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Assessing Factors Leading to Commercial Driver Seat Belt Non-Compliance

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EXECUTIVE SUMMARY

In 2017, 5,005 people were killed in traffic crashes involving large trucks or buses; among large truck occupants who were killed in crashes, at least 39% were not wearing a seat belt.[1] While belt use among commercial motor vehicle (CMV) drivers increased from 65% in 2007 to 86% in 2016,[2] there are troubling seat belt usage trends that indicate additional improvement is needed. In 2013, failing to properly wear a seat belt was one of the top five driver violations cited in roadside inspections.[2] Past attempts to study seat belt usage have focused on single aspects of compliance, such as implementing seat belt policies or providing technological countermeasures.[3]

The current research study utilized a literature review and analysis of two data sources to determine situational factors associated with reduced belt use among CMV drivers. The literature review identified characteristics of seat belt use, reasons drivers may or may not use seat belts, methods to improve seat belt use rates, and important gaps in the literature. The data analysis used data collected in two separate studies to assess seat belt use rates and explore the relationship between seat belt use and environmental, roadway, vehicle, and driver factors. The first study collected observational data in 2015 from multiple sites in Michigan with high rates of truck/bus-involved crashes.[4] The second study collected naturalistic driving data during the Federal Motor Carrier Safety Administration's Advanced System Testing Utilizing a Data Acquisition System on Highways (FAST DASH) second Safety Technology Evaluation Project (commonly referred to as FAST DASH 2), which aimed to assess the performance, safety impact, and driver acceptance of an onboard monitoring system.[5] The naturalistic driving data set included safety-critical events (SCEs), which were reduced for driver behaviors and environmental and roadway information.

In the current study, driver seat belt use was observed in 93% of the FAST DASH 2 naturalistic driving SCEs and in 81% of SCEs in the observational data set. The analysis of observational and FAST DASH 2 naturalistic driving study data identified several factors where seat belt use patterns changed significantly across the factor levels; however, the analyses for each data set did not show consistency in statistical significance. In the observational data, fewer drivers used their seat belt on Wednesdays, Fridays, and Saturdays, and drivers were more likely to use their seat belt in the evening (5 p.m. to 7 p.m.) compared to the morning, midday, and afternoon hours. Further, truck drivers were found to use their seat belt less often while driving on a two-lane road compared to driving on single-lane road or road with three or more travel lanes. The observational data revealed a lower propensity for seat belt use among drivers of construction vehicles, specifically concrete mixers and dump truck drivers, compared to most other truck types. Truck type was also significantly associated with seat belt use in the analysis of tractor trailer data. Gravel train truck drivers showed lower seat belt use compared to several other tractor trailer truck types. Drivers operating a double trailer were less likely to use their seat belt compared to drivers operating a single trailer. In addition, local fleet drivers were less likely to use their seat belt compared to national fleet drivers. Little correlation was found between seat belt use and other driver behaviors. The analysis of observational study data did find seat belt use to be significantly higher in observations where drivers were using a hands-free cell phone with earpiece compared to drivers not using a cell phone or talking on a handheld cell phone. The naturalistic driving data showed that drivers operating on divided highways had higher seat belt use compared to those driving on non-physically divided roadways.

The literature review identified gaps in published research on seat belt use and opportunities for future research. These gaps include the need for new data on CMV drivers' seat belt use during normal driving and in crashes, studies on characteristics of effective technology (frequency of alerts, type of alerts, etc.) and information on consumer/driver acceptance of these technologies, and investigations into the qualities of safety programs targeting seat belt use in commercial fleets and drivers.

This study was an important step in addressing these research gaps, and findings could be used in safety program development. Further research should investigate a larger, more diverse sample that is not impacted by important limitations in the current study sample and qualities of existing safety programs targeting seat belt use in commercial fleets and drivers. Future work to develop a safety program could incorporate findings from the current study into proposed future studies, with the goal of increasing driver seat belt use across industry segments and driving scenarios. Using a seat belt is one of the easiest ways for a driver to increase the likelihood of surviving a crash and arriving home safely. Research that can be used to increase seat belt use in commercial drivers is thus incredibly important for saving lives.

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LIST OF ABBREVIATIONS AND SYMBOLS

CI	confidence interval
CMV	commercial motor vehicle
CMVT	commercial motor vehicle miles of travel
DAS	data acquisition system
FAST DASH	Federal Motor Carrier Safety Administration's Advanced Safety Technology Utilizing a Data Acquisition System on Highways
FMCSA	Federal Motor Carrier Safety Administration
NDS	naturalistic driving study
NHTSA	National Highway Traffic Safety Administration
OBMS	onboard monitoring system
OR	odds ratio
SCE	safety-critical event

CHAPTER 1. INTRODUCTION

In 2017, 5,005 people were killed in traffic crashes involving large trucks or buses; among large truck occupants who were killed in crashes, at least 39% were not wearing a seat belt.[1] While belt use among commercial motor vehicle (CMV) drivers increased from 65% in 2007 to 86% in 2016,[6] there are troubling seat belt usage trends that indicate additional improvement is needed. In 2013, failing to properly wear a seat belt was one of the top five driver violations cited in roadside inspections.[2] Past attempts to study seat belt usage have focused on single aspects of compliance, such as implementing seat belt policies or providing technological countermeasures.[3]

The current research study utilized a literature review and analysis of two data sources to determine situational factors associated with reduced belt use among CMV drivers. The data for analysis was collected (1) in a prior observational data collection study and (2) in a naturalistic driving study (NDS). Factors that were explored included:

- environmental (e.g., urban versus rural, time of day, day of week),
- roadway (e.g., average traffic volumes, roadway functional classification, number of travel lanes),
- vehicle (e.g., carrier type, type of truck), and
- driver factors (engagement in distraction tasks).

Seat belt use was compared across factor levels to identify levels associated with significantly higher or lower rates of seat belt use. The information derived from this project may be helpful for stakeholders (e.g., heavy vehicle fleets and/or their insurance companies) in developing safety programs targeted at those fleets and drivers most at risk for driving unbelted, based on the fleet or driver exposure to environmental, roadway, vehicle, or driver conditions associated with high rates of unbelted driving.

CHAPTER 2. LITERATURE REVIEW

Wearing a seat belt greatly reduces rates of injury and fatalities in traffic crashes.(7) The National Highway Transportation Safety Administration (NHTSA) estimates that 14,955 lives were saved by seat belts in 2017.(8) However, ubiquitous seat belt use has not been attained, despite the implementation of countermeasures such as encouragement campaigns, warning devices, and even an ignition interlock restricting vehicle operation when the seat belt is not fastened.(9) Though countermeasures have not resulted in 100% use of seat belts, progress has been made, and seat belt use among passenger vehicle drivers has increased nationally, from 86% in 2012(10) to 91.6% in 2022.(11) Given this success among passenger vehicle drivers, attention is shifting to CMV drivers, where seat belt use is less prevalent.(12)

Research focusing on seat belt use in CMVs is relevant and necessary because of the increasing number of CMVs on the roadways. In 2021, there were over 13 million registered large trucks in the United States.(13) The increased quantity and disproportionate size of these vehicles increases crash potential and severity.(14) The National Institute for Occupational Safety & Health has specifically identified CMV research as a priority because of the excessive risk of injury and death compared to average workers in the U.S.(15) The increase in crash severity among CMVs is reflected in the literature: between 2005 and 2009 there was a 34% decrease in fatal crashes, but that trend inverted to a 52% increase between 2010 and 2021, with an 18% increase between 2020 and 2021 in fatal crashes specifically involving large trucks and buses.(13) Additionally, CMV drivers were responsible for approximately $13 billion in freight being transported in 2018.(16) Considering the significance of CMV drivers not only to the economy, but in contributing to crash statistics, it is essential to understand how increasing seat belt use in this population can positively affect crash statistics. This literature review aims to understand trends in seat belt use for CMV drivers, to describe the current strategies used by fleets to improve seat belt use, and to identify research gaps within this topic.

2.1 CHARACTERISTICS OF SEAT BELT USE

Professional drivers have historically low rates of seat belt use compared to passenger vehicle drivers. In 2003, the Federal Motor Carrier Safety Administration (FMCSA) completed a study investigating CMV seat belt use in all medium- and heavy-duty trucks and buses.(17) The results estimated that only 65% of CMV occupants used seat belts, whereas 80% of passenger vehicle drivers used seat belts. Over time, both groups have improved their numbers. The most recent data on CMV seat belt use is from a 2016 FMCSA driver survey showing 86% of CMV drivers use seat belts.(12) The number of passenger vehicle drivers who use seat belts reached 90.1% in the same year.(18) The most recent data on passenger vehicle seat belt use is from a 2023 NHTSA study showing that nationwide seat belt use reached 91.6%; however, there is no current data from CMV drivers to use as a comparison.(19)

Some data suggests that various subgroups of CMV drivers may use seat belts more or less often than reported by the NHTSA study. For example, a 2013 FMCSA seat belt survey reported the lowest seat belt use among dump truck (70%) and commercial bus drivers (74%).(20) This report may suggest that trip duration and number of stops are possible predictors of seat belt use. Another FMCSA survey conducted in 2010 analyzed CMV seat belt use from 2007 to 2010.(21)

The observational data indicates that seat belt use varies as a function of enforcement type, employment type, vehicle type, and environment.

In terms of enforcement type, states with primary belt use laws have higher compliance than states with secondary enforcement laws. Primary seat belt laws allow law enforcement officers to conduct a stop and issue a citation solely because a driver is not wearing their seat belt, whereas secondary seat belt laws dictate that law enforcement cannot conduct a traffic stop based only on a driver not wearing a seat belt. Secondary seat belt laws require an officer to pull over drivers for a separate violation (i.e., speeding) and then issue a citation to the driver if they are not wearing a seat belt. This result was replicated by an FMCSA study incorporating data from 2013.[20] The comparison of seat belt use rates by states with primary seat belt laws versus secondary seat belt laws is illustrated in Figure 1.

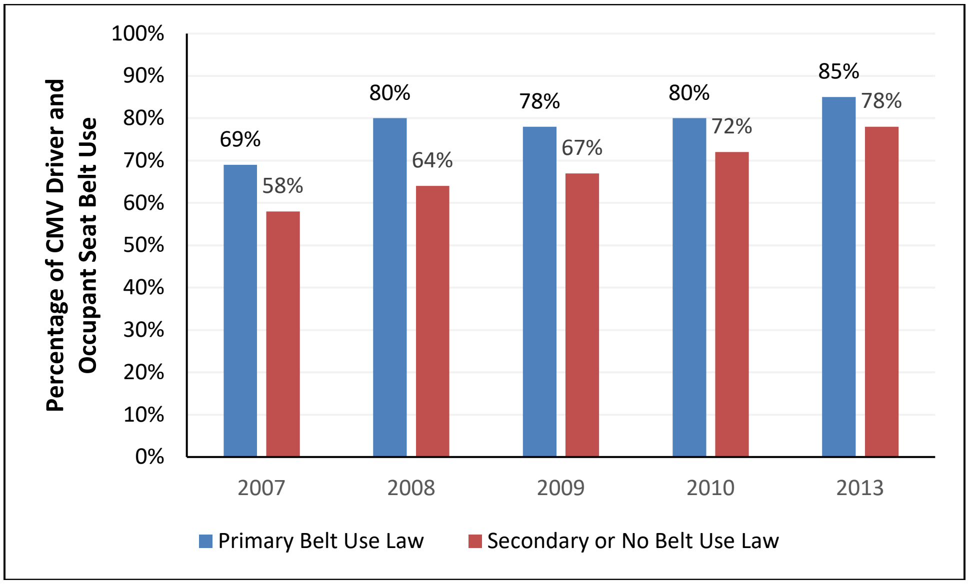

Figure 1. Bar graph. CMV driver and occupant seat belt use in states with primary seat belt laws compared to states with secondary or no seat belt laws.

The 2013 FMCSA data shows carrier and vehicle type may also influence seat belt use. For example, drivers who are employed by regional or national trucking fleets have higher use rates than independent owner-operators.[20] Based on vehicle type, commercial buses (47%), dump trucks (65%), and bobtail tractors (71%) had the lowest compliance rates. Articulated single (80%), double (87%), and triple trailer (95%) drivers had the highest seat belt use rates. This observation supports the idea that drivers who travel for greater distances at a time have higher seat belt use rates as opposed to drivers with frequent stops. Further support for this idea comes from differences in seat belt use based on environment or roadway type. For example, drivers on expressways, or roads with limited access points, have higher seat belt use (86%) than drivers on cities or surface streets (78%) with more access points.

Driver age points to another possible trend in seat belt use. In an analysis of CMV crashes nationwide, older drivers (60 + years) correctly used both lap and shoulder seat belts more often (92.1%) compared with drivers aged 27–59 years (87.7%).[22] In contrast to this positive trend, truck drivers aged 60 and older were found to be over-represented in fatal crashes.[23] However, this trend has confounding variables such as driving experience, aversion to risk taking behaviors, and susceptibility to injury. For example, the older drivers in this study may have been more likely to wear their seat belt due to more driving experience or the risk of greater injury in the event of a crash as compared to younger drivers.

An interesting trend in the transport and delivery of people and products is the increased growth of the short-trip food delivery industry, especially since the COVID-19 pandemic. It is expected that seat belt use will be a critical countermeasure to mitigate injuries for these occupational drivers. In fact, the United States Postal Service has recognized the temptation to not wear restraints by publishing a safety bulletin that, at the top of each safety section for city and rural carriers, lists the requirement to wear a seat belt at all times when the vehicle is in motion.[24] Along these lines of research, a study targeting the safety of delivery drivers looked at a community program to foster increased seat belt use.[25] As mortality statistics continue to be collected, the focus on seat belt use and general safety strategies for short-duration drivers will undoubtedly grow. However, independent of vehicle type and trip duration, researchers have been able to correlate tight delivery schedules among long-haul truck drivers with low opinions of safety regulations and unsafe driving behaviors.[26] As such, fleet managers and safety officers need to be vigilant as to how implicit, often non-stated business-related goals affect overall driver safety.

Although there is a plethora of research that examines the effectiveness of seat belts in passenger vehicles, there is surprisingly little research that examines that same for CMV drivers. One study by Benn et al. compared the odds ratio of injury when wearing a safety restraint versus not wearing a seat belt.[27] The results indicate that the odds of injury were increased by 2.25 times when drivers or occupants were not wearing their seat belt. Despite this evidence that seat belts save lives, 14% of truck drivers in a 2010 national survey of 1,265 drivers responded that they only sometimes or never use a seat belt.[28] The same survey found that this subset of drivers who did not wear a seat belt were far more likely to exhibit other risky driving behaviors such as speeding, to receive a greater number of moving violations, and to work for a company with no written safety policy.

2.2 WHY DRIVERS CHOOSE NOT TO BELT UP

Understanding trends in seat belt use for CMV drivers helps highlight characteristics of the vehicle, roadway, and driver that may influence seat belt use. These trends may provide insights into why CMV drivers are not buckling up. A 2007 study by the University of Hawaii sought to answer this question by surveying 791 drivers via written questionnaire at weigh stations across the state.[29] Drivers were asked to self-report their seat belt use and their general attitudes towards safety. Table 1 shows responses to the question: “What are the reasons why CMV drivers do not use seat belts” and the percentage of respondents who selected this answer.

Table 1. Cited reasons for seat belt disuse.

Cited Reasons	% of Respondents
Frequent Stops/Inconvenient	29%
Not safety conscious	23%
Discomfort	12%

Cited Reasons	% of Respondents
I don’t know	12%
No seat belt/Faulty	6%
I feel safe in a large vehicle	5%
Other	13%

The most cited reason for not using a seat belt was frequent stops or inconvenience (29%). This is supported by the fact that drivers who reported making four or fewer stops per hour were more likely to report “always” using their seat belt in their truck (70.4%–73.1%) as opposed to drivers with five or more stops per hour (61.5%). Additionally, those who received “constant encouragement” from their supervisors to wear their seat belt had the highest proportion of “always” using their seat belt (80.8%) as opposed to only 53.5% who did not receive any encouragement to buckle up. The authors reported one key demographic consideration of this study. The participating drivers were all in Hawaii, which does not have long-haul truck drivers like the continental U.S. This may mean that drivers with very few stops per day are underrepresented in the data.

A similar study conducted as part of Truck and Bus Safety Synthesis Program collected data from 120 fleet managers seeking to understand why CMV drivers chose to not wear a seat belt.(17) Table 2 shows possible reasons for no seat belt use, as reported by driver managers via a survey.

Table 2. Possible reasons why CMV drivers do not wear seat belts according to a 2005 FMCSA study.

Possible Reasons	% of Managers Citing Reason
Worried about being trapped in vehicle	26%
Just forget	25%
Uncomfortable for other reasons	25%
Frequently getting in and out of cab	24%
Habit	23%
Restricts movement in vehicle	23%
Just don’t like them	23%
Too much trouble and effort	21%
Belt does not fit well	18%
Part-time users; e.g. only in bad weather	15%
They don’t believe seat belts increase safety	14%
Infringement on personal freedom	11%
N/A all of our drivers always wear safety belts	10%

Respondents were able to select up to three of the responses as reasons why their drivers did not wear their seat belts. The most selected reason for why they thought their drivers did not wear a seat belt was fear of being trapped in the vehicle (26%). Other reasons were related to discomfort with the belt (25%), forgetfulness (25%), and frequency of entering and exiting the cab (24%). The same study asked 238 drivers why they chose not to wear a seat belt. The responses were coded by theme, and the most cited reason for not using a seat belt was discomfort (38%) and personal choice or general dislike (34%). Interestingly, drivers did not mention the number of stops as an influence of their seat belt use. In a follow-up question, 64% of drivers indicated that discomfort or reduced mobility was a reason for not wearing a seat belt. Considering these statistics, the best method for encouraging behavior change in seat belt non-users is far from obvious. In fact, when these same 791 drivers were asked what would encourage CMV drivers to buckle up, 95% checked that "nothing" would encourage more belt use among CMV drivers.(29)

2.3 METHODS TO IMPROVE SEAT BELT USE

Over the years, many different approaches—ranging from public messaging campaigns to vehicle interlocks—have been used to encourage seat belt use among all drivers. As stated previously, there have been government mandates to disable vehicles when the restraint system was not employed (safety interlocks). Seat belt reminder systems have long been standard equipment, and their efficacy has been studied. For example, McGehee et al. found that understanding why people choose not to wear their seat belt is only part of the issue.(30) Reminders have been effective, but safety interlocks have not been shown to have the same success.

Understanding how to effectively design safety interlocks and reminder systems so that they will be accepted could play a role in getting more people to buckle up. When the trip involved low-speed, short-duration trips (e.g. drivers need to move vehicles to switch parking spaces or move to a loading dock), drivers reacted negatively to buckling their seat belts if, in those situations, they typically would not buckle.(31) This was corroborated in a recent study testing a restraint reminder system in conjunction with an onboard monitoring system (OBMS). A typical negative comment from drivers testing the system cited "seat belt warning set at too low of a speed; should be at least 20 mi/h, verbal warning while moving in yard, 5 mi/h = too slow."(32) In fact, from the results of this study and the recorded seat belt violations, 85% were in parking lots or at low speeds (under 15 mph).

For many years, the FMCSA has been invested in aiding the industry in encouraging seat belt use. A detailed manual (FMCSA, 2006) was developed to target implementation of a seat belt program within a fleet operation.(33) It covers the impacts of having a policy and the policy's relation to existing laws, a driver pledge, detailed risk statistics about belt non-use, how to evaluate and reinforce a safety program, and knowledge tests for drivers. Current campaigns like "Y I Buckle Up" provide printed material, public service announcement videos, and social media aids encouraging large truck and bus drivers to always buckle up.(34) The "social media playbook" is designed for fleet managers to easily post and integrate into their safety strategies. As stated in the material, it contains "… shareable social media content to help spread the word about the importance of always buckling up." CMV driving tips are available on the FMCSA website that state such facts as

> It is critical that when you are driving, either short distances or on long trips, you should always wear your seat belt … In case of a sudden stop or crash, a seat belt will keep you secured to the seat, helping prevent injury or death that may occur from you being thrown from your seat into the steering wheel, dash, or windshield.

Warnings of dangers of non-use are given in a series of "Did you know?" factoids like, "When you are not wearing a seat belt, your chances of being killed are almost 25 times higher if you are thrown from a vehicle in a crash." Actual crash event summaries are presented to highlight the dangers of belt non-use.

The use of technology has also been studied and piloted to increase fleet seat belt use. Camden et al. developed a manual to implement an OBMS to provide continuous or event-based measures on a wide variety of driving behaviors previously unavailable to fleet safety managers.(35) Systems like this can provide managers with real-time alerts of safety-related events (e.g., seat belt use) via in-cab audible alerts and email and/or text messages to safety managers. Of course, these systems must be integrated with care into the fleet. Huang et al. found drivers' opinions of this technology were positive.(36) Although drivers preferred feedback from their safety managers rather than from the OBMS system, they indicated a desire for the OBMS system to provide feedback on the safe behaviors they performed. However, if OBMSs are used to alert managers of risky choices, drivers prefer for the OBMS to alert them in the cab while allowing the driver to correct the risky behavior prior to alerting a manager.(37)

Another study designed a driving training program to provide weekly aggregates of driver performance, commonly referred to as "scorecards," containing the following data metrics: instances of (1) hard acceleration, (2) hard braking, (3) hard cornering, (4) speeding, and (5) seat belt violation while driving.(38) These metrics were designed to help fleet managers who are responsible for ensuring departmental adherence to regulations, tracking and maintaining fleet vehicles, and optimizing organizational costs. With regards to seat belt usage, the training group experienced a 73.7% decrease in seat belt violations. Another review supports this data by showing converging evidence in support of enhanced seat belt reminders and other new technologies.(39) Finally, a study conducted in Australia found effective seat belt use programs improve seat belt comfort and design, dispel driver misconceptions about the safety of seat belts, increase perception of penalty for not wearing a seat belt, and improve fleet management support.(40) CMV seats with an integrated seat belt may help improve driver comfort compared to vehicles with the seat belt anchored to the B-pillar. These seats have become standard CMV in the U.S. already.

2.4 GAP ANALYSIS

Although seat belts have been a topic of research for a long time, there are still unanswered questions about how to change the behavior of non-users, especially in the CMV driver population where use rates are lower than for passenger vehicle drivers. Currently, additional research and data are needed to better understand factors associated with CMV driver seat belt use. The results of this literature review showed that the following are needed to inform effective programs to improve CMV driver seat belt use:

1. New data on CMV drivers' seat belt use during normal driving and in crashes.
2. Characteristics of effective technology (frequency of alerts, type of alerts, etc.) and information on consumer acceptance.
3. Qualities of programs that improve seat belt use.

CHAPTER 3. STUDY METHODS

3.1 DATA SOURCES

The current study assessed commercial truck driver seat belt use in data collected from two distinct studies: an observational study and an NDS.

3.1.1 Observational Study Data

Observational data for CMV driver seat belt use was obtained from a Michigan study where researchers systematically collected seat belt data at intersections.[4] This project collected observational data from 39 counties in Michigan selected based on high rates of truck/bus involved crashes from 2010 to 2014. The counties selected accounted for 91.9% of Michigan's total truck/bus-involved crashes from the given time period. These 39 counties were split into five strata based upon total CMV miles of travel (CMVT), and 220 data collection locations were selected across each stratum based on the CMVT therein. The locations included rest areas, exit ramps of limited access highways, and signalized intersections. This data included freeway and non-freeway CMVT. The data collection team was trained on field data collection and were previously involved in reliability and repeatability studies. The observers were limited to identifying the shoulder belt of the three-point seat belt system, as the lap belt was not visible from the observers' vantage points. It is possible that an individual driver was observed across multiple locations during the study; however, this was not tracked in the dataset and is expected to be a rare occurrence given the range of locations and times of data collection. A detailed description of the study methodology is included in the study final report.[4] The current study analyzed this previously collected data on seat belt use and driver, environment, roadway, and vehicle factors.

3.1.2 Naturalistic Driving Study Data

The NDS data was collected during the FMCSA's second FAST DASH project (commonly referred to as FAST DASH 2).[5] The study aimed to assess the performance, safety impact, and driver acceptance of an OBMS. During the study, naturalistic driving data was collected from 25 Class 8 tractors, instrumented with a Virginia Tech Transportation Institute data acquisition system (DAS) and the OBMS. The vehicles were part of a single fleet, and the study targeted up to 20 drivers for participation. The final naturalistic driving data set included safety-critical events (SCEs), reduced for driver behaviors and environmental and roadway information, and a random sample of OBMS-triggered "violations," including speeding, unbuckled seat belt, and aggressive driving incidents. Individual drivers may have multiple epochs in the final data set, depending on their driving behavior during the study. A detailed description of the FAST DASH 2 methodology is included in the study final report.[5] For the current study, SCE data was used to understand seat belt use in relation to various driver, environmental, and roadway factors.

3.2 ANALYSIS APPROACH

Each data set was analyzed separately for significant differences in seat belt use by driver, environmental, roadway, or vehicle factor. The data was first summarized using descriptive statistics, presenting frequency counts of seat belt use and proportion of observations with use, by each factor level. Both data sets were further analyzed using a series of logistic regression models. For the observational study data set, it would be difficult to discern observations from the same driver, given that driver-identifying data was not collected. This data was analyzed using a logistic regression model. For the NDS data set, each SCE is listed with the study driver ID. Drivers could contribute multiple SCEs to the data set, and these observations could be correlated. For this data, mixed effect logistic regression models were used to control for correlated data.

The model setup for the mixed effect logistic regression models was as follows. For each observation j from driver i, driver seat belt use status Y_{ij} was coded as a binary outcome (1 = yes, seat belt used; 0 = no, seat belt not used) and Y_{ij} was assumed to follow a Bernoulli distribution where the probability of seat belt use in an observation is p_{ij}.

$$Y_{ij} = \begin{cases} 1 \; Driver\ was\ not\ using\ seat\ belt\ in\ observation \\ 0 \; Driver\ did\ not\ have\ seat\ belt\ on\ in\ observation \end{cases} = Bernoulli(p_{ij})$$

The logit or log odds of p_{ij} was related to the study factors of interest by:

$$logit(p_{ij}) = \log\left(\frac{p_{ij}}{1 - p_{ij}}\right) = X'_{ij}\beta + z'_{ij}u_i$$

The components of the model included:

- β which represents the vector of regression parameters, including β_0 and parameters β_1 and β_2 for the tested factor(s) in this study, and which measures the change;
- X_{ij} which is the observed values for the j^{th} observation of the i^{th} driver;
- z_{ij} which is the incidence matrix for random effects; and
- u_i which is the driver-specific random effect to account for observations from the same driver.

The assessment of NDS data included the random effects component, as a specific driver was associated with each observation. However, the assessment of observational driving data did not include the random effects component in the model. Odds ratios comparing seat belt use by levels of the modeled factor were calculated using the model output and are presented in the results below. Odds ratios are a comparison of two different factor levels for their associated odds of seat belt use.

CHAPTER 4. ASSESSMENT OF OBSERVATIONAL STUDY DATA

The observational study dataset included 4,147 observations, marked for driver seat belt use and other key driver and environmental variables. Observations with null driver seat belt use values (199 total) were excluded from the current study. The observations were collected over five locations or strata. Table 3 presents the observation frequency count overall and by strata, with counts and percentage of observations by driver seat belt use status. Approximately 81% of all observations showed driver seat belt use and nearly 19% of observations showed drivers without their seat belt. Total observations per strata location ranged between 112 observations in Strata No. 5 and 1,226 in Strata No. 2. Seat belt use rates across strata ranged between 71% (Strata No. 5) and 83% (Strata No. 2).

Table 3. Driver seat belt use in observational study data, overall and by sample location strata.

Sample Location Stratification	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations with Data
All Strata Locations	3,377 (81.43%)	770 (18.57%)	4,147
Strata No. 1	588 (81.78%)	131 (18.22%)	719
Strata No. 2	1,021 (83.28%)	205 (16.72%)	1,226
Strata No. 3	844 (80.23%)	208 (19.77%)	1,052
Strata No. 4	844 (81.31%)	194 (18.69%)	1,038
Strata No. 5	80 (71.43%)	32 (28.57%)	112

Seat belt use patterns in the observational study data were assessed across environmental factors, roadway factors, vehicle factors, and driver factors. The results are presented below.

4.1 ENVIRONMENTAL FACTORS

Environmental factors assessed in the observational study data included day of the week, time of day, a cross-examination of time of day on weekdays and weekends, and weather condition.

4.1.1 Day of the Week

Table 5 and Figure 2 present driver seat belt use over the days of the week. Monday and Tuesday observations had the highest driver seat belt use at 84%. Nearly 78% of Wednesday observations showed driver seat belt use. Thursday observations had 83% driver seat belt use. Approximately 79% of Friday and Saturday observations and 80% of Sunday observations showed driver seat belt use.

Table 4. Driver seat belt use by day of the week in observational study data.

Day of the Week	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Monday	586 (84.44%)	108 (15.56%)	694
Tuesday	548 (83.92%)	105 (16.08%)	653
Wednesday	375 (77.80%)	107 (22.20%)	482
Thursday	650 (83.12%)	132 (16.88%)	782
Friday	786 (79.31%)	205 (20.69%)	991
Saturday	248 (78.73%)	67 (21.27%)	315
Sunday	184 (80.00%)	46 (20.00%)	230

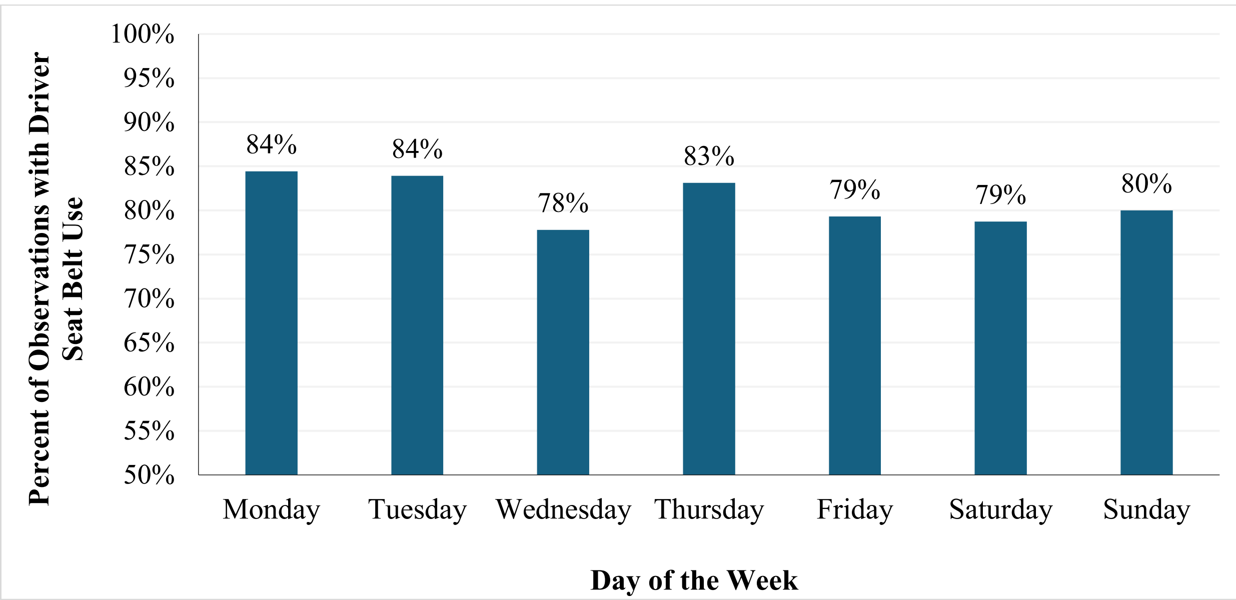

Figure 2. Bar graph. Driver seat belt use by day of the week in observational study data.

A logistic regression model, with a term for strata, assessed seat belt use by day of the week. Model output in terms of odds ratios (ORs) and 95% confidence intervals (CIs) are included in Table 5 (significant findings only; see Appendix A.1 for all results). Several comparisons showed significant differences in seat belt use.

- **Drivers were significantly more likely to be using their seat belt on Monday compared to Wednesday** [OR = 1.548, 95% CI = (1.150, 2.084)], **Friday** [OR = 1.415, 95% CI = (1.095, 1.829)], **and Saturday** [OR = 1.466, 95% CI = (1.044, 2.058)].

- **Drivers were also significantly more likely to be using their seat belt on Tuesday compared to Wednesday** [OR = 1.489, 95% CI = (1.103, 2.009)], **Friday** [OR = 1.361, 95% CI = (1.050, 1.764)], **and Saturday** [OR = 1.410, 95% CI = (1.002, 1.983)].

- **Wednesday showed significantly lower seat belt use compared to Thursday** [OR = 0.712, 95% CI = (0.535, 0.946)].

- **Seat belt use was slightly higher on Thursdays compared to Friday** [OR = 1.284, 95% CI = (1.008, 1.636)].

Table 5. OR estimates and corresponding 95% CI for seat belt use by day of the week (significant results only).

Day of the Week Comparison	OR Estimate	*df*	95% Confidence Limits
Monday vs. Wednesday	1.548	4,136	(1.150, 2.084)
Monday vs. Friday	1.415	4,136	(1.095, 1.829)
Monday vs. Saturday	1.466	4,136	(1.044, 2.058)
Tuesday vs. Wednesday	1.489	4,136	(1.103, 2.009)
Tuesday vs. Friday	1.361	4,136	(1.050, 1.764)
Tuesday vs. Saturday	1.410	4,136	(1.002, 1.983)
Wednesday vs. Thursday	0.712	4,136	(0.535, 0.946)
Thursday vs. Friday	1.284	4,136	(1.008, 1.636)

4.1.2 Time of Day

Data was collected between 7 a.m. and 7 p.m. For the current study, observation time of day was categorized into four buckets: morning (7 a.m.–10 a.m.), midday (11 a.m.–1 p.m.), afternoon (2 p.m.–4 p.m.), and evening (5 p.m.–7 p.m.). Table 6 presents the total count and percentage of observations with seat belt use by time of day. Figure 3 plots the percentage of seat belt use by time of day. The observations included:

- 1,211 collected during the morning (overall seat belt use rate of 81%);
- 1,658 collected during midday (overall seat belt use rate of 81%);
- 1,166 collected during the afternoon (overall seat belt use rate of 81%; and
- 112 collected during the evening (overall seat use rate of 90%).

Table 6. Driver seat belt use by time of day in observational study data.

Time of Day	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Morning (7 a.m.–10 a.m.)	982 (81.09%)	229 (18.91%)	1,211
Midday (11 a.m.–1 p.m.)	1,350 (81.42%)	308 (18.58%)	1,658
Afternoon (2 p.m.–4 p.m.)	944 (80.96%)	222 (19.04%)	1,166
Evening (5 p.m.–7 p.m.)	101 (90.18%)	11 (9.82%)	112

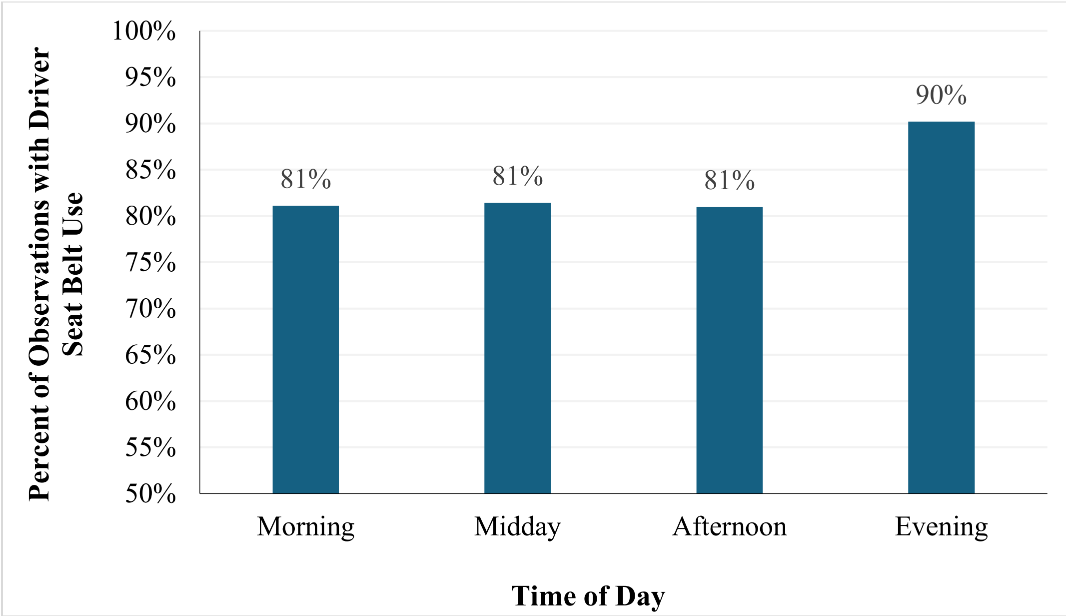

Figure 3. Bar graph. Driver seat belt use by time of day in observational study data.

A logistic regression model, with a term for strata, assessed seat belt use by time of day, and significant findings in terms of ORs and 95% CIs are included in Table 7 (see Appendix A.1 for all results).

- **Drivers were more than twice as likely to use their seat belt in the evening compared to the morning** [OR = 2.565, 95% CI = (1.320, 4.985)], **midday** [OR = 2.519, 95% CI = (1,305, 4.865)], **and afternoon** [OR = 2.516, 95% CI = (1.299, 4.870)].
- **No significant differences in seat belt use were observed between morning, midday, and afternoon times.**

Table 7. OR estimates and corresponding 95% CI for seat belt use by time of day.

Day of the Week Comparison	OR Estimate	*df*	95% Confidence Limits
Evening vs. Morning	2.565	4,139	(1.320, 4.985)
Evening vs. Midday	2.519	4,139	(1.305, 4.865)
Evening vs. Afternoon	2.516	4,139	(1.299, 4.870)

Figure 4 presents the rate of seat belt use during different times of day for weekdays and weekends. Counts are included in Table 8. Weekday evenings showed the highest seat belt use (96% of observations). Weekend mornings showed the lowest seat belt use (74% of observations).

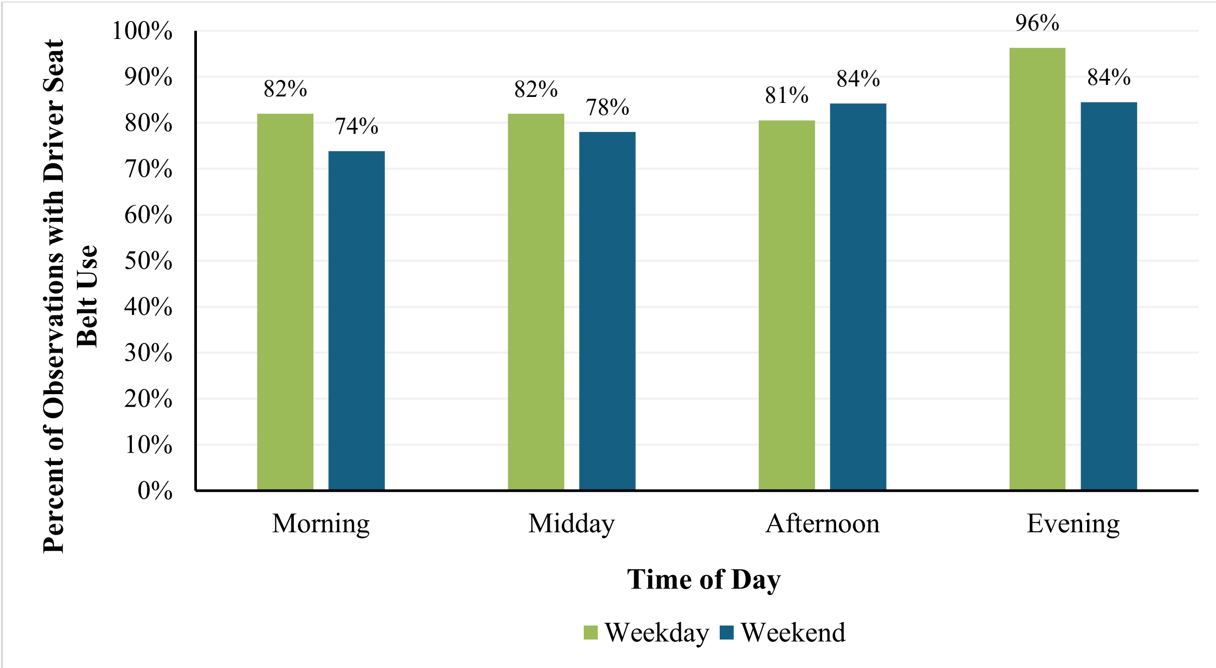

Figure 4. Bar graph. Driver seat belt use by time of day and day of the week in observational study data.

Table 8. Driver seat belt use by time of day and day of the week in observational study data.

Time of Day	Driver Seat Belt Use Observed on Weekdays	No Driver Seat Belt Use Observed on Weekends
Morning (7 a.m.–10 a.m.)	886 (81.96%)	96 (73.85%)
Midday (11 a.m.–1 p.m.)	1,180 (81.94%)	170 (77.98%)
Afternoon (2 p.m.–4 p.m.)	827 (80.53%)	117 (84.17%)
Evening (5 p.m.–7 p.m.)	52 (96.30%)	49 (84.48%)

A logistic regression model, with a term for strata, assessed seat belt use by time of day and day of week. The findings from this analysis identified the impact time of day and day of week have on driver seat belt use. Significant findings in terms of ORs and 95% CIs are included in Table 9 (see Appendix A.1 for all results).

- **On weekday evenings, drivers were six times more likely to use their seat belt compared to weekend mornings** [OR = 6.177, 95% CI = (1.439, 26.519)] **and eight times more likely compared to weekend midday** [OR = 8.123, 95% CI = (1.865, 35.379)].

- **On weekdays, drivers were five times more likely to use their seat belt in evenings compared to mornings** [OR = 5.442, 95% CI = (1.311, 22.598)], **midday** [OR = 5.511, 95% CI = (1.330, 22.827)], **and afternoons** [OR = 5.877, 95% CI = (1.415, 24.414)].

- **On weekends, drivers were more than twice as likely to use their seat belt in the afternoon** [OR = 2.062, 95% CI = (1.114, 3.819)] **or evening** [OR = 2.559, 95% CI = (1.085, 6.034)] **compared to the morning.**

Table 9. OR estimates and corresponding 95% CI for seat belt use by time of day and day of week.

Comparison Level 1	Comparison Level 2	OR Estimate	*df*	95% Confidence Limits
Weekday Evening	**Weekday Morning**	5.442	4,135	(1.311, 22.598)
Weekday Evening	**Weekday Midday**	5.511	4,135	(1.330, 22.827)
Weekday Evening	**Weekday Afternoon**	5.877	4,135	(1.415, 24.414)
Weekday Evening	**Weekend Morning**	8.123	4,135	(1.865, 35.379)
Weekday Evening	**Weekend Midday**	6.177	4,135	(1.439, 26.519)
Weekend Afternoon	**Weekend Morning**	2.062	4,135	(1.114, 3.819)
Weekend Evening	**Weekend Morning**	2.559	4,135	(1.085, 6.034)

4.1.3 Weather Condition

Weather conditions in the observational data were categorized as clear, light fog, or light rain. Table 10 presents observation frequency counts and seat belt use in each weather condition category. The data included:

- 3,791 observations in clear weather (81.11% seat belt use);
- 65 observations in light fog (85% seat belt use); and
- 291 observations in light rain (85% seat belt use).

A comparison of the three weather condition categories found no statistically significant difference in seat belt use between the categories ($p = 0.4707$).

Table 10. Driver seat belt use by weather condition in observational study data.

Weather Condition	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Non-adverse	279 (93.94%)	18 (6.06%)	297
Adverse	19 (95.00%)	1 (5.00%)	20

4.2 ROADWAY FACTORS

For the observational study data, one roadway factor was assessed in the current study: number of travel lanes in the observed direction.

4.2.1 Number of Travel Lanes

Table 11 presents observation frequency counts and seat belt use by number of travel lanes; the data is also summarized in Figure 5. For the current study, the original travel lane coding was revised to combine levels into fewer levels. Any observation with travel lanes of 3, 4, 5, or 6 was recoded as having 3 or more travel lanes ("3+"). Observations with "unknown" or "null" number of travel lanes were excluded from the analysis. The data included:

- 865 observations in a single travel lane (84% seat belt use);
- 1,463 observations on roads with two travel lanes (79% seat belt use); and
- 1,819 observations on roads with three or more travel lanes (82% seat belt use).

Table 11. Driver seat belt use by number of travel lanes in observational study data.

Number of Travel Lanes	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
1	728 (84.16%)	137 (15.84%)	865
2	1,160 (79.29%)	303 (20.71%)	1,463
3+	1,489 (81.86%)	330 (18.14%)	1,819

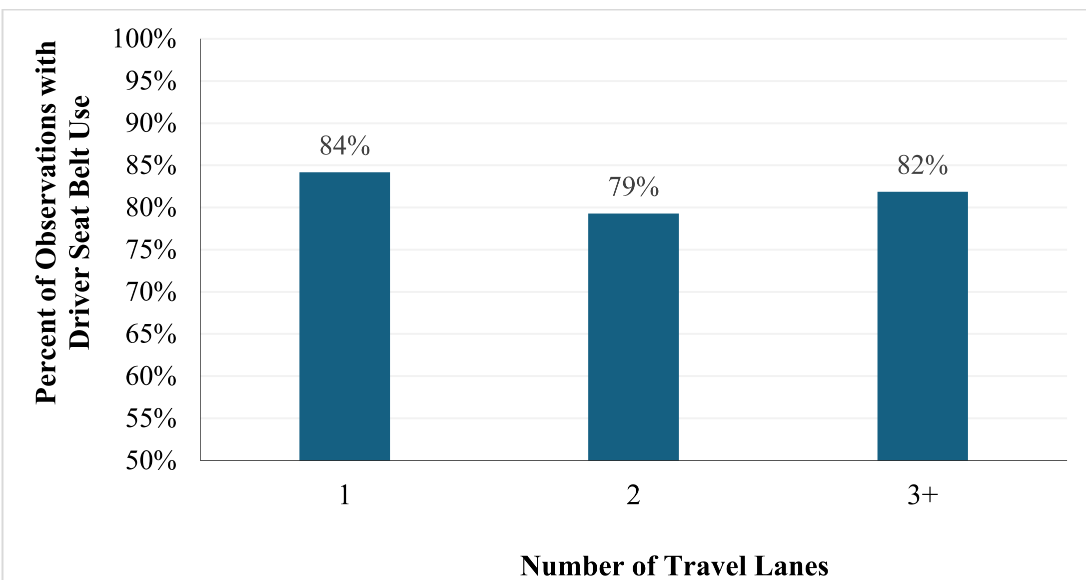

Figure 5. Bar graph. Driver seat belt use by number of travel lanes in observational study data.

Output from the logistic regression model assessing seat belt use by number of travel lanes showed statistically significant differences between the travel lane categories. The model output in terms of significant ORs and 95% CIs is included in Table 12. Non-significant findings are included in the Appendix A.1.

- **Drivers on a single travel lane** [OR = 1.431, 95% CI = (1.145, 1.789)] **or with three or more travel lanes** [OR = 1.232, 95% CI = (1.025, 1.481)] **were slightly more likely to use their seat belt compared to drivers on roadways with two travel lanes.**

Table 12. OR estimates and 95% CI for seat belt use in different travel lane categories using observational study data.

Number of Travel Lanes Comparison	OR Estimate	*df*	95% Confidence Limits
1 vs. 2	1.431	4,140	(1.145, 1.789)
3+ vs. 2	1.232	4,140	(1.025, 1.481)

4.3 VEHICLE FACTORS

Vehicle factors in the observational study data included truck type, fleet type, cargo type, and trailer type. Truck type was further broken down into types of single unit trucks and types of tractor trailer trucks.

4.3.1 Truck Type

Truck type was categorized separately for single unit trucks and tractor trailer trucks. Table 13 presents observed counts and proportion of seat belt use by single unit truck type. Figure 6 shows the distribution of seat belt use across single unit truck types. The data included:

- 1,925 box trucks (83% seat belt use);
- 176 dump trucks (72% seat belt use);
- 208 flatbed trucks (73% seat belt use);
- 57 concrete mixers (30% seat belt use);
- 67 garbage trucks (79% seat belt use);
- 49 tanker trucks (16% seat belt use); and
- 113 trucks classified as “other” (82% seat belt use).

Table 13. Driver seat belt use by single unit truck type in observational study data.

Single Unit Truck Type	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Box	855 (83.41%)	170 (16.59%)	1,025
Dump	126 (71.59%)	50 (28.41%)	176
Flatbed	152 (73.08%)	56 (26.92%)	208
Concrete mixer	17 (29.82%)	40 (70.18%)	57
Garbage truck	53 (79.10%)	14 (20.90%)	67
Tanker	8 (16.33%)	41 (83.67%)	49
Other	93 (82.30%)	20 (17.70%)	113

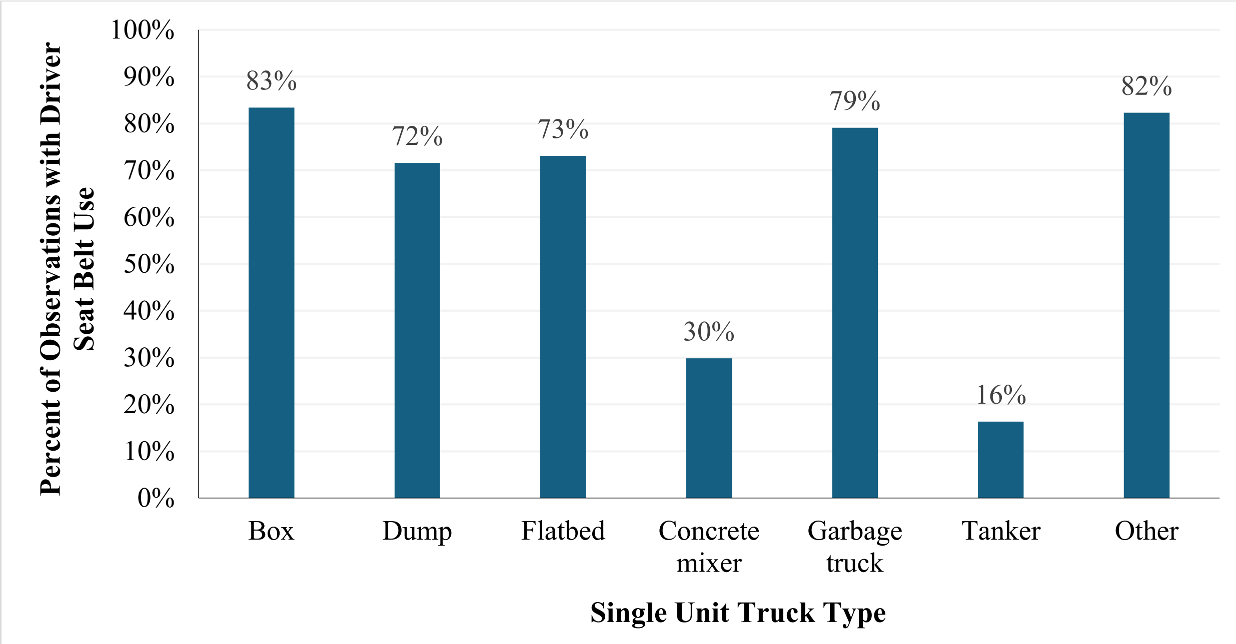

Figure 6. Bar graph. Driver seat belt use by single unit truck type in observational study data.

The logistic regression model results, in terms of ORs and 95% CIs, assessing seat belt use by single unit truck type are presented in Table 14. The table includes significant findings only; all other comparisons are included in Appendix A.1.

- **Compared to concrete mixer drivers, the odds of a driver using their seat belt were approximately 12 times higher for box trailer drivers** [OR = 12.571, 95% CI = (6.912, 22.863)], **tanker drivers** [OR = 12.897, 95% CI = (4.962, 33.521)], **and drivers of trucks classified as "other"** [OR = 11.593, 95% CI = (5.450, 24.660)].

- **Dump truck drivers** [OR = 6.327, 95% CI = (3.261, 12.277)], **flatbed drivers** [OR = 6.771, 95% CI = (3.522, 12.018)], **and garbage truck drivers** [OR = 9.716, 95% CI = (4.253, 22.196)] **also showed increased likelihood of seat belt use compared to concrete mixer drivers.**

Other significant findings included:

- **Higher seat belt use in box truck drivers compared to dump truck drivers** [OR = 1.987, 95% CI = (1.375, 2.870)] **and flatbed drivers** [OR = 1.857, 95% CI = (1.309, 2.633)].

- **Lower seat belt use in dump truck drivers compared to drivers of trucks classified as "other"** [OR = 0.546, 95% CI = (0.304, 0.981)].

Table 14. OR estimates and 95% CI for seat belt use in different single unit truck type categories using observational study data.

Single Unit Truck Type Comparison	OR Estimate	*df*	95% Confidence Limits
Box vs. Dump	1.987	1,684	(1.375, 2.870)
Box vs. Flatbed	1.857	1,684	(1.309, 2.633)
Box vs. Concrete mixer	12.571	1,684	(6.912, 22.863)
Dump vs. Concrete mixer	6.327	1,684	(3.261, 12.277)
Dump vs. Other	0.546	1,684	(0.304, 0.981)
Flatbed vs. Concrete mixer	6.771	1,684	(3.522, 13.018)
Garbage truck vs. Concrete mixer	9.716	1,684	(4.253, 22.196)
Tanker vs. Concrete mixer	12.897	1,684	(4.962, 33.521)
Other vs. Concrete mixer	11.593	1,684	(5.450, 24.660)

Table 15 presents observed counts and proportion of seat belt use by tractor trailer truck type. The seat belt use distribution by tractor trailer truck type is plotted in Figure 7. The data included:

- 1,565 box trucks (86% seat belt use);
- 84 container trucks (81% seat belt use);
- 239 flatbed trucks (80% seat belt use);
- 204 gravel train trucks (66% seat belt use);
- 192 tanker trucks (82% seat belt use);
- 51 auto transporter trucks (86% seat belt use);
- 107 rig only trucks (83% seat belt use); and
- 10 trucks classified as “other” (80% seat belt use).

Table 15. Driver seat belt use by tractor trailer truck type in observational study data.

Tractor Trailer Truck Type	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Box	1,347 (86.07%)	218 (13.93%)	1,565
Container	68 (80.95%)	16 (19.05%)	84
Flatbed	192 (80.33%)	47 (19.67%)	239
Gravel train	135 (66.18%)	69 (33.82%)	204
Tanker	157 (81.77%)	35 (18.23%)	192
Auto transporter	44 (86.27%)	7 (13.73%)	51
Rig only	89 (83.18%)	18 (16.82%)	107
Other	8 (80.00%)	2 (20.00%)	10

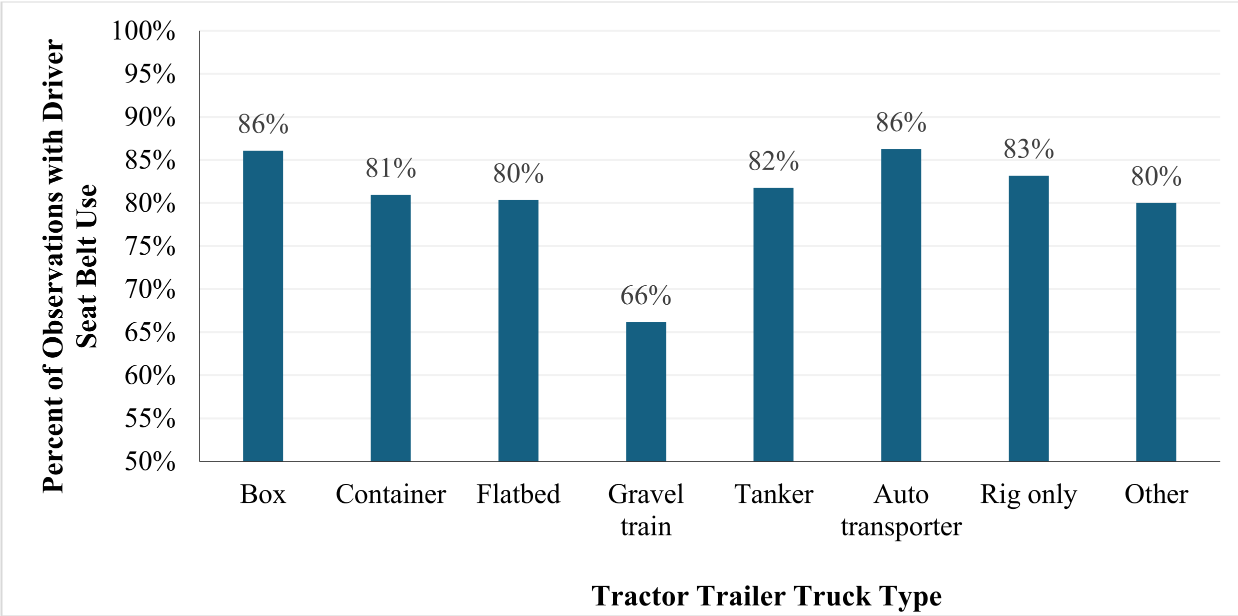

Figure 7. Bar graph. Driver seat belt use by tractor trailer truck type in observational study data.

The logistic regression model results, presented in terms of ORs and 95% CIs, assessing seat belt use by tractor trailer truck type are given in Table 16. The table includes significant findings only; all other comparisons are included in Appendix A.1.

- **The odds of a driver using their seat belt were 3 times higher for box trailer drivers compared to gravel train truck drivers** [OR = 3.008, 95% CI = (2.170, 4.170)].
- **In addition, compared to gravel train truck drivers, the odds of a driver using their seat belt were twice as high for container** [OR = 1.992, 95% CI = (1.070, 3.709)], **flatbed** [OR = 2.145, 95% CI = (1.384, 3.326)], **tanker** [OR = 2.414, 95% CI = (1.503, 3.878)], **auto transporter** [OR = 2.827, 95% CI = (1.204, 6.638)], **and rig only drivers** [OR = 2.250, 95% CI = (1.248, 4.057)].

Table 16. OR estimates and 95% CI for seat belt use in different tractor trailer truck type categories using observational study data.

Tractor Trailer Truck Type Comparison	OR Estimate	*df*	95% Confidence Limits
Box trailer vs. Gravel train	3.008	2,440	(2.170, 4.170)
Container vs. Gravel train	1.992	2,440	(1.070, 3.709)
Flatbed vs. Gravel train	2.145	2,440	(1.384, 3.326)
Tanker vs. Gravel train	2.414	2,440	(1.503, 3.878)
Auto transporter vs. Gravel train	2.827	2,440	(1.204, 6.638)
Rig only vs. Gravel train	2.250	2,440	(1.248, 4.057)

4.3.2 Fleet Type

Table 17 and Figure 8 present observed counts and proportion of seat belt use by national and local fleet type. The data included:

- 2,133 national fleet observations (87% seat belt use); and
- 2,014 local fleet observations (76% seat belt use).

A logistic regression model comparing seat belt use for drivers by fleet type found that:

- **Drivers operating a truck from a national fleet were twice as likely to use their seat belt compared to drivers operating a truck from a local fleet** [OR = 2.019, 95% CI = (1.716, 2.376)].

Table 17. Driver seat belt use by fleet type in observational study data.

Fleet Type	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
National	1,845 (86.50%)	1,845 (13.50%)	2,133
Local	1,532 (76.07%)	482 (23.93%)	2,014

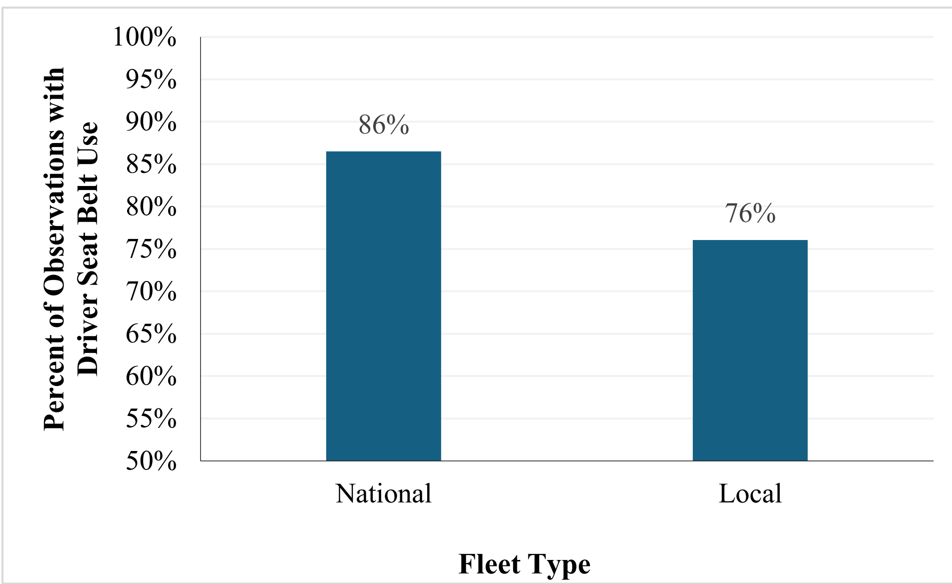

Figure 8. Bar graph. Driver seat belt use by fleet type in observational study data.

4.3.3 Cargo Type

Table 18 and Figure 9 present observed counts and proportion of seat belt use by hazardous and non-hazardous cargo type. The data included:

- 4,019 observations with non-hazardous cargo (81% seat belt use); and
- 128 observations with hazardous cargo (83% seat belt use).

A logistic regression model comparing seat belt use for drivers by cargo type found:

- **No significant difference in seat belt use behavior in non-hazardous and hazardous trucks** [OR = 0.851, 95% CI = (0.532, 1.361)].

Table 18. Driver seat belt use by cargo type in observational study data.

Cargo Type	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Non-Hazardous	3,271 (81.39%)	748 (18.61%)	4,019
Hazardous	106 (82.81%)	22 (17.19%)	128

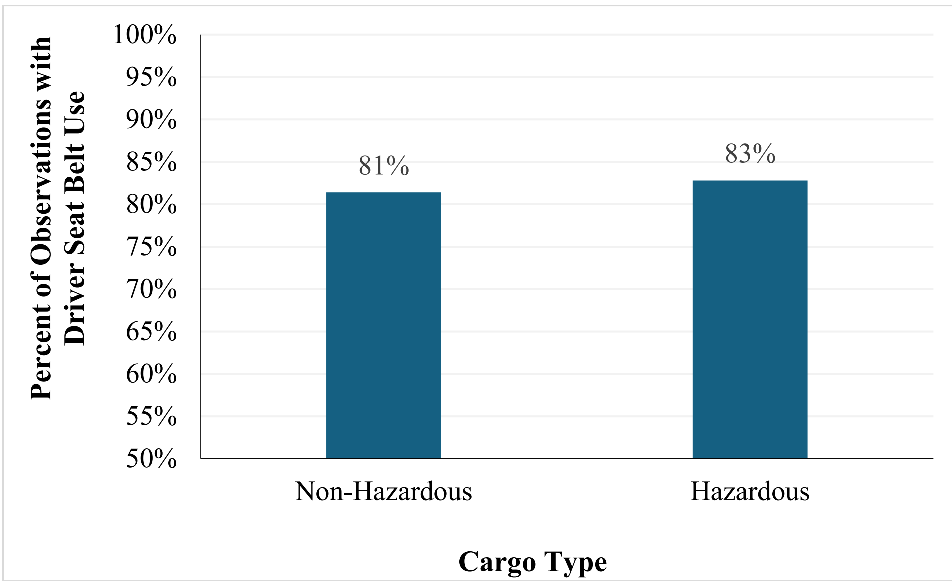

Figure 9. Bar graph. Driver seat belt use by cargo type in observational study data.

4.3.4 Trailer Type

Table 19 presents observed counts and proportion of seat belt use by trailer type, if applicable to the truck observed. The data included:

- 2,229 observations with a single trailer (84% seat belt use); and
- 139 observations with a double trailer (70% seat belt use).

A logistic regression model comparing drivers with single and double trailers for seat belt use found:

- **Drivers with a single trailer were more than twice as likely to use their seat belt** [OR = 2.206, 95% CI = (1.504, 3.237)].

Table 19. Driver seat belt use by trailer type in observational study data.

Trailer Type	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Single	1,871 (83.94%)	358 (16.06%)	2,229
Double	97 (69.78%)	42 (30.22%)	139

4.4 DRIVER FACTORS

Driver factors noted in the observational study data included:

- driver gender;
- driver age; and
- driver cell phone use.

Driver gender and age were estimated by the original study team and not reported directly by observed drivers, and therefore these variables were not analyzed for the current study.

4.4.1 Driver Cell Phone Use

Table 20 presents observed counts and proportion of seat belt use by observed driver cell phone use. The distribution of seat belt use across driver cell phone use options is presented in Figure 10. The data included:

- 3,765 drivers not using their cell phone (81% seat belt use);
- 81 drivers talking on a handheld cell phone (75% seat belt use);
- 53 drivers typing on a handheld cell phone (89% seat belt use);
- 164 drivers using a hands-free cell phone with earpiece (92% seat belt use); and
- 2 drivers using a hands-free cell phone without an earpiece (100% seat belt use).

Table 20. Driver seat belt use by driver cell phone use in observational study data.

Cell Phone Use	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
No cell phone use	3,048 (80.96%)	717 (19.04%)	3,765
Handheld talking	61 (75.31%)	20 (24.69%)	81
Handheld typing	47 (88.68%)	6 (11.32%)	53
Hands-free, earpiece	151 (92.07%)	13 (7.93%)	164
Hands-free, no earpiece	2 (100.00%)	0 (0.00%)	2

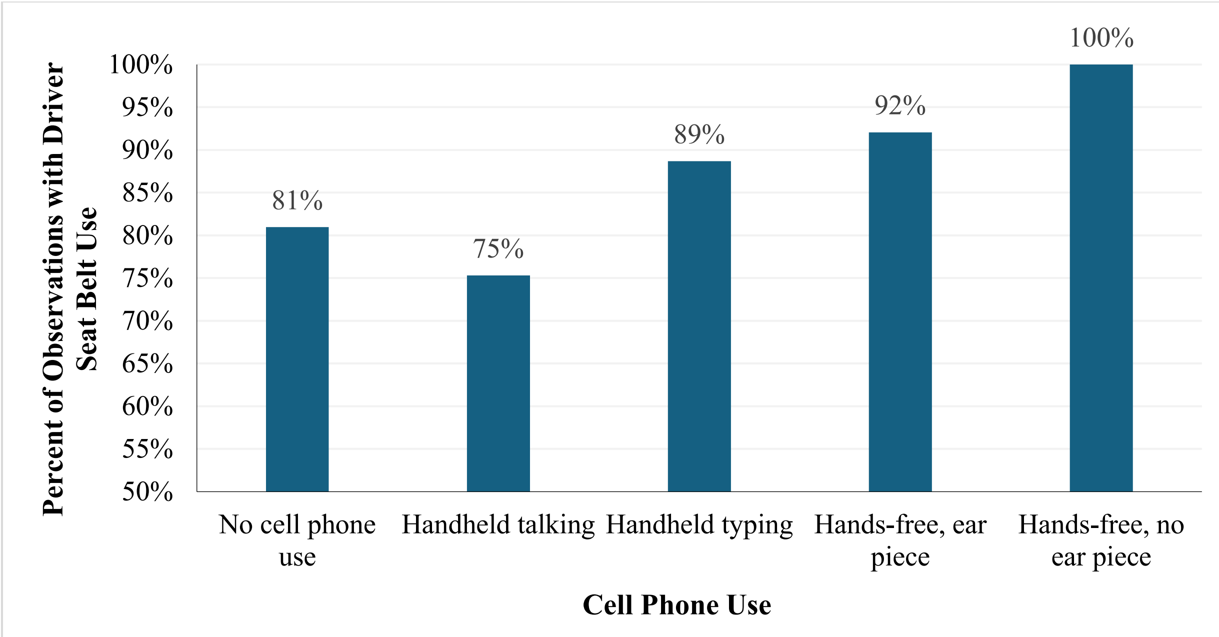

Figure 10. Bar graph. Driver seat belt use by driver cell phone use in observational study data.

A logistic regression model assessing seat belt use by driver cell phone use found significant differences, which are presented in terms of ORs and 95% CIs in Table 21. Non-significant results are included in Appendix A.1.

- **Drivers who were using a hands-free cell phone with an earpiece were significantly more likely to be using their seat belt compared to drivers not using a cell phone** [OR = 2.790, 95% CI = (1.572, 4.949)] **or talking on a handheld cell phone** [OR = 3.877, 95% CI = (1.814, 8.291)].

Table 21. OR estimates and corresponding 95% CI for seat belt use by cell phone use.

Driver Cell Phone Use Level 1	Driver Cell Phone Use Level 2	OR Estimate	*df*	95% Confidence Limits
Hands-free, earpiece	No cell phone use	2.790	4,056	(1.572, 4.949)
Hands-free, earpiece	Handheld talking	3.877	4,056	(1.814, 8.291)

CHAPTER 5. ASSESSMENT OF NATURALISTIC DRIVING DATA

The NDS dataset included 319 SCEs. Each SCE was marked for driver seat belt use, with seat belt use status coding options of "no," "unknown," and "yes." Table 22 presents the SCE frequency count and percentage of total by observed seat belt use status. Approximately 93% of SCEs had observed driver seat belt use and nearly 6% of SCEs showed drivers without their driver seat belts. Less than 1% of SCEs had unknown observable seat belt use. Table 22 also presents the number of drivers observed with each seat belt use status. The participant sample included 19 drivers who used their seat belt in at least one SCE, 11 drivers who did not use their seat belt in at least one SCE, and 2 drivers with unknown seat belt use in at least one SCE. Eight drivers used seat belts in each of their SCE observations (these drivers are included in the yes row of the table and not in the no row of the table). Every driver with an SCE without seat belt use also had SCEs with unknown or yes seat belt use status (i.e., all drivers with observations of no seat belt use also had observations in other seat belt use categories).

Table 22. Observed seat belt use in naturalistic driving data SCEs.

Observed Seat Belt Status	SCE Frequency	SCE Percent	Driver Frequency
No	19	5.96	11
Unknown	2	0.63	2
Yes	298	93.42	19
Total	319	100.00	19

Seat belt use patterns in NDS SCEs were assessed across environmental factors, roadway factors, and driver factors. The results are presented below.

5.1 ENVIRONMENTAL FACTORS

Environmental factors assessed in the naturalistic driving data included:

- lighting condition;
- weather condition;
- roadway surface condition; and
- construction zone status.

5.1.1 Lighting Condition

Table 23 presents SCE frequency counts and seat belt use in lighting condition categories. The SCEs included 286 in daylight lighting condition and 30 in dawn, dusk, or dark lighting conditions. SCEs with "unknown" lighting condition were excluded from the analysis. Seat belt use was observed in 94% of SCEs with daylight lighting conditions and 97% of SCEs with dawn/dusk/dark lighting conditions. A comparison of the two lighting condition categories found no statistically significant difference in seat belt use between the categories [OR = 1.95, 95% CI = (0.24, 15.95)].

Table 23. Driver seat belt use by light condition in naturalistic driving SCE data.

Light Condition	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Daylight	19	268 (93.71%)	18 (6.29%)	286
Dawn, Dusk, or Dark	10	29 (96.67%)	1 (3.33%)	30

5.1.2 Weather Condition

Weather conditions in SCEs were categorized as adverse (rain, light rain, mist, fog; no observations of snow or ice were in the current dataset) or non-adverse. Table 24 presents SCE frequency counts and seat belt use in each weather condition category. The SCEs included 297 in non-adverse weather conditions and 20 in adverse weather conditions. SCEs with "unknown" weather conditions were excluded from the analysis. Seat belt use was observed in 94% of SCEs with non-adverse weather conditions and 95% of SCEs with adverse weather conditions. A comparison of the two weather condition categories found no statistically significant difference in seat belt use between the categories [OR = 1.23, 95% CI = (0.15, 10.20)].

Table 24. Driver seat belt use by weather condition in naturalistic driving SCE data.

Weather Condition	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Non-adverse	19	279 (93.94%)	18 (6.06%)	297
Adverse	12	19 (95.00%)	1 (5.00%)	20

5.1.3 Roadway Surface Condition

Table 25 presents SCE frequency counts and seat belt use in each roadway surface condition category. The SCEs included 282 in dry surface conditions, 28 in wet surface conditions, and 6 in snow/ice/slush surface conditions. SCEs with "unknown" surface conditions were excluded from the analysis. Seat belt use was observed in 94% of SCEs with dry surface conditions, 96% of SCEs in wet surface conditions, and 83% of SCEs in snow/ice/slush surface conditions. Comparisons of seat belt use in the different roadway surface conditions found no statistically significant differences in seat belt use across the categories ($p = 0.5122$).

Table 25. Driver seat belt use by roadway surface condition in naturalistic driving SCE data.

Roadway Surface Condition	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Dry	19	265 (93.97%)	17 (6.03%)	282
Wet	11	27 (96.43%)	1 (3.57%)	28
Snow/Ice/Slush	5	5 (83.33%)	1 (16.67%)	6

5.1.4 Construction Zone Status

SCEs were coded for occurrence in or near a construction zone and included 9 in a construction zone, 1 in a construction zone-related area, and 307 not construction zone-related/unknown. Table 26 presents SCE frequency counts and seat belt use in each construction zone status. Seat belt use was observed in 78% of SCEs in construction zones and in 94% of SCEs that were not construction-zone related. The single SCE in a construction-related zone did have seat belt use. Only two categories had sufficient data to analyze further: construction zone and not construction-zone related. The model for this comparison excluded a driver intercept term. The comparisons of seat belt use in these categories found no statistically significant differences [OR = 0.21, 95% CI = (0.04, 1.07)].

Table 26. Driver seat belt use by construction zone status in naturalistic driving SCE data.

Construction Zone Status	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Construction zone (SCE occurred in zone)	6	7 (77.78%)	2 (22.22%)	9
Construction zone-related (SCE occurred in approach)	1	1 (100.00%)	0 (0.00%)	1
Not construction zone-related (or unknown)	19	290 (94.46%)	17 (5.54%)	307

5.2 ROADWAY FACTORS

Roadway factors assessed in the naturalistic driving data included:

- number of travel lanes in the subject vehicle's direction;
- relation to junction;
- level of service;
- trafficway flow;
- roadway alignment; and
- roadway profile.

5.2.1 Number of Travel Lanes

Table 27 presents SCE frequency counts and seat belt use by number of travel lanes. For the current study, the original travel lane coding was revised to feature fewer levels. Any SCE with travel lanes of 3, 4, 5, 6, or 7+ was recoded as having three or more travel lanes ("3+"). SCEs with "unknown" number of travel lanes were excluded from the analysis. The SCEs included 105 occurrences in a single travel lane, 120 on roads with two travel lanes, and 91 on roads with three or more travel lanes. Seat belt use was observed in 90% of SCEs in a single travel lane, in 96% of SCEs on roads with two travel lanes, and in 97% of SCEs on roads with three or more travel lanes. Output from the logistic regression model assessing seat belt use by number of travel lanes indicated no statistically significant differences between the travel lane categories ($p = 0.1414$).

Table 27. Driver seat belt use by number of travel lanes in naturalistic driving SCE data.

Number of Travel Lanes	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
1	18	95 (90.48%)	10 (9.52%)	105
2	18	115 (95.83%)	5 (4.17%)	120
3+	16	88 (96.70%)	3 (3.30%)	91

5.2.2 Relation to Junction

Relation to junction in SCEs was categorized as:

- non-junction (152 SCEs),
- intersection or intersection-related (122),
- entrance/exit ramp (19),
- on a bridge (6),
- driveway/alley access (2), or
- parking lot (16).

SCEs with an "unknown" relation to junction were excluded from the analysis. Table 28 presents SCE frequency counts and seat belt use in each relation to junction category. Seat belt use was observed in:

- 95% of SCEs in non-junctions,
- 92% of SCEs at intersection or intersection-related road segments,
- 100% of SCEs on entrance/exit ramp road segments,
- 100% of SCEs on a bridge,
- 100% of SCEs on driveway/alley access road segments, and
- 88% of SCEs in parking lots.

The relation to junction categories with sufficient data for further testing included non-junction, intersection or intersection-related, and parking lot. Output from the logistic regression model assessing seat belt use by relation to junction indicated no statistically significant differences between the categories with sufficient data for testing ($p = 0.8059$).

Table 28. Driver seat belt use by relation to junction in naturalistic driving SCE data.

Relation to Junction	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Non-Junction	18	145 (95.39%)	7 (4.61%)	152
Intersection or Intersection-Related	18	112 (91.80%)	10 (8.20%)	122
Entrance/Exit Ramp	10	19 (100.00%)	0 (0.00%)	19
On a Bridge	2	6 (100.00%)	0 (0.00%)	6
Driveway/Alley Access	2	2 (100.00%)	0 (0.00%)	2
Parking Lot	8	14 (87.50%)	2 (12.50%)	16

5.2.3 Level of Service

The current study compared seat belt use by level of service categories A, B, C, and combined D, E, and F. Table 29 presents SCE frequency counts and seat belt use in each level of service category. The dataset included:

- 181 SCEs in level of service A (93% overall seat belt use);
- 97 SCEs in level of service B (95% overall seat belt use);
- 25 SCEs in level of service C (96% overall seat belt use); and
- 14 SCEs in levels of service D, E, or F (100% overall seat belt use).

The level of service categories with sufficient data for further testing included A, B, and C. Output from the logistic regression model assessing seat belt use in these level of service categories indicated no statistically significant differences ($p = 0.8799$).

Table 29. Driver seat belt use by level of service in naturalistic driving SCE data.

Level of Service	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Level A	18	168 (92.82%)	13 (7.18%)	181
Level B	18	92 (94.85%)	5 (5.15%)	97
Level C	11	24 (96.00%)	1 (4.00%)	25
Levels D, E, F	10	14 (100.00%)	0 (0.00%)	14

5.2.4 Trafficway Flow

Table 30 presents SCE frequency counts and seat belt use by trafficway flow categories.

- 165 SCEs on divided roads with a median strip or barrier trafficway flow (98% seat belt use);
- 3 SCEs in driveway or alley access trafficway flow (33% seat belt use);

- 106 SCEs on roads that were not physically divided but had a two-way trafficway flow (90% seat belt use);
- 16 SCEs on roads that were not physically divided but had a center two-way left turn lane (100% seat belt use); and
- 27 SCEs in one-way trafficway flow (93% seat belt use).

The trafficway flow categories with sufficient data for further testing included divided roads with a median strip or barrier, not physically divided with a two-way trafficway flow, and one-way trafficway.

Output from the logistic regression model assessing seat belt use in these trafficway flow categories indicated a significant increase in seat belt use on divided roadways compared to not physically divided roadways with two-way trafficways [OR = 4.661, 95% CI = (1.437, 15.117)]. The other comparisons were not statistically significant; all results are included in Appendix A.2.

Table 30. Driver seat belt use by trafficway flow in naturalistic driving SCE data.

Trafficway Flow	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Divided (median strip or barrier)	19	161 (97.58%)	4 (2.42%)	165
Driveway, alley access, etc.	3	1 (33.33%)	2 (66.67%)	3
Not physically divided (two-way trafficway)	16	95 (89.62%)	11 (10.38%)	106
Not physically divided (center two-way left turn lane)	10	16 (100.00%)	0 (0.00%)	16
One-way trafficway	11	25 (92.59%)	2 (7.41%)	27

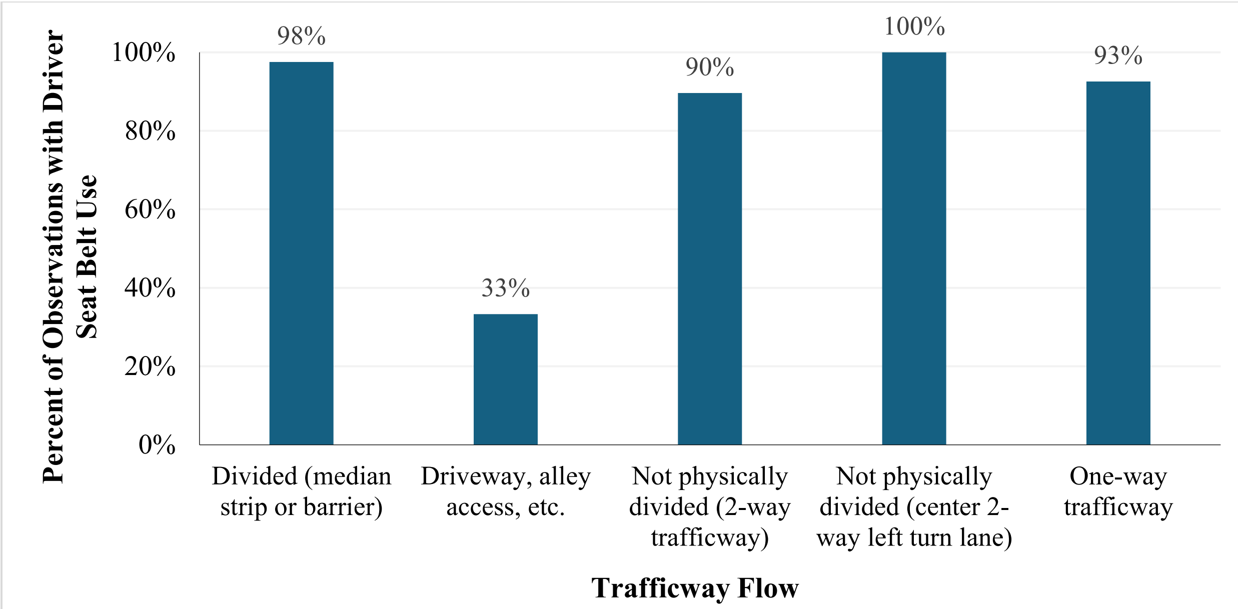

Figure 11. Bar graph. Driver seat belt use by trafficway flow in naturalistic driving SCE data.

5.2.5 Roadway Alignment

Table 31 presents SCE frequency counts and seat belt use by roadway alignment. For the current study, roadway alignment categories of "curve left" and "curve right" were combined into a single category of "curved" and straight roadway alignment was kept as is. SCEs with an unknown roadway alignment were excluded from analysis.

- 96 SCEs on curved roadways (97% seat belt use); and
- 220 SCEs on straight roadways (93% seat belt use).

A logistic regression model assessing seat belt use by roadway alignment indicated no significant difference [OR = 2.268, 95% CI = (0.621, 8.286)].

Table 31. Driver seat belt use by roadway alignment in naturalistic driving SCE data

Roadway Alignment	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Curved left or right	15	93 (96.88%)	3 (3.13%)	96
Straight	19	205 (93.18%)	15 (6.82%)	220

5.2.6 Roadway Profile

Table 32 presents SCE frequency counts and seat belt use by roadway profile. For the current study, roadway profile categories of "grade up" and "grade down" were combined into a single category of "grade up/down" and roadway profile categories of "level" and "hillcrest" were kept as they were. Unknown roadway profiles were excluded.

- 96 SCEs on level roadways (94% seat belt use); and
- 2 SCEs on roadways with hillcrests (100% seat belt use).
- 42 SCEs on roadways with a grade up or down (93% seat belt use)

Seat belt use was compared for SCEs on level and grade up or grade down roadways and the logistic regression model found no significant difference between the two roadway profile categories [OR = 0.809, 95% CI = (0.224, 2.920)].

Table 32. Driver seat belt use by roadway profile in naturalistic driving SCE data.

Roadway Profile	Driver Count	Driver Seat Belt Use Observed	No Driver Seat Belt Use Observed	Total Observations
Level (or unknown)	19	257 (94.14%)	16 (5.86%)	96
Hillcrest	2	2 (100.00%)	0 (0.00%)	2
Grade Up/Down	13	39 (92.86%)	3 (7.14%)	42

5.3 DRIVER FACTORS

Driver factors assessed in the naturalistic driving data included a multitude of driver distraction tasks and driver behaviors. For each SCE, up to three driver distraction tasks and up to three driver behavior tasks were noted.

5.3.1 Driver Distraction Tasks

- Table 33 presents a list of distraction tasks noted during video reduction. The table includes the total number of SCEs with these tasks observed and the proportion of these observations with seat belt use. The table also includes the total number of SCEs without the distraction task and the proportion of these observations with seat belt use. A single SCE could have up to three distraction tasks noted. The most frequently observed tasks included:
- 132 driving-related inattention to the forward roadway observations95% seat belt use);
- 128 look at side mirrors observations (95% seat belt use);
- 53 external distraction observations (89% seat belt use);
- 48 look at outside vehicle, person, animal, or object observations (88% seat belt use); and
- 39 look at internal object observations (95% seat belt use).

Table 33. Driver seat belt use by driver distraction-related tasks in naturalistic driving SCE data.

Distraction Task	Driver Count with Distraction Task	Total Observations with Distraction Task	Seat Belt Use Proportion for SCEs with Distraction Task	Total Observations without Distraction Task	Seat Belt Use Proportion for SCEs without Distraction Task
Adjust earpiece/headset	1	1	100.00%	316	93.99%
Adjust instrument panel	1	1	100.00%	316	93.99%
Bite nails/cuticles	1	1	100.00%	316	93.99%
Browse/read cell phone	5	10	90.00%	307	94.14%
Check speedometer	1	4	100.00%	313	93.93%
Cigarette in hand or mouth	3	8	100.00%	309	93.85%
Dial cell phone	4	4	100.00%	313	93.93%
Drink from a container	5	8	100.00%	309	93.85%
Driving-related inattention to the forward roadway (Look at right-side mirror; Look at left-side mirror; Check speedometer)	17	132	95.45%	185	92.97%
Eating	7	12	100.00%	305	93.77%
External distraction (Wave to passing vehicle/driver; Look at outside vehicle, person, animal, object)	14	53	88.68%	264	95.08%
Grooming (Bite nails/cuticles; Other personal hygiene	3	3	100.00%	314	93.95%
Hand-held cell phone use- Visual/manual tasks (Browse/Read cell phone; Text message on cell phone)	10	20	95.00%	297	93.94%
Interact with dispatching device	3	8	75.00%	309	94.50%
Interact with GPS	2	2	100.00%	315	83.97%
Interact with or look at other occupant(s)	1	1	100.00%	316	93.99%
Interact with satellite radio	1	1	100.00%	316	93.99%
Look at internal object	13	39	94.87%	278	93.88%
Look at outside vehicle, person, animal, object	14	48	87.50%	269	95.17%

Distraction Task	Driver Count with Distraction Task	Total Observations with Distraction Task	Seat Belt Use Proportion for SCEs with Distraction Task	Total Observations without Distraction Task	Seat Belt Use Proportion for SCEs without Distraction Task
Look back in sleeper berth	1	1	100.00%	316	93.99%
Look at side mirrors (Look at right-side mirror; Look at left-side mirror)	17	128	95.31%	189	93.12%
Pull air horn	4	5	100.00%	312	93.91%
Put on/remove/adjust sunglasses or reading glasses	2	2	50.00%	315	94.29%
Other personal hygiene	2	2	100.00%	315	93.97%
Other potentially distracting behavior	3	5	80.00%	312	94.23%
Reach for object in vehicle (including cell phone, CB/other communications device)	12	30	90.00%	287	94.43%
Read book, newspaper, paperwork, etc.	3	4	100.00%	313	93.93%
Talk/listen on cell phone (Talk or listen to hand-held phone; Talk or listen to hands-free phone)	11	16	93.75%	301	94.02%
Talk/listen on hand-held phone	4	5	80.00%	312	94.23%
Talk/listen on hands-free phone	7	11	100.00%	306	93.79%
Talk/listen to CB microphone	2	2	100.00%	315	93.97%
Talk/sing/dance with no indication of passenger	3	3	100.00%	314	93.95%
Text message on cell phone	9	13	100.00%	304	93.75%
Turn on/off cab light	1	1	100.00%	316	93.99%
Use/reach for other device	1	1	100.00%	316	93.99%
Wave to passing vehicle/driver	3	7	100.00%	310	93.87%

Several distraction tasks had sufficient data for further analysis. Individual logistic regression models predicted seat belt use as a binary response variable by distraction task involvement, with a random intercept term for driver. Table 34 presents the OR estimates and 95% CI comparing seat belt use when involved in a specific distraction task to seat belt use when not involved in the distraction task. The results indicate no significant difference in seat belt use behaviors when performing the distraction tasks compared to driving when *not* performing the distraction tasks. Distraction tasks excluded from the following table had insufficient data for further assessment.

Table 34. OR and 95% CI comparing driver seat belt use by driver distraction-related task involvement in naturalistic driving SCE data.

Distraction Task	OR Estimate	Df	95% CI
Look at internal object	1.205	49	(0.258, 5.639)
Handheld cell phone use	1.226	49	(0.147, 10.201)
Browse/read cell phone	0.561	49	(0.064, 4.928)
External distraction	0.406	49	(0.143, 1.150)
Look at outside object	0.355	49	(0.125, 1.012)
Look side mirrors	1.502	49	(0.542, 4.164)
Driving related inattention	1.587	49	(0.573, 4.399)
Reach in-vehicle object	0.531	49	(0.141, 2.005)

5.3.2 Driver Behavior Tasks

Table 35 presents a list of driver behavior tasks noted during video reduction. The table includes the frequency of SCEs with the driver behavior and the proportion with seat belt use, as well as the frequency count of observations without the driver behavior and the proportion of these SCEs with seat belt use. A single SCE could have up to three driver behaviors noted. The most frequently observed driver behaviors included:

- 126 distracted, drowsy, or inattentive driving observations (94% seat belt use);
- 125 inattentive or distracted driving observations (94% seat belt use);
- 29 other improper turning behaviors observations (93% seat belt use); and
- 21 angry driving observations (95% seat belt use).

All other driver behaviors had observation counts of 10 or fewer SCEs.

Table 35. Driver seat belt use by driver behaviors in naturalistic driving SCE data.

Driver Behavior	Driver Count with Driver Behavior	Total Observations with Driver Behavior	Seat Belt Use Proportion for SCEs with Driver Behavior	Total Observations without Driver Behavior	Seat Belt Use Proportion for SCEs without Driver Behavior
Aggressive driving, other	5	8	100.00%	309	93.85%
Aggressive driving, any (Aggressive driving, other; Aggressive driving, specific, directed menacing actions)	5	10	100.00%	307	93.81%
Aggressive driving, specific, directed menacing actions	2	2	100.00%	315	93.97%
Angry	8	21	95.24%	296	93.92%
Apparent excessive speed for conditions or location (does not include tailgating, unless above speed limit)	4	6	100.00%	311	93.89%
Apparent unfamiliarity with roadway	5	5	80.00%	312	94.23%
Avoiding object	6	8	75.00%	309	94.50%
Avoiding other vehicle	4	5	80.00%	312	94.23%
Avoiding pedestrian	2	2	100.00%	315	93.97%
Cutting in, too close (behind other vehicle or in front)	3	3	100.00%	314	93.95%
Cutting in, too close behind other vehicle	1	1	100.00%	316	93.99%
Cutting in, too close in front of other vehicle	2	2	100.00%	315	93.97%
Did not see other vehicle during lane change or merge	3	5	100.00%	312	93.91%
Driving slowly; below speed limit or in relation to other traffic	1	1	100.00%	316	93.99%
Drowsy, sleepy, asleep, fatigued, other reduced alertness	3	3	100.00%	314	93.95%
Distracted, drowsy, or inattentive (Drowsy, sleepy,	15	126	93.65%	191	94.24%

Driver Behavior	Driver Count with Driver Behavior	Total Observations with Driver Behavior	Seat Belt Use Proportion for SCEs with Driver Behavior	Total Observations without Driver Behavior	Seat Belt Use Proportion for SCEs without Driver Behavior
asleep, fatigued, other reduced alertness)					
Following too close	4	4	100.00%	313	93.93%
Improper turn: cut corner on left turn	5	7	100.00%	310	93.87%
Improper turn: wide right turn	2	4	75.00%	313	94.25%
Inadequate evasive action	6	7	85.71%	310	94.19%
Inattentive or distracted	15	125	93.60%	192	94.27%
Loss of control on slippery road surface	1	1	100.00%	316	93.99%
Making turn from wrong lane (e.g., across lanes)	2	2	100.00%	315	93.97%
Non-signed crossing violation (e.g., driveway entering roadway)	1	1	100.00%	316	94.30%
Other	2	2	100.00%	315	94.29%
Other improper turning	7	29	93.10%	288	94.10%
Other sign violation	1	1	100.00%	316	93.99%
Signal violation, tried to beat signal change	3	3	100.00%	314	93.95%
Wrong side of road, not overtaking (includes partial or full drift into oncoming lane)	4	4	100.00%	313	93.93%
Passing on right		2	100.00%	315	93.97%
Illegal passing (i.e., across double line)	2	2	100.00%	315	93.97%

Four driver behaviors had sufficient data for further analysis:

- angry;
- distracted, drowsy, or inattentive (drowsy, sleepy, asleep, fatigued, other reduced alertness);
- inattentive or distracted; and
- other improper turning.

Individual logistic regression models predicted seat belt use as a binary response variable by driver behavior occurrence, with a random intercept term for driver. Table 36 presents the OR estimates and 95% CI comparing seat belt use when performing the specific driver behavior to seat belt use when not performing the specific driver behavior. The results indicate no significant difference in seat belt use *with* each of the four driver behaviors compared to during driving *without* the four driver behaviors. Driver behaviors excluded from the following table had insufficient data to assess further.

Table 36. OR and 95% CI comparing driver seat belt use by driver behavior task involvement in naturalistic driving SCE data.

Driver Behavior	OR Estimate	Df	95% CI
Angry	1.295	49	(0.156, 10.750)
Distracted, drowsy, or inattentive (drowsy, sleepy, asleep, fatigued, other reduced alertness)	0.901	49	(0.344, 2.363)
Inattentive or distracted	0.889	49	(0.339, 2.330)
Other improper turning	0.847	49	(0.179, 4.014)

CHAPTER 6. CONCLUSIONS

The current study assessed factors associated with seat belt use and disuse in CMV drivers via a literature review and analysis of two different data collections. Factors investigated in the data analysis included environmental, roadway, and vehicle factors as well as driver distraction behaviors.

In the NDS data, drivers used their seat belts in approximately 93% of observed SCEs, slightly higher than the 2016 federal estimate for driver seat belt use of 86%. The observational data showed lower seat belt use, with driver seat belt use in approximately 81% of all observations. Seat belt use was not consistent across observed locations, with different strata showing a range of seat belt use proportions from a high of 83% to a low of 71%. Differences in seat belt use by location has been documented in previous studies where FMCSA found seat belt use ranged from 76% to 91% in different regions of the country and varied based on road type or traffic conditions.(12)

The analysis of observational and NDS data identified several environmental or roadway factors where seat belt use patterns changed significantly across the factor levels. In the observational data, in general, fewer drivers used their seat belt on Wednesdays, Fridays, and Saturdays, and drivers were more likely to use their seat belt in the evening (5 p.m. to 7 p.m.) compared to morning, midday, and afternoon. Several studies of passenger vehicles found seat belt use to be significantly lower at night compared to day hours.(41,42) These patterns may be due to traffic volumes on the road or driving behaviors of others sharing the road, during typical post-work rush hour periods. Truck drivers in the current study were found to use their seat belt less often while driving on a two-lane road compared to driving on single-lane road or road with three or more travel lanes. The naturalistic driving data found trafficway flow associated with significant differences in seat belt use patterns. Driving on divided highways was associated with higher seat belt use compared to driving on non-physically divided roadways. Previous research from FMCSA found CMV driver seat belt use to be higher on expressways compared to cities or surface streets.(12) Possible reasons for these seat belt use patterns could be due to perceived risk by the driver given traffic speeds or volumes or changes in proximity of the driver to work-related or rest-related stops on different roadway types.

Multiple vehicle factors showed statistically significant relationships with seat belt use. The observational data revealed a lower propensity for seat belt use among drivers of construction vehicles, specifically concrete mixers and dump truck drivers compared to most other truck types. Truck type was also significantly associated with seat belt use in the analysis of tractor trailer data. Gravel train truck drivers showed lower seat belt use compared to several other tractor trailer truck types. At construction sites, drivers may be operating at low speeds or under unclear seat belt use recommendations. It is possible that drivers did not change their seat belt use behaviors once off the site. Previous research using the NDS data found that drivers operating in parking lots or at lower speeds showed higher rates of seat belt violations.(32) However, seat belt use is important for driver safety both on and off site. A 2008 study by the Occupational Safety and Health Administration investigating 50 rollover crashes in a different type of construction vehicle found 14 of 19 crashes without seat belt use resulted in a fatality.(43)

In the current study, drivers operating a double trailer were less likely to use their seat belt compared to drivers operating a single trailer. In addition, local fleet drivers were less likely to use their seat belt compared to national fleet drivers. There is little published information on crash rates for these high-risk vehicle factors due to the classification of vehicles in crash databases and tracking of exposure data for these vehicles. These vehicle factor findings reveal opportunities for fleets with these vehicles to increase efforts to encourage or enforce seat belt use amongst drivers.

The current study found little correlation between seat belt use and other driver behaviors. The analysis of observational study data did find seat belt use to be significantly higher in observations where drivers were using a hands-free cell phone with an earpiece compared to drivers not using a cell phone or talking on a handheld cell phone. Handheld cell phone use has been found to be risky for truck drivers,(44,45) and driver propensity to engage in risky behaviors could explain the tie between seat belt use patterns in these observations. However, driver seat belt use in observations without cell phone use would need further research to fully explain any relationship.

The analysis of NDS data found one significant factor associated with seat belt use. Naturalistic driving data provides a unique opportunity to assess seat belt use within participant observations, which can be useful in identifying conditions associated with changes in seat belt use behaviors. Naturalistic driving data also allows researchers to observe seat belt use in environmental and roadway conditions, such as night driving or rural driving, that may be difficult to observe in an alternative data collection method. However, the original NDS included an OBMS, which may have affected drivers' seat belt use. Accuracy of seat belt use violations for the OBMS study was 100% and seat belt use violations dropped 56% in the early intervention period from the baseline phase.(5) The effectiveness of the OBMS in changing seat belt use behavior may have resulted in consistently higher seat belt use across the factors levels. In addition, the study had very few observations without seat belt use, making it difficult to detect significant differences across factor levels. An analysis of baseline driving data or other NDS datasets may improve chances of understanding factors impacting seat belt use.

The literature review identified several methods to improve seat belt use. These methods include distribution of information to fleets by FMCSA, federal safety campaigns with diverse messaging approaches, and fleet use of OBMS to provide coaching on seat belt use to drivers. A literature review performed by the University of Australia identified key features of effective seat belt safety programs.(40) These features include improving seat belt comfort and design, dispelling driver misconceptions about the safety of seat belts, increasing perception of penalties for not wearing a seat belt, and support by fleet management.

6.1 LIMITATIONS

While the current study did have strengths, such as the use of two distinct data sets representing different geographic regions and sampling approaches, there were also important limitations to note. The naturalistic driving data set was limited in terms of available data. For example, the original study focused on SCE and triggered violation data reduction, leaving the dataset with limited event types for analysis. In addition, drivers in the NDS received feedback on their seat belt use during the study. Further, the data set had limited driver demographic data for analysis.

The data set featured 19 drivers from a single fleet based in one geographic location of the United States. For these reasons, it may be useful to analyze seat belt use in baseline and SCE driving data from other naturalistic driving data sets to better understand driver seat belt use in non-SCE driving epochs. Including data collected from additional NDSs would also expand the driver sample beyond a single carrier and geographic location and add opportunities to assess driver demographic factors or carrier factors and seat belt use patterns.

The observational data set also had limitations. For example, due to the data collection approach, the locations for data collection were limited to those where an observer could note seat belt use and vehicle data of passing trucks. These roadway locations (and driver seat belt use) may be different from roadway locations where it is easier to collect observational seat belt use data. In addition, the study was not able to collect driver demographic data that could be validated. Also, the data set did not include observations for times of day between 7 p.m. and 7 a.m. Naturalistic driving data and driver survey data can provide information on driver seat belt use in roadway locations and driving conditions not suitable for observational data collection and could be used to better understand seat belt use patterns across driver demographic and roadway factors.

6.2 FUTURE RESEARCH

The literature review identified gaps in published research on seat belt use and opportunities for future research. One gap was the need for new data on CMV drivers' seat belt use during normal driving and in crashes. Although the current study partially addressed this research gap, future research could assess seat belt use in baselines and SCEs across a larger sample of drivers in NDS data by analyzing multiple NDS datasets for seat belt use patterns. Analyzing a larger sample of NDS datasets would also allow for analysis of driver demographic factors that may be related to seat belt use patterns.

There is a need for studies on characteristics of effective technology (frequency of alerts, type of alerts, etc.) and information on consumer/driver acceptance of these technologies. The FAST DASH 2 study found a change in seat belt use behavior with the implementation of an OBMS.[5] However, as options for OBMSs grow, there may be room for fleets and drivers to pick OBMSs that are effective and accepted. An analysis of existing naturalistic driving data where an OBMS was also installed in the study vehicles may identify differences between OBMS characteristics and effectiveness. However, a stronger approach would be to assess baseline and intervention periods of performance with different OBMS characteristics and obtain fleet management and driver ratings of acceptance, within and between multiple fleets.

In addition, future research should investigate qualities of safety programs targeting seat belt use in commercial fleets and drivers. Future work to develop a safety program could incorporate findings in the current study into the program. Additional research into the reasons drivers choose not to wear their seat belt in scenarios with typically lower seat belt use could be useful in developing an effective safety program with suggested strategies for improving seat belt use. Further, to highlight the impact of seat belt use on driver safety, a future research study could use federal crash data collected in the Fatality Analysis Reporting System or Crash Report Sampling System to calculate the number of lives saved by changing seat belt use behavior in the scenarios identified in the current study as high risk for non-seat belt use. Assessments of safety programs should measure seat belt use in drivers before and after program implementation at a fleet and gather driver feedback to continue improvement of a safety program. Using a seat belt is one of the easiest ways for a driver to increase their likelihood of surviving a crash and arriving home safely. Research that can be used to increase seat belt use in CMV drivers is thus incredibly important for saving lives.

APPENDIX A. ADDITIONAL ANALYSIS OUTPUT

A.1 OBSERVATIONAL STUDY DATA

Day of the Week

OR and 95% CI calculations from the model assessing seat belt use by day of the week are presented in Table 37.

Table 37. OR estimates and 95% CI for seat belt use on different days of the week using observational study data.

Day of the Week Comparison	OR Estimate	*df*	95% Confidence Limits
Sunday vs. Monday	0.737	4,136	(0.503, 1.081)
Sunday vs. Tuesday	0.767	4,136	(0.522, 1.126)
Sunday vs. Wednesday	1.141	4,136	(0.774, 1.683)
Sunday vs. Thursday	0.812	4,136	(0.559, 1.180)
Sunday vs. Friday	1.043	4,136	(0.729, 1.492)
Sunday vs. Saturday	1.081	4,136	(0.709, 1.647)
Monday vs. Tuesday	1.040	4,136	(0.776, 1.393)
Monday vs. Wednesday	1.548*	4,136	(1.150, 2.084)
Monday vs. Thursday	1.102	4,136	(0.835, 1.455)
Monday vs. Friday	1.415*	4,136	(1.095, 1.829)
Monday vs. Saturday	1.466*	4,136	(1.044, 2.058)
Tuesday vs. Wednesday	1.489*	4,136	(1.103, 2.009)
Tuesday vs. Thursday	1.060	4,136	(0.801, 1.403)
Tuesday vs. Friday	1.361*	4,136	(1.050, 1.764)
Tuesday vs. Saturday	1.410*	4,136	(1.002, 1.983)
Wednesday vs. Thursday	0.712*	4,136	(0.535, 0.946)
Wednesday vs. Friday	0.914	4,136	(0.702, 1.190)
Wednesday vs. Saturday	0.947	4,136	(0.671, 1.337)
Thursday vs. Friday	1.284*	4,136	(1.008, 1.636)
Thursday vs. Saturday	1.330	4,136	(0.958, 1.848)
Friday vs. Saturday	1.036	4,136	(0.759, 1.413)

Table 38 presents a comparison of seat belt use on weekdays to weekends; however, no significant difference was found between the two.

Table 38. Driver seat belt use during weekdays and weekends in observational study data.

Day of the Week	Driver Seatbelt Use Observed	No Driver Seatbelt Use Observed	Total Observations
Weekday	2,945 (81.76%)	657 (18.24%)	3,602
Weekend	432 (79.27%)	113 (20.73%)	545

Time of Day

OR and 95% CI calculations from the model assessing seat belt use by time of day are presented in Table 39.

Table 39. OR estimates and corresponding 95% CI for seat belt use by time of day.

Time of Day Comparison	OR Estimate	*df*	95% Confidence Limits
Morning vs. Midday	0.982	4,139	(0.810, 1.191)
Afternoon vs. Morning	1.020	4,139	(0.829, 1.255)
Afternoon vs. Midday	1.002	4,139	(0.826, 1.215)
Evening vs. Morning	2.565	4,139	(1.320, 4.985)
Evening vs. Midday	2.519	4,139	(1.305, 4.865)
Evening vs. Afternoon	2.516	4,139	(1.299, 4.870)

OR and 95% CI calculations from a model assessing the impact of time of day and day of the week on seat belt use are presented in Table 40.

Table 40. OR estimates and corresponding 95% CI for seat belt use by time of day and day of week.

Comparison Level 1	Comparison Level 2	OR Estimate	*df*	95% Confidence Limits
Weekday Afternoon	**Weekday Evening**	0.170	4,135	(0.041, 0.707)
Weekday Afternoon	**Weekday Morning**	0.926	4,135	(0.743, 1.154)
Weekday Afternoon	**Weekday Midday**	0.938	4,135	(0.763, 1.153)
Weekday Afternoon	**Weekend Afternoon**	0.670	4,135	(0.405, 1.108)
Weekday Afternoon	**Weekend Evening**	0.540	4,135	(0.246, 1.184)
Weekday Afternoon	**Weekend Morning**	1.382	4,135	(0.904, 2.114)
Weekday Afternoon	**Weekend Midday**	1.051	4,135	(0.725, 1.524)
Weekday Evening	**Weekday Morning**	5.442	4,135	(1.311, 22.598)
Weekday Evening	**Weekday Midday**	5.511	4,135	(1.33, 22.827)
Weekday Evening	**Weekend Afternoon**	3.938	4,135	(0.883, 17.573)

Comparison Level 1	Comparison Level 2	OR Estimate	*df*	95% Confidence Limits
Weekday Evening	**Weekend Evening**	3.175	4,135	(0.633, 15.918)
Weekday Evening	**Weekend Morning**	8.123	4,135	(1.865, 35.379)
Weekday Evening	**Weekend Midday**	6.177	4,135	(1.439, 26.519)
Weekday Morning	**Weekday Midday**	1.013	4,135	(0.823, 1.246)
Weekday Morning	**Weekend Afternoon**	0.724	4,135	(0.436, 1.2)
Weekday Morning	**Weekend Evening**	0.583	4,135	(0.265, 1.284)
Weekday Morning	**Weekend Morning**	1.493	4,135	(0.975, 2.284)
Weekday Morning	**Weekend Midday**	1.135	4,135	(0.781, 1.649)
Weekday Midday	**Weekend Afternoon**	0.715	4,135	(0.433, 1.179)
Weekday Midday	**Weekend Evening**	0.576	4,135	(0.263, 1.263)
Weekday Midday	**Weekend Morning**	1.474	4,135	(0.967, 2.247)
Weekday Midday	**Weekend Midday**	1.121	4,135	(0.776, 1.619)
Weekend Afternoon	**Weekend Evening**	0.806	4,135	(0.339, 1.914)
Weekend Afternoon	**Weekend Morning**	2.062	4,135	(1.114, 3.819)
Weekend Afternoon	**Weekend Midday**	1.568	4,135	(0.893, 2.755)
Weekend Evening	**Weekend Morning**	2.559	4,135	(1.085, 6.034)
Weekend Evening	**Weekend Mid Day**	1.946	4,135	(0.864, 4.38)
Weekend Morning	**Weekend Mid Day**	0.760	4,135	(0.454, 1.273)

Number of Travel Lanes

OR and 95% CI calculations from the model assessing seat belt use by number of travel lanes are presented in Table 41.

Table 41. OR estimates and 95% CI for seat belt use in different travel lane categories using observational study data.

Number of Travel Lanes Comparison	OR Estimate	*df*	95% Confidence Limits
1 vs. 2	1.431	4,140	(1.145, 1.789)
1 vs. 3+	1.161	4,140	(0.929, 1.452)
2 vs. 3+	1.232	4,140	(1.025, 1.481)

Truck Type

OR and 95% CI calculations from the model assessing seat belt use by truck type for single unit trucks are presented in Table 42.

Table 42. OR estimates and 95% CI for seat belt use in different single unit truck type categories using observational study data.

Single Unit Truck Type Comparison	OR Estimate	*df*	95% Confidence Limits
Box vs. Dump	1.987	1,684	(1.375, 2.870)
Box vs. Flatbed	1.857	1,684	(1.309, 2.633)
Box vs. Concrete mixer	12.571	1,684	(6.912, 22.863)
Box vs. Garbage truck	1.294	1,684	(0.700, 2.392)
Box vs. Tanker	0.975	1,684	(0.448, 2.122)
Box vs. Other	1.084	1,684	(0.649, 1.812)
Dump vs. Flatbed	0.934	1,684	(0.596, 1.466)
Dump vs. Concrete mixer	6.327	1,684	(3.261, 12.277)
Dump vs. Garbage truck	0.651	1,684	(0.331, 1.281)
Dump vs. Tanker	0.491	1,684	(0.214, 1.123)
Dump vs. Other	0.546	1,684	(0.304, 0.981)
Flatbed vs. Concrete mixer	6.771	1,684	(3.522, 13.018)
Flatbed vs. Garbage truck	0.697	1,684	(0.358, 1.358)
Flatbed vs. Tanker	0.525	1,684	(0.231, 1.192)
Flatbed vs. Other	0.584	1,684	(0.329, 1.037)
Concrete mixer vs. Garbage truck	0.103	1,684	(0.045, 0.235)
Concrete mixer vs. Tanker	0.078	1,684	(0.030, 0.202)
Concrete mixer vs. Other	0.086	1,684	(0.041, 0.183)
Garbage truck vs. Tanker	0.753	1,684	(0.287, 1.975)
Garbage truck vs. Other	0.838	1,684	(0.390, 1.801)
Tanker vs. Other	1.113	1,684	(0.452, 2.740)

OR and 95% CI calculations from the model assessing seat belt use by truck type for tractor trailers are presented in Table 43.

Table 43. OR estimates and 95% CI for seat belt use in different tractor trailer truck type categories using observational study data.

Tractor Trailer Truck Type Comparison	OR Estimate	*df*	95% Confidence Limits
Box trailer vs. Container	1.510	2,440	(0.857, 2.660)
Box trailer vs. Flatbed	1.402	2,440	(0.982, 2.002)
Box trailer vs. Gravel train	3.008	2,440	(2.170, 4.170)
Box trailer vs. Tanker	1.246	2,440	(0.835, 1.860)

Tractor Trailer Truck Type Comparison	OR Estimate	*df*	95% Confidence Limits
Box trailer vs. Auto transporter	1.064	2,440	(0.472, 2.402)
Box trailer vs. Rig only	1.337	2,440	(0.787, 2.272)
Box trailer vs. Other	1.476	2,440	(0.310, 7.038)
Container vs. Flatbed	0.929	2,440	(0.490, 1.759)
Container vs. Gravel train	1.992	2,440	(1.070, 3.709)
Container vs. Tanker	0.825	2,440	(0.425, 1.602)
Container vs. Auto transporter	0.705	2,440	(0.268, 1.856)
Container vs. Rig only	0.885	2,440	(0.420, 1.867)
Container vs. Other	0.978	2,440	(0.188, 5.084)
Flatbed vs. Gravel train	2.145	2,440	(1.384, 3.326)
Flatbed vs. Tanker	0.889	2,440	(0.543, 1.454)
Flatbed vs. Auto transporter	0.759	2,440	(0.319, 1.805)
Flatbed vs. Rig only	0.953	2,440	(0.519, 1.751)
Flatbed vs. Other	1.053	2,440	(0.215, 5.160)
Gravel train vs. Tanker	0.414	2,440	(0.258, 0.665)
Gravel train vs. Auto transporter	0.354	2,440	(0.151, 0.831)
Gravel train vs. Rig only	0.444	2,440	(0.246, 0.801)
Gravel train vs. Other	0.491	2,440	(0.101, 2.386)
Tanker vs. Auto transporter	0.854	2,440	(0.352, 2.070)
Tanker vs. Rig only	1.073	2,440	(0.569, 2.023)
Tanker vs. Other	1.185	2,440	(0.239, 5.862)
Auto transporter vs. Rig only	1.256	2,440	(0.487, 3.237)
Auto transporter vs. Other	1.387	2,440	(0.241, 7.979)
Rig only vs. Other	1.104	2,440	(0.215, 5.676)

Driver Cell Phone Use

OR and 95% CI calculations from the model assessing driver cell phone behaviors and seat belt use are presented in Table 44.

Table 44. OR estimates and corresponding 95% CI for seat belt use by driver cell phone use.

Driver Cell Phone Use Level 1	Driver Cell Phone Use Level 2	OR Estimate	*df*	95% Confidence Limits
No cell phone use	Handheld talking	1.390	4,056	(0.832, 2.321)
No cell phone use	Handheld typing	0.538	4,056	(0.229, 1.266)
No cell phone use	Hands-free, earpiece	2.790	4,056	(1.572, 4.949)
Handheld talking	Handheld typing	0.387	4,056	(0.144, 1.042)
Handheld talking	Hands-free, earpiece	3.877	4,056	(1.814, 8.291)
Handheld typing	Hands-free, earpiece	0.667	4,056	(0.239, 1.855)

A.2 NATURALISTIC DRIVING STUDY DATA

Trafficway Flow

OR and 95% CI calculations from the model assessing seat belt use by trafficway flow are presented in Table 45. The model for this comparison excluded a driver intercept term.

Table 45. OR estimates and 95% CI for seat belt use in different trafficway flow categories using naturalistic driving SCE data.

Trafficway Flow Comparison	OR Estimate	*df*	95% Confidence Limits
Divided (median strip or barrier) vs. Not physically divided (two-way trafficway)	4.661	312	(1.437, 15.117)
Divided (median strip or barrier) vs. One-way trafficway	3.220	312	(0.556, 18.636)
Not physically divided (two-way trafficway) vs. One-way trafficway	0.691	312	(0.143, 3.340)

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