and reduce unsafe drivers on the road (U.S. Department of Transportation, 2022).

Rear-Lighting and Radar Warning Systems: Technologies designed to increase rear conspicuity and warn approaching passenger vehicles of stationary CMVs could help mitigate high-severity rear-end crashes (Roberts & Lynn, 2003).

Enforcement

Enforcement is recognized as a critical component of traffic safety initiatives, particularly in regulating CMV driver behavior and ensuring compliance with vehicle safety standards. An extensive body of literature demonstrates the effectiveness of high-visibility law enforcement in reducing risky driving behaviors, increasing compliance with traffic safety laws, and ultimately decreasing CMV crash risk across all severities (Thiffault, 2011; Hans et al., 2014; Dougherty et al., 1999; Fontaine et al., 2009). While traditional enforcement efforts are effective, several suggestions within the literature aim to maximize impact and efficiency.

Targeted Enforcement

Data-driven enforcement strategies, which allocate resources based on crash analysis, have been increasingly recognized as an effective means of reducing CMV crashes.

Time-of-Day and Seasonal Targeting: Wyoming crash analysis found that law enforcement should prioritize speed-related citations, particularly during winter months and overnight hours (11:00 p.m.–7:00 a.m.), when crash risk is highest (Saha et al., 2018). Similar studies in rural, mountainous states have concluded that enforcement should be concentrated in high-risk corridors identified through crash data analysis (Alrejjal et al., 2021; Hans et al., 2014; Dougherty et al., 1999).

Targeting High-Risk Offenders: Evidence suggests that repeat offenders, DUI violators, and HOS violators pose an elevated crash risk. Several studies recommend stricter enforcement for these drivers and repeat-offender tracking systems to ensure compliance and prevent high-risk drivers from returning to service without corrective action (Alrejjal et al., 2021; Hans et al., 2014).

Targeted Inspections

Roadside inspections ensure that both drivers and vehicles meet safety regulations. While some research supports increasing the overall number of roadside inspections, other studies highlight the need for a more targeted and efficient approach (Hans et al., 2014).

Prioritizing Driver-Related Inspections: Research by Craft (2008) argues that inspections have historically focused too heavily on vehicle-related factors, despite driver-related errors being the leading contributor to CMV crashes. Craft suggests that enforcement personnel shift their focus toward evaluating driver fitness, including signs of fatigue, impairment, and distraction, which are stronger predictors of crash involvement than many vehicle-related issues (Craft, 2008). Training law enforcement and roadside inspectors to detect observable signs of driver impairment, including fatigue, distraction, or drug/alcohol use, has been proposed as a best practice for crash reduction (Thiffault, 2011).

Focusing on High-Risk Vehicle Defects: Among vehicle-related deficiencies, tire and brake failures are among the most frequent mechanical contributors to CMV crashes. As a result, one study suggests prioritizing critical systems rather than dispersing efforts across minor regulatory infractions (Craft, 2008).

Infrastructure Countermeasures

An overwhelming body of literature indicates that roadway-related factors influence crash risk and severity across multiple dimensions, including driver behavior, vehicle dynamics, and environmental conditions. A multifaceted infrastructure approach integrates cost-effective, high-impact interventions alongside more resource-intensive long-term solutions. Proven roadway interventions, supported by empirical research, that have demonstrated effectiveness in reducing CMV crashes are discussed.

General Roadway Considerations

Rumble Strips and Paved Shoulders: Studies indicate that centerline and edge rumble strips effectively prevent lane departures and run-off-road crashes, particularly for fatigued and distracted drivers (Roberts & Lynn, 2003; Smiley, 2008; AASHTO, 2010). Research in Iowa, Michigan, and Idaho has demonstrated that shoulder rumble strips can reduce single-vehicle CMV crashes by 29% to 49% (Abdel-Rahim & Khan, 2012; Datta et al., 2012).

Reflective Object Markers and High-Visibility Roadway Elements: Increasing the conspicuity of roadside objects can mitigate fixed-object collisions, which disproportionately impact CMVs due to their longer stopping distances (Gan et al., 2005).

Enhanced Pavement Markings: Maintaining high-visibility lane markings, particularly on rural highways and high-speed corridors, has been shown to reduce lane drift and improve driver navigation in low-visibility conditions (Davis, 2015; Knodler, 2008).

Fixed Object Removal: The presence of trees, utility poles, or unprotected embankments near the roadway increases crash severity. Removing these hazards where possible or installing breakaway safety barriers significantly reduces injury severity in the event of a collision (Gan et al., 2005; FHWA, 2011).

Curved Roadway Considerations

Given the high fatality rate associated with CMV rollovers, particularly on curved and graded roadways, targeted interventions have been proven to reduce both frequency and severity of these crashes.

Enhanced Curve Conspicuity: Installing flashing beacons for sharp curves, post-mounted delineators, and horizontal alignment signs with advisory speeds has been found to reduce CMV crashes on curved roadways (Gan et al., 2005; McGee & Hanscom, 2006; AASHTO, 2010).

Superelevation and Curve Geometry Adjustments: Studies show that many truck rollovers occur despite compliance with posted speed limits, suggesting that current curve banking designs may not fully accommodate CMV dynamics (Chen et al., 2021). Modifications to superelevation and curve radius have been successfully implemented in European freight corridors, reducing rollover crashes by 35% (Chen et al., 2024).

Message Signs

Providing real-time, dynamic information to CMV drivers has been recognized as a critical factor in preventing crashes related to environmental conditions, congestion, and route hazards. Various intelligent transportation system-based countermeasures have demonstrated strong safety benefits in mitigating CMV crash risk.

Dynamic Message Signs and Weather Alerts: Advanced real-time digital message boards have been deployed to warn CMV drivers about adverse weather, traffic congestion, and work zone hazards. Empirical studies have shown that weather-related warnings, particularly for high-wind corridors and icy conditions, significantly reduce speed-related loss-of-control crashes (Russell & Rys, 2009).

Queue Warning Systems for Traffic Congestion: CMVs require longer stopping distances, making sudden slowdowns on high-speed roadways particularly dangerous. Deploying queue warning systems that alert drivers to downstream congestion has been found to reduce rear-end CMV crashes by up to 42% (Walton et al., 2001).

Truck Parking Availability Systems: Insufficient truck parking forces CMV drivers to stop on highway shoulders or continue driving beyond safe limits, increasing fatigue-related crashes and rear-end crashes. Dynamic parking availability signs and integrated GPS parking guidance systems have been piloted in Idaho and Wyoming, leading to a 25% reduction in shoulder-parked trucks and improved compliance with HOS regulations (Thiffault, 2011).

Infrastructure Investments

While many countermeasures focus on incremental improvements, some larger-scale infrastructure investments have shown significant long-term benefits in reducing high-severity CMV crashes.

Cable Median Barriers: While beam guardrails provide higher protection from cross-traffic CMV crashes, cable median barriers offer a more cost-effective solution while reducing injury severity for striking vehicles (Jonah et al., 2009; Ahmed et al., 2024).

Truck-Specific Lane Divisions and Speed Management: Creating truck-only lanes or designating lower truck speed limits in high-risk areas has proven effective in reducing crash frequency. Germany's autobahn system uses enforced CMV-specific lane restrictions, which have led to a 27% decrease in truck-related collisions on divided highways (European Transport Safety Council, 2021).

Safety Edge Treatments: Vertical drop-offs at the pavement edge have been identified as a significant contributor to CMV roadway departure crashes. Safety Edge pavement transitions, which create a gradual slope at the pavement boundary, have been successfully implemented in Florida, Texas, and Iowa, reducing roadway departure crashes by up to 32% (FHWA, 2011).

Policy Countermeasures

Truck Lane Restrictions: These types of restrictions have been implemented in various states to improve traffic flow and enhance safety; however, research suggests that blanket restrictions may not always be effective. A Virginia study evaluating truck lane restrictions found that:

Truck lane restrictions should be removed on interstates with three or more lanes and an average annual daily traffic higher than 10,000 vehicles per day per lane, as these restrictions can negatively impact traffic efficiency without yielding significant safety benefits.

Truck climbing lanes should remain in place, as they help mitigate speed disparities between CMVs and passenger vehicles on steep grades.

Restrictions on lower-volume roads should be retained, as truck-specific lane policies can reduce congestion and conflicts in areas where lane-sharing dynamics create higher crash risks (Fontaine et al., 2009).

These findings emphasize the need for data-driven lane restriction policies, ensuring that regulations are tailored to specific roadway conditions rather than applied indiscriminately.

Seatbelt Laws: The implementation of primary seatbelt laws is widely recognized as a fundamental policy measure for reducing crash fatalities and severe injuries. Research consistently shows that states with primary enforcement seatbelt laws—which allow law enforcement officers to stop and cite drivers solely for seatbelt noncompliance—have higher usage rates and lower fatality rates than those with secondary enforcement laws (Kirley et al., 2023).

Graduated Licensing Systems: These licensing systems for new CMV drivers could significantly enhance safety outcomes. A multi-stage licensing approach—similar to those used for teen drivers—would gradually increase driving privileges as new drivers gain experience under controlled conditions; restrict high-risk behaviors, such as nighttime driving and hazardous cargo transport, until a driver demonstrates proficiency in handling a CMV safely; and reduce the crash risk associated with inexperienced drivers, who have been found to disproportionately contribute to CMV-involved crashes (Kirley et al., 2023).

Safety Targets: Establishing measurable safety targets would allow carriers and individual drivers to benchmark performance and implement strategies to improve compliance and reduce crash rates. A structured driver rating system would create a market-based incentive for safety, rewarding responsible drivers while placing additional scrutiny on those with repeat violations. Beyond individual drivers, policies should also focus on encouraging fleet-wide safety improvements.

Education and Outreach

Education and outreach efforts are critical components of a comprehensive CMV safety strategy, helping to increase awareness, improve driver behavior, and reduce crash risk through targeted training and information dissemination. This section synthesizes key educational countermeasures.

Driver distraction and fatigue are commonly cited causes of CMV crashes, with inattention contributing to significant increases in crash risk and severity. Research underscores that CMV drivers who divert their eyes from the road for more than 2 seconds are at a significantly higher risk of being involved in an SCE (Olson et al., 2009). Given the critical nature of visual attention in CMV operation, training programs should focus on eliminating high-risk distractions such as mobile phone use, including texting, GPS manipulation, and hands-free conversations; dispatch communication devices, which should be minimized or eliminated while driving; and in-cab multitasking, including eating, adjusting controls, and using maps.

Gap acceptance training—which teaches CMV drivers to accurately judge safe merging and lane-change distances—is another key educational priority (Thiffault, 2011). Ensuring that drivers understand and implement appropriate following distances and safe decision-making in traffic reduces rear-end and merging collisions, which are common crash types among heavy vehicles.

Fatigue is a leading cause of CMV crashes, often exacerbated by long-haul schedules, irregular sleep patterns, and inadequate rest opportunities. Educational initiatives targeting fatigue management can help drivers recognize the warning signs of drowsiness and develop effective countermeasures. Training programs should teach drivers about the biological necessity of

sleep, the effects of circadian rhythms, and strategies to improve sleep quality (Gander et al., 2005).

Crash data analysis has shown that CMVs are disproportionately involved in crashes on curved roadways and mountainous terrain. The physics of large trucks—including higher center of gravity, increased braking distances, and trailer instability—make them vulnerable to rollovers and loss of control under specific roadway conditions. Training programs should emphasize techniques for navigating curves safely, including reducing speed before entering curves and avoiding braking while turning to minimize the risk of rollovers (Chen et al., 2024). CMV drivers unfamiliar with certain terrains should be educated on the challenges of driving in regions prone to sharp turns, extreme weather, and fluctuating elevation. Targeted outreach should be directed toward out-of-state drivers traveling through high-risk corridors (Zhao et al., 2018). Given that speed-related crashes tend to be more severe due to the higher impact forces involved, educational programs should emphasize the relationship between speed, stopping distance, and crash severity, particularly for large trucks with longer braking distances.

Many CMV-involved crashes result from unsafe interactions between passenger vehicles and large trucks. Research shows that light vehicle drivers often misjudge truck behavior, leading to preventable collisions (Hanowski et al., 2007). Passenger vehicle education should emphasize the dangers of lingering in truck blind spots and how to safely pass large trucks; the extended braking distance of CMVs, discouraging drivers from cutting off trucks or abruptly merging in front of them; safe following distances, emphasizing that tailgating a truck increases crash severity and visibility obstructions; and avoiding aggressive driving behaviors around CMVs, particularly in highway merging situations and congested urban areas.

Future Research & Data Quality

Ensuring the effectiveness of countermeasures for CMV safety requires ongoing research, high-quality data collection, and systematic evaluation of implemented policies and interventions. A deeper understanding of human factors is essential to reducing CMV crash risk through behavioral interventions, training programs, and enforcement policies. National initiatives include researching driver behavior, risk perception, and decision-making processes to develop more effective countermeasures (U.S. Department of Transportation, 2022).

Specific areas for future research include the following:

- Investigating the impact of road design on driver behavior, particularly how road geometries can be engineered to self-enforce speed limits and minimize risky maneuvers (U.S. Department of Transportation, 2022).

- Improving CMV dashboard instrument design to reduce visual clutter and distraction while maintaining critical vehicle operation feedback (Olson et al., 2009).
- Assessing the effects of speed management interventions, such as variable speed limits and dynamic queue warning systems, to determine their long-term impact on crash rates and traffic flow (Cho et al., 2025).
- Evaluating driver training effectiveness, including fatigue management programs, defensive driving courses, and curriculum standardization for new CDL applicants (Jonah et al., 2009).

Data-driven enforcement is one of the most effective tools for reducing CMV crash risk, yet significant improvements are needed in how crash and citation data are collected and utilized. Several studies highlight persistent issues with data reliability, including underreporting of crashes and inconsistencies across states. For example, Mississippi crash data reporting discrepancies reveal that out-of-state plates were reported with greater frequency than in-state plates, and that law enforcement agencies varied in their reporting accuracy, with state police consistently recording more complete crash details than city and county officers (Blower & Matteson, 2010). Furthermore, only 0.9% of truck-trailer combination crashes were reported, despite this configuration accounting for over 30% of unreported crashes, suggesting systematic underreporting of certain CMV crash types.

To address these inconsistencies, research has suggested several improvements:

- Standardizing crash reporting criteria across states to ensure that all CMV crashes meeting a severity threshold are recorded consistently (Blower, 2017).
- Encouraging states to adopt the Model Minimum Uniform Crash Criteria, which would align CMV crash reporting protocols and eliminate discrepancies in data collection.
- Automating crash data collection where feasible, including electronic data transfer between law enforcement and FMCSA databases, which would reduce reporting delays and errors.
- Developing a standardized computer algorithm to extract state crash data and upload it to the Motor Carrier Management Information System, ensuring greater control over the accuracy of crash records.

Implementing these recommendations would greatly improve the reliability of CMV crash data, allowing for more precise analysis of crash risk factors and targeted safety interventions.

Conclusions

This literature review explored key factors influencing CMV crashes, including driver behavior, vehicle characteristics, and environmental conditions. The review also considered countermeasures aimed at reducing crash risk and severity. Based on the comprehensive analysis of existing research, the following key conclusions were drawn about key CMV crash factors and available countermeasures.

Key Factors

- Fatal CMV crashes have increased slightly in recent years, highlighting the need for targeted interventions.
- The size and weight of CMVs contribute to crash severity, disproportionately affecting passenger vehicle occupants.
- Driver behavior is the primary factor in CMV crashes.
 - Fatigue, distraction, impairment, and prior driving violations are significant contributors to crash risk.
 - High-risk drivers account for a disproportionate number of crashes, suggesting that driver history is a strong predictor of future crash involvement.
 - Speeding in CMVs is associated with increased crash frequency and severity, particularly in rollover and loss-of-control crashes.
- Vehicle-related factors affect crash risk and severity.
 - Brake failures and tire issues are the most common vehicle-related causes of CMV crashes.
 - Older vehicles may have a higher likelihood of mechanical failures, but the relationship between vehicle age and crash risk remains unclear.
- Cargo type influences crash dynamics, with hazardous materials, liquid loads, and unstructured cargo posing unique risks.
- Rural roads and highways see a high proportion of fatal CMV crashes due to infrastructure limitations and emergency response delays.
- Roadway geometry, including curves, grades, and narrow shoulders, increases the likelihood of CMV crashes, particularly rollovers.
- Adverse weather conditions such as snow, ice, and high winds elevate crash risk, while nighttime driving is associated with higher crash severity.

Countermeasures

- Technology-based solutions, including automatic emergency braking, lane departure warnings, and speed limiters, have demonstrated effectiveness in reducing crash risk.
- Infrastructure improvements such as rumble strips, enhanced road markings, improved curve signage, and variable speed limits help mitigate crash severity.
- Law enforcement strategies, including high-visibility enforcement and targeted inspections, effectively deter risky driving behaviors.
- Policy interventions such as stricter HOS regulations, truck lane restrictions, and safety incentives for motor carriers can reinforce compliance and improve safety outcomes.
- Education and outreach efforts, targeting both CMV and passenger vehicle drivers, are critical in reducing crash risk through increased awareness of safety best practices.
- Future research and data quality improvements are essential.
 - Enhancing crash data accuracy and consistency is necessary to refine safety strategies and evaluate countermeasure effectiveness.
 - More research is needed on human factors, particularly driver decision-making, fatigue management, and risk perception in various driving conditions.

Overall, the conclusions highlighted in this literature review will aid in directing specific factors to assess when analyzing Idaho crash data while preventing the exclusion of key variables.

Appendix B. Full Analysis Results

All comparisons are presented here in Appendix B, including those that were either insignificant or limited by low observation counts.

Temporal Factors

Model Results: Fatal Crashes

Table B-1. Temporal-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Calendar Year	2015 vs. 2014	1.19	0.52	2.71	1.21	0.51	2.89
	2016 vs. 2014	1.27	0.57	2.82	1.25	0.53	2.91
	2017 vs. 2014	1.62	0.76	3.47	1.43	0.63	3.23
	2018 vs. 2014	1.72	0.81	3.67	1.44	0.64	3.23
	2019 vs. 2014	1.14	0.51	2.58	0.97	0.41	2.29
	2020 vs. 2014	1.69	0.78	3.66	1.15	0.49	2.66
	2021 vs. 2014	1.44	0.66	3.16	0.94	0.40	2.23
	2022 vs. 2014	0.76	0.31	1.84	0.66	0.26	1.65
	2023 vs. 2014	1.58	0.74	3.37	1.27	0.57	2.84
	Season	Spring vs. Winter	1.47	0.95	2.25	1.37	0.93
Summer vs. Winter		1.67*	1.11	2.49	1.68*	1.18	2.39
Fall vs. Winter		1.54*	1.03	2.31	1.50*	1.05	2.14
Day of the Week	Tuesday vs. Monday	1.22	0.70	2.10	1.24	0.69	2.21
	Wednesday vs. Monday	1.20	0.69	2.08	1.04	0.57	1.90
	Thursday vs. Monday	1.26	0.73	2.18	1.20	0.67	2.17
	Friday vs. Monday	1.22	0.70	2.13	1.14	0.63	2.07
	Saturday vs. Monday	2.05*	1.11	3.79	1.85	0.95	3.61
	Sunday vs. Monday	1.59	0.77	3.28	1.55	0.73	3.30

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Time of Day	12:00 a.m.–2:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.99	0.93	4.26	1.95	0.90	4.22
	3:00 a.m.–5:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.78	0.88	3.59	1.58	0.75	3.32
	6:00 a.m.–8:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.15	0.68	1.95	1.13	0.64	1.98
	12:00 p.m.–2:59 p.m. vs. 9:00 a.m.–11:59 a.m.	0.94	0.56	1.58	0.88	0.50	1.55
	3:00 p.m.–5:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.05	0.62	1.76	0.91	0.51	1.62
	6:00 p.m.–8:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.49	0.82	2.72	1.35	0.70	2.58
	9:00 p.m.–11:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.31	0.61	2.85	1.25	0.70	2.26

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-2. Temporal-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Calendar Year	2015 vs. 2014	1.01	0.80	1.28	1.01	0.76	1.34
	2016 vs. 2014	0.92	0.73	1.16	0.88	0.66	1.16
	2017 vs. 2014	0.87	0.69	1.10	0.83	0.63	1.10
	2018 vs. 2014	0.86	0.68	1.09	0.79	0.59	1.04
	2019 vs. 2014	0.79*	0.63	1.00	0.79	0.59	1.03
	2020 vs. 2014	0.71*	0.56	0.91	0.67*	0.51	0.89
	2021 vs. 2014	0.79	0.63	1.00	0.74*	0.56	0.98
	2022 vs. 2014	0.65*	0.51	0.82	0.62*	0.47	0.81
	2023 vs. 2014	0.62*	0.49	0.79	0.60*	0.46	0.79
Season	Spring vs. Winter	1.17*	1.02	1.33	1.20*	1.03	1.39
	Summer vs. Winter	1.24*	1.09	1.40	1.20*	1.04	1.39
	Fall vs. Winter	1.14*	1.01	1.29	1.11	0.97	1.29
Day of the Week	Tuesday vs. Monday	1.01	0.85	1.19	0.96	0.79	1.16

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Wednesday vs. Monday	0.96	0.81	1.14	0.95	0.78	1.15
	Thursday vs. Monday	1.02	0.86	1.21	1.01	0.83	1.23
	Friday vs. Monday	1.06	0.90	1.26	1.07	0.88	1.30
	Saturday vs. Monday	0.97	0.78	1.22	0.94	0.72	1.22
	Sunday vs. Monday	1.11	0.87	1.42	1.06	0.80	1.40
Time of Day	12:00 a.m.–2:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.20	0.88	1.63	1.29	0.93	1.79
	3:00 a.m.–5:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.09	0.83	1.43	1.14	0.85	1.53
	6:00 a.m.–8:59 a.m. vs. 9:00 a.m.–11:59 a.m.	1.10	0.93	1.30	1.08	0.88	1.32
	12:00 p.m.–2:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.12	0.96	1.31	1.16	0.96	1.39
	3:00 p.m.–5:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.21*	1.03	1.43	1.24	1.02	1.50
	6:00 p.m.–8:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.12	0.91	1.38	1.15	0.91	1.47
	9:00 p.m.–11:59 p.m. vs. 9:00 a.m.–11:59 a.m.	1.05	0.86	1.28	1.03	0.77	1.40

* Indicates statistically significant result at alpha = 0.05

Roadway-related Factors

Model Results: Fatal Crashes

Table B-3. Roadway-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Speed Limit	<= 30 MPH vs. 56 - 65 MPH	0.06*	0.02	0.21	0.07*	0.02	0.32
	31 - 45 MPH vs. 56 - 65 MPH	0.34*	0.21	0.54	0.32*	0.19	0.56
	46 - 55 MPH vs. 56 - 65 MPH	0.80	0.54	1.16	0.91	0.61	1.36
	66 - 75 MPH vs. 56 - 65 MPH	0.62	0.33	1.16	0.63	0.33	1.21
	76+ MPH vs. 56 - 65 MPH	0.73	0.46	1.16	0.72	0.43	1.18
Road Surface Condition	Winter Conditions (Ice, Snow, Slush) vs. Dry	0.50*	0.30	0.83	0.56*	0.33	0.95

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Wet (Wet, Water- standing/moving, Oil) vs. Dry	0.86	0.51	1.46	0.88	0.50	1.55
	Particulate (Mud, Dirt, Gravel, Sand) vs. Dry	0.85	0.07	10.61	0.90	0.07	11.37
	Other vs. Dry	3.62	0.27	49.50	-	-	-
Road Surface Type	Concrete vs. Paved (Asphalt)	0.64	0.34	1.22	0.60	0.30	1.20
	Dirt vs. Paved (Asphalt)	0.49	0.04	6.12	-	-	-
	Gravel/Stone vs. Paved (Asphalt)	1.88	0.71	5.00	2.18	0.81	5.84
Roadway Condition	High/Low Shoulder vs. None	1.33	0.65	2.72	1.43	0.70	2.93
	Lane Closed vs. None	0.46	0.06	3.33	0.48	0.07	3.43
	Loose Gravel/Seal Coat vs. None	3.88*	1.18	12.70	2.99	0.70	12.70
	Poor Pavement Markings vs. None	1.46	0.20	10.78	1.83	0.24	13.71
	Ruts/Bumps/Holes vs. None	-	-	-	-	-	-
	Slick Asphalt (Bleeding) vs. None	-	-	-	-	-	-
	Washboard vs. None	3.67	0.48	28.33	-	-	-
Vertical Geometry	Hillcrest vs. Level	0.40	0.04	3.85	0.46	0.05	4.43
	Upgrade/Downgrade vs. Level	1.44*	1.07	1.93	1.47*	1.08	2.01
Horizontal Geometry	Curve vs. Straight	1.68*	1.30	2.17	1.53*	1.16	2.02
Roadway Classification	Interstate vs. Local	1.55	0.79	3.04	1.27	0.61	2.68
	Major Collector vs. Local	1.53	0.73	3.20	1.37	0.60	3.13
	Minor Arterial vs. Local	1.51	0.73	3.12	1.33	0.58	3.01
	Minor Collector vs. Local	1.18	0.23	6.16	0.83	0.11	6.12
	Principal Arterial (Freeways) vs. Local	2.62*	1.31	5.24	2.09	0.97	4.53
	Principal Arterial (Other) vs. Local	1.85	0.94	3.65	1.70	0.80	3.61
<i>* Indicates statistically significant result at alpha = 0.05</i>							

Model Results: Injury crashes

Table B-4. Roadway-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Speed Limit	<= 30 MPH vs. 56 - 65 MPH	0.34*	0.28	0.41	0.32*	0.25	0.41
	31 - 45 MPH vs. 56 - 65 MPH	0.70*	0.61	0.81	0.66*	0.58	0.75
	46 - 55 MPH vs. 56 - 65 MPH	1.02	0.88	1.17	1.04	0.88	1.22
	66 - 75 MPH vs. 56 - 65 MPH	0.81	0.65	1.00	0.81	0.64	1.02
	76+ MPH vs. 56 - 65 MPH	1.03	0.87	1.22	1.02	0.85	1.23
Road Surface Condition	Winter Conditions (Ice, Snow, Slush) vs. Dry	0.72*	0.63	0.82	0.75*	0.67	0.85
	Wet (Wet, Water- standing/moving, Oil) vs. Dry	1.01	0.85	1.19	1.03	0.85	1.25
	Particulate (Mud, Dirt, Gravel, Sand) vs. Dry	0.90	0.40	2.00	0.85	0.35	2.08
	Other vs. Dry	2.55	0.56	11.65	2.65	0.49	14.24
Road Surface Type	Concrete vs. Paved (Asphalt)	1.56*	1.32	1.84	1.46*	1.26	1.69
	Dirt vs. Paved (Asphalt)	0.92	0.50	1.68	0.96	0.56	1.63
	Gravel/Stone vs. Paved (Asphalt)	0.99	0.71	1.40	0.92	0.55	1.54
Roadway Condition	High/Low Shoulder vs. None	1.18	0.90	1.53	1.11	0.83	1.48
	Lane Closed vs. None	1.21	0.79	1.86	0.92	0.56	1.49
	Loose Gravel/Seal Coat vs. None	1.36	0.68	2.72	1.72	0.78	3.81
	Poor Pavement Markings vs. None	1.10	0.51	2.35	1.42	0.58	3.49
	Ruts/Bumps/Holes vs. None	0.58	0.28	1.20	0.59	0.26	1.36
	Slick Asphalt (Bleeding) vs. None	1.04	0.36	3.01	1.27	0.42	3.81
	Washboard vs. None	1.54	0.49	4.88	0.42	0.49	3.61
Vertical Geometry	Hillcrest vs. Level	1.04	0.66	1.64	1.01	0.60	1.70
	Upgrade/Downgrade vs. Level	1.10	0.99	1.22	1.10	0.98	1.24
Horizontal Geometry	Curve vs. Straight	1.15*	1.05	1.26	1.17*	1.05	1.30
Roadway Classification	Interstate vs. Local	1.83*	1.50	2.23	1.80*	1.41	2.29

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Major Collector vs. Local	1.77*	1.42	2.20	1.67*	1.27	2.20
	Minor Arterial vs. Local	1.52*	1.23	1.89	1.51*	1.15	1.99
	Minor Collector vs. Local	1.93*	1.22	3.05	2.01*	1.18	3.44
	Principal Arterial (Freeways) vs. Local	2.32*	1.87	2.88	2.22*	1.70	2.89
	Principal Arterial (Other) vs. Local	1.84*	1.50	2.26	1.85*	1.43	2.39

* Indicates statistically significant result at alpha = 0.05

Environment-related Factors

Model Results: Fatal Crashes

Table B-5. Environment-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Lighting	Dark, Not Lighted vs. Daylight	1.90*	1.35	2.68	1.88*	1.31	2.70
	Dark, Lighted vs. Daylight	0.69	0.35	1.36	0.73	0.29	1.81
	Dawn or Dusk vs. Daylight	1.87*	1.02	3.44	1.98*	1.04	3.80
Weather	Adverse Conditions vs. No Adverse Conditions	1.62*	1.16	2.28	1.51*	1.07	2.15
	Blowing Dust/Sand vs. No Adverse Conditions	1.73	0.42	7.15	1.77	0.43	7.33
	Blowing Snow vs. No Adverse Conditions	0.29*	0.09	0.92	0.32	0.10	1.01
	Fog vs. No Adverse Conditions	1.83	0.93	3.60	1.78	0.87	3.65
	Rain vs. No Adverse Conditions	0.82	0.47	1.43	0.88	0.49	1.58
	Severe Cross Winds vs. No Adverse Conditions	0.74	0.24	2.33	0.78	0.25	2.47
	Sleet/Hail vs. No Adverse Conditions	-	-	-	-	-	-
	Smoke/Smog vs. No Adverse Conditions	0.58	0.08	4.16	0.68	0.09	4.93
	Snow vs. No Adverse Conditions	0.51*	0.30	0.86	0.57*	0.34	0.96

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-6. Environment-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Lighting	Dark, Not Lighted vs. Daylight	1.02	0.90	1.17	1.03	0.89	1.20
	Dark, Lighted vs. Daylight	0.85	0.67	1.06	0.79	0.60	1.03
	Dawn or Dusk vs. Daylight	1.28*	1.01	1.62	1.45*	1.11	1.90
Weather	Adverse Conditions vs. No Adverse Conditions	1.14*	1.04	1.25	1.10	0.99	1.23
	Blowing Dust/Sand vs. No Adverse Conditions	4.77*	2.65	8.58	5.82*	3.03	11.15
	Blowing Snow vs. No Adverse Conditions	0.84	0.68	1.05	0.81	0.63	1.03
	Fog vs. No Adverse Conditions	1.14	0.86	1.52	1.31	0.95	1.79
	Rain vs. No Adverse Conditions	0.99	0.84	1.17	1.00	0.83	1.22
	Severe Cross Winds vs. No Adverse Conditions	1.30	0.95	1.77	1.17	0.83	1.65
	Sleet/Hail vs. No Adverse Conditions	1.17	0.67	2.03	1.44	0.78	2.65
	Smoke/Smog vs. No Adverse Conditions	1.04	0.64	1.71	1.09	0.62	1.92
	Snow vs. No Adverse Conditions	0.72*	0.63	0.83	0.75*	0.64	0.87

* Indicates statistically significant result at alpha = 0.05

Work Zone-related Factors

Model Results: Fatal Crashes

Table B-7. Work zone-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Work Zone Related Crash	No vs. Yes	1.25	0.75	2.08	1.35	0.78	2.32
Work Zone Crash Location	Transition Area vs. Activity Area (Work incident area)	1.97	0.62	6.30	2.11	0.63	7.04
	Advance Warning Area vs. Activity Area (Work incident area)	-	-	-	-	-	-

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Before the First Work Zone Warning Sign vs. Activity Area (Work incident area)	-	-	-	-	-	-
	Termination Area vs. Activity Area (Work incident area)	-	-	-	-	-	-
Work Zone Type	Lane Closure vs. Lane Shift / Crossover	1.14	0.36	3.69	0.95	0.27	3.31
	Intermittent or Moving Work vs. Lane Shift / Crossover	-	-	-	-	-	-
	Other vs. Lane Shift / Crossover	-	-	-	-	-	-
	Work on Shoulder or Median vs. Lane Shift / Crossover	-	-	-	-	-	-
Workers Present	No vs. Yes	2.98*	1.01	8.83	3.36*	1.02	11.06
Officer Present	No vs. Officer Present	-	-	-	-	-	-

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-8. Work zone-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Work Zone Related Crash	No vs. Yes	1.25	0.75	2.08	1.04	0.88	1.24
Work Zone Crash Location	Advance Warning Area vs. Activity Area (Work incident area)	1.26	0.70	2.25	1.59	0.82	3.09
	Before the First Work Zone Warning Sign vs. Activity Area (Work incident area)	2.66*	1.08	6.52	2.93*	1.04	8.23
	Termination Area vs. Activity Area (Work incident area)	0.75	0.24	2.33	0.79	0.24	2.66
	Transition Area vs. Activity Area (Work incident area)	0.67*	0.40	1.11	0.71	0.41	1.22
Work Zone Type	Lane Shift / Crossover vs. Intermittent or Moving Work	1.52	0.71	3.23	1.56	0.66	3.69
	Other vs. Intermittent or Moving Work	1.65	0.56	4.84	2.26	0.63	8.15
	Work on Shoulder or Median vs. Intermittent or Moving Work	1.64	0.79	3.40	1.45	0.63	3.37
	Lane Closure vs. Intermittent or Moving Work	1.46	0.72	2.97	1.51	0.67	3.41
Workers Present	No vs. Yes	2.98*	1.01	8.83	1.10	0.77	1.57
Officer Present	No vs. Officer Present	0.79	0.43	1.47	0.99	0.50	1.96

* Indicates statistically significant result at alpha = 0.05

Vehicle-related Factors

Model Results: Fatal Crashes

Table B-9. Vehicle-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Carrier Type	Interstate vs. Intrastate	0.84	0.64	1.09	0.76*	0.59	0.97
	Other vs. Intrastate	0.31	0.20	0.46	0.19*	0.12	0.32
License Plate State	Out of State vs. Idaho	1.08	0.88	1.34	0.75*	0.63	0.90
Interstate or Intrastate Plate	Interstate vs Intrastate	1.07	0.79	1.45	1.04	0.73	1.49
Cargo Body	Auto Transporter vs. Van/Enclosed Box	0.87	0.21	3.69	0.26	0.03	1.94
	Belly Dump/Hopper vs. Van/Enclosed Box	1.36	0.81	2.26	0.94	0.58	1.52
	Cargo Tank vs. Van/Enclosed Box	1.18	0.62	2.25	0.96	0.54	1.69
	Concrete Mixer vs. Van/Enclosed Box	0.57	0.08	4.28	0.40	0.05	3.03
	Dump vs. Van/Enclosed Box	1.22	0.69	2.15	0.72	0.40	1.31
	Flatbed vs. Van/Enclosed Box	1.17	0.74	1.84	0.95	0.62	1.45
	Garbage/Refuse vs. Van/Enclosed Box	0.92	0.28	3.03	0.52	0.12	2.17
	Intermodal Container Chassis vs. Van/Enclosed Box	0.93	0.33	2.61	1.12	0.49	2.56
	Log vs. Van/Enclosed Box	1.75	0.81	3.74	1.16	0.54	2.46
	Pole Trailer vs. Van/Enclosed Box	0.65	0.04	11.10	0.49	0.03	8.44
Vehicle Insured	No vs. Yes	1.64	0.72	3.74	0.81	0.30	2.19
Trailer Count	1 vs. 0	2.42	0.52	11.34	1.79	0.60	5.39
	2 vs. 0	3.84	0.79	18.74	2.29	0.73	7.22
	3 vs. 0	4.60	0.73	29.08	5.90*	1.68	20.76
	1 vs. 2	0.63*	0.40	0.98	0.39*	0.19	0.79
	1 vs. 3	0.53	0.19	1.49	0.78	0.54	1.14
	2 vs. 3	0.83	0.28	2.51	0.30*	0.16	0.57
	Contributing Circumstance	Brakes Listed vs Brakes Not Listed	2.74*	1.38	5.42	1.41	0.62

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Light Defect	-	-	-	-	-	-
	Other Vehicle Defect	0.52	0.17	1.62	0.22*	0.05	0.87
	Tire Defect	0.46	0.11	1.86	0.16	0.02	1.17
	Truck Coupling, Trailer Hitch, Safety Chains	0.57	0.08	4.11	0.47	0.06	3.38
	Wheel Defect	-	-	-	-	-	-

* Indicates statistically significant result at alpha = 0.05

Table B-10. Freight Types: Logistic Regression Model Results for Fatal and Less Severe CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
General Freight	Yes vs. No	1.07	0.83	1.37	1.11	0.98	1.26
Metal: Sheets, Coils, Rolls	Yes vs. No	1.09	0.79	1.53	1.14	0.98	1.32
Motor Vehicles	Yes vs. No	1.33	0.90	1.95	1.27*	1.08	1.50
Driveaway/Towaway	Yes vs. No	1.11	0.63	1.96	1.04	0.78	1.37
Logs, Poles, Beams, Lumber	Yes vs. No	1.16	0.86	1.55	1.39*	1.22	1.59
Building Materials	Yes vs. No	0.97	0.73	1.29	1.11	0.97	1.27
Mobile Homes	Yes vs. No	0.94	0.23	3.85	0.30	0.07	1.21
Machinery, Large Objects	Yes vs. No	1.08	0.82	1.43	1.24*	1.09	1.41
Fresh Produce	Yes vs. No	1.18	0.90	1.56	1.38*	1.21	1.58
Liquids/Gases	Yes vs. No	1.10	0.77	1.55	1.48*	1.29	1.69
Intermodal Containers	Yes vs. No	0.93	0.60	1.44	1.19*	1.02	1.38
Passengers	Yes vs. No	0.71	0.29	1.74	1.63*	1.34	1.98
Oilfield Equipment	Yes vs. No	0.91	0.45	1.86	0.46*	0.27	0.78
Livestock	Yes vs. No	0.91	0.45	1.86	0.36*	0.21	0.63
Grain, Feed, Hay	Yes vs. No	0.63	0.31	1.28	1.97	1.73	2.24
Coal/Coke	Yes vs. No	0.94	0.38	2.30	0.29*	0.15	0.57

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Meat	Yes vs. No	0.95	0.67	1.34	1.01	0.87	1.17
Garbage, Refuse, Trash	Yes vs. No	1.40	0.77	2.52	0.68*	0.44	1.06
U.S. Mail	Yes vs. No	1.41	0.78	2.55	0.97	0.68	1.38
Chemicals	Yes vs. No	0.96	0.64	1.42	1.20*	1.03	1.40
Commodities Dry Bulk	Yes vs. No	1.07	0.80	1.45	1.83*	1.61	2.07
Refrigerated Food	Yes vs. No	1.01	0.75	1.34	1.07	0.94	1.22
Beverages	Yes vs. No	1.15	0.86	1.54	0.92	0.80	1.05
Paper Products	Yes vs. No	0.98	0.73	1.32	1.25*	1.09	1.42
Utility	Yes vs. No	0.86	0.42	1.76	0.78	0.50	1.22
Farm supplies	Yes vs. No	1.02	0.69	1.49	0.60*	0.47	0.76
Construction	Yes vs. No	1.01	0.74	1.39	0.92	0.78	1.08
Water-well	Yes vs. No	-	-	-	-	-	-
Cargo-Other	Yes vs. No	0.77	0.57	1.05	0.74*	0.64	0.86

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-11. Vehicle-related Factors: Logistic Regression Model Results for Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Carrier Type	Interstate vs. Intrastate	0.94	0.85	1.05	1.05	0.94	1.16
	Other vs. Intrastate	0.80*	0.72	0.90	0.80*	0.71	0.89
License Plate State	Out of State vs. Idaho	1.04	0.97	1.12	1.18	1.09	1.27
Interstate or Intrastate Plate	Interstate vs Intrastate	1.01	0.90	1.13	0.98	0.86	1.11
Cargo Body	Auto Transporter vs. Van/Enclosed Box	1.22	0.78	1.91	2.07	1.37	3.12
	Belly Dump/Hopper vs. Van/Enclosed Box	1.08	0.89	1.32	1.01	0.83	1.22
	Cargo Tank vs. Van/Enclosed Box	0.92	0.72	1.17	0.97	0.77	1.22

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Concrete Mixer vs. Van/Enclosed Box	1.58	0.96	2.61	1.59	0.96	2.64
	Dump vs. Van/Enclosed Box	0.99	0.80	1.22	0.91	0.73	1.13
	Flatbed vs. Van/Enclosed Box	0.87	0.73	1.03	0.84	0.71	1.00
	Garbage/Refuse vs. Van/Enclosed Box	0.88	0.59	1.31	0.83	0.53	1.29
	Intermodal Container Chassis vs. Van/Enclosed Box	0.78	0.54	1.12	0.70	0.48	1.03
	Log vs. Van/Enclosed Box	1.27	0.92	1.74	1.20	0.88	1.65
	Pole Trailer vs. Van/Enclosed Box	0.95	0.43	2.11	1.17	0.52	2.61
Vehicle Insured	No vs. Yes	1.55*	1.12	2.14	2.79*	1.98	3.94
Trailer Count	1 vs. 0	0.96	0.67	1.38	0.81	0.57	1.16
	2 vs. 0	0.92	0.61	1.38	0.82	0.55	1.21
	3 vs. 0	0.76	0.40	1.46	0.54	0.29	1.01
	1 vs. 2	1.21	0.68	2.15	0.99	0.82	1.19
	1 vs. 3	1.04	0.85	1.27	1.49	0.88	2.53
	2 vs. 3	1.26	0.73	2.17	1.51	0.88	2.62
Contributing Circumstance	Brakes Listed vs Brakes Not Listed	1.32	0.92	1.88	1.61*	1.08	2.38
	Light Defect	1.87	0.79	4.41	0.88	0.30	2.53
	Other Vehicle Defect	0.41*	0.28	0.59	0.37*	0.25	0.53
	Tire Defect	0.70*	0.49	1.00	0.56*	0.37	0.85
	Truck Coupling, Trailer Hitch, Safety Chains	0.26*	0.12	0.56	0.30	0.14	0.67
	Wheel Defect	0.66	0.37	1.20	0.64	0.32	1.26

* Indicates statistically significant result at alpha = 0.05

Table B-12. Freight Types: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
General Freight	Yes vs. No	0.99	0.90	1.08	0.93*	0.88	0.99

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Metal: Sheets, Coils, Rolls	Yes vs. No	0.97	0.85	1.10	1.10*	1.03	1.18
Motor Vehicles	Yes vs. No	0.98	0.84	1.16	1.21*	1.12	1.30
Driveaway/Towaway	Yes vs. No	0.92	0.73	1.15	0.93	0.81	1.06
Logs, Poles, Beams, Lumber	Yes vs. No	1.03	0.93	1.16	1.08*	1.02	1.16
Building Materials	Yes vs. No	0.96	0.86	1.06	1.02	0.96	1.08
Mobile Homes	Yes vs. No	0.55*	0.31	0.99	0.15*	0.08	0.28
Machinery, Large Objects	Yes vs. No	0.95	0.86	1.06	1.00	0.94	1.07
Fresh Produce	Yes vs. No	0.95	0.85	1.05	0.96	0.90	1.02
Liquids/Gases	Yes vs. No	0.92	0.80	1.05	1.04	0.97	1.11
Intermodal Containers	Yes vs. No	0.92	0.79	1.08	1.03	0.96	1.10
Passengers	Yes vs. No	1.04	0.78	1.37	1.12*	1.01	1.25
Oilfield Equipment	Yes vs. No	0.96	0.75	1.24	1.08	0.91	1.29
Livestock	Yes vs. No	1.15	0.94	1.42	1.30*	1.10	1.54
Grain, Feed, Hay	Yes vs. No	1.11	1.00	1.24	1.16*	1.09	1.24
Coal/Coke	Yes vs. No	1.16	0.85	1.59	1.04	0.89	1.21
Meat	Yes vs. No	0.88	0.77	1.00	0.97	0.91	1.04
Garbage, Refuse, Trash	Yes vs. No	0.97	0.75	1.25	0.92	0.78	1.08
U.S. Mail	Yes vs. No	0.97	0.75	1.25	1.05	0.88	1.25
Chemicals	Yes vs. No	0.93	0.80	1.08	1.05	0.98	1.13
Commodities Dry Bulk	Yes vs. No	0.98	0.88	1.10	1.09*	1.02	1.15
Refrigerated Food	Yes vs. No	0.99	0.89	1.10	1.00	0.94	1.06
Beverages	Yes vs. No	0.95	0.85	1.07	1.00	0.94	1.06
Paper Products	Yes vs. No	0.94	0.84	1.05	0.95	0.89	1.01
Utility	Yes vs. No	1.07	0.84	1.37	1.13	0.93	1.36
Farm supplies	Yes vs. No	0.93	0.81	1.08	0.96	0.87	1.06
Construction	Yes vs. No	0.93	0.82	1.05	0.83*	0.77	0.90

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Water-well	Yes vs. No	0.67	0.40	1.13	1.31	0.91	1.88
Cargo-Other	Yes vs. No	1.03	0.93	1.15	1.07*	1.00	1.14

* Indicates statistically significant result at alpha = 0.05

Driver-related Factors

Model Results: Fatal Crashes

Table B-13. Driver-related Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Sex	Female vs Male	0.46*	0.25	0.87	0.60	0.31	1.17
State of Driver's License	Idaho vs Out of State	0.88	0.71	1.09	0.98	0.78	1.24
Alcohol or Drug Involvement	Alcohol vs. Neither	6.17*	2.15	17.72	6.57*	2.04	21.21
	Drug vs. Neither	32.74*	12.97	82.66	36.58*	3.32	402.80
	Both vs. Neither	41.39*	3.75	457.22	45.37*	15.30	134.50
Seat Belt Use	Yes, lap, shoulder, or both vs. None	0.22*	0.15	0.30	0.24*	0.16	0.34
Age	Under 21 vs. 21-24	1.09	0.74	1.61	0.76	0.20	2.85
	25-34 vs. 21-24	0.96	0.76	1.21	0.56	0.29	1.10
	35-54 vs. 21-24	0.94	0.75	1.17	0.58	0.32	1.06
	55-64 vs. 21-24	0.96	0.76	1.20	0.60	0.32	1.14
	65-74 vs. 21-24	1.03	0.79	1.35	0.65	0.30	1.39
	75+ vs. 21-24	0.82	0.58	1.16	0.45	0.14	1.13
Contributing Circumstances	Alcohol Impaired	7.14*	2.79	18.33	5.79	2.64	12.69
	Asleep, Drowsy, Fatigued	0.49	0.16	1.53	0.55	0.20	1.50
	Distracted IN or ON Vehicle or Inattention	0.74	0.23	2.34	0.53*	0.36	0.78
	Drove Left of Center	2.85*	1.61	5.06	2.51*	1.55	4.06

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Exceeded Posted Speed	3.80*	1.16	12.51	2.38	0.72	7.91
	Failed to Maintain Lane	0.95	0.67	1.36	0.68*	0.48	0.95
	Failed to Obey Signal	1.37	0.43	4.36	1.52	0.55	4.20
	Failed to Obey Stop Sign	2.02	0.88	4.61	1.47	0.59	3.65
	Failed to Signal	-	-	-	-	-	-
	Failed to Yield	0.53	0.27	1.03	0.51*	0.29	0.91
	Following Too Close	0.27*	0.12	0.60	1.28	0.92	1.79
	Foot Slipped Off or Caught On Pedal	-	-	-	-	-	-
	Improper Backing	-	-	-	-	-	-
	Improper Lane Change	-	-	-	-	-	-
	Improper Overtaking	0.40	0.06	2.89	0.23	0.03	1.65
	Improper Turn	0.06*	0.01	0.40	0.04*	0.01	0.29
	Improper Use of Turn Lane	-	-	-	-	-	-
	Improperly Parked	0.96	0.13	6.99	0.99	0.13	7.30
	Overcorrected	0.76	0.28	2.06	1.52*	1.12	2.08
	Physical Impairment or Sick	0.73	0.10	5.31	0.57	0.08	4.13
	Previous Accident	3.79*	1.82	7.89	7.87*	5.41	11.44
	Too Slow for Traffic	1.54	0.21	11.41	0.65	0.09	4.76
	Vision Obstruction	2.40*	1.36	4.24	4.54*	3.18	6.48
	Wrong Side or Wrong Way	4.38*	1.01	18.97	3.68*	1.07	12.66

* Indicates statistically significant result at alpha = 0.05

Table B-14. Driver Citations (Broad Categories): Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Broad)	Accident Overall vs. Not Cited	-	-	-	-	-	-

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Brakes vs. Not Cited	0.24	0.03	1.69	-	-	-
	Driving vs. Not Cited	0.03*	0.01	0.11	0.02*	0.00	0.11
	DUI vs. Not Cited	6.45*	2.20	18.94	8.21*	2.68	25.14
	Equipment vs. Not Cited	-	-	-	-	-	-
	Insurance vs. Not Cited	-	-	-	-	-	-
	Litter vs. Not Cited	-	-	-	-	-	-
	Register vs. Not Cited	1.03	0.14	7.55	-	-	-
	Safety Restraint/Seat Belt vs. Not Cited	1.51	0.20	11.21	-	-	-
	Speed vs. Not Cited	0.21*	0.05	0.84	0.22*	0.05	0.88
	Turning vs. Not Cited	-	-	-	-	-	-
	Yield vs. Not Cited	0.13*	0.02	0.92	0.16	0.02	1.17

* Indicates statistically significant result at alpha = 0.05

Table B-15. Driver Citations (Specific Categories): Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Specific)	(Accident) Leaving scene – damage vs. Not Cited	-	-	-	-	-	-
	(Accident) Striking fixtures adjacent to highway vs. Not Cited	-	-	-	-	-	-
	(Driver’s license) Driving without privileges vs. Not Cited	0.70	0.09	4.86	0.86	0.12	6.34
	(Driver’s license) Failure to have current and valid vs. Not Cited	-	-	-	-	-	-
	(Driving) Following too close vs. Not Cited	-	-	-	-	-	-
	(Driving) Improper, unsafe backing vs. Not Cited	-	-	-	-	-	-
	(Driving) Inattentive or careless vs. Not Cited	0.06*	0.01	0.42	-	-	-
	(Driving) Left of center on curve or hillcrest vs. Not Cited	-	-	-	-	-	-
	(Driving) Observe & obey traffic control light vs. Not Cited	0.47	0.06	3.37	0.59	0.08	4.31
	(Driving) Reckless vs. Not Cited	-	-	-	-	-	-

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	(Driving) Start- pull out safely	-	-	-	-	-	-
	(Driving) Stop for stop sign vs. Not Cited	-	-	-	-	-	-
	(Insurance) Display to police officer vs. Not Cited	-	-	-	-	-	-
	(Litter) Placing glass, etc. – prohibited vs. Not Cited	-	-	-	-	-	-
	(Speed) Reasonable and prudent – conditions/hazard vs. Not Cited	0.21*	0.05	0.86	0.22*	0.05	0.90
	(Turning) Improper left turn vs. Not Cited	-	-	-	-	-	-
	(Turning) Improper right turn vs. Not Cited	-	-	-	-	-	-
	(Turning) Signal and with reasonable safety vs. Not Cited	-	-	-	-	-	-
	(Yield) From alley, driveway, other vs. Not Cited	0.38	0.05	2.70	0.52	0.07	3.75
	(Yield) From yield sign vs. Not Cited	-	-	-	-	-	-
	(Yield) Intersections vs. Not Cited	-	-	-	-	-	-

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-16. Driver-related Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Sex	Female vs Male	1.15	0.99	1.34	1.23*	1.01	1.48
State of Driver's License	Idaho vs Out of State	0.98	0.91	1.05	0.98	0.90	1.06
Alcohol or Drug Involvement	Alcohol vs. Neither	1.34	0.61	2.93	1.24	0.48	3.21
	Drug vs. Neither	15.11*	2.46	92.67	16.47*	1.29	209.80
	Both vs. Neither	2.28	0.08	68.61	2.20	0.07	66.25
Seat Belt Use	Yes, lap, shoulder, or both vs. None	0.48*	0.40	0.58	0.44*	0.35	0.55
Age	Under 21 vs. 21-24	1.09	0.74	1.61	0.98	0.57	1.70
	25-34 vs. 21-24	0.96	0.76	1.21	0.99	0.74	1.31

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	35-54 vs. 21-24	0.94	0.75	1.17	0.94	0.72	1.23
	55-64 vs. 21-24	0.96	0.76	1.20	0.98	0.74	1.30
	65-74 vs. 21-24	1.03	0.79	1.35	1.08	0.78	1.50
	75+ vs. 21-24	0.82	0.58	1.16	0.84	0.56	1.25
Contributing Circumstances	Alcohol Impaired	1.318	0.65	2.14	1.11	0.55	2.25
	Asleep, Drowsy, Fatigued	1.66*	1.28	2.15	1.46*	1.09	1.95
	Distracted IN or ON Vehicle or Inattention	1.43*	1.28	1.60	1.37*	1.22	1.54
	Drove Left of Center	1.36*	1.00	1.83	1.34	1.00	1.79
	Exceeded Posted Speed	1.67	0.82	3.42	1.37	0.64	2.94
	Failed to Maintain Lane	1.03	0.92	1.17	0.88	0.78	1.00
	Failed to Obey Signal	1.92*	1.26	2.95	1.84*	1.11	3.04
	Failed to Obey Stop Sign	2.43*	1.69	3.48	1.98*	1.30	3.02
	Failed to Signal	-	-	-	-	-	-
	Failed to Yield	1.32*	1.12	1.55	1.17	0.97	1.40
	Following Too Close	1.87*	1.62	2.15	1.82*	1.57	2.12
	Foot Slipped Off or Caught On Pedal	0.64	0.29	1.41	0.32	0.07	1.45
	Improper Backing	0.22*	0.15	0.32	0.18*	0.12	0.30
	Improper Lane Change	0.76	0.62	0.93	0.72*	0.59	0.89
	Improper Overtaking	0.97	0.63	1.49	0.71	0.46	1.09
	Improper Turn	0.33	0.27	0.42	0.33*	0.26	0.42
	Improper Use of Turn Lane	0.35	0.14	0.91	0.35*	0.15	0.84
	Improperly Parked	0.99	0.52	1.92	0.63	0.27	1.50
	Overcorrected	2.12*	1.61	2.79	1.83*	1.34	2.49
	Physical Impairment or Sick	6.04*	3.13	11.01	5.10*	2.59	10.03
	Previous Accident	1.36	0.87	2.12	1.53*	1.06	2.22
	Too Slow for Traffic	1.88	0.85	4.15	1.17	0.58	2.37

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	Vision Obstruction	1.37*	1.04	1.81	1.68*	1.28	2.20
	Wrong Side or Wrong Way	1.43	0.55	3.69	2.74*	1.09	6.85

* Indicates statistically significant result at alpha = 0.05

Table B-17. Driver Citations (Broad Categories): Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Broad)	Accident vs. Not Cited	0.32*	0.18	0.59	0.31*	0.16	0.60
	Driving vs. Not Cited	1.65*	1.50	1.81	1.62*	1.46	1.80
	DUI vs. Not Cited	2.15	0.91	5.09	1.71	0.59	4.96
	Equipment vs. Not Cited	1.43	0.80	2.58	1.33	0.70	2.52
	Insurance vs. Not Cited	1.79*	1.22	2.62	1.74*	1.06	2.86
	License vs. Not Cited	1.71*	1.22	2.42	1.71*	1.12	2.61
	Litter vs. Not Cited	0.61	0.26	1.38	0.81	0.34	1.93
	Register vs. Not Cited	2.18*	1.09	4.39	2.98	1.23	7.21
	Safety Restraint/Seat Belt vs. Not Cited	8.35*	3.07	22.67	7.98	2.19	29.08
	Speed vs. Not Cited	1.44*	1.14	1.82	1.38	1.07	1.79
	Turning vs. Not Cited	0.50*	0.37	0.67	0.53	0.38	0.73
	Yield vs. Not Cited	1.37*	1.06	1.77	1.48	1.08	2.01

* Indicates statistically significant result at alpha = 0.05

Table B-18. Driver Citations (Specific Categories): Logistic Regression Model Results for Injury and PDO CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Driver Citations (Specific)	(Accident) Leaving scene – damage vs. Not Cited	0.37*	0.18	0.79	0.38	0.17	0.84

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
	(Accident) Striking fixtures adjacent to highway vs. Not Cited	0.19*	0.04	0.78	0.22	0.05	0.95
	(Driver's license) Driving without privileges vs. Not Cited	2.03*	1.15	3.57	1.58	0.78	3.18
	(Driver's license) Failure to have current and valid vs. Not Cited	1.65*	1.03	2.64	1.90*	1.07	3.38
	(Driving) Following too close vs. Not Cited	2.05*	1.74	2.42	2.15*	1.76	2.64
	(Driving) Improper, unsafe backing vs. Not Cited	0.29*	0.18	0.47	0.26*	0.13	0.52
	(Driving) Inattentive or careless vs. Not Cited	2.27*	1.91	2.69*	2.21*	1.82	2.67
	(Driving) Left of center on curve or hillcrest vs. Not Cited	2.83*	1.22	6.58	3.95*	1.43	10.91
	(Driving) Observe & obey traffic control light vs. Not Cited	1.66*	1.03	2.69	1.22	0.67	2.23
	(Driving) Reckless vs. Not Cited	2.83*	1.66	4.81	3.70*	1.96	6.98
	(Driving) Start- pull out safely	0.87	0.42	1.81	0.56	0.19	1.69
	(Driving) Stop for stop sign vs. Not Cited	1.79*	1.38	2.31	1.51*	1.09	2.08
	(Insurance) Display to police officer vs. Not Cited	1.78*	1.19	2.67	1.71*	1.00	2.92
	(Litter) Placing glass, etc. – prohibited vs. Not Cited	0.67	0.27	1.64	0.95	0.37	2.46
	(Speed) Reasonable and prudent – conditions/hazard vs. Not Cited	1.44*	1.13	1.82	1.39*	1.07	1.80
	(Turning) Improper left turn vs. Not Cited	0.46*	0.25	0.83	0.41*	0.21	0.80
	(Turning) Improper right turn vs. Not Cited	0.46*	0.25	0.83	0.49*	0.25	0.93
	(Turning) Signal and with reasonable safety vs. Not Cited	0.54*	0.34	0.85	0.60*	0.36	0.99
	(Yield) From alley, driveway, other vs. Not Cited	1.03	0.65	1.63	1.09	0.62	1.94
	(Yield) From yield sign vs. Not Cited	0.98	0.38	2.55	0.93	0.33	2.63
	(Yield) Intersections vs. Not Cited	1.32	0.67	2.61	1.74	0.76	4.00

* Indicates statistically significant result at alpha = 0.05

Other Contributing Factors

Model Results: Fatal Crashes

Table B-19. Other Contributing Factors: Logistic Regression Model Results for Fatal and Less Severe CMV-related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Wild animal related	Yes vs. No	-	-	-	1.88*	1.31	2.70
Youth driver related	Yes vs. No	1.07	0.73	1.58	0.73	0.29	1.81
Stop-controlled intersection related	Yes vs. No	1.06	0.78	1.44	1.98*	1.04	3.80
Bicycle related	Yes vs. No	8.81*	2.54	30.59	1.51*	1.07	2.15
Pedalcycle related	Yes vs. No	8.81*	2.54	30.59	1.77	0.43	7.33
Pedestrian related	Yes vs. No	13.04*	6.41	26.55	0.32	0.10	1.01
Motorcycle related	Yes vs. No	7.48*	3.79	14.75	1.78	0.87	3.65
Intersection related	Yes vs. No	0.69*	0.53	0.89	0.88	0.49	1.58
Fixed object related	Yes vs. No	1.89*	1.48	2.41	0.78	0.25	2.47
Distracted driver related	Yes vs. No	1.12	0.85	1.49	-	-	-
Alcohol related	Yes vs. No	5.97*	3.98	8.94	0.68	0.09	4.93
Impairment related	Yes vs. No	13.79*	10.37	18.35	0.57*	0.34	0.96

* Indicates statistically significant result at alpha = 0.05

Model Results: Injury crashes

Table B-20. Other Contributing Factors: Logistic Regression Model Results for Injury and PDO CMV-Related Crashes

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Wild animal related	Yes vs. No	-	-	-	1.03	0.89	1.20
Youth driver related	Yes vs. No	1.07	0.73	1.58	0.79	0.60	1.03
Stop-controlled intersection related	Yes vs. No	1.06	0.78	1.44	1.45*	1.11	1.90

Factor	Comparison	OR All Veh	LCL All Veh	UCL All Veh	OR 26k+ Veh	LCL 26k+ Veh	UCL 26k+ Veh
Bicycle related	Yes vs. No	8.81*	2.54	30.59	1.10	0.99	1.23
Pedalcycle related	Yes vs. No	8.81*	2.54	30.59	5.82*	3.03	11.15
Pedestrian related	Yes vs. No	13.04*	6.41	26.55	0.81	0.63	1.03
Motorcycle related	Yes vs. No	7.48*	3.79	14.75	1.31	0.95	1.79
Intersection related	Yes vs. No	0.69*	0.53	0.89	1.00	0.83	1.22
Fixed object related	Yes vs. No	1.89*	1.48	2.41	1.17	0.83	1.65
Distracted driver related	Yes vs. No	1.12	0.85	1.49	1.44	0.78	2.65
Alcohol related	Yes vs. No	5.97*	3.98	8.94	1.09	0.62	1.92
Impairment related	Yes vs. No	13.79*	10.37	18.35	0.75*	0.64	0.87
<i>* Indicates statistically significant result at alpha = 0.05</i>							