A FRAMEWORK TO EVALUATE CAUSES AND EFFECTS OF TRUCK DRIVER AT-FAULT CRASHES

Final Report

SPR-810

Oregon Department of Transportation

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16. Abstract: This study presents the analysis of truck driver-at-fault crashes, providing a framework to assess such crashes moving forward. This was accomplished through a series of analyses. First, an agency survey was administered to local, state, federal, and law enforcement agencies throughout the U.S. to gather opinions on truck driver-at-fault crashes and truck driver distractions in their respective jurisdiction. Next, a survey was administered to drivers of large trucks whose trips originate or are destined to the Pacific Northwest; namely, drivers who use Oregon freight highways. The focus of the driver survey was to gain driver perceptions on various truck-related issues, including safety and distracted driving. Following the surveys, an analysis of data obtained from an Oregon Motor Carrier pilot program was conducted. Specifically, the analysis investigated the relationship between driver-at-fault crashes and truck inspection frequency on Oregon highways. The next data analysis used Oregon crash data to generate a series of crash severity models to determine significant contributing factors to driver-at-fault crash severity. Finally, using data obtained from the Oregon Motor Carrier pilot program, the estimated savings due to driver-at-fault crash reduction was determined. This report concluded by providing a comprehensive summary that is accompanied by specific recommendations as it pertains to the framework presented in the current study.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
~NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION

Large truck crashes have a considerable impact on society and the economy. It has been estimated that the average cost of no injury crashes (i.e., property-damage-only), non-fatal injury crashes, and fatal crashes involving large trucks are $15,114, $195,258, and $3,604,518, respectively (Zaloshnja & Miller, 2007). In terms of 2015 dollars, these estimates increase by 21.4% to $18,342, $236,964, and $4,374,415 (Bureau of Labor Statistics, 2016; Sahr, 2016). Nearly all the products that the public purchase, utilize, and consume are transported to market by large trucks. This is seen in the percentage of freight moved by large trucks, approximately 73% of all freight by value and 71% of all freight by weight, and is projected to increase through 2040.

Of special concern is the injury severity of truck driver at-fault crashes in Oregon. Although the state experienced a decrease in the number of truck driver at-fault crashes (757 to 709) and crash rate (0.44 to 0.39) in 2015, it was followed by an increase (684 to 737) in the number of truck driver at-fault crashes and crash rate (0.39 to 0.43) in 2016 (Crash Analysis and Reporting Unit, 2017). In addition, the number of fatal crashes associated with commercial motor vehicles increased from 29 to 49 from 2014 to 2015, with a slight decrease from 49 to 45 in 2016 (Crash Analysis and Reporting Unit, 2017). Common belief is that most truck driver at-fault crashes are a result of driver behavior, such as speeding, following too close, unsafe/improper lane changes, failure to yield right-of-way, and driver fatigue. However, what is not clearly understood is how driving habits have been affected by the increased penetration of smartphones and their applications, on board technologies, and other distracting activities while driving. Distracted driving is becoming a primary threat on Oregon's roads. Any form of distraction, including texting, other cellphone usage, eating, and momentarily taking one's hands off the wheel, presents a threat to all roadway users. In particular, when driving a large commercial truck, distracted driving can be deadly. Recent studies have found that distracted truck driving was a factor in 71% of all truck driving accidents and 6% of all fatal crashes (Federal Motor Carrier Safety Administration, 2016; Olson, Hanowski, Hickman, & Bocanegra, 2009).

With this in mind, the goal of this research is to evaluate the impact of distracted driving on truck driver at-fault crashes through confirming the effectiveness of existing countermeasures (e.g., increased law enforcement presence) or identifying new counter measures. This research is highly relevant to an existing active study "SPR 783 - Truck Parking: An Emerging Safety Hazard to Highway Users". And, this research supports the RAC priority of "Enhance Transportation and/or Employee Safety", "Improve the Reliability of Oregon's Transportation System", and "Lead to Other Efficiencies, Cost Savings, and Cost Avoidance".

1.1 PROJECT OBJECTIVES

In recent years, Oregon has experienced an increase in the number of truck driver at-fault crashes. According to a recent tabulation of large truck crashes, there was a 7.8% increase (684 to 737) in truck driver at-fault crashes and a 10.3% increase (0.39 to 0.43) in the number of truck driver at-fault crashes per million-vehicle-miles-traveled from 2015 to 2016 (Crash Analysis and Reporting Unit, 2017). With this in mind, recent studies have researched the effects of urban/rural crashes, time-of-day, crash type, and roadway classification on large truck injury severities (Al-Bdairi & Hernandez, 2017; Anderson & Hernandez, 2017b; Khorashadi, Niemeier, Shankar, & Mannering, 2005; Pahukula, Hernandez, & Unnikrishnan, 2015). Furthermore, the effects of roadway classification and ton-miles of freight on large truck crash rate and fatality rate have been examined (Anderson & Hernandez, 2017a; Islam & Hernandez, 2015). Although these studies have shed light on the effects of specific crash conditions, the effect of truck driver at-fault crashes as a result of distraction are much less documented, both in terms of injury severity and crash rate. Therefore, this research will focus on the effect of driver distraction on sustained injury severities.

2.0 LITERATURE REVIEW

This chapter provides detailed results of a thorough and comprehensive literature review pertaining to truck driver at-fault crashes with a particular emphasis on distracted driving. Included are recent policies adopted by Oregon that mitigate the effects of distracted driving, as well as federal mandates imposed on commercial motor vehicle (CMV) carriers. The review of literature is based on the following:

- Distracted Driving
- Department of Transportation (DOT) studies and academic literature relating to distracted driving
- Oregon House Bill 2597

A summary of DOT reports focus on applicable research regarding driver distraction, while a summary of academic literature provides insight into the role distracted driving has on driver performance and associated crash risk.

2.1 DISTRACTED DRIVING

In this subchapter, driver distraction will be defined as found in current literature. Additionally, recent crash studies pertaining to distracted driving in both commercial and non-commercial vehicle drivers will be presented. Finally, potential countermeasures identified in past driver distraction-related studies will be summarized.

2.1.1 What is Distracted Driving?

The following narrative comprises a thorough definition of driver distraction. The following definition, as identified by previous studies, suggests that driver distraction is a form of driver inattention. Understanding driver distraction as a whole is necessary to fully comprehend the problems associated with driver distraction, for example those related to truck at-fault crashes.

Driving is a complex task that involves auditory, visual, manual and cognitive resources to ensure safe operation and navigation of a motor vehicle. The combination of these resources requires the majority, if not all, of an individual’s mental attention. Through driving experience, however, a significant portion of the driving task becomes automated and drivers allocate less attentional resources. Thus, with additional resources that can be distributed to other non-driving tasks, drivers feel confident in engaging in concurrent activities without significantly impairing their driving performance or safety (Young & Regan, 2007). This concept of relocating attentional resources from the driving task to a secondary task, or inattention, is considered as distracted driving (Lee, Young, & Regan, 2008). Regan et. al. (2011) summarized existing literature and conclude that driver diverted attention, which is the basis of distracted driving, is a subset of driver inattention. In regards to motor vehicle crashes, distraction is a contributing factor when the attention demanded by the roadway exceeds the driver's allocated amount of attention to the roadway due to a competing secondary task (Ranney, 2008; Regan, Lee, & Young, 2008). The effect of distracted driving and inattention on transportation safety needs to be understood so that techniques can be implemented to reduce both the occurrence of distracted driving and resulting consequences (e.g., truck at-fault crashes).

As technology continues to advance and increasingly penetrate society, drivers are more susceptible of engaging in concurrent tasks involving electronic mobile devices or other external devices. Still, as Ranney (2008) mentions, cellular phone use represents a small amount of a bigger distraction problem. Distraction can occur while engaging in daily activities, such as eating, drinking, adjusting the radio, or consumed in thought. Additionally, distraction may occur when drivers interact with either internal or external Intelligent Transportation Systems (ITS) that provide transportation related information (Ranney, 2008). Therefore, distraction can occur when performing a driving task (i.e.: reading transportation information or route signs). This finding is consistent of Regan et. al.'s conclusion that distracted driving is a subset of driver inattention as all the previously mentioned tasks involves a relocation of attentional resources away from the driving task. Together with the idea that distracted driving can be initiated by many sources and since the use of cellular phones has been shown to implicate roadway safety (Haigney, Taylor, & Westerman, 2000; Mccartt, Hellinga, & Bratiman, 2006) , the rapid emergence of electronic mobile devices prompts further research in the area of distracted driving.

While driver distraction has been a concern for many years, research regarding distracted driving is limited and may be considered to be in its infancy. As a result, a consistent definition has yet to be attained among researchers in this field. However, through extensive research, many definitions have been identified with similar themes. The following is a brief list of driver distraction definitions:

- "Driver distraction is a diversion of attention away from activities critical for safe driving toward a competing activity" (Lee et al., 2008)
- "Any activity that takes the attention of a driver away from the task of driving" (Ranney, Mazzae, Garrott, & Goodman, 2000)
- Diversion of attention from the driving task that is compelled by an activity or event inside or outside the vehicle (Treat, 1980)
- "When a driver's attention is diverted away from driving by a secondary task that requires focusing on an object, event, or person not related to the driving task" (Ranney, 2008)

The aforementioned definitions of distracted driving indicate that a relocation of attention from the driving task to a secondary task is the basis of distracted driving. With this common theme across several definitions, distracted driving is a form of driving inattention, whether intended by the driver or not (Young & Regan, 2007). It is important to recognize that distracted driving can occur with or without the presence of an external electronic device and must be considered when analyzing the effects of driver inattention.

Figure 2.1 is a taxonomy of driver inattention developed by Regan et. al (2011). The figure shows that driver inattention is the basis for this taxonomy and the various forms of inattention can be categorized into five different subgroups (Regan, Hallett, & Gordon, 2011). The subgroups are differentiated by tasks that require drivers to divert their auditory, visual, manual and cognitive resources. Specifically, the subgroups in Figure 2.1 are defined as:

- **Driver Restricted Attention**: innate (biological or physical) characteristics of the driver that limits their capability to detect and interpret necessary information for safe driving.

- **Driver "Misprioritized" Attention**: driver focuses on information relating to the driving task that is less important than the task critical for safe driving, such as looking at roadway signs or speedometer rather than forward vehicle.

- **Driver Neglected Attention**: type of inattention caused by a driver who fails to recognize activities critical for safe driving, such as scanning for road/traffic hazards.

- **Driver Cursory Attention**: insufficient attention given to activities critical for safe driving, such as not checking blind spots when merging, due to external influences on the driver, such as being in a hurry.

- **Driver Diverted Attention**: commonly known as distracted driving, this type of inattention is caused by events, activities, or tasks not related to safe driving. This subgroup of inattention is further divided as follows:

    - Non-Driving related: Driver diverts their attention to a non-driving activity, such as dialing a cell phone or adjusting CB radio. This type of inattention also includes internalized mental activities, similar to daydreaming.

    - Driving-related: Driver intentionally, or unintentionally diverts, their attention away from primary driving tasks critical for safe driving to a competing driving-related activity.

This taxonomy attempts to provide a foundation for future research on distracted driving and driver inattention as researchers can develop studies around a specific form of driver inattention. For the present project, the study will focus on Non-Driving Related Driver Diverted Attention (distracted driving) on truck driver at-fault crashes.

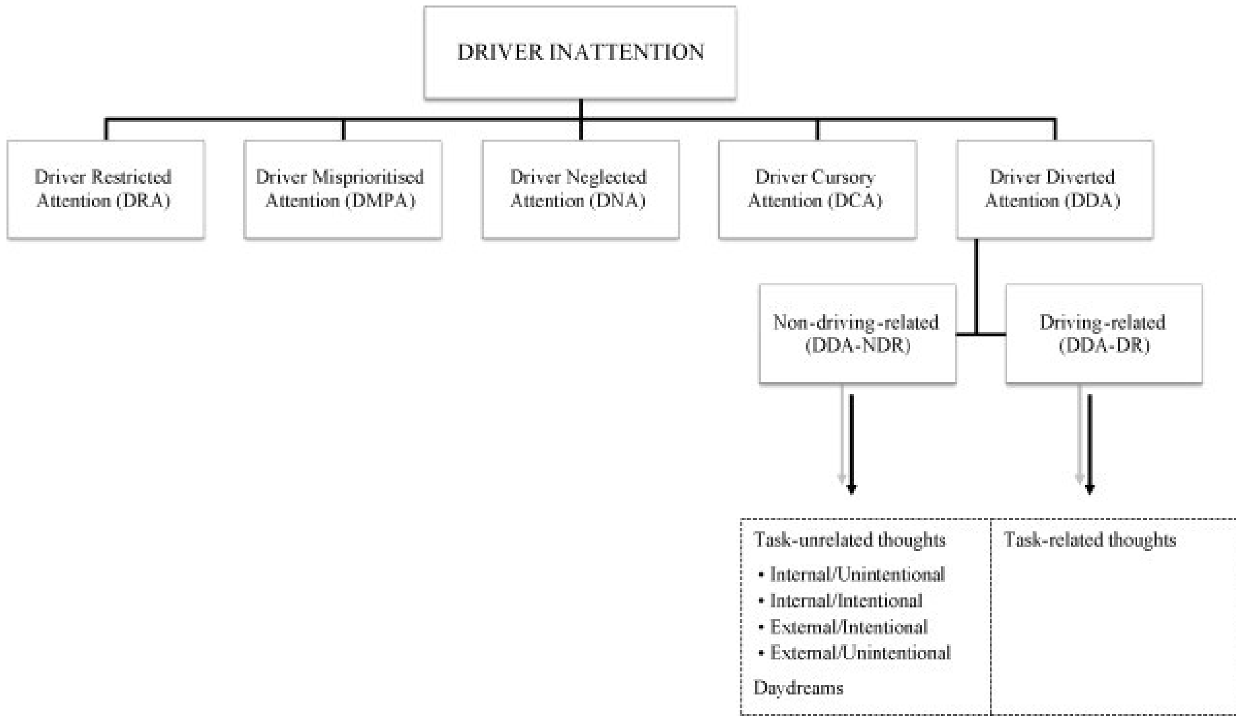


Figure 2.1: Taxonomy of driver inattention (Regan et al., 2011)

Lastly, the National Highway Traffic Safety Administration (NHTSA) supports the idea that driver distraction is an element of driver inattention and defines driver distraction as “the inattention that occurs when drivers divert their attention away from the driving task to focus on another activity” (National Highway Traffic Safety Admininistration, 2010). The notion of driver distraction is inherently complex as it can occur at any given moment through a variety of mechanisms. To simplify this complexity, the following are categories of distracted driving developed by NHTSA (2010):

- **Visual distraction**: tasks that require the driver to take their eyes off of the forward roadway, such as reading the speedometer or looking at a cell phone (p.3)
- **Manual distraction**: tasks that require physical engagement of the driver, such as reaching for a citizens’ band (CB) radio or holding a hand-held device (p.4)
- **Cognitive distraction**: tasks that involve a portion of the mental workload, such as thinking about something other than the driving task (p.4)
- **Auditory distraction**: tasks that take away from the driver’s ability to hear audible clues while driving (p.3)

Any activity involving at least one of the above categories developed by NHTSA constitutes driver distraction. Although visual and manual distraction can be detected externally, activities that involve audible and cognitive distraction are not noticeable and will require an extensive research study to assess the frequency and severity of cognitive distractions on roadway safety.

From the extensive review of distracted driving, it is evident that distracted driving is a component of driver inattention and is a subset of a larger problem. Although distracted driving can occur in many ways without drivers' awareness, engineers need to be diligent in minimizing the frequency of driver distraction. Eliminating a portion of driver inattention, such as distraction due to electronic mobile devices, will significantly benefit society as distracted related crashes will be reduced. As mentioned previously, this project will focus on driver distraction as it relates to truck driver at-fault crashes through the relocation of attention to a secondary task or activity, including, but not limited to, manipulating cell phones, CB radio, or electronic logging devices (ELDs) and others to be identified through this research. Future studies may need to be conducted to assess and analyze the effects of other forms of driver inattention on roadway safety.

2.1.2 Distracted Driving Studies

Attempts to measure the effects of driver distraction on driving performance has typically been done by either crash data, which are derived from police reports and crash investigations, or observational studies, such as naturalistic or simulation based studies (Regan, Lee, et al., 2008). The two methods each have limitations and benefits. Naturalistic observational studies enable researchers to examine driver behavior while operating a vehicle on a roadway by installing video cameras in the cab of a vehicle and monitoring the driver's eyes and body. This method is not only data intensive as researchers have to review countless hours of driver miles, but the awareness of being recorded may affect typical driver behavior (Ranney, 2008). Traditional studies, on the other hand, provide direct information regarding the frequency and severity of distraction-affected crashes. Although this method is both less time consuming and expensive than naturalistic observational studies, this method has multiple deficiencies. These deficiencies include the underlying retroactive nature of the data collection process, significant amounts of unknown or missing information, and inconsistent data reporting caused by differing views of driver distraction of different officers recording the accident (Regan, Lee, et al., 2008).

The following is a summary of previous studies that utilized these strategies.

2.1.2.1 100 Car Naturalistic Study

In 2006, Klauer et. al. undertook an extensive research study under the Virginia Tech Transportation Institute for the NHTSA (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Prior to this study, previous research found that driver inattention was identified in approximately 25 to 30% of all vehicular crashes (Ranney et al., 2000; Wang, Knipling, & Goodman, 1996), but these studies relied on crash data and police accident reports. As mentioned previously, there are disadvantages to traditional studies as they are retroactive, potentially biased, and inconsistent due to differences in accident report generation.

This study intended to eliminate the shortcomings of traditional crash data analysis by being the first instrumented vehicle study designed to collect extensive naturalistic driving data for a large number of drivers over an extended period of time. The subjects for this test were 100 recruited drivers who commuted into or out of the Northern Virginia/Washington, DC metropolitan area. Drivers chose to drive either their personal or leased passenger car vehicles with the unobtrusive instrumentation package installed. Since the goal of this study was to maximize the number of crash and near-crash events, a larger sample of drivers below 25 years old and those who drove more than the average number of miles were selected. Through a 12- to 13-month data collection process that involved 109 cars, approximately 2,000,000 vehicles miles and 43,000 hours of data were obtained (Dingus et al., 2006). Due to the extensive amount of data collected, the research team conducted a sensitivity analysis of post-event triggers. These triggers included both single and multiple attributes that exceeded certain thresholds, such as any lateral acceleration greater than 0.6g or longitudinal deceleration rate greater than -0.5g. Once this sensitivity analysis identified possible events meeting the set criteria, the researchers reviewed the data and classified them as either a valid or invalid safety critical event. Once the data went through this extensive reduction process, the number and definitions of recorded events were as follows:

- Crash – 69
    - Any contact between a vehicle and a moving or fixed object
- Near-crash – 761
    - Any event that required a rapid or evasive maneuver conducted by the driver or external participant (pedestrian, cyclist, etc.) to avoid a crash
- Incidents – 8,295
    - Any event that required a maneuver that is less severe than a rapid, evasive maneuver, but greater than a normal maneuver, conducted by the driver or external participant (pedestrian, cyclist, etc.) to avoid a crash
    - Any event resulting in extremely close proximity of the subject vehicle or external participant, including fixed objects, due to apparent unawareness on part of any participant not resulting in a avoidance maneuver or response

As mentioned previously, driver inattention and driver distraction has been used either interchangeably or separated in transportation literature. In the 100-Car Naturalistic Study, the authors acknowledge that driver inattention refers to a broader range of behaviors and that distracted driving only occurs when a driver is engaged in a secondary task, such as using a cell phone or eating. Additionally, the authors define four levels of driver inattention as follows:

- **Secondary Task Distraction**: driver's attention is diverted away from the driving task to a secondary task, such as eating, using a cell phone, or talking to a passenger

- **Driving-Related inattention to the forward roadway**: behavior related to the driving task but diverts driver's attention away from the forward view, such as reading the speedometer or checking blind spots

- **Drowsiness**: behavior that includes signs of driver drowsiness

- **Non-Specific eye glance away from the forward roadway**: behavior that includes moments when the driver momentarily glances away from the roadway to an undiscernible object or location

As shown in Figure 2.2, of all crashes and near-crashes, engagement in a secondary task, driving-related inattention, and drowsiness were the most frequent contributing factors. Additionally, of the 20,000 randomly selected baseline segments, which are segments where no crash, near-crash, or incident occurred, 70% of drivers were in engaged in at least one of the four forms of driver inattention defined above. Specifically, secondary task engagement accounted and driving-related inattention to the forward roadway accounted for 54% and 27% of the baseline cases.

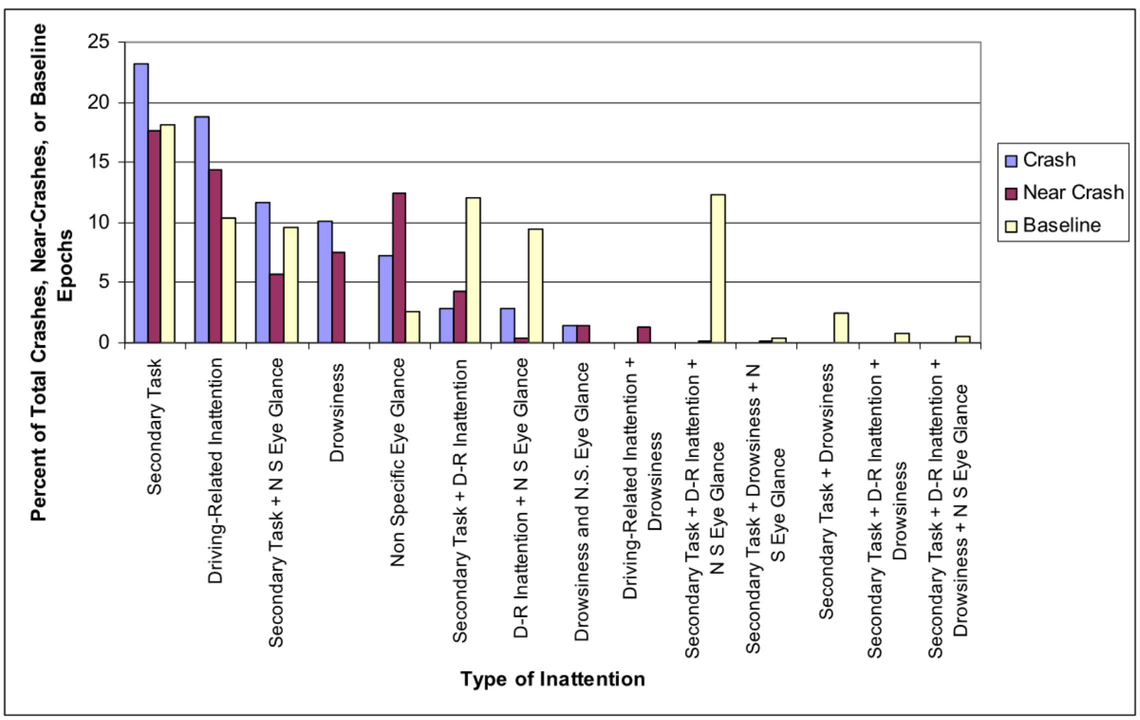


Figure 2.2: Percent involvement of driver inattention in the 100-car naturalistic study (Klauer, 2006)

In addition to determining the frequency of driver inattention involvement, the authors of this study performed an odds ratio and population attributable risk (PAR) calculation. An odds ratio measures the odds that an event of interest (crash or near-crash) will occur given a particular exposure (driver inattention) compared to the event of interest occurring in the absence of that exposure (Bland & Altman, 2000; Szumilas, 2010). Odds ratios greater than 1 indicate that the presence of a particular exposure increases the risk of being involved in the event of interest. Population attributable risk provides an assessment of the crashes and near-crashes occurring in the entire population that are directly attributable to a certain driver behavior.

Table 2.1: Odds Ratios and PAR from 100 Car Naturalistic Study (Klauer, 2006)

Type of Inattention	Odds Ratio	PAR(%)
Complex Secondary Task (dialing on cell-phone, operating a PDA, locating/reaching/answering hand-held device)	3.10	4.26
Moderate Secondary Task (talking/listening to hand-held device, eating, reaching for object)	2.10	15.23
Moderate to Severe Drowsiness (isolated from other types of inattention)	6.23	22.16
Moderate to Severe Drowsiness (all occurrences)	4.24	24.67

These results help understand the prevalence of driver distraction and inattention on driver behavior and how they impact roadway safety. Although this study was conducted on passenger vehicles, the information identified in this study is transferable to large trucks as it provides a relative baseline of the safety impacts caused by a particular type of driver inattention. Since commercial motor vehicles are less agile than passenger cars, the odds of being involved in either a crash or near-crash while engaged in any form of inattention are expected to increase.

2.1.2.2 Driver Distraction in Commercial Motor Vehicles

In 2009, Olson et. al. expanded upon previous naturalistic studies to specifically examine the impact of driver distraction in commercial motor vehicle operations (Olson et al., 2009). This study utilizes the data collected from two earlier naturalistic studies in which the authors created a data set specific to CMV and truck drivers and their involvement in distracted driving tasks.

The authors combined the data from the earlier truck driver naturalistic studies and categorized safety-critical events into classifications similar to the 100 Car Naturalistic Study. These classifications included: crashes, near-crash, crash-relevant conflict, and unintentional lane deviation. The definitions for crash and near-crash are defined in the previous section, but crash-relevant conflict and unintentional lane deviation are defined below:

- **Crash-relevant conflict**: event that requires a maneuver that is less severe than a rapid evasive maneuver, but greater in severity than a normal maneuver, performed by either the subject vehicle or external participant
- **Unintentional lane deviation**: any event where the vehicle crosses over a lane marking with no hazard present

With these safety critical events, the authors, similarly to Klauer et al. (2006), classified tasks into two categories: secondary and tertiary. Secondary tasks are related to the driving tasks, but do not necessarily keep the vehicle on course. Tertiary tasks are other tasks, such as talking on a cell phone, that are not related to driving. In addition to separating tasks into two categories, the authors disaggregated the tertiary tasks into three categories in a similar way that Klauer et al. (2006) utilized. The disaggregated tertiary tasks included: complex, moderate, and simple tertiary tasks. As defined by Klauer et al. (p.25):

> *Complex tertiary tasks are defined as a task that requires either multiple steps, multiple eye glances away from the forward roadway, and/or multiple button presses (Dingus, Antin, Hulse, and Wierwill, 1989). Moderate secondary tasks are those that require, at most, two glances away from the roadway and/or at most two button presses. Simple secondary tasks are those that require none or one button press and/or one glance away from the forward roadway.*

Once the safety critical events, baselines (events where no critical events occur), and tasks had been identified, the authors conducted a series of statistical analyses to determine the risk associated with various tasks. Through data reduction of the two previous naturalistic studies, the authors identified 4,452 safety critical events and about 20,000 baseline scenarios. These analyses conducted odds ratios and PAR calculations on this set of data. The definitions of these statistical analyses are present in the previous section.

The results from this study found that at least one tertiary task was present in 60% of all safety-critical events where the participant driver (CMV or truck driver) was at-fault. Furthermore, a tertiary task was present in 71% of crashes, 46% of near-crashes, 54% of crash-relevant conflicts, and 76% of unintentional lane deviations. Additionally, as presented in Table 2 below, the calculated odds ratios show that engagement in any level of a tertiary task results in an increased risk of a CMV or truck driver being at-fault and involved in a safety critical event. Table 2.2 also provides a summary of the PAR calculated for each type of task. As shown in Table 2.2, engagement in a complex tertiary task results in the highest odds of a CMV or truck driver being at-fault and involved in a safety critical event. The odds ratio calculation show that complex tertiary tasks increases the likelihood of being involved in a safety critical event by at least 11.5 times and as high as 16.92 times. Lastly, engagement in a complex tertiary task led to 34% of safety critical events in the population where the CMV or truck driver was at-fault when compared with driving while not engaged in a complex tertiary task.

Table 2.2: Odds Ratio and PAR from CMV Driver Behavior Study (Olson et al., 2009)

	Odds Ratio			Population Attributable Risk		
Task	**Odds Ratio**	**Lower Confidence Limit**	**Upper Confidence Limit**	**Percentage**	**Lower Confidence Limit**	**Upper Confidence Limit**
Complex Tertiary Task	13.92	11.5	16.92	34.38	34.2	34.56
Moderate Tertiary Task	1.55	1.38	1.74	19.77	19.35	20.2
Simple Tertiary Task	1.41	1.22	1.62	10.56	9.83	11.3
Secondary Task	1.33	1.18	1.5	11.91	11.43	12.39

Since complex tertiary tasks were found to be the most severe and prevalent in terms of odds ratio and PAR, the authors developed odds ratios and PAR for tasks considered to be complex. Table 2.3 below summarizes these statistical findings for specific activities related to complex tertiary tasks. Text messaging on cell phone was found to be the riskiest complex tertiary task a CMV or truck driver can perform as it increases the likelihood of being involved in a safety critical event by about 28 times. Although text messaging results in the highest odds of being involved in a safety critical event, it is one of the least frequently occurring task occurring in the population as indicated by the PAR. The effects of interacting with/looking at dispatching device is of importance for this study as it is a typical task performed by CMV and truck drivers. The researchers of this study found that interaction with a dispatching device increases the likelihood of being involved in a safety critical event by 11.9 times. This particular task, along with texting while driving, should not be performed by CMV or truck operators.

In summary, this study calculated the odds ratios for various tasks, including secondary and tertiary tasks. The results of this study show the odds of being involved in a safety critical event for CMV or truck drivers when engaged in a particular form of driver inattention or distraction.

Table 2.3: Table 2.4: Odds Ratios and PAR for Specific Complex Tertiary Tasks from CMV Study (Olson et al., 2009)

Task	Odds Ratio			Population Attributable Risk		
	Ratio	Lower Confidence Limit	Upper Confidence Limit	Percentage	Lower Confidence Limit	Upper Confidence Limit
Complex Tertiary Task						
Text Message on Cell Phone	27.71	11.52	66.61	0.8	0.48	1.12
Other - Complex (i.e.: cleaning side mirror, rummaging through a grocery bag)	12.4	3.82	40.28	0.23	-0.72	1.18
Interact with/look at dispatching device	11.9	8.97	15.8	3.8	3.55	4.04
Write on pad, notebook, etc.	11.07	5.82	21.05	0.7	0.12	1.29
Use Calculator	10.11	3.73	27.34	0.27	-0.71	1.26
Look at map	8.67	5.7	13.2	1.37	0.88	1.86
Dial Cell Phone	7.06	5.42	9.18	3.01	2.64	3.39
Read Book, newspaper, paperwork, etc.	4.76	3.61	6.27	2.07	1.49	2.66

2.1.2.3 Large Truck Crash Causation Study

The Large Truck Crash Causation Study (LTCCS) was a multiyear, nationwide studies of the contributing factors leading to truck crashes. This study was conducted by the Federal Motor Carrier Safety Administration (FMCSA) and NHTSA to identify the areas that needed to be addressed to mitigate the number of truck crashes on US roadways (FMCSA, 2005). Prior to this study, crash databases did not include factors related to large truck crashes.

The LTCCS consisted of data from official reports, in-depth interviews, and onsite investigation of the scene, truck, and driver at 24 data collection sites in 17 State from NHTSA's National Automotive Sampling System (NASS) and State truck inspectors. Data was collected on large truck (GVW greater than 10,000 pounds) crashes that had at least one injury occurring in any of the 24 sites from 2001 to 2003. Two expert witnesses consisting of a trained researcher and a State truck inspector evaluated each crash site to identify the various elements involved in a crash. The scene investigation included a 28-page truck driver interview form that included areas related to inattention/distraction, perception, decisions, and other characteristics that cannot be physically determined. Post-crash assessments were conducted to gather additional information from both drivers and witnesses. The contributing factors identified in each crash were divided into critical reasons (describes why the critical event occurred) and associated factors (factors present at the time of a crash, such as person, vehicle, and environmental conditions).

Overall, this study provides information on 967 crashes that each involve one large truck. Additionally, the data collection process resulted in about 1,000 variables for each crash.

Based on the total number of truck involved crashes during 2001 and 2003 reported by the FMCSA, the 967 crashes assessed during the three year period were assigned a sampling weight that allows for national estimates of total truck crashes. Table 2.4 below is a summary of the nationally weighted involvement of trucks and passenger cars in crashes for Driver Recognition Factor. Among all other critical reasons identified in the LTCC, driver recognition error was the second most frequent cause in crashes behind driver decision factors.

Table 2.4: Frequency of "Driver Recognition Factors" Determined in the LTCC

Critical Reason	Percentage of Involvement	
	Trucks	Passenger Vehicle
Driver Recognition Factor	35%	30%
Inattention (i.e. daydreaming)	7%	4%
Internal distraction	3%	9%
External distraction	6%	2%
Inadequate surveillance	19%	11%
Other recognition error	0%	1%
Unknown recognition error	1%	40%

Source*:* Large Truck Crash Causation Study Summary Tables, Table 16, Federal Motor Carrier Safety Administration and National Highway Traffic Safety Administration, U.S. Department of Transport.

The results from this study show that when either the truck or passenger vehicle is assigned the critical reason, driver recognition error accounts for 35% and 30% of all national crashes, respectively. Since the LTCC only investigated crashes with at least one injury, this finding is lower than the results found in the 100 Car Naturalistic study. Specifically, for trucks, inadequate surveillance, inattention, and external distraction were found to be the most frequently occurring critical reason in a large truck crash. This study shows that engagement of truck drivers in either driver inattention or distraction are more likely to be involved in an accident than passenger car drivers.

2.2 ACADEMIC LITERATURE

The previous subchapter extensively summarized the methods and results of three large scale FHWA studies pertaining to distracted driving in both passenger vehicles and heavy trucks. While the data from those studies provide significant details into the prevalence and risks associated with distracted driving, they are time and cost intensive. The following section summarizes academic research that provide insight into the role of distracted driving, but are less time and cost intensive than the previous studies

A majority of the identified literature collected data through the naturalistic data collection method or utilized data from previously conducted observational studies (Dingus et al., 2016;

Fitch et al., 2013; Klauer et al., 2006; Olson et al., 2009; Osman, Ye, & Ishak, 2017). These studies typically result in identifying the prevalence of a particular tertiary task and their respective odds ratio of being involved in a safety critical event. These studies have primarily been focused on passenger cars with the exception of Olson et al. in 2009 where they performed a naturalistic study on commercial motor vehicle drivers. From these studies, one form of driver inattention was consistently found to be the contributing factor in about 70% to 80% of crashes and engagement in a secondary task resulted in drivers being twice as likely to be involved in a safety critical event (Dingus et al., 2016; Klauer et al., 2006).

Unlike naturalistic or crash data studies, simulator studies provide information on the effects of distracted driving on cell phone use and compensatory behaviors to ensure safe driving. Haigney et al. (2000) conducted a study on 30 participants using a driver simulator that replicates real-world driving scenarios to assess driving performance while using a handheld or hands-free cell phone (Haigney et al., 2000). The participants were also fitted with a heart rate sensor as a means to quantify increase task demand by measuring heart rate. Each participant completed four driving simulations in which they were required to answer a cellular phone call. The results of this study show that drivers decrease their travel speed when engaged in a cell phone call and the task demand needed to ensure safe driving increased, as measured by increases in heart rate. Similarly, Strayer et al. (2004) conducted a simulator study that assessed the driver performance differences between older and younger drivers (Strayer & Drew, 2004). The study found that younger drivers (age between 18 and 25 years) responded more quickly to the events of the forward vehicle when engaged in a cell phone conversation than older drivers (age between 65 and 74 years). Consistent with Haigney et al. (2000), this study found that drivers decrease their travel speed, but also increase their following distance to compensate for the additional demand created by the cell phone conversation. Understanding compensatory driving behavior when engaged in a distracting task while driving may assist authorities, while also assisting the establishment of probable cause during on-highway enforcement, in enforcing distracted driving legislation.

Other studies identified in this literature review utilized accident report data, such as the General Estimates System of the National Automotive Sampling System (GES) or the Fatality Analysis Reporting System (FARS) developed and maintained by NHTSA. These types of studies typically identify the prevalence and roles of various factors contributing to a crash. For instance, Beanland et al. (2013) investigated the role of driver inattention in serious traffic crashes in Australia and found that about 58% of eligible crash information involved some form of driver inattention (Beanland, Fitzharris, Young, & Lenné, 2013). The study also found that driver diverted attention (distracted driving), such as using mobile phone or adjusting vehicle systems, was present in approximately 16% of crashes. This finding is similar to NHTSA's recent report that distraction was present in 14% of all police-reported motor vehicle crashes in 2015 (National Center for Statistics and Analysis, 2017). Of police reported crashes in 2015, cell phone use was reported in 8% of all crashes. While these types of studies provide valuable information regarding the frequency of distracted driving in traffic crashes, they do not address the probability or causation of traffic accidents, such as truck at-fault crashes, due to distracted driving.

Studies utilizing data collected from distributed surveys or in-person interviews overcome this limitation by collecting information not provided from observational studies or crash reports.

The results of these studies can identify particular behaviors, risk perception, or other factors that influence decisions to engage in secondary tasks while driving (Márquez, Cantillo, & Arellana, 2015; Oviedo-Trespalacios, King, Haque, & Washington, 2017; Swedler, Pollack, & Gielen, 2015). These types of studies consist of a questionnaire that may solicit sociodemographic information, driving characteristics, and perception of cell phone use risk and result in an understanding of driver behavior. For instance, Oviedo-Trespalacio et al. (2017) distributed a survey that respondents self-reported their engagement with texting/browsing and using a mobile phone while driving (Oviedo-Trespalacios et al., 2017). The information collected from this survey (sociodemographic, priority of call, etc.) allowed the authors to find various factors that increase or decrease the likelihood of an individual engaging in a cell phone activity while driving. Regarding commercial trucks, Swedler et al. (2015) distributed a survey to truck drivers to understand how truck drivers make decisions whether or not to engage in a secondary task (Swedler et al., 2015). This study, among many other findings, determined that drivers are less likely to engage in a secondary task (texting or using dispatch device) while driving if their supervisor both strongly opposes its use and motivates compliance to safe driving. This finding suggests that mitigating cell phone use among truck drivers must start at the managerial level that prioritizes and establishes norms for safe driving practices within their company's culture. If CMV carriers establish distracted driving safety polices and convey their position against cell phone use while driving, truck drivers will likely exhibit this behavior while driving (Swedler et al., 2015). These studies show that survey data provides information that cannot be directly measured and identifies possible solutions to reduce distracted driving.

The examined literature encompassed studies utilizing observational, police reports, and survey data sets to assess the prevalence and likelihood of being involved in a crash or near crash when engaged in a secondary task, primarily cell phones. These studies, however, primarily investigated the role of cell phones on passenger vehicles and there is an evident deficiency in distracted driving studies and commercial motor vehicles. Additionally, the statistical measures utilized in the examined studies are severely limited and do not consider any unobserved effects not captured through any of the data collection methods. The results of this project will contribute to the existing literature by focusing on distracted driving and commercial motor vehicle drivers, particularly with truck at-fault crashes. Finally, to the authors' knowledge, the methods used in this project will be the first to use state of the art econometric models that account for unobserved heterogeneity between or among truck at-fault crashes involving distracted driving.

2.3 COUNTERMEASURES

As seen in the previous subchapter, driver distraction was found to be the contributing factor in about 23% of all crashes and near-crashes (Regan et al. 2008). With the continuous growth of technology and penetration into society, the frequency of safety critical events caused by distracted driving is expected to increase, such as the mandate to require electronic logging devices in commercial trucks. Engineers and planners must hold public safety paramount and identify possible mechanisms for mitigating and preventing the impact of emerging technology on roadway safety, such as truck at-fault crashes.

2.3.1 Reporting

Regan et al. (2009) suggest that driver distraction can be mediated by effective data collection, legislation and enforcement, vehicle fleet management, and driver licensing. Through improved crash reporting methods, more precise information about the impact of distracted driving can be determined by researchers. Understanding the effects of various forms of driver distraction can lead to countermeasures for a specific type of distraction. For example, ELDs can have their interfaces changed, or policies implemented, if it is determined that majority of truck drivers got into an accident due to looking at or using the ELD. One method that may improve crash data collection is by improving police report forms to capture extensive information about distracted driving. Identifying the role and type of distracted driving on vehicular crashes, especially truck at-fault crashes, is the initial step in solving this safety epidemic. As stated by Regan et al., "better data are needed to more accurately characterize and quantify the problem and to prioritize countermeasure development" (Regan et al. 2008).

2.3.2 Policies

Legislation and enforcement are critical methods for influencing driver behavior regarding driver distraction (Regan, Young, & Lee, 2009). For legislation to effectively mitigate the occurrence of distracted driving, they should:

- Be precise without any loopholes or confusion
- Have support from members of the judicial branch
- "place minimal burden on law enforcement in observing and documenting the prohibited behavior and in documenting and assisting in the prosecution of the offence" (p. 544)
- Keep up-to-date with the continuous enhancements of communication technologies.

Legislation that aims at reducing distracted driving should be written as any other effective traffic laws, such as speed limits. Additionally, this type of legislation should explicitly define the punishments for engaging in distractive activities while driving. In the psychological field, the theory of operant conditioning suggests that imposing a form of punishment decreases the likelihood of reoccurrence of a particular behavior (McLeod, 2007; Reynolds, 1975; Skinner, 1990).

Although legislation can be developed to mitigate distracted driving, enforcing such laws and policies has shown to be difficult (Retting, Sprattler, Rothenberg, & Sexton, 2017). Different enforcement strategies such as spotter, and self-initiated and its varieties (stationary/cover, stationary/patrol, roving patrol) were tested in different counties in Connecticut and Massachusetts. Though these strategies were found to be feasible means of enforcing distracted driving laws, participant officers and law enforcement agencies emphasized the importance of training, law enforcement partnerships, and prioritization as the most effective ways to improve enforcement (Retting et al., 2017).

At the truck operation level, commercial motor carriers are in a strong position to develop strategies that mitigate the occurrence and effect of distracted driving on their employees (Regan et al. 2008). CMV carriers have the ability to influence driving behavior at the strategic, tactical, and operational levels of their organization. For instance, they can impose policies that explicitly state the organization's position on distracted driving. This policy may include clarification on when it is acceptable to engage in distractive activities while driving, the penalties and incentives of violating or adhering to the policy, and provide guidance on ways to minimize the occurrence of engaging in distracted driving. Additionally, CMV carriers can establish education and training programs that instills opposition to distracted driving in the organization's culture. Education programs should educate CMV drivers about existing national/state legislation, sources and relative risk of the different types of distraction, and strategies for minimizing distraction. Training should teach drivers how to use on-board technologies, such as ELDs, that minimize distraction, such as utilizing voice activation processes. Lastly, CMV carriers can control the amount of distractive elements integrated into the truck cabin by procuring devices and trucks that comply with best practice human factors and ergonomic guidelines and standards for minimizing driver distraction (Regan et al., 2009).

2.3.3 Education Outreach

Legislation, enforcement, and policies are instrumental for mitigating distracted driving, but the source of distracted driving lies within society itself and to resolve the issue, society must be convinced that distracted driving is detrimental to driving performance. NHTSA's High Visibility Enforcement (HVE) is a mechanism that induces information regarding adverse driver behaviors into society by using earned and paid media (Schick, Vegega, & Chaudhary, 2014). This method has been has shown to reduce the usage of cell phone use while driving after implementation as it conveys the associated risks and current penalties of distracted driving (Cosgrove, Chaudhary, & Reagan, 2011; Schick et al., 2014). Hand-held cell phone use reduced by about 34% and 57% in the Sacramento, CA area and Hartford, CT, respectively, following implantation of the HVE. Such programs seem to be more effective because they reach a wider range of audience.

2.3.4 Additional Considerations

Unlike passenger vehicles, truck drivers are subjected to additional electronic devices that are required to effectively perform their job responsibilities. These devices, such as CB radios, ELDs, and GPS routing, within the cab of a truck create additional opportunities for drivers to engage in distracted driving. Specifically, these additional in-cab devices may include, but not limited to:

- Weigh Station Preclearance Transponder
- Multiple toll transponders
- GPS Routing
- Business Band Radio

- Citizens Band Radio
- Dispatch Communication Equipment
- Electronic Logging Devices
- Brake Monitoring Equipment
- Load Temperature Monitoring Equipment

Having this many devices, in addition to mobile cell phones, in a cab may increase the likelihood of distracted driving due to either eyes off the roadway or amplified mental workload. Unlike cell phones, engaging with these technologies are often unavoidable. These technologies provide vital information, through either displays or communication with the field office, for drivers to understand their current route or truck status route.

There are potential countermeasures to mitigate the effects of multiple device distractions that can be investigated for potential implementation. One such countermeasure is to conduct research from the perspective of human machine interface design and human ergonomics. Researchers in these fields can identify either optimal placements of these devices, consolidate all these information sources into one user-friendly display, or both. Considering which devices are most commonly used among truck drivers and placing them in more convenient areas within the cab of a truck or on a single devices may lead to decreased mental workload and distracted driving. Further, technologies that abate distracted driving currently exist and can be implemented as additional countermeasures. These technologies include:

- In-Cab Camera
- Bio-Monitoring Technology (http://www.guardiansystem.com/guardian/#section_4)

These systems record truck driver activity and alarms drivers when they are either distracted or fatigued. The ability of these systems to alarm drivers and regain their attention to the driving task will substantially aid in preventing distracted or fatigue related crashes. Additionally, these systems can create detailed reports that summarize the time, place, and event of distracted or fatigued driving. This data collection will provide detailed information that will help researchers, and government and private entities further understand how distracted driving affects driver performance. Econometric models, such as the models that will be used in this present study, can be used with this collected information to determine the relationships between distracted driving and driver behavior. Implementation of these technologies may be a significant step in mitigating the effects of distracted driving among truck drivers.

2.3.5 Summary of Countermeasures

There are a variety of countermeasures that can be implemented to mitigate the frequency of drivers engaging in distracted driving activities and reduce the number of crashes attributed to distracted driving. Based on the reviewed literature on possible countermeasures, countermeasures for distracted driving in CMV operations require collaboration between governments and private carriers. Governments should take the proactive lead in prohibiting distractive driving activates by developing legislation and providing guidance to public and private employers in developing vehicle safety policies (Regan et al., 2009). Governments can also require CMV carriers to implement technologies that abate distracted driving, such as the technologies listed in section 2.5.4. CMV carriers should actively encourage and instill safe driving behaviors into their organization's culture and train their drivers on circumstances when it is appropriate to engage in distractive activities. To truly minimize the occurrence of distracted driving, strategies, such as NHTSA's HVE campaign, should be employed to reach a broader audience and educate society about the relative risks of distracted driving.

2.4 OREGON HOUSE BILL 2597

According to the Governors Highway Safety Association, 15 states (including Oregon), Washington D.C., Puerto Rico, Guam and the U.S. Virgin Islands have primary enforcement laws banning hand-held cell phone use while driving (GHSA, 2017). At the time of retrieval, the GHSA reports that no state has enacted legislation banning all cell phone use while driving. However, Oregon House Bill 2597, which became effective on October 1, 2017, prohibits the use of electronic mobile devices, in any form, while driving. This legislation, also known as the distracted driving law, is a sufficient example that includes the necessary components to effectively mitigate the occurrence of driver distraction: clarity of offense and penalty. By understanding both what constitutes distracted driving in Oregon and the punishment for engaging in such activities, citizens would likely to decrease their engagement in distracted driving.

While there is good intention of this recent law to reduce distracted driving occurrences and crashes, it presents an obstacle for CMV carriers and drivers. Operators of CMVs, such as large trucks, have inherent job responsibilities that require them to utilize electronic mobile devices, such as dispatch radios and ELDs, which will become required on December 18, 2017. Oregon House Bill 2597 acknowledges this reality by including an exception for CMV drivers. House Bill 2597 states that the law does not apply to those who are:

> *Employed as a commercial motor vehicle driver, or as a school bus driver, and is using a mobile electronic device within the scope of the person's employment if the use is permitted under regulations promulgated pursuant to 49 U.S.C. 31136 (Assembly, 2017)*

The exception to CMV drivers relies on the understanding of what tasks fall within the scope of the person's employment. To ensure that this exception is adequately allowing CMV operators to utilize electronic mobile devices and detecting those who are in violation, there needs to be constant collaboration between CMV carriers, CMV leaders, state and local policy makers, and enforcement agencies. The collaboration needs to include discussion about the changing nature of CMV driving operations and how electronic mobile devices are used to perform those functions.

The present study will be able to analyze the effectiveness of this bill by evaluating trends in cell phone and other electronic mobile device use in CMV drivers after the enactment of this bill through the application of a survey distributed to truck drivers.

2.5 SUMMARY

Distracted driving, as a subset of driver inattention, has been present since the inception of driving, but research regarding the subject has only recently commenced. Distracted driving is a small part of a larger driver inattention problem, but minimizing distraction due to secondary activities, such as cell phone use or other electronic devices, will significantly improve roadway safety. Studies have shown that driver distraction is present in about 23% of all crashes and near-crashes with some studies reporting one form of driver inattention in as much as 78% of all safety critical events for passenger vehicles (Dingus et al., 2006; Regan, Lee, et al., 2008). Regarding CMV drivers, 60% of all crashes and near-crashes in which the CMV driver was at-fault had at least one tertiary task present (Olson et al., 2009).

From the examined literature, there is a clear deficiency of distracted driving research on CMV drivers or truck drivers as they have primarily focused on passenger vehicles only. The literature does, however, provide insight into the prevalence, relative risk, and driver attitudes towards distracted driving. The studies consistently show that engagement in a tertiary task, like using a cell phone, increases the likelihood of being involved in a safety critical event by at least two times (Dingus et al., 2016; Klauer et al., 2006). Research in this field determined various forms of compensatory behavior executed by drivers engaged in a secondary task with reduced speed and increased headway being the most prominent (Haigney et al., 2000; Strayer & Drew, 2004).

Countermeasures for distracted driving can be deployed at both the government and organizational levels (Regan et al., 2009). Types of possible measures include: effective legislation and policies, revamped data collection and crash reporting, education and training programs, and public awareness campaigns. CMV carriers are at the forefront of reducing CMV accidents due to distracted driving by sustaining and promoting a culture of safe driving practices, such as eliminating distracted driving. This can be attained by only purchasing equipment that follow best practice human factors and ergonomic guidelines and standards for minimizing driver distraction.

As mentioned previously, driver distraction is a growing concern as technology continues to influence our engagement in secondary tasks. Little is known about the role of distracted driving on CMV drivers and truck at-fault crashes. The present study will expand on the examined literature by conducting State Department of Transportation and CMV truck driver surveys to assess the perceptions and behaviors regarding distracted driving. The results will determine contributing factors influencing truck at-fault crashes in regard to distracted driving that can be targeted for potential countermeasures. Additionally, a data analysis pertaining to truck driver-at-fault crashes will be conducted. For all data analyses, excluding the survey, all driver-at-fault crashes are considered. The premise behind including all driver-at-fault crashes is two-fold: (1) the ability to use data obtained from ODOT's pilot program regarding truck inspections and (2) ensure an adequate sample size for the crash severity analysis of truck driver-at-fault crashes.

3.0 AGENCY SURVEYS

To understand current concerns and mitigation efforts regarding distracted driving among drivers of large trucks, the research team developed and administered a stated-preference survey to State and Federal Transportation agencies. The survey instrument consisted of 22 questions that were chosen by the research team through the information gathered from the literature review conducted in Task 2. Prior to distribution, the Technical Advisory Committee (TAC) reviewed and commented on the survey. All comments were incorporated into the final survey instrument prior to distribution.

To administer the survey instrument, contact information for state and federal agency representatives were obtained through online resources (e.g., agency websites) and the research team's existing contact list. Agencies that were contacted to participate in this survey include the Federal Highway Administration (FHWA) and other State Departments of Transportation (DOTs), such as Wisconsin DOT, Arizona DOT, New Mexico DOT, and Kentucky DOT. Additionally, the research team contacted several law enforcement professionals who either manage or enforce commercial motor vehicle (CMV) laws and regulations, and associated members of the Commercial Vehicle Safety Alliance (CVSA). The survey was developed and distributed using Qualtrics, LLC, an online survey platform, through Oregon State University.

303 agency representatives were invited to participate in the survey via email. Of the 303 agency representatives reached, 24 completed the survey. The 24 completed surveys correspond to a response rate of approximately 8%. The geographical locations of the agency representatives who have completed the survey are shown in Figure 3.1. As seen in Figure 3.1, different regions of the United States are represented in this survey, which provides regional perspectives regarding distracted driving.

The following subchapters provide descriptive statistics of the 24 completed survey responses. This information provides insight on current distracted driving concerns and mitigation efforts in other transportation agencies.

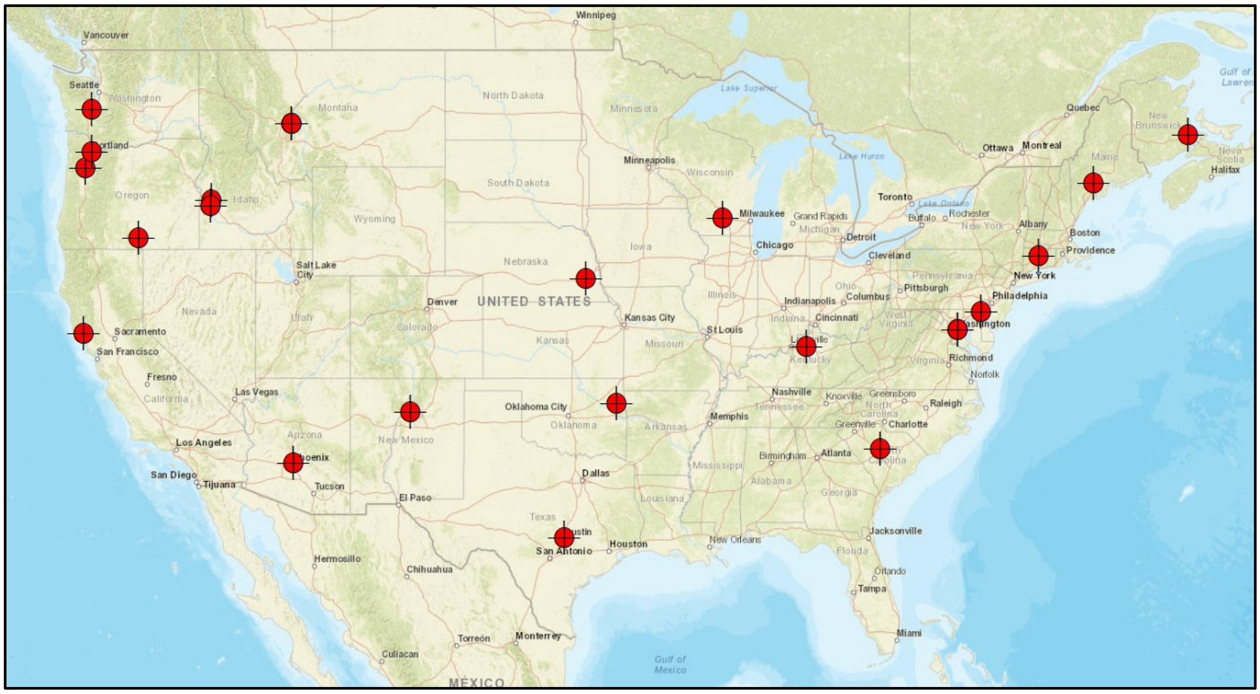


Figure 3.1: Agency survey respondent locations

3.1 AGENCY SURVEY RESULTS

3.1.1 Respondent Demographics

Various occupations, including planning director (1), engineers (9), enforcement officers (7), and motor vehicle safety enforcement (3) are represented in this survey. These various occupations provide information on distracted driving from the perspectives of individuals who manage and create mitigation solutions to those who enforce such policies.

As shown in Figure 3.2 the agencies represented in this survey include: FHWA Federal Agency Field Offices, State DOTs, County Level Agencies, and “other” agencies. “Other” agencies include State Highway Patrol, State Police, and Territorial Department of Transportation.

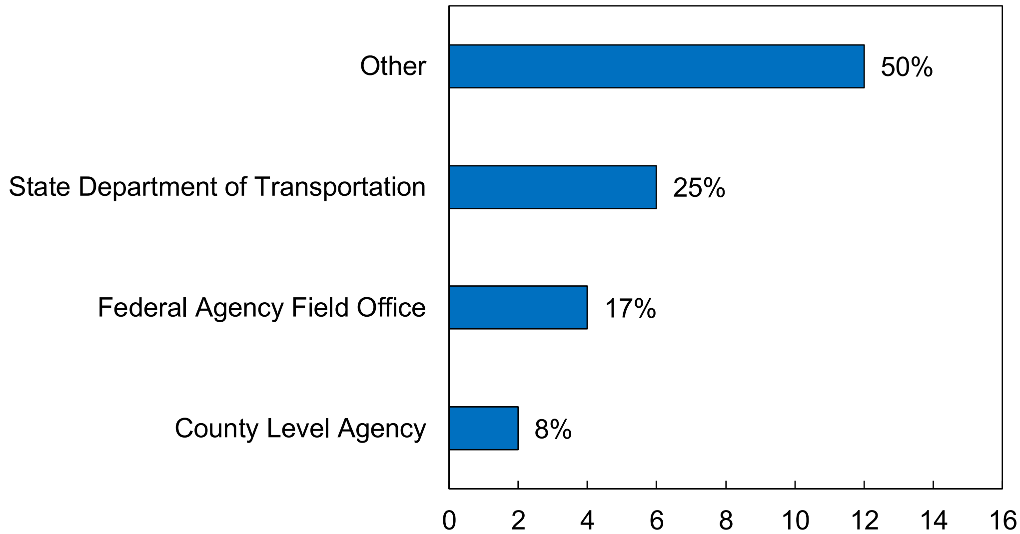


Figure 3.2: Agencies represented

3.1.2 In General, Would You Say That The Majority of Truck At-Fault CMV Crashes in Your State Are Due to the: Driver, Vehicle, Environment, "Other" Reason?

This question was posed to agency representatives to get an understanding of perceived reasons of contributing factors to truck at-fault crashes. Respondents were asked to rank the likelihood (extremely likely, somewhat likely, somewhat unlikely, or extremely unlikely) of truck at-fault crashes resulting from driver, vehicle, environmental, or "other" reasons. If a respondent indicated "other" reasons for truck at-fault crashes, the survey instrument allowed manual text entry for respondents to provide specific information. Respondent's answers to this question are summarized in Figure 3.3.

As seen in Figure 3.3, majority (64%) of survey respondents perceive that driver related factors are the most extremely likely cause of truck at-fault crashes. According to the Federal Motor Carrier Safety Administration (FMCSA), driver related factors include driver distraction and inattention, prompting the need to understand distracted driving among drivers of large trucks (FMCSA, 2017). Secondly, 55% of survey respondents perceive that environmental factors, which may include, but are not limited to, weather, time-of-day operations, and traffic characteristics, are somewhat likely causes of truck at-fault crashes. Studies by Pahukula et al. (2015), and Anderson and Hernandez (2017) have investigated the effects of time-of-day operations and roadway characteristics on large-truck involved crashes. The reader is referred to these studies for further insight of the effects of certain environmental factors on truck-involved crashes. Of the "other" factors, perceived causes include route length, other drivers, and adverse weather.

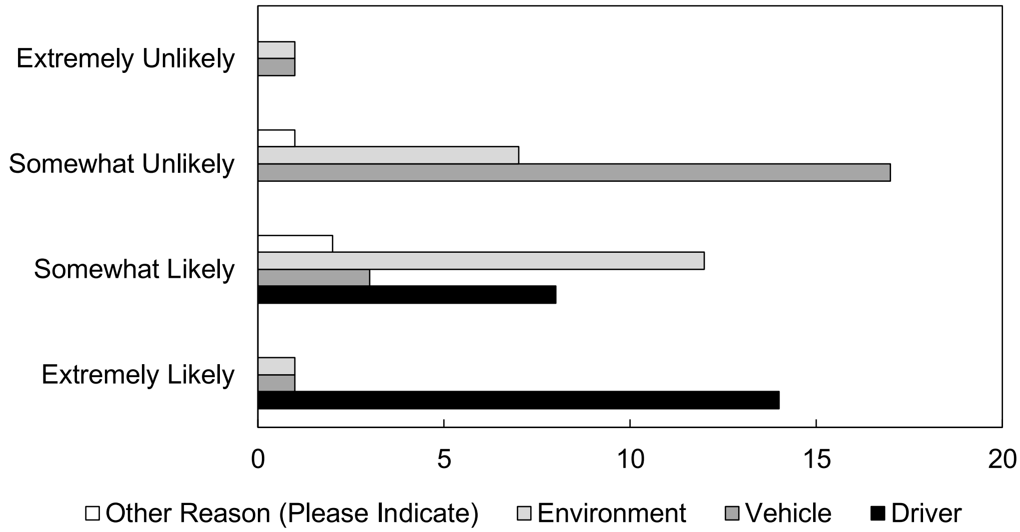


Figure 3.3: Perceived causes of truck at-fault crashes

3.1.3 How Concerned is Your Agency With Distracted Driving by CMV Operators?

Because distracted driving behavior is frequently involved in truck-involved crashes due to an increased crash risk, this question seeks to understand the level of concern regarding distracted driving among other agencies (FMCSA, 2017; Hickman and Hanowski, 2012). As seen in Figure 3.4, 36% and 41% of respondents indicate that their agency is either extremely or very concerned with this adverse driving behavior, respectively.

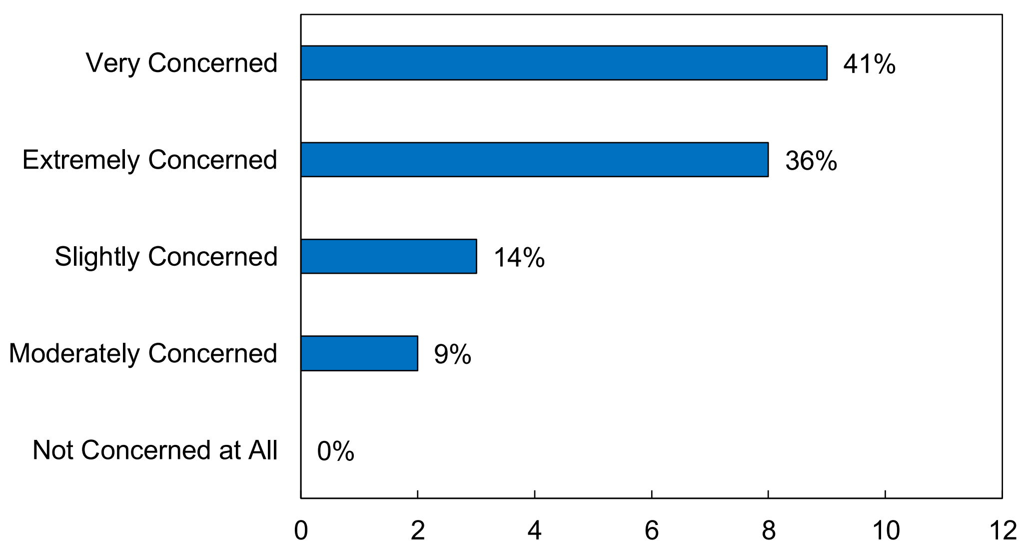


Figure 3.4: Level of concern among agencies regarding distracted driving

3.1.4 Driver Distraction, From All Sources (Internal and External), is a Significant Safety Issue for my Agency.

As determined in Task 2, distracted driving can arise from many sources and the intent of this question was to gain specific concerns on driver internal and external sources of distractions (Lee et al., 2008). Consistent with the results of the previous subsection, Figure 3.5 shows that an overwhelming majority of respondents strongly agree that driver distraction is a significant safety issue for their agency.

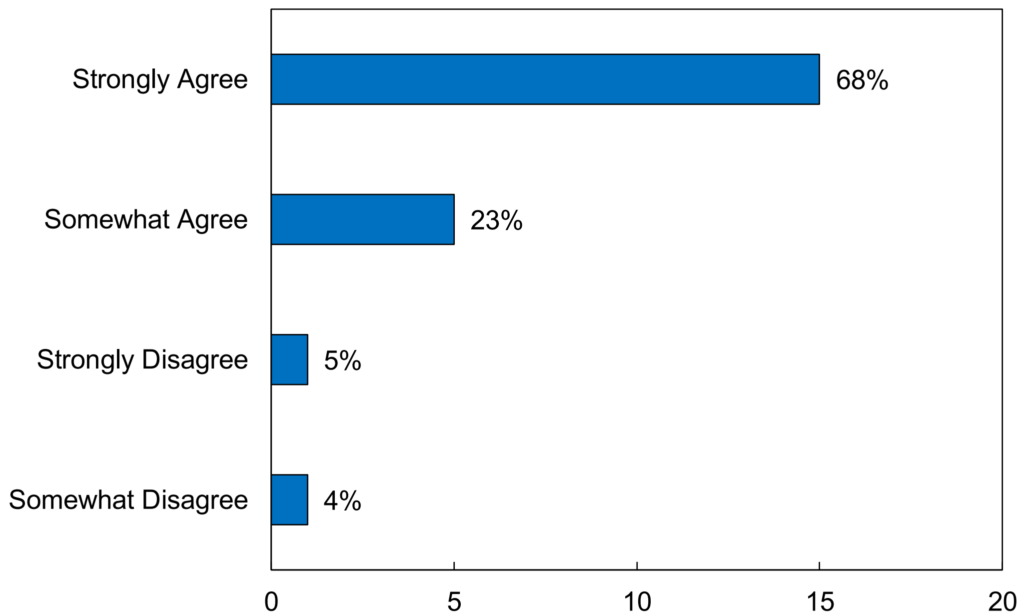


Figure 3.5: Agency concerns with internal and external driver distraction

3.1.5 Please Indicate Which of the Following Devices You Believe Contribute to Distracted Driving by CMV Operators (Select All That Apply)

As shown in Figure 3.6, respondents believe that distracted driving among CMV drivers arises from many sources; however, personal electronic devices (e.g., cell phones) is perceived to be the most prevalent source of distracted driving. Percentages may sum to greater than 100%, as agency representatives were asked to select all that apply. Surprisingly, required electronic devices, such as Electronic Logging Devices (ELDs), is only perceived by 10% of survey respondents as a distracting device. In terms of ELDs, this perception may result from an understanding that CMV drivers only use these devices when starting or resuming their drives.

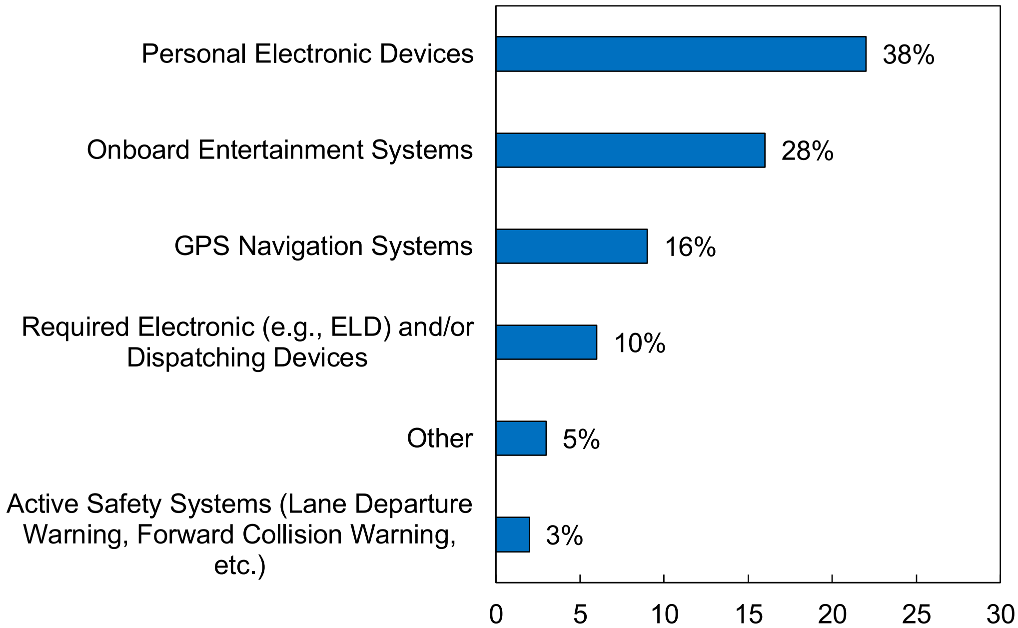


Figure 3.6: Distractive devices

3.1.6 What Steps Has Your Agency Taken to Help Mitigate Distracted Driving by CMV Operators Arising From Cell Phones and/or Other Distracting Devices, if Any?

This prompt allowed agency representatives to provide information on their agency's efforts to mitigate distracted driving among CMV operators. Table 3.1 shows the responses to this prompt. Among the responses to this prompt, education and increased enforcement appear to be the most common types of mitigating distracted driving among other DOTs.

Table 3.1: Agency Mitigation Techniques

"No cell phone usage while driving policy, which likely includes all electronics"	"Working overtime shift that concentrate on distracted driving"
"Enforcement"	"Legislation and adoption of FMCSR's"
"Public awareness only"	"Advertising"
"Focused enforcement for distracted driving on all vehicles, including CMV"	"Encourage active enforcement on driving infractions including distracted driving"
"Working with law enforcement and the trucking association to get information out about don't text and drive"	"Participated in statewide safety work groups that create the strategies for addressing distracted driving. Specific strategies are outlined in Maine's Strategic Highway Safety Plan on pages 44 and 45: http://maine.gov/mdot/safety/docs/Strategic-Highway-Safety-Plan_2017.pdf "
"Our agency is introducing new distracted driving legislation and regulations that affect all drivers, including CMV operators"	"Stepped up enforcement and monitoring of driver behavior, education, and outreach"
"Education, training, enforcement. See WSP website (http://wadrivetozero.com/distracted-driving/) for operational plan for further info"	"Enforcement efforts – trooper in a truck, position troopers on overpasses with binoculars"
"Enforcing state law and federal regulation and documenting distracted driving on crash reports"	"Education, directed and increased enforcement, increase in CVSA certified patrol troopers"
"Developed a distracted driving grant for overtime activities"	"Engineering, Education, and Enforcement"
" Same as for other motor vehicles, more enforcement of the rules and citations where appropriate"	

3.1.7 In Your Opinion, How effective do you feel the Following Areas Are in Mitigating Distracted Driving by CMV Operators?

This question allowed the research team to determine the perceived effectiveness of common mitigation techniques against distracted driving. The following mitigation techniques were presented to the agency representatives:

- Increase enforcement
- Educational outreach
- Legislation
- Fee/Penalties

For each mitigation strategy, the agency representative was asked to provide the perceived effectiveness of each strategy by choosing one of the following:

- Extremely effective
- Very effective
- Moderately effective
- Slightly effective
- Not effective at all

3.1.7.1 Increase Enforcement

As shown in Figure 3.7, 77% of surveyed agency representatives perceive that increased enforcement is an extremely effective or very effective distracted driving countermeasure.

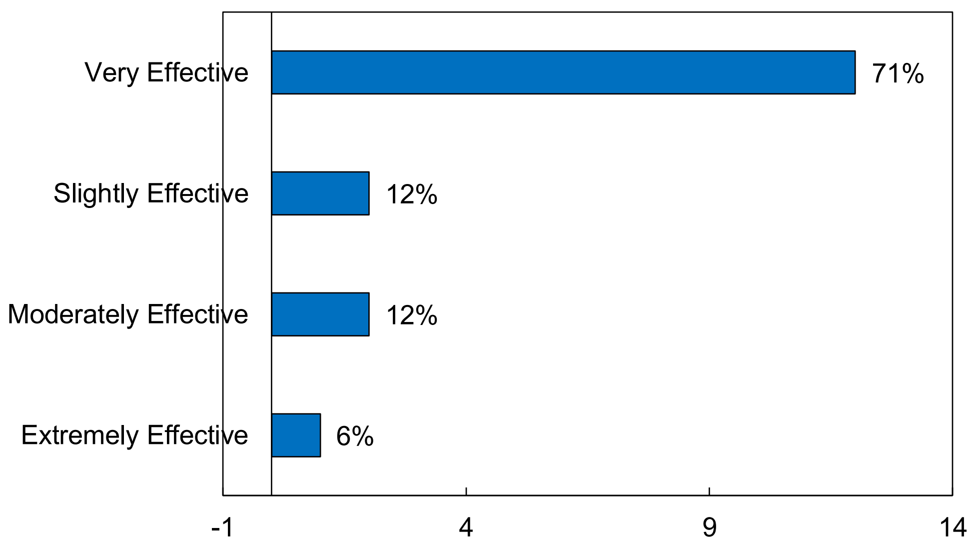


Figure 3.7: Perceived effectiveness of increased enforcement

3.1.7.2 Educational Outreach

In terms of educational outreach (see Figure 3.8), the majority of agency representatives perceive that this mitigation strategy is either very or moderately effective. Through educational outreach programs, hazards of distracted driving can be conveyed to many drivers. However, its effect on mitigating distracted driving is not profound as recent distracted driving crash statistics show an increasing trend (National Center for Statistics and Analysis, 2017).

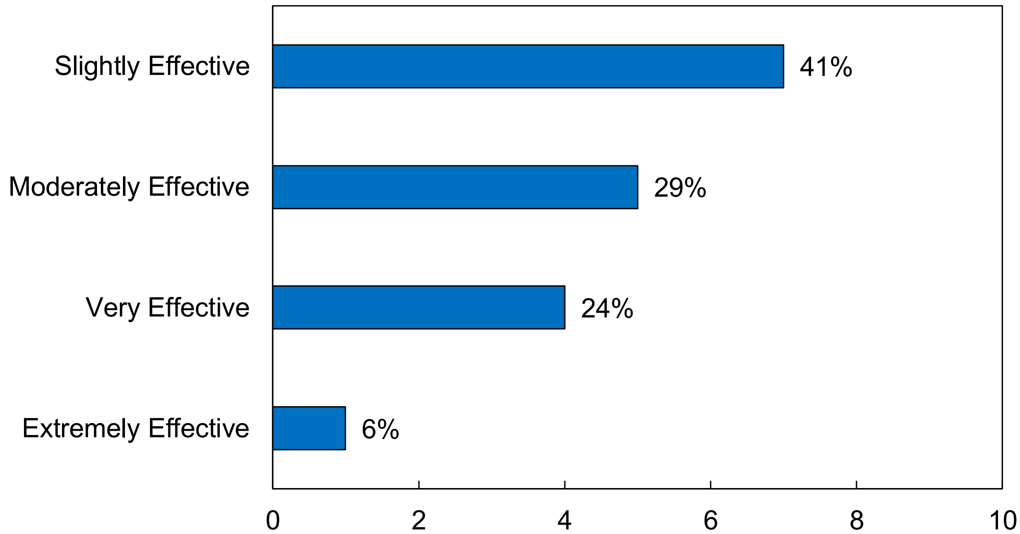


Figure 3.8: Perceived effectiveness of educational outreach

3.1.7.3 Legislation

As seen in Figure 3.9, 82% of agency representatives perceive legislation to be a moderately effective mitigation technique against distracted driving. This perception may arise from the fact that legislation alone is an ineffective strategy to mitigate distracted driving. Adequate enforcement of the developed legislation is needed to effectively mitigate distracted driving among drivers of large trucks.

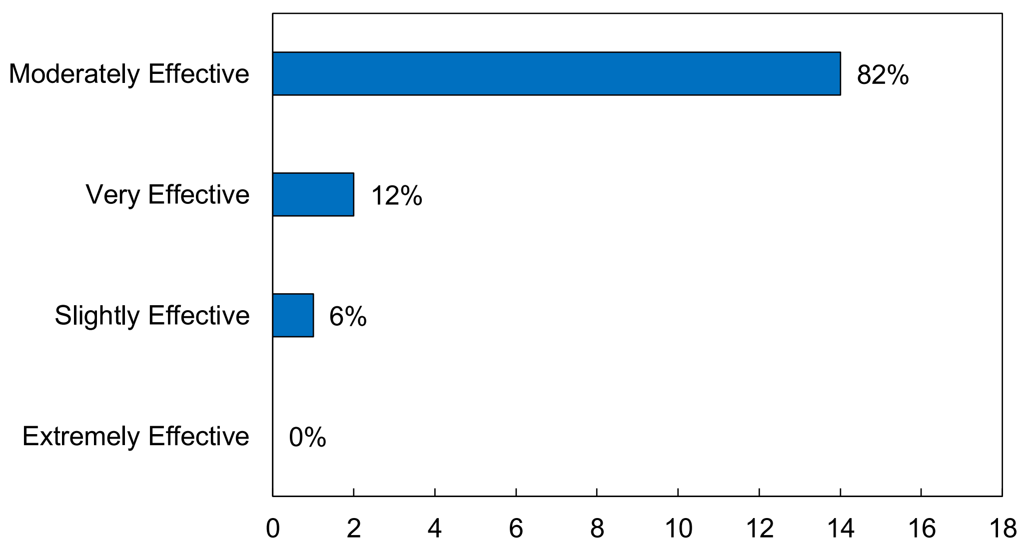


Figure 3.9: Perceived effectiveness of legislation

3.1.7.4 Fees/Penalties

Lastly, as indicated in Figure 3.10, majority of the surveyed agency representatives indicate that fees and/or penalties are either extremely or moderately effective. Specifically, about 24% and 59% of surveyed agency respondents perceive that fees and/or penalties are extremely or very effective, respectively. As with enacted legislation, the effectiveness of fees and/or penalties relies on enforcement to catch infractions and administer the associated fees/penalties. The difficulty of identifying distracted driving behavior and enforcing fees/penalties may explain why there is a difference in perceived effectiveness of this mitigation technique against distracted driving (Gordon, 2009).

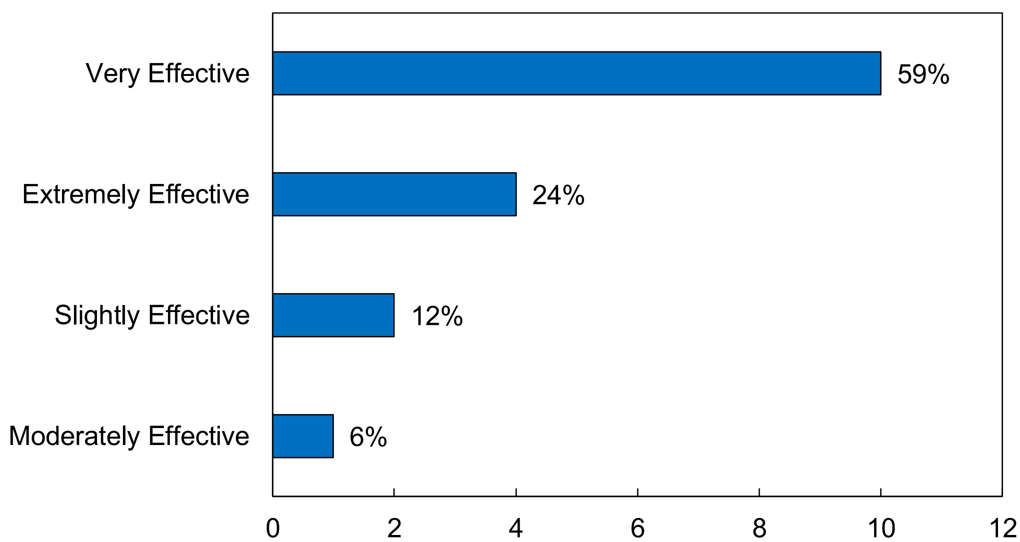


Figure 3.10: Perceived effectiveness of fees/penalties

3.1.8 Collecting Distracted Driving Information in Crash Report Forms

This subchapter summarizes four questions that were presented to agency representatives that pertain to crash reporting of distracted driving behavior. Specifically, the questions asked include:

1. Do crash report forms in your state require law enforcement officers to gather information pertaining to distracted driving?

2. Is adequate information about distracted driving being collected from these crash report forms to advance your agency's knowledge about distracted driving?

3. How might crash report forms be improved to gather adequate information about distracted driving?

4. What elements of the crash reporting form are most effective in gathering distracted driving data?

As seen in Figure 3.11 (a), almost all of surveyed agency representatives (89%) indicated that their state requires law enforcement officers to gather distracted driving information in crash report forms. Of the agency representatives who indicate that their agency collects distracted driving information on crash report forms, 29% perceive that adequate information is not being collected form these report forms (Figure 3.11 (b)).

(a) (b)

Figure 3.11: (a) Do crash report forms in your state require law enforcement officers to gather information pertaining to distracted driving?; (b) Is adequate information about distracted driving being collected from these crash report forms to advance your agency's knowledge about distracted driving?

In an attempt to understand the deficiencies within these crash report forms, the survey asked agencies to provide insight on how these forms can be improved to gather adequate information about distracted driving. As seen in Table 3.2, two responses indicate that the forms themselves are not the issues. Rather, the deficiencies of collecting distracted driving information is due to the reliance of information provided by the drivers involved, who are typically unwilling to report such behavior for fear of additional consequences (Beanland et al., 2013; Gordon, 2009). To resolve this deficiency, one respondent suggested, "seizing cell phones and crashing related data," as a possible means to gather more accurate and definitive distracted driving information. In terms of the crash report forms, two respondents indicate that additional fields, such as more descriptive types of distracted driving, should be listed and the "unknown" category be removed to eliminate ambiguity and provide more direct and clear distracted driving information.

Table 3.2: Suggestions to Improve Crash Report Forms to Gather Distracted Driving Information

"Hard to say, law enforcement has trouble getting honest answers from drivers about distraction so even if there was more information on the form, I doubt we would get more actual information."
"Descriptive types of distracted driving should be listed (i.e. using a cellular phone/personal entertainment device/texting)"
"Seizing cell phones and crash related data from vehicles but this is not always possible or permitted in law without warrants"
"More assurance that distracted driving is actually an issue vs. self-reporting"
"Better training for officers and removal of certain elements like unknown"
"Not sure if the form is the issue"

Lastly, agency representatives were also asked to identify the effective areas of the crash reporting procedure that gather adequate distracted driving information (statements from agency representatives are shown in Table 3.3). These statements reiterate that providing specific descriptions of distracted driving on crash report forms can result in more direct and clear distracted driving information that can be used to develop additional countermeasures.

Table 3.3: Effective Areas of Crash Reporting Procedures to Gather Distracted Driving Information

"All of the data describing the cause of collision"
"If we can show distracted driving, simply a box to record it."
"Explanation of the distraction, what the distraction was"
"In addition to specific fields to identify cell phone distraction, an extra category of "distracted by unknown cause" gives officers at the scene the discretion to identify distraction as the cause of a crash when direct information might not be obtainable due to privacy concerns."
"Identified crash/driver contributing behavior"
"Investigative synopsis and contributing factors"

3.1.9 Enforcing Distracted Driving

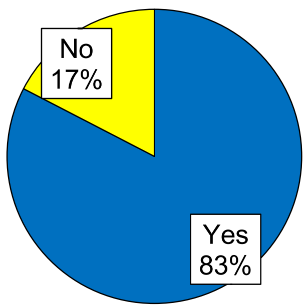
This subchapter summarizes the results of four questions related to how different states enforce distracted driving. Agency representatives were asked:

1. Are law enforcement officers in your state trained to detect distracted driving?
2. Does your state adopt any specific enforcement strategies (i.e., spotter technique, roving, marked and unmarked patrol vehicles) to identify distracted driving?

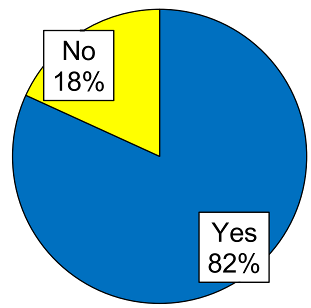
a. Please describe the enforcement strategy.

3. How effective is this enforcement strategy?

To combat distracted driving, as shown in Figure 3.12(a), 83% of surveyed agency representatives indicated that law enforcement officers in their state are trained to detect distracted driving. Similarly, 82% of surveyed respondents report that their state adopts a specific enforcement strategy to combat distracted driving among drivers of large trucks.



(a)



(b)

Figure 3.12: (a) Are law enforcement officers in your state trained to detect distracted driving?; (b) Does your state adopt any specific enforcement strategies (i.e., spotter technique, roving, marked and unmarked patrol vehicles) to identify distracted driving?

Following these questions, survey respondents were asked to specify the enforcement strategy employed by their state to combat distracted driving. Responses to this prompt is provided in Table 3.4. The reported strategy of "trooper in a truck, trooper on a[n] overpass with binoculars" has the potential to be an effective enforcement strategy to identify distracted driving behavior among drivers of large trucks due to officers being either at eye-level with truck drivers or at a higher vantage point to detect such behavior. Additionally, unmarked vehicles (or units) was a commonly reported enforcement strategy to combat distracted driving behavior.

Table 3.4: Specialized Enforcement Strategies against Distracted Driving

"Visual observation, crash scene interviews etc."
"On view patrol, directed distracted driving enforcement, spotter (unmarked) vehicles observing violation."
"Unmarked enforcement vehicles"
"All officers are trained. Specifically have unmarked units looking specifically for distracted and aggressive drivers."
"Trooper in a truck, trooper on a overpass with binoculars"
"There is no strategy per se"
"Conduct high visibility distracted driving enforcement"
"Daytime and Nighttime enforcement focused on driver behavior, including distracted driving"
"Corridor enforcement"
"Unmarked vehicles, task forces, spotter vehicles"
"Reduce crashes with high enforcement of drivers behaviors"
"Overhead observation, unmarked units, overtime activities directed toward distracted driving"
"Observation / unmarked vehicles / spotters"

After providing the specific enforcement strategy employed by their state, the survey asked agency representatives to report their perceived effectiveness of such a strategy. As shown in Figure 3.13, almost all of the survey respondents (94%) indicated that the specific enforcement strategy was either very or moderately effective. Regarding the positioning of enforcement officers to be at eye-level with truck drivers or at a higher vantage point, the perceived effectiveness of this strategy is considered moderately effective.

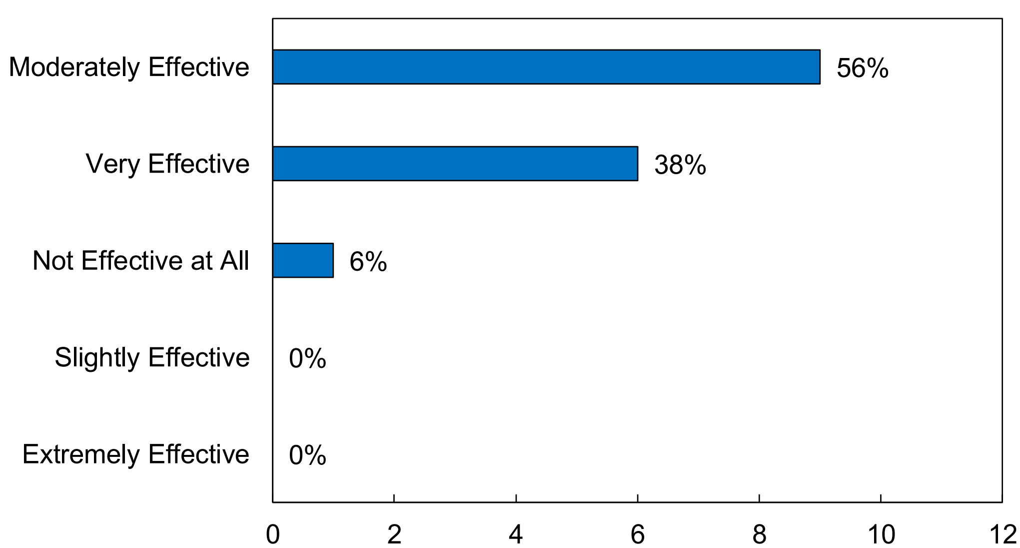


Figure 3.13: Perceived effectiveness of reported enforcement strategy

3.1.10 Additional Information

The last prompt in the survey instrument allowed the surveyed agency representatives to provide additional information regarding distracted driving that was not directly asked or presented. Exact responses to this prompt are provided in Table 3.5.

Table 3.5: Additional Information

"Distracted driving is of course hard to quantify and control and since most of the negative consequences involve crashes (which are rare) it is hard to show people cause and effect of bad behaviors."
"Three offences for cell phone use results in suspended driver's license."
"With the growing number of municipalities gaining cellular phone service in our territory known as Nunavut (noo-nah-voot), Canada's youngest territory....it is becoming more of a common sight to see drivers using cellular phones while operating a motor vehicle."
"Enforcement is only moderately effective due to the adjudication of such charges by prosecutors/judges and subsequent Data Q challenges. If a strong stance was actually taken you would see increased enforcement efforts and increased compliance."
"Maine will begin an annual Distracted Driving Observational Survey in 2018."
"Education and Enforcement efforts show the truck driving industry and general motoring public the state's dedication to prevention of crashes caused by distracted driving."
"Distracted driving is often referred to regarding cell phone usage, but in reality it's anything that causes a distraction that also causes driver error or a violation of traffic law (e.g. eating, talking, entertainment system, manipulating GPS, etc.)"
"We have far more issues with distracted auto drivers than we do commercial truck drivers in Oregon"

3.2 SUMMARY

The research team developed and administered a stated-preference survey using Qualtrics, LLC. 303 state and federal agency representatives were invited to participate in the survey via email. Of these representatives, 24 fully completed the survey.

Survey respondents provided their perceptions of how distracted driving is addressed in their state. As reported in this technical memorandum, agency representatives reported their perceptions and understanding of distracted driving among drivers of large trucks as well as the perceived effectiveness of various distracted driving mitigation techniques. Additionally, agency representatives were given opportunities to provide information on specific distracted driving techniques and suggestions to improve crash report forms to gather more direct and clear distracted driving information.

The survey results provide an understanding of other agency's perspectives on distracted driving, particularly regarding drivers of large trucks. Transportation agencies, such as ODOT, engineers, planners, and policy makers can consider this information when developing mitigation strategies to combat distracted driving.

4.0 COMMERCIAL MOTOR VEHICLE OPERATOR SURVEYS

To uncover the potential confounding factors that might affect the relationship between HOS and SCE of Commercial Motor Vehicle (CMV) driver, a representative stated-preference survey was conducted and distributed to operators of commercial motor vehicles. The stated-preference survey was administered utilizing the Qualtrics platform through Oregon State University. The findings of the presented survey can provide useful insights and guidance to assist regional policy and decision makers in regards to truck at-fault crash safety.

4.1 STATED-PREFERENCE SURVEY

The survey began with three questions serving as a natural screening process:

- Do you drive a commercial grade truck for your profession?
- Do you pick up or deliver goods in the Pacific Northwest?
- To get the most accurate measures of your opinions, it is important that you thoughtfully provide your best answers to each question in this survey. Do you commit to thoughtfully provide your best answers to each question in the survey?

If drivers answered ‘yes’ to each of these questions, they were to continue with the survey. In the end, a total of 515 adequate responses for 63 survey questions were received and used for the ensuing analysis. Lastly, to ensure the survey is representative of a random sample of drivers in the Pacific Northwest, the location of origin of the surveyed drivers is provided in Figure 4.1.

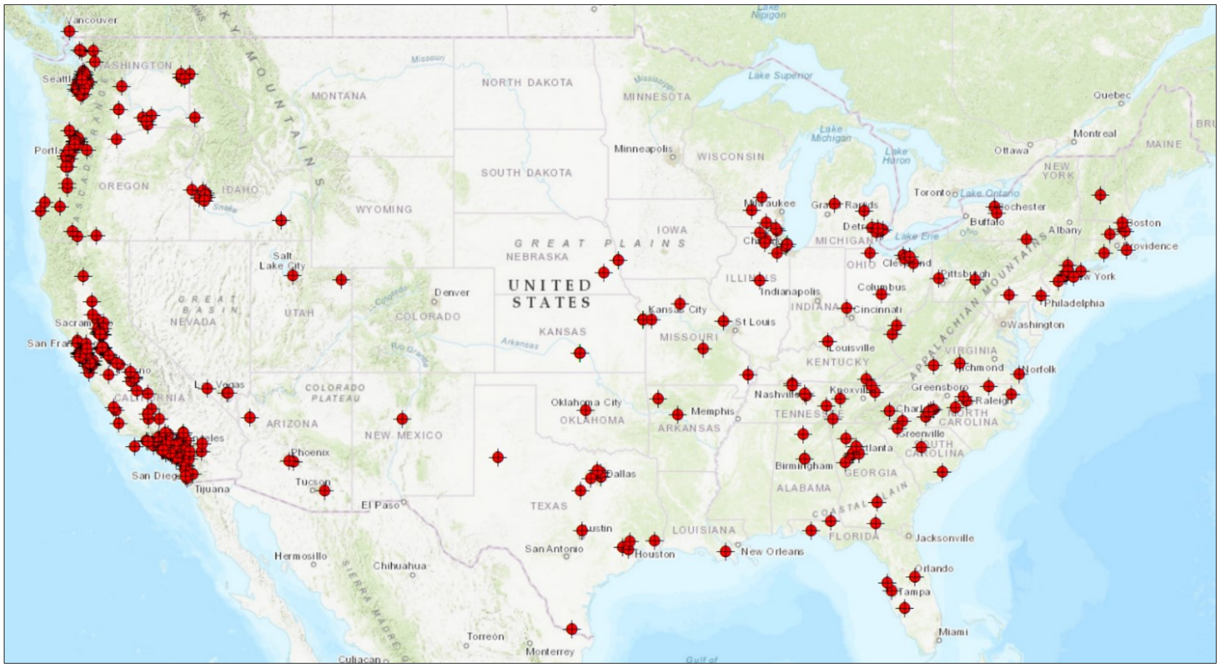


Figure 4.1: Location of origin for surveyed commercial motor vehicle drivers

As stated previously, each survey question and corresponding responses will be detailed in the succeeding sub-chapters. Accompanying each discussion is a corresponding plot to illustrate the distribution of driver responses.

4.1.1 Driver Related Characteristics

The first set of questions are designed to obtain information regarding the driver of the commercial motor vehicle.

4.1.1.1 Are You Male or Female?

The first non-screening question was related to gender of the driver. As shown in Figure 4.2, 77% of surveyed drivers are male and 23% of surveyed drivers are female.

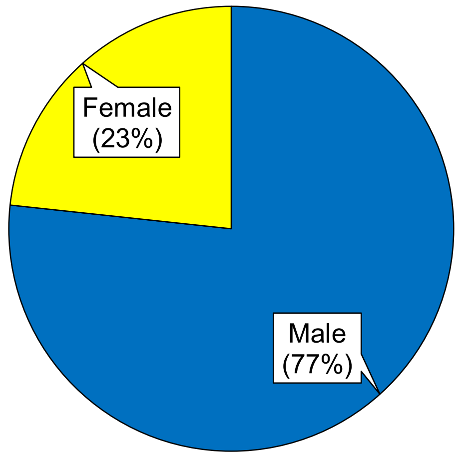


Figure 4.2: Distribution of surveyed drivers by gender

4.1.1.2 How Old Are You?

Figure 4.3 shows the age distribution of surveyed drivers. Age groups have been defined for ease of visualizing the distribution. As shown, the majority of drivers (33%) reported being 30 to 39 years of age. Drivers who reported being in their twenties represent the second largest age group at 23%, while drivers 40 to 49 years of age account for 21%. Notably, younger drivers (18 to 21 years) and older drivers (60 years and older, as defined here) both account for the smallest proportion at 5%.

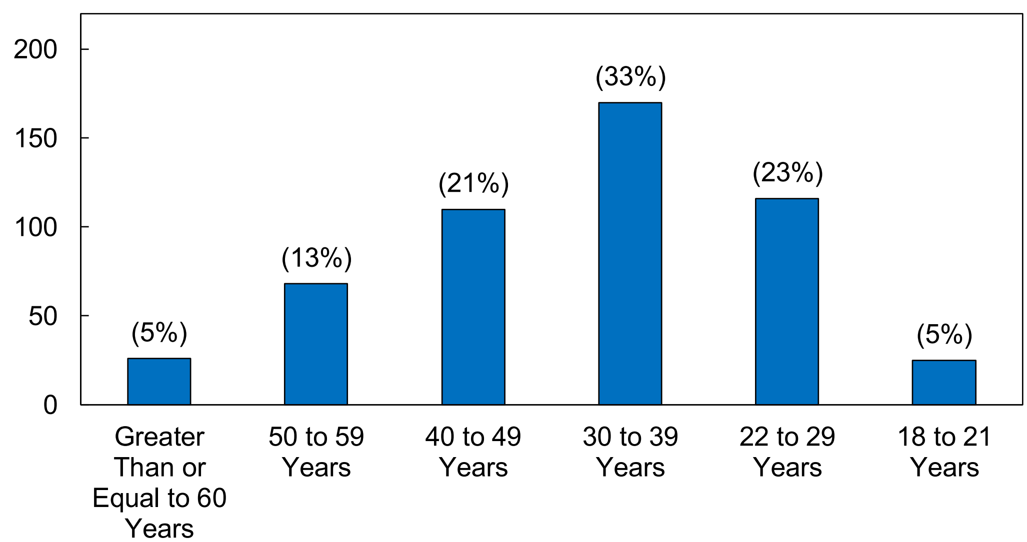


Figure 4.3: Distribution of surveyed drivers by age

4.1.1.3 Which of the Following Annual Income Categories Best Describes You?

This question aimed to determine the annual income of surveyed drivers. Notably, annual income of more than $60,000 has the highest share among surveyed drivers at 40% (see Figure 4.4). The remaining annual income distribution is as follows:

- 28% of drivers reported having an annual income of $50,000 to $59,999.
- 14% of drivers reported having an annual income of $40,000 to $49,999.
- 9% of drivers reported having an annual income of $30,000 to $39,999.
- 6% of drivers reported having an annual income of $20,000 to $29,999.
- 3% of drivers reported having an annual income of less than $19,999.

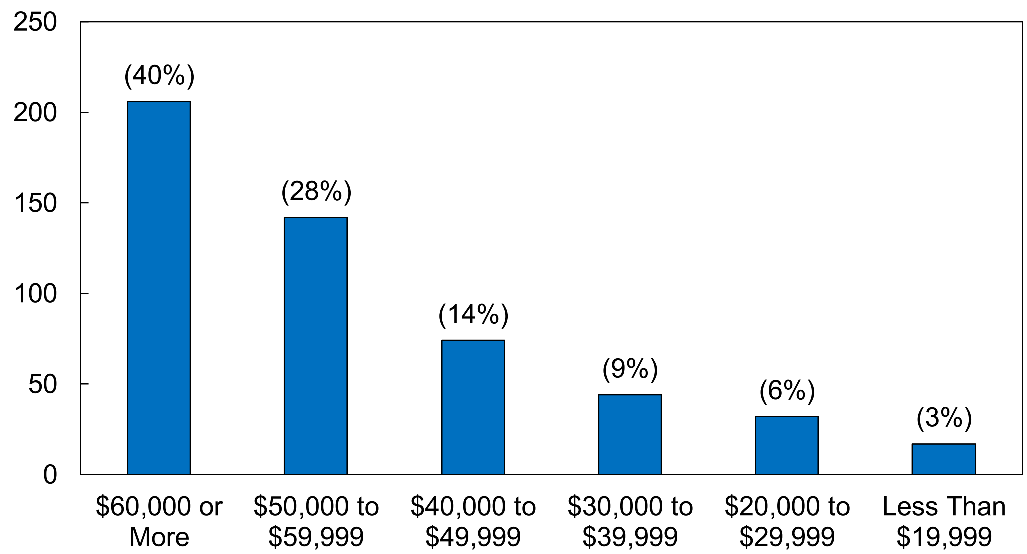


Figure 4.4: Distribution of surveyed drivers by annual income

4.1.1.4 How Are You Normally Paid?

As shown in Figure 4.5, approximately 37% of drivers are paid based on an hourly rate and 17% are paid based on flat rate for every container or truck load carried. Other payment categories are fairly consistent, with the exception of a trip being part of a long-term contract and being paid for each pallet carried. These two payment categories both represent 5% of driver responses, while the remaining methods of payment range from 8% to 11% of driver responses.

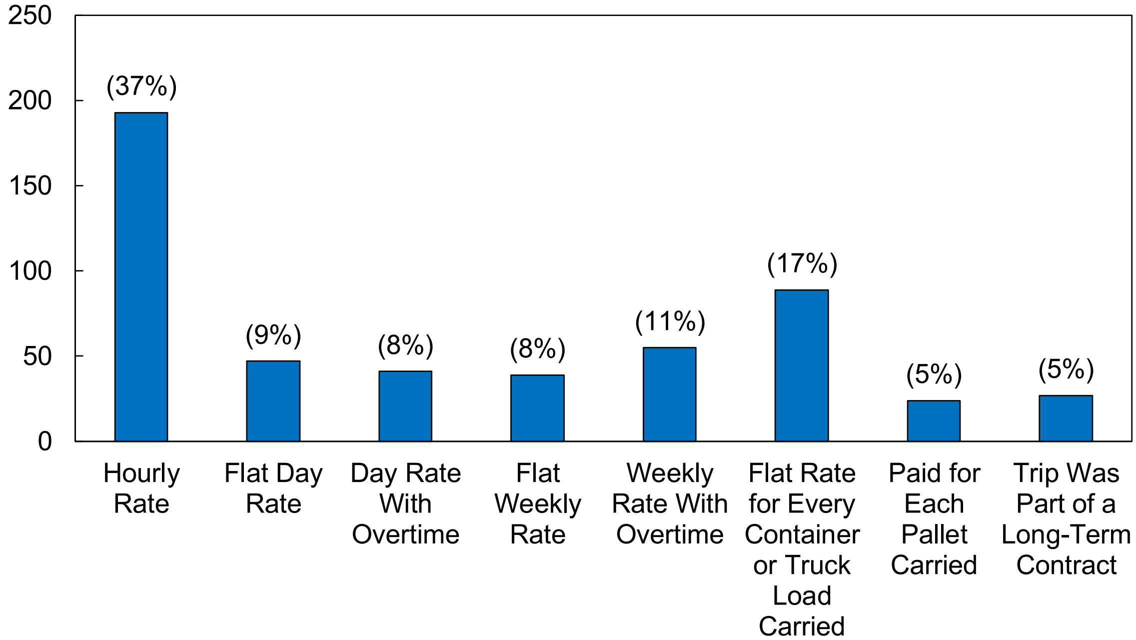


Figure 4.5: Distribution of surveyed drivers by how they are paid

4.1.1.5 Which of the Following Best Describes Your Marital Status?

Referring to Figure 4.6, 67% of drivers reported being married or in a defacto relationship. Accounting for more than one-quarter of the responses are drivers who reported being single (26%), while divorced or separated and widowed accounted for 6% and 1% of driver responses, respectively.

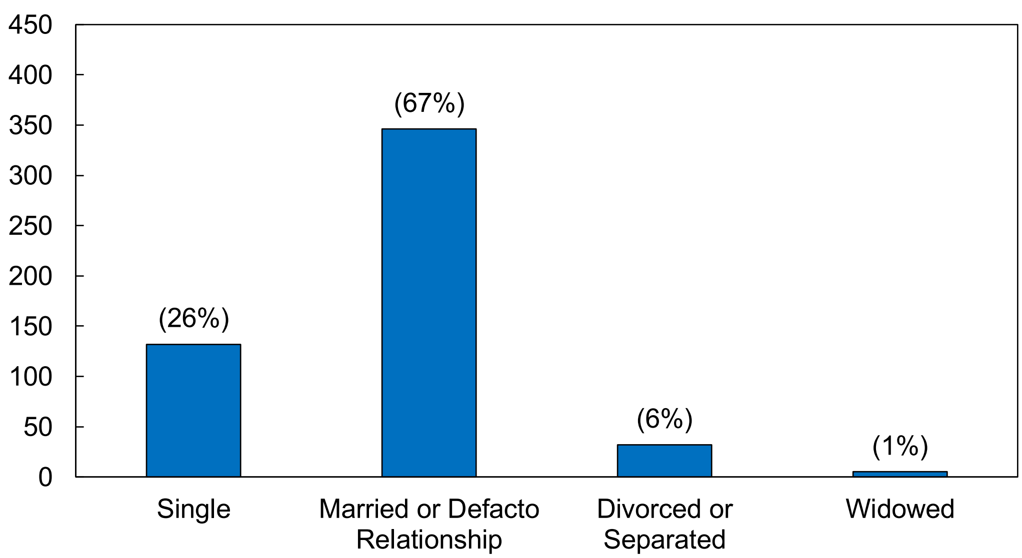


Figure 4.6: Distribution of surveyed drivers by marital status

4.1.1.6 What is Your Highest Completed Level of Education?

Figure 4.7 illustrates the highest completed level of education among the surveyed drivers. Drivers who reported completing high school/technical school, completing secondary diploma/degree, or completing a trade or technical certificate constitute the majority of responses at 28%, 25%, and 23%, respectively. In addition, about 16% of drivers reported having some secondary education. For the last two levels of education, 6% of drivers reported some high school/technical school as their highest level of completed education and 1% of drivers reported primary/elementary/middle school as their highest level of education.

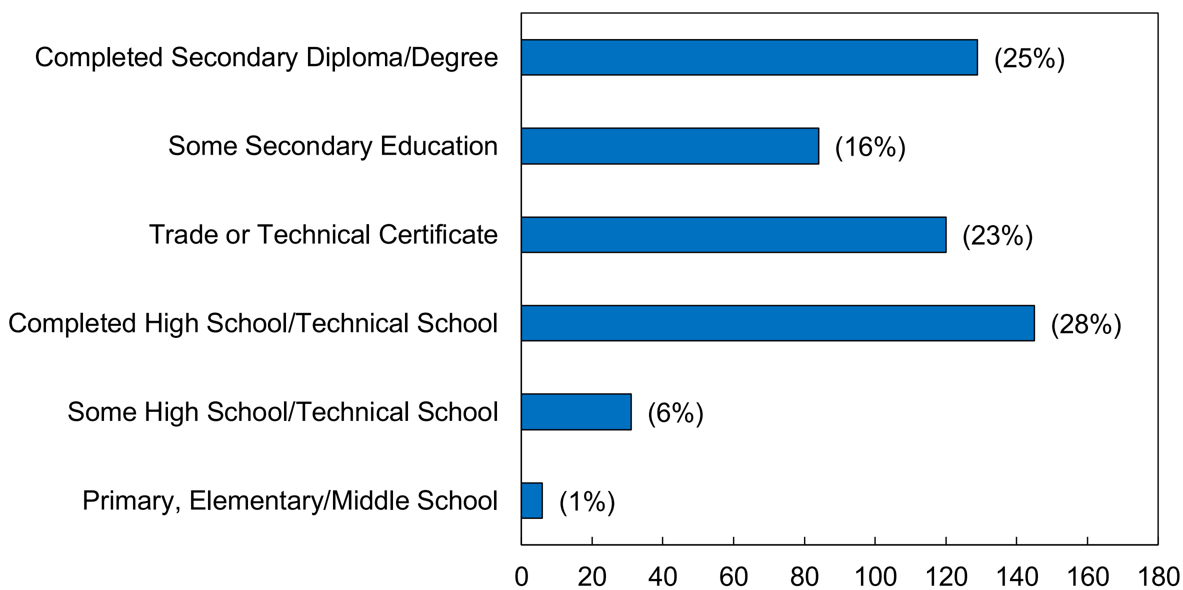


Figure 4.7: Distribution of surveyed drivers by level of education

4.1.2 Company-Related Characteristics

The next set of questions are designed to obtain information regarding the company the driver of the commercial motor vehicle works for.

4.1.2.1 What Type of Company do You Work or Contract For?

Figure 4.8 shows that drivers were given here choices in regards to type of company the driver works or contracts for. Based on survey results, 36% of drivers reported working for both for-hire and private, 35% of drivers reported working for a private carriage, 28% of drivers reported working as for-hire, and 1% of drivers reported they did not know or that they refuse to divulge what type of company they work for.

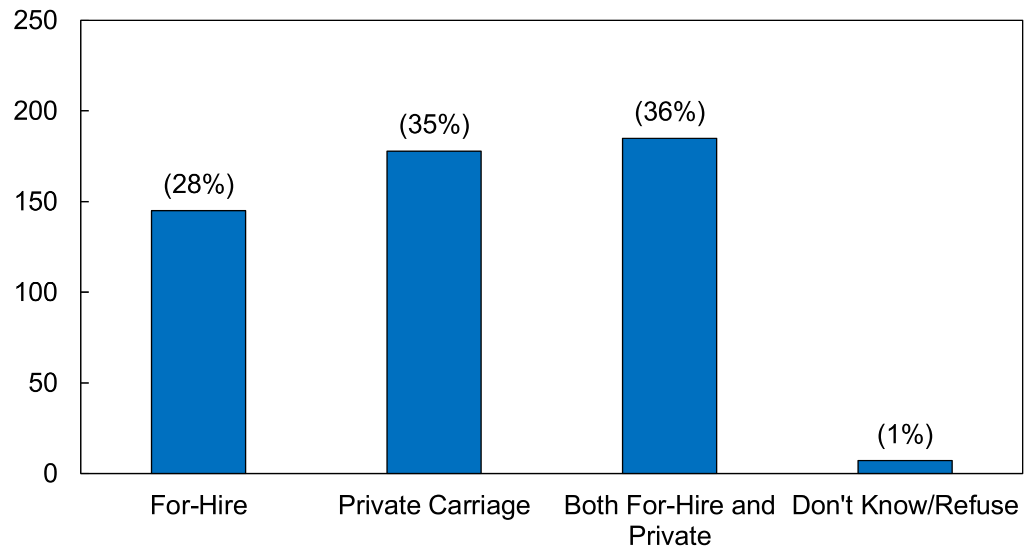


Figure 4.8: Distribution of surveyed drivers by company

4.1.2.2 To the Best of Your Knowledge, What is the Total Number of Trucks Operating in Your Company?

In this question, drivers were asked to provide an estimate about the total number of trucks operating in their company. Drive responses ranged from 1 to 50,000, with a mean of 614 trucks and a standard deviation of 3,164. As the statistics show, the answers are dependent on the type and size of the company that drivers work for or with. For example, some companies have small fleets, whereas others are operating large fleets. Figure 4.9 shows a distribution of the estimated number of trucks at a driver's company.

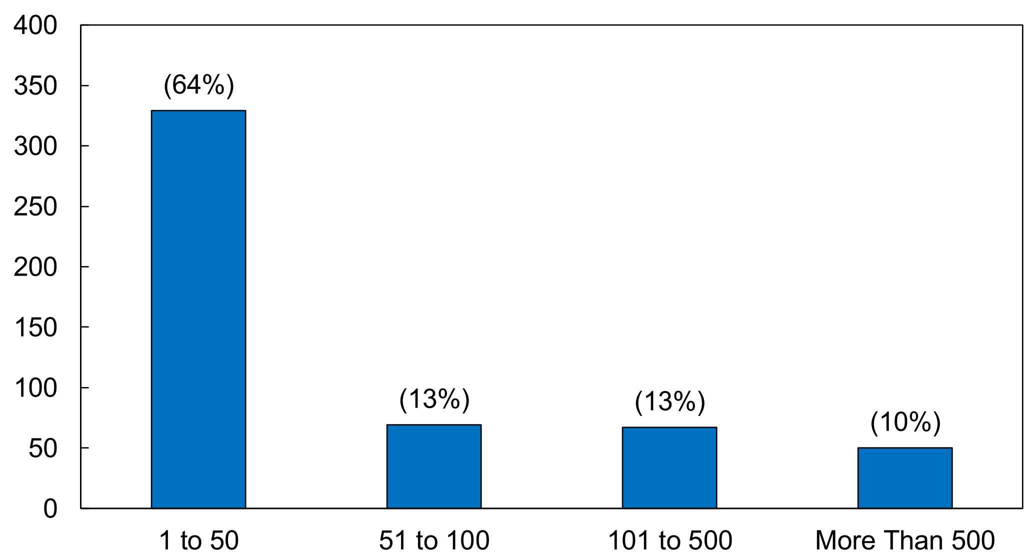


Figure 4.9: Estimated number of trucks at a driver's company

4.1.2.3 To the Best of Your Knowledge, What is the Total Number of Drivers Operating in Your Company?

In an attempt to determine the total number of drivers operating in a company, drivers were asked this question. Similar to the question presented in Section 4.1.2.2, driver responses ranged from 1 to 50,000, with a mean of 763 drivers and a standard deviation of 4,022. The idea underlying this question is to determine if there is a shortage in truck drivers and how that impacts truck companies. This also illustrates the size of some of the truck companies the drivers work for. It should also be noted, that these answers were based on the knowledge of the driver; therefore, the driver may overestimate the total number of drivers at a company. Figure 4.10 shows that the distribution of drivers is nearly identical to the distribution of reported trucks.

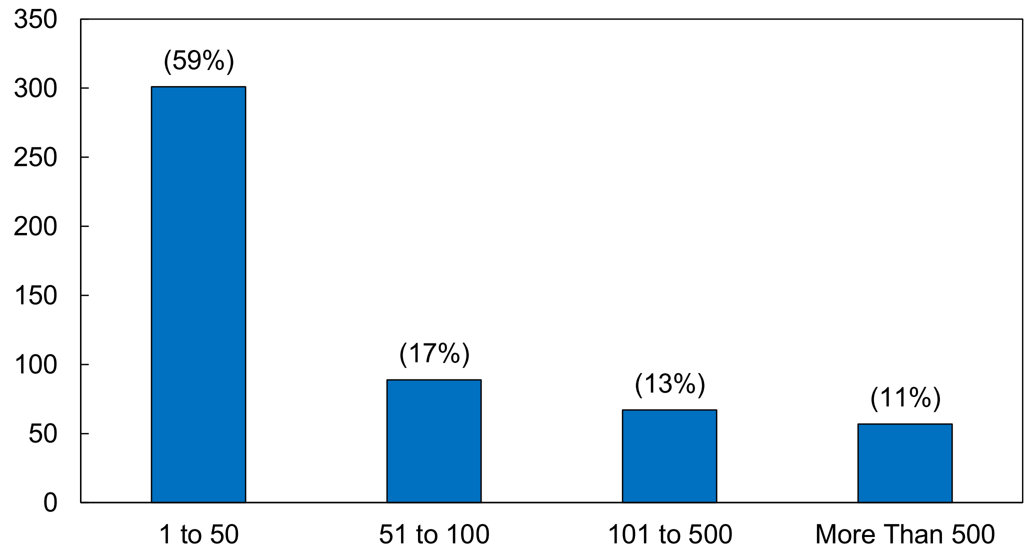


Figure 4.10: Estimated number of drivers at a driver's company

4.1.3 Trip-Related Characteristics

The next set of questions are designed to obtain information regarding trips made by the driver of the commercial motor vehicle works for.

4.1.3.1 On Average, How Many Freight Related Trips do You Make Weekly?

Drivers were asked about the number of freight related trips that they make weekly. The responses are disproportionate, in which driver responses range from 0.5 to 500,000 trips, with a mean of with a mean of 1,513 trips and a standard deviation of 22,808. The large variation, and high mean, are likely a result of error in entering the number of trips. Such outliers or anomalies will be addressed before further analysis. Figure 4.11 shows the distribution of weekly freight trips among the surveyed drivers.

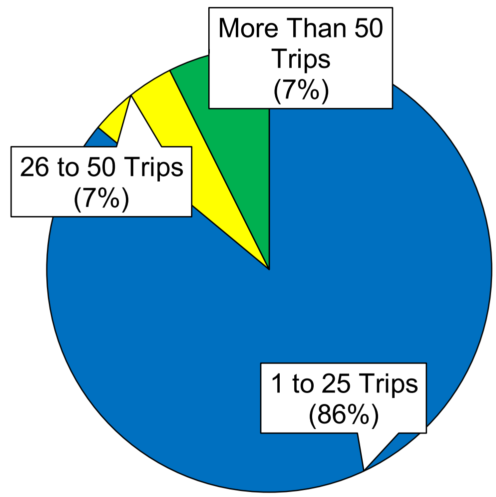


Figure 4.11: Average number of freight related trips in a week by surveyed drivers

4.1.3.2 On Average, How Many Miles do You Drive Trucks Each Week?

In this question, surveyed drivers were asked about the total number of miles they drive each week. The responses to this question have extreme variation and provide evidence in potential error in responses. This is observed in the range of miles driven that drivers reported: 1 to 25,000,000. As defined previously, these outliers or anomalies must be addressed before further analysis can be conducted. Based on FMCSA rules regarding HOS, these responses clearly contradict the allowable drive hours. Still, a distribution of responses is shown in Figure 4.12.

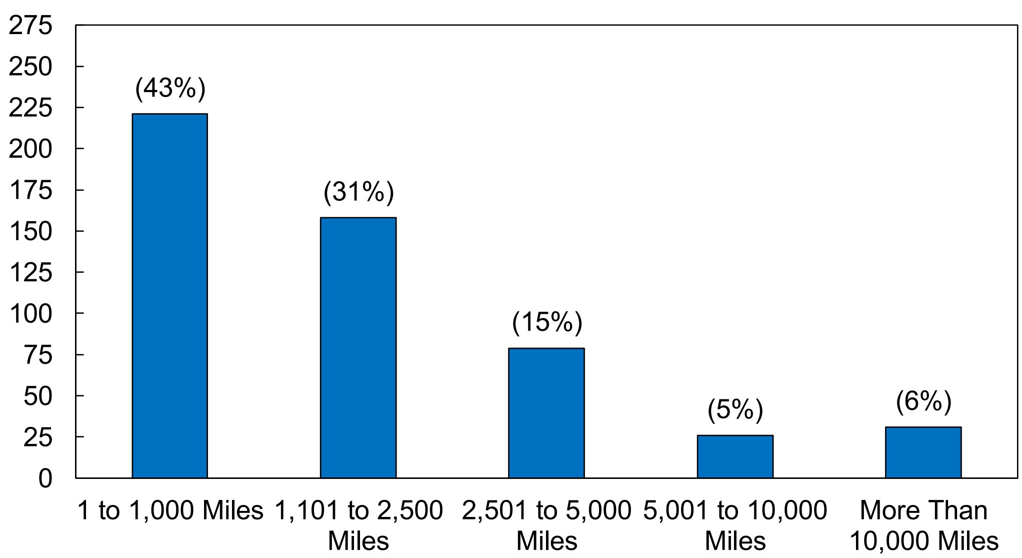


Figure 4.12: Average number of miles driven in a week by surveyed drivers

4.1.3.3 About What Percentage of Your Total Freight Related Trips (Trips Loaded or Empty) Are With the Following Ranges?

The first question asked drivers the percentage of their freight related trips that are less than 50 miles. As seen in Figure 4.13, 38% of drivers reported that 0% of their trips are less than 50 miles and 46% of drivers reported that 1% to 25% of their trips are less than 50 miles.

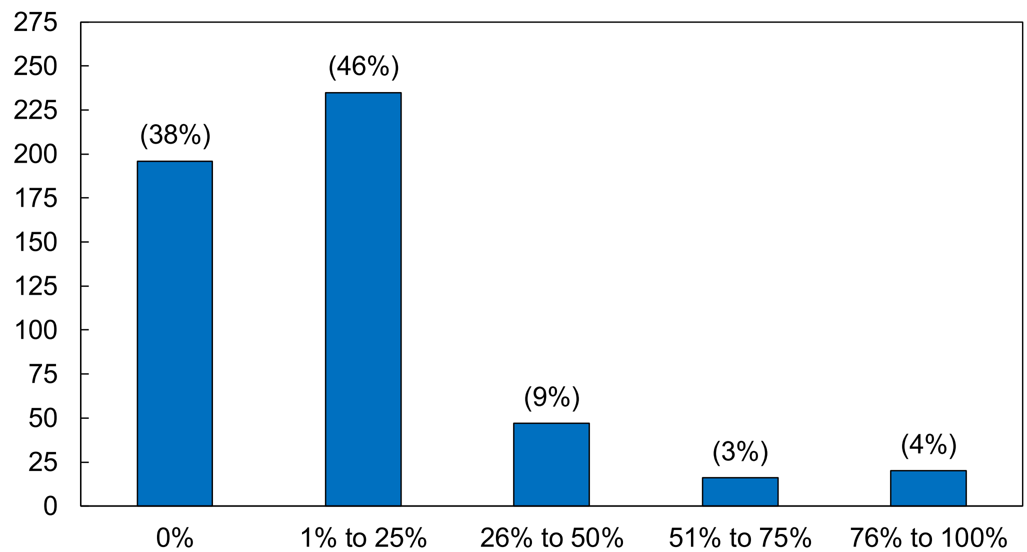


Figure 4.13: Distribution of freight-related trips of less than 50 miles

Figure 4.14 shows that the distribution of freight related trips between 50 miles and 99 miles is similar to the distribution of freight trips of less than 50 miles. Specifically, 33% of drivers reported that 0% of their trips are between 50 miles and 99 miles, and 51% of drivers reported that 1% to 25% of their trips are between 50 miles and 99 miles.

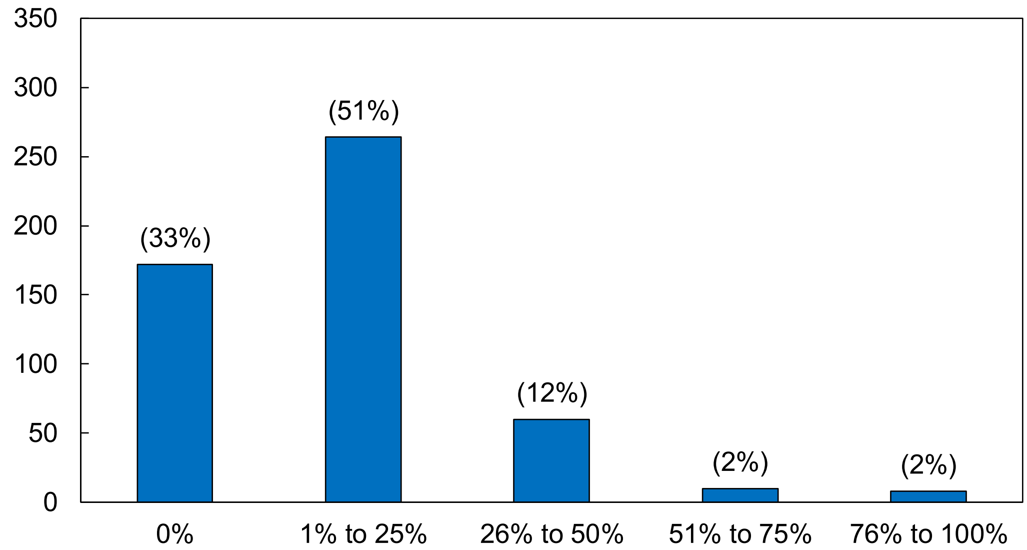


Figure 4.14: Distribution of freight related trips between 50 miles and 99 miles

Once more, the distribution of freight related trips between 100 miles and 249 miles (Figure 4.15) is similar to the previous distributions. Of the surveyed drivers, 28% reported that 0% of their trips are between 100 miles and 249 miles, and 45% of drivers reported that 1% to 25% of their trips are between 100 miles and 249 miles.

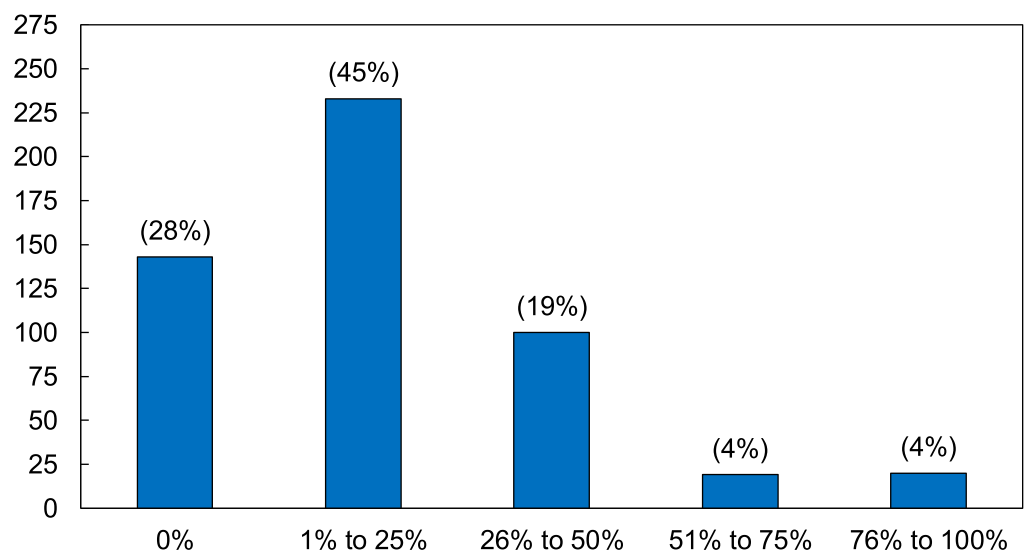


Figure 4.15: Distribution of freight related trips between 100 miles and 249 miles

Although the distribution is still similar to the previous distributions, this range (250 miles to 500 miles) had the largest proportion of drivers report 76% to 100% of their trips fall within this range (6% of drivers). Still, a large proportion of drivers reported that 0% of their trips fall within 250 miles and 500 miles (28%). Also with a large proportion, 39% of drivers reported that 1% to 25% of their trips are between 250 miles and 500 miles. A distribution of this trip range can be seen in

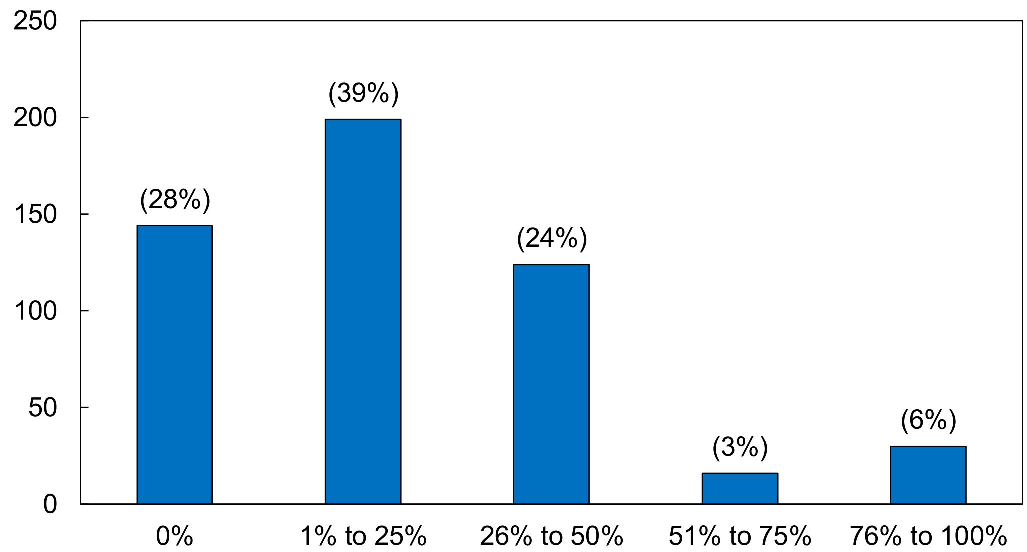


Figure 4.16: Distribution of freight-related trips between 250 miles and 500 miles

Freight related trips of greater than 500 miles had the largest proportion of drivers report that 76% to 100% of their trips fall within this range at 13%. As for drivers who reported percentages of 0% and 1% to 25%, the proportion of drivers was similar to previous trip ranges at 33% of surveyed drivers and 35% of surveyed drivers, respectively.

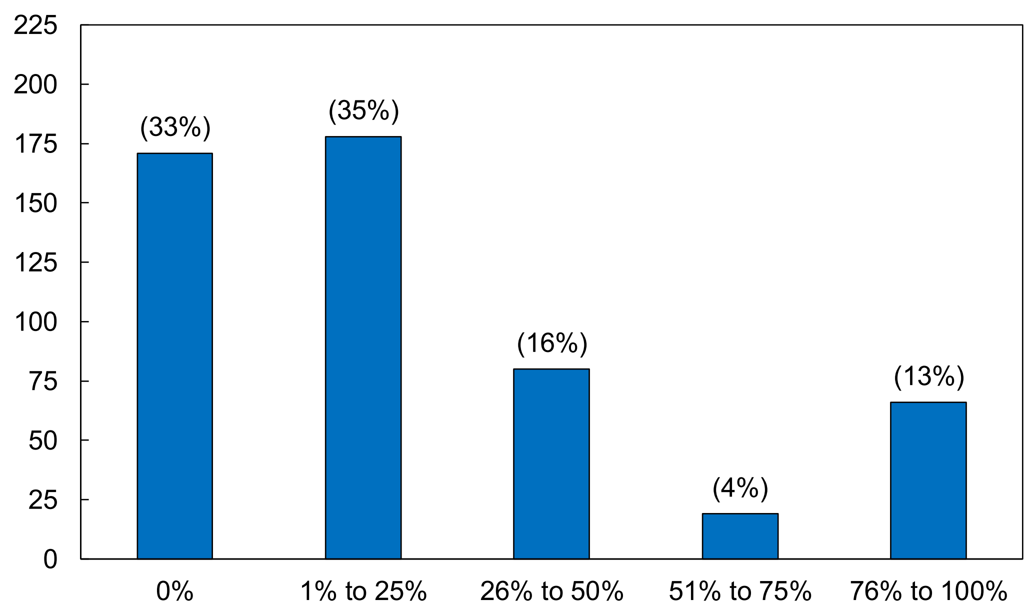


Figure 4.17: Distribution of freight-related trips greater than 500 miles

To summarize, Figure 4.18 shows the distribution of freight related trips by distance and the percent of drivers who reported each distance. The largest proportion of drivers to report 76% to 100% occurred with trips of greater than 500 miles, while the largest proportion of drivers reported 1% to 25% for each of proposed distances.

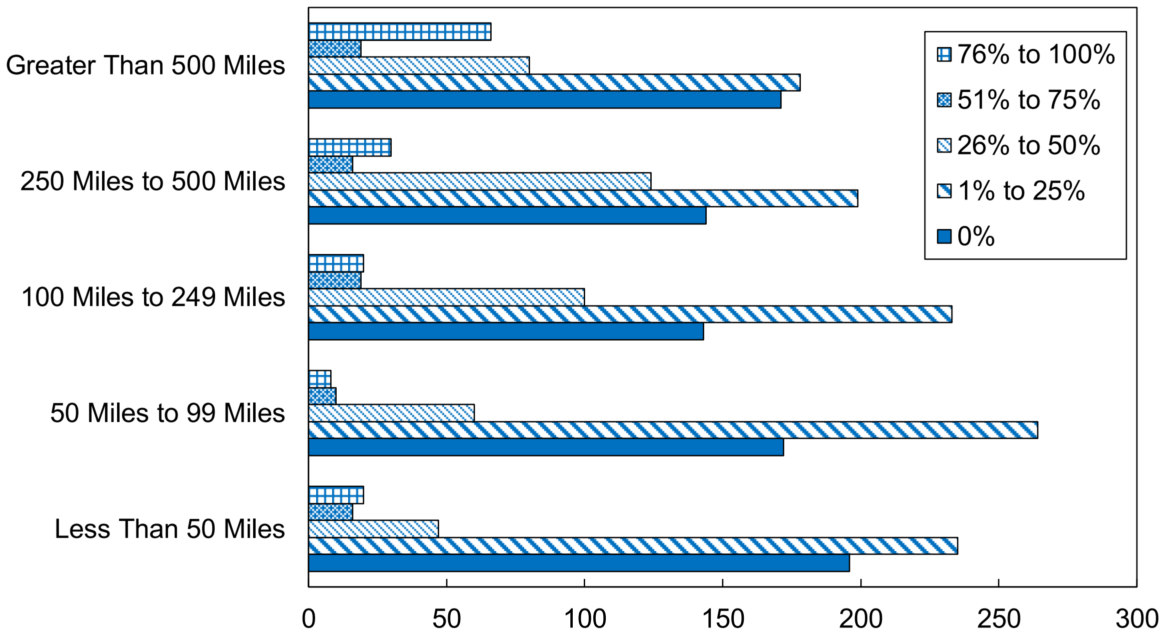


Figure 4.18: Freight-related trips by distance and proportion of surveyed drivers

4.1.3.4 On Average, What Type of Shipments do Your Trips Consist of?

Figure 4.19 illustrates the type of shipments that drivers' trips consist of. The majority of drivers, at 82%, reported that their shipments typically consist of truckload shipments. Of the remaining shipment types, 13% of drivers reported less-than-truckload shipments, 4% reported parcel shipments, and 1% reported that they did not know or they refused to disclose their type of shipment.

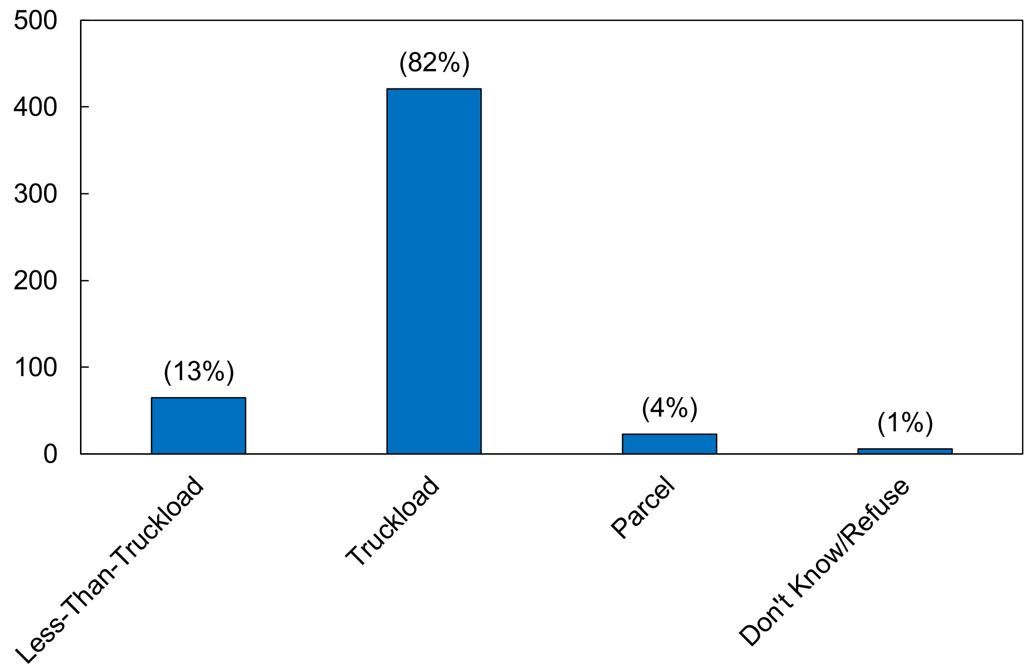


Figure 4.19: Distribution of shipments of surveyed drivers

4.1.4 Driving-Related Characteristics

The next set of questions are designed to obtain information regarding driving characteristics of the driver of the commercial motor vehicle.

4.1.4.1 How Many Years Have You Been Driving Commercial Motor Vehicles?

The majority of surveyed drivers reported driving commercial vehicles for two years to five years and six years to 10 years, both accounting for 31% of the surveyed drivers. Referring to Figure 4.20, the next largest proportion of drivers reported driving commercial vehicles for 11 years to 15 years (14%) and greater than 20 years (13%). Driver responses ranged from one year to 50 years, with a mean of 10.7 years and a standard deviation of 8.9.

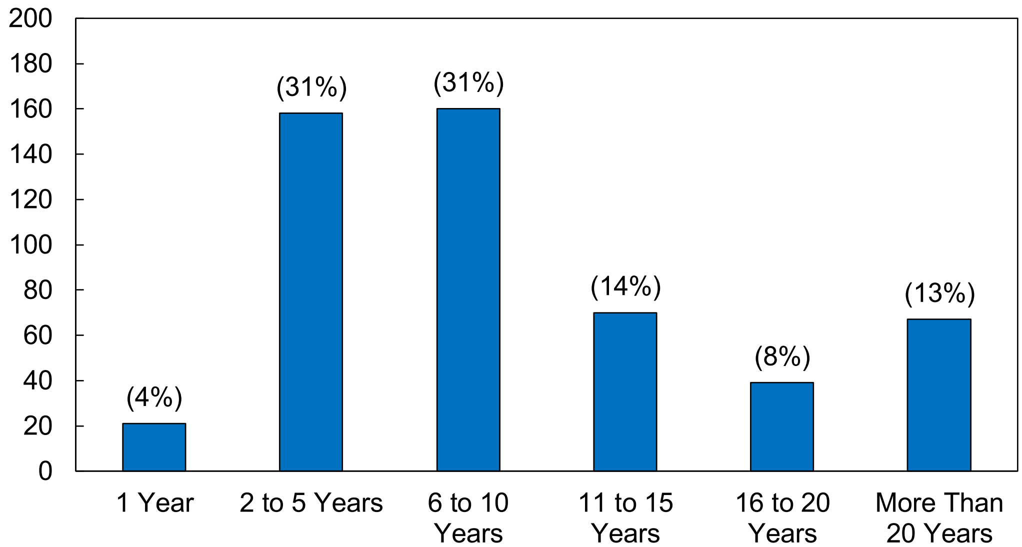


Figure 4.20: Distribution of surveyed drivers by years driving

4.1.4.2 How Did You Learn How To Drive The Semi-Truck You Drive?

Based on survey responses,
Figure 4.21 shows how surveyed drivers reported learning how to drive their semi-truck. The majority of drivers, 43%, reported learning how to drive their semi-truck in driving school. The following two methods used to learn how to drive their semi-truck account for approximately the same proportion of drivers: self-taught and previous or present employer. For self-taught, 18% of driver reported they taught themselves how to driver their semi-truck. In regards to employers, 17% of drivers reported learning how to drive their semi-truck from their current or previous employer. At smaller proportions, 12% of drivers reported learning from a relative, 8% reported learning from a friend, and 3% reported learning from military services.

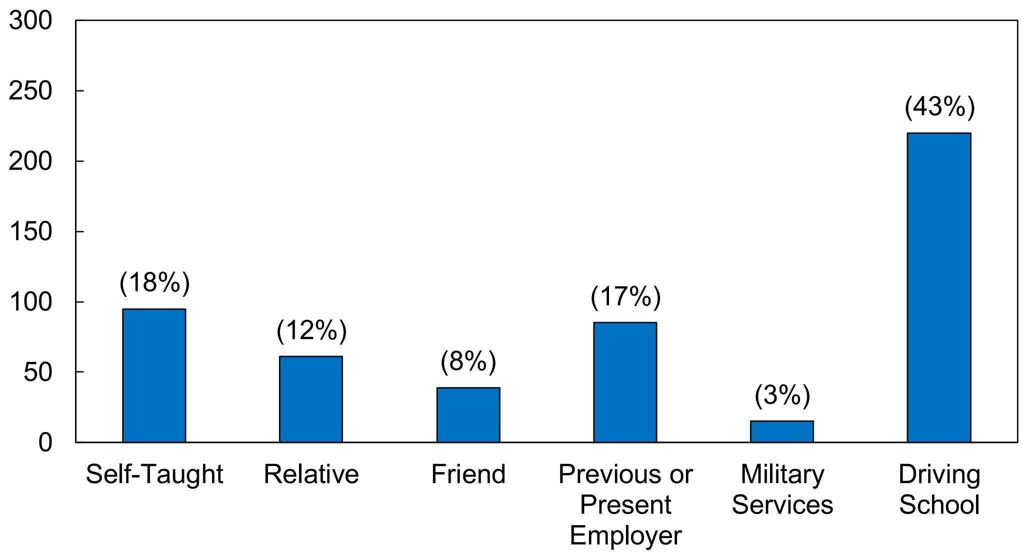


Figure 4.21: Distribution of surveyed drivers and how they learned to drive their truck

4.1.4.3 Do You Usually Drive On?

The surveyed drivers were asked to reveal where they usually drive with regard to the type of roadway. The majority of drivers (55%) reported that they usually drive on highways, while 35% of drivers reported they usually drive on a mixture of roadways (i.e., highways, rural roads, city roads). The distribution of roadways drivers reported driving on is shown in Figure 4.22.

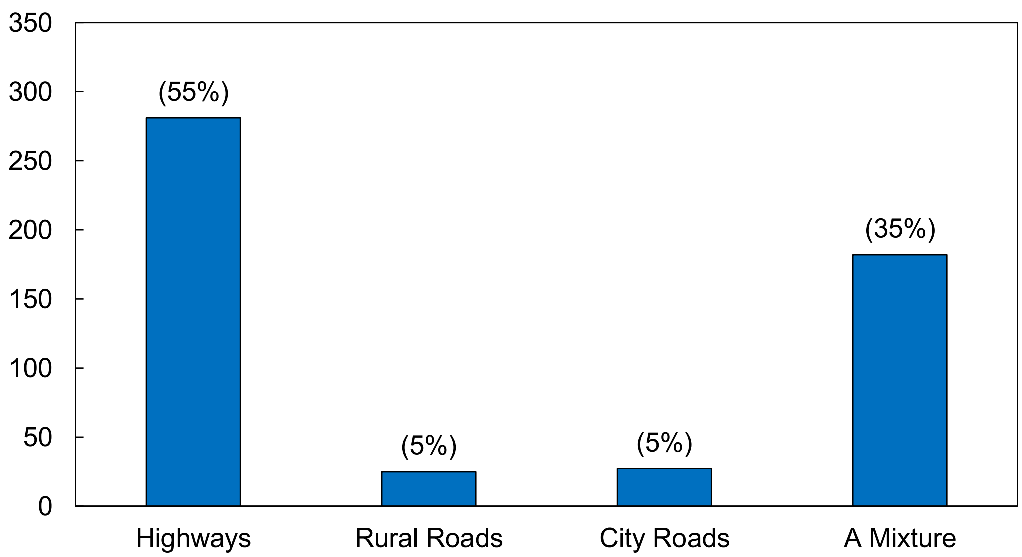


Figure 4.22: Distribution of surveyed drivers by type of roadway they usually drive on

4.1.4.4 *How Often Would You Check Your Truck Over Each Week?*

Regular maintenance of vehicles can extend the life of the vehicle and save drivers costs that they can incur in repairs. Given that, the drivers were asked how often they check their trucks over each week (see Figure 4.23). 46% of drivers reported that they check their trucks before starting each trip and 35% of drivers reported checking their truck before starting their and at every stop. Other responses show that some drivers, 5%, think that it is not their job to check their trucks, while 13% of drivers reported occasionally checking their trucks. A very small percentage of drivers (1%) reported checking their trucks only when they think something is wrong.

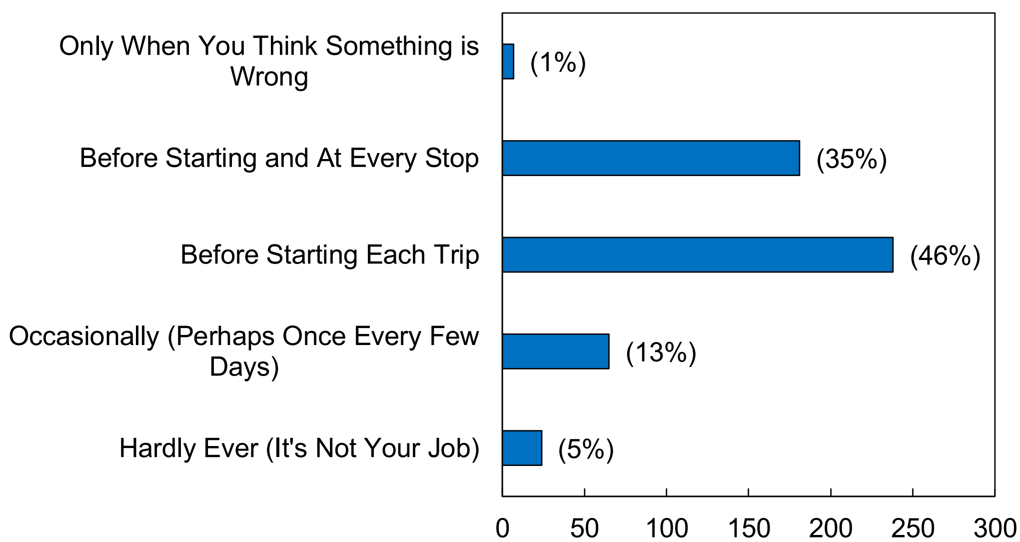


Figure 4.23: Distribution of surveyed drivers by how often they check their truck

4.1.4.5 *Do You Participate in Team Driving?*

Figure 4.24 shows the distribution of drivers as it pertains to team driving. Of the surveyed drivers, 23% reported they never participate in team driving, 30% reported they rarely participate in team driving, and 31% reported they sometimes participate in team driving. However, there was a proportion of drivers who reported that they often participate in team driving (9%) and a proportion of drivers who reported always participating in team driving (8%).

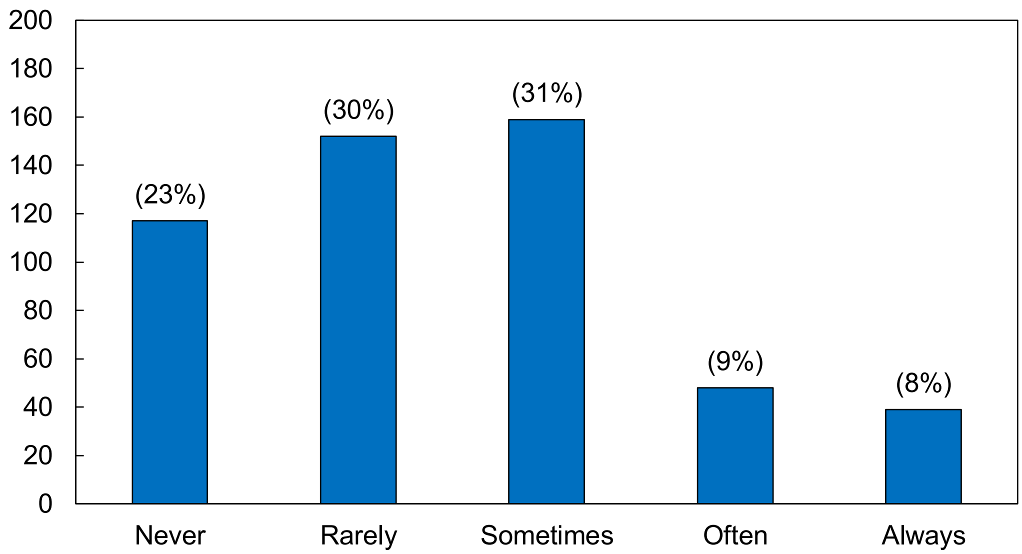


Figure 4.24: Distribution of surveyed drivers by team driving frequency

4.1.4.6 When do You Normally Start Your Work?

The time-of-day that drivers normally start their work is presented in Figure 4.25. Morning times account for the largest portion of driver responses, as 41% of driver reported they normally start their work in the morning (6:00 a.m. to 9:59 a.m.) and 37% of drivers reported they normally start their work in the early morning (midnight to 5:59 a.m.). The proportion of other work start times are substantially less than the two aforementioned start times. Specifically, 11% of drivers reported they normally start their work during midday (10:00 a.m. to 3:59 p.m.), 5% reported starting in the evening (4:00 p.m. to 8:59 p.m.), and 5% reported starting at night (9:00 p.m. to 11:59 p.m.).

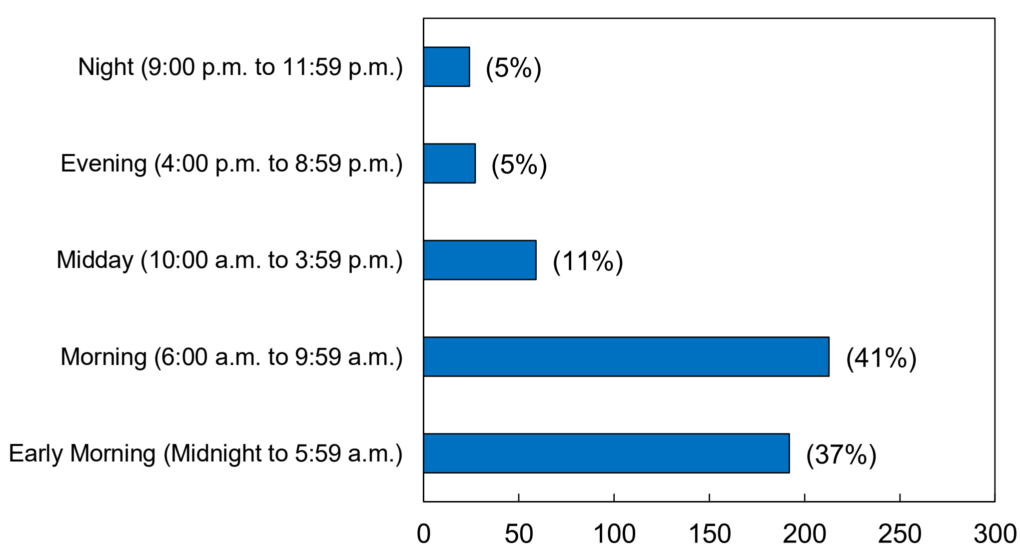


Figure 4.25: Distribution of surveyed drivers by when they start their work

4.1.5 Safety-Related Characteristics

The next set of questions are designed to obtain information regarding safety characteristics of the driver of the commercial motor vehicle.

4.1.5.1 Have You Ever Had Any Specific Road Safety Training?

As a means of enhancing traffic safety for drivers of large trucks, safety training programs are important. To determine if drivers had taken any road safety training program, this question was developed. Figure 4.26 shows that 87% of drivers reported taking a specific road safety training, whereas 13% of drivers reported not having specific road safety training.

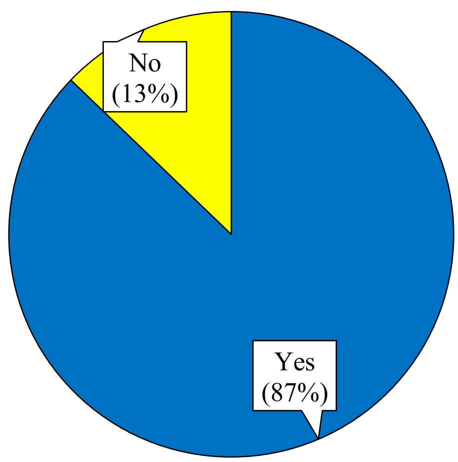


Figure 4.26: Distribution of surveyed drivers by road safety training

4.1.5.2 How Confident Are You In Your Abilities to Professionally Drive a Semi-Truck?

Results of this question indicate that 93% of drivers reported being extremely (53%) and very confident (40%) in their abilities to professionally drive a semi-truck (see Figure 4.27). Only 6% of surveyed drivers reported being moderately confident with their abilities to professionally drive a semi-truck, while 1% of drivers reported both being slight confident and not at all confident.

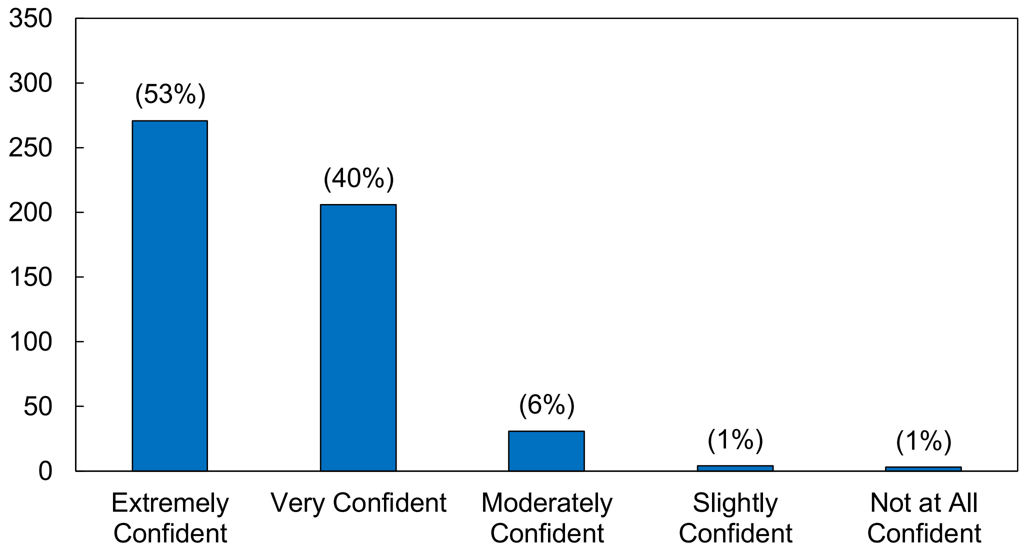


Figure 4.27: Distribution of surveyed drivers by confidence in professionally driving a semi-truck

4.1.5.3 What is the Average Speed That you drive on Non-Freeways in Miles per Hour?

Referring to Figure 4.28, the majority of surveyed drivers reported driver faster than 40 mi/hr on non-freeways. Specifically, 25% reported that their average speed is between 40 mi/hr and 50 mi/hr, 27% reported their average speed to be between 50 mi/hr and 60 mi/hr, and 18% reported their average speed to be greater than 60 mi/hr. The average reported speed was 46 mi/hr, with a standard deviation of 15 mi/hr.

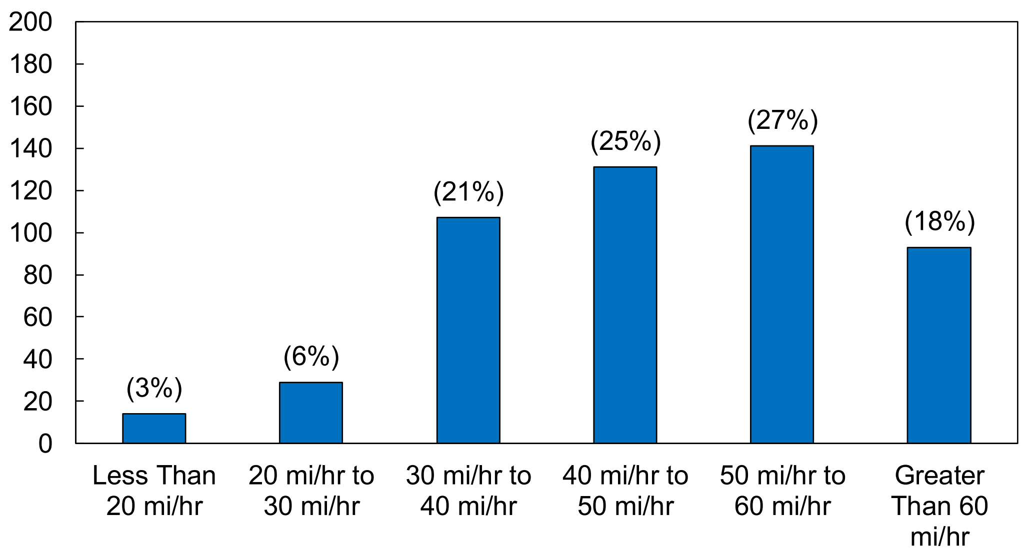


Figure 4.28: Distribution of surveyed drivers by reported average speed on non-freeways

4.1.5.4 What is the Average Speed That you drive on Freeways/Interstates in Miles per Hour?

As observed in Figure 4.29, the reported average speed of surveyed drivers for freeways/interstates is substantially higher than those reported for non-freeways. To illustrate, 58% of drivers reported their average freeway/interstate speed to be greater than 60 mi/hr. In addition, 32% of drivers reported their average speed to be between 50 mi/hr and 60 mi/hr. The average reported speed is 58 mi/hr, with a standard deviation of 13 mi/hr.

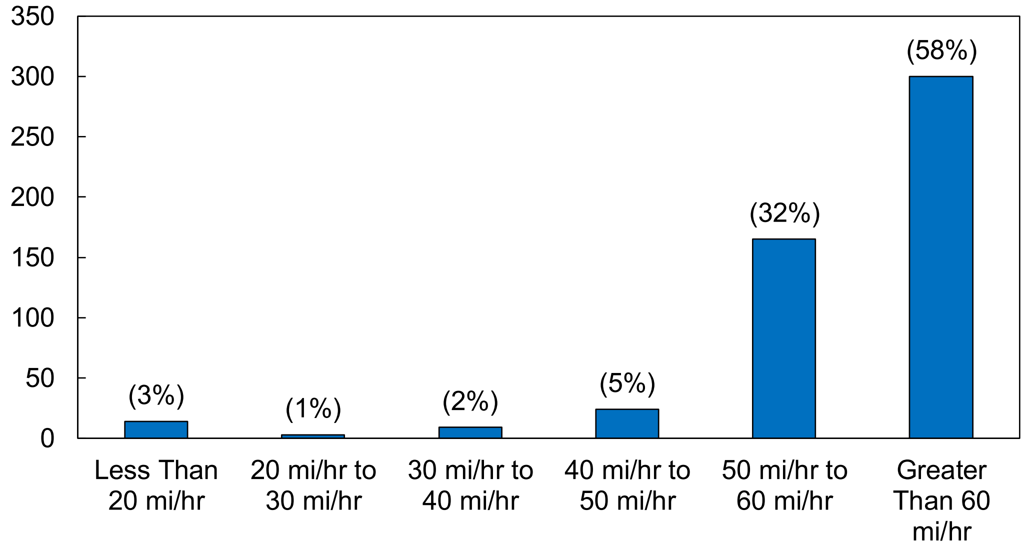


Figure 4.29: Distribution of surveyed drivers by reported average speed on freeways/interstates

4.1.5.5 Which Situation Poses the Highest Safety Hazard?

Figure 4.30 shows driver responses to situations they perceive to pose the highest safety hazard. In this question, three areas have been deemed as high risk for truck drivers: front of truck, behind of truck, and either side of truck. These areas are called blind spots or no-zone areas in trucks. Survey results show that 39% of drivers reported that passenger vehicle on either side of their truck poses the highest safety hazard, with passenger vehicles in front of the truck also leading drivers to perceive high safety hazards (24% of drivers reported that a passenger vehicle in front of them poses the highest safety hazard). However, the presence of trucks do not appear to result in the surveyed drivers perceiving a safety hazard. Specifically, 11% of drivers reported that a truck in front poses the highest safety hazard and 3% of drivers reported that a truck behind poses the highest safety hazard.

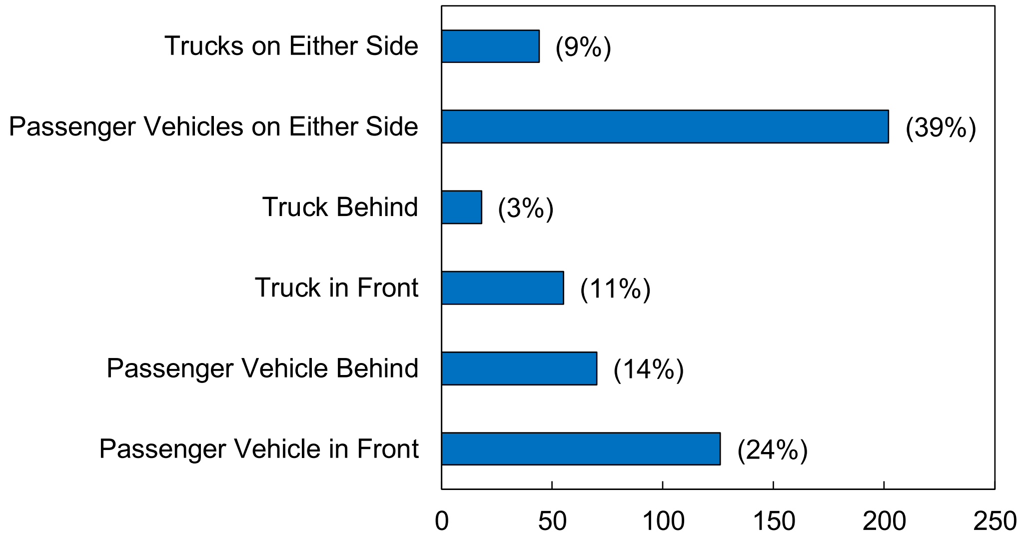


Figure 4.30: Distribution of surveyed drivers by perceived safety hazards

4.1.5.6 Do You Change Lanes to Avoid Traveling With…

This question posed a series of scenarios based on the aforementioned situations that potentially pose the highest safety hazard. As a result, the survey asked drivers if they would change lanes to avoid traveling with a passenger vehicle or truck located in one of the truck's no-zone areas. As shown in Figure 4.31, the majority of driver reported sometimes changing lanes for each of the proposed scenarios. It is also observed that the largest percentage of responses for often changing lanes is associated with passenger vehicles in front and passenger vehicles on either side. The largest proportion of response for never changing lanes is related to the position of other trucks, specifically if another truck is traveling behind.

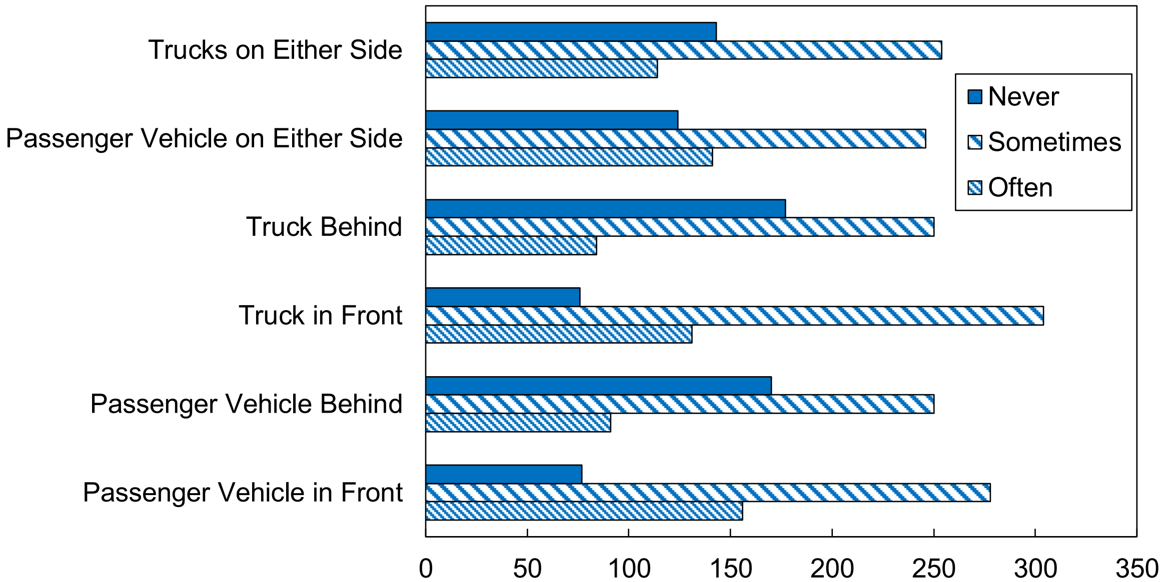


Figure 4.31: Distribution of surveyed drivers by lane changing scenarios

4.1.5.7 How Often Do You Find Your Concentration Lapsing After Driving for a Long Time?

To highlight the impact of working hours on truck drivers, drivers were asked if they experience lapses in concentration after driving for a long time. Referring to Figure 4.32, 35% of drivers reported they rarely experience lapses in concentration after driving for a long time. On the other hand, 31% of drivers reported sometimes experiencing lapses in concentration, 15% of drivers reported experiencing lapses in concentration quite often, and 12% of drivers reported experiencing lapses in concentration very often.

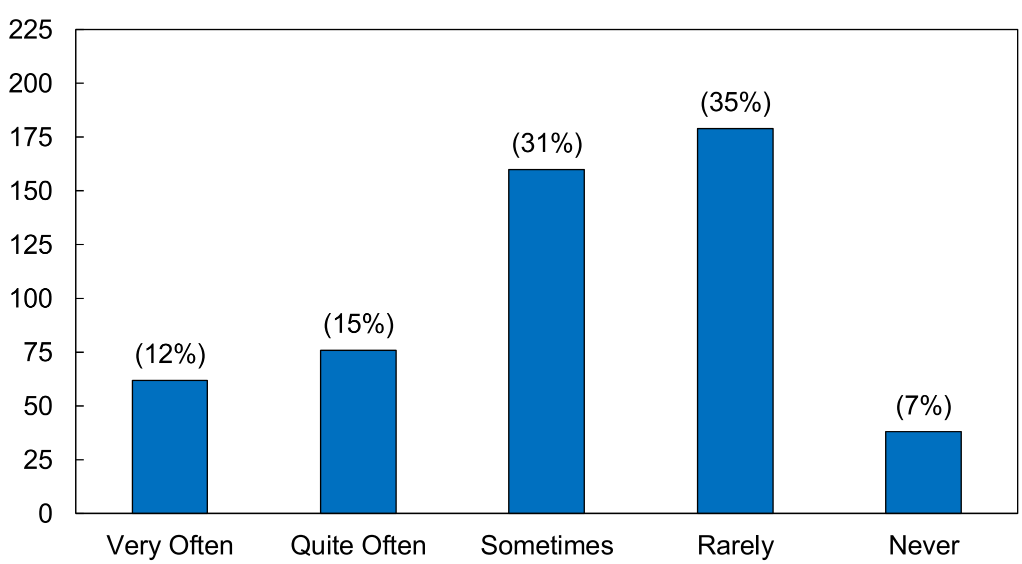


Figure 4.32: Distribution of surveyed drivers by frequency of lapses in concentration

4.1.5.8 Do You Use a Cell Phone While Driving (Handheld or Hands-Free)?

As seen in Figure 4.33, 45% of surveyed drivers reported that they do use their cell phone while driving and 55% of drivers reported that they do not use their cell phone while driving.

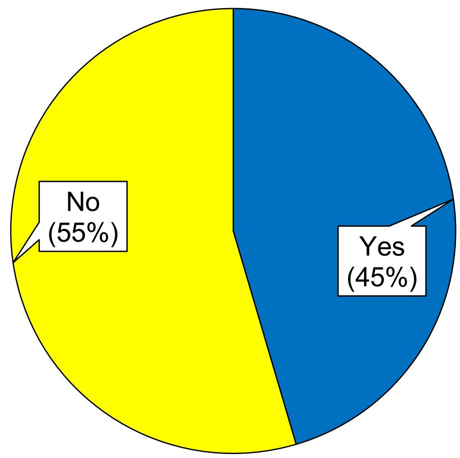


Figure 4.33: Distribution of drivers who reported using their cell phone while driving

4.1.5.9 If You Do Use Your Cell Phone, On Average, How Long Are You Usually On the Phone While Driving (in Minutes)?

Drivers who reported using their cell phone while driving were asked to provide how many minutes they use their cell phone while driving. Referring to Figure 4.34, more than half (53%) of drivers reported using their cell phone for five minutes or less. However, with 18% of drivers reporting using their cell phone for more than 20 minutes, the average reported time on the phone is 15.9 minutes with a standard deviation of 26.8 minutes.

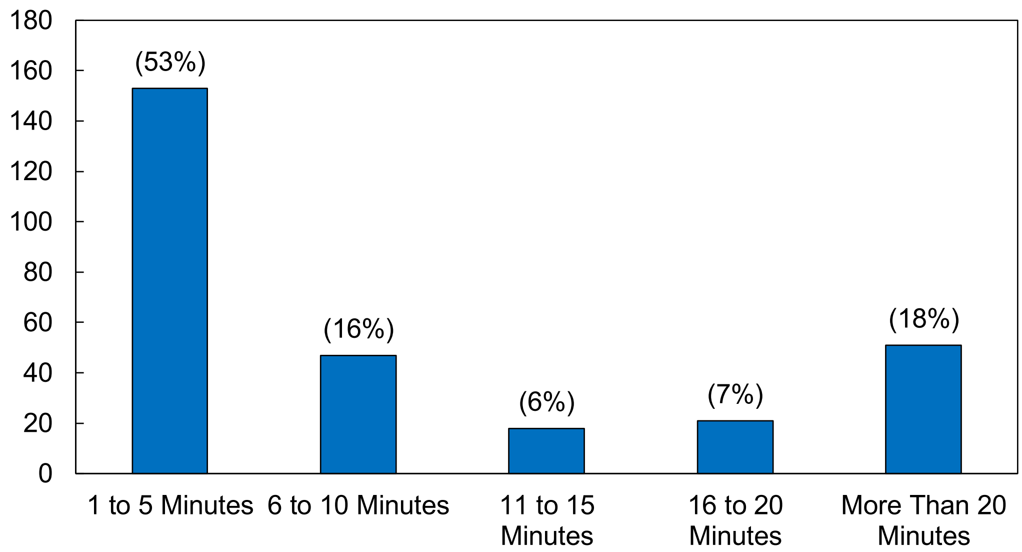


Figure 4.34: Distribution of surveyed drivers by average time on cell phone while driving

4.1.5.10 During the Last Five Years, How Many Crashes Have you had in which the Police Had to Attend?

As seen in Figure 4.35, 76% of drivers reported they did not have crash in the last five years in which the police had to attend. Of drivers that did report having a crash in which the police had to attend, 13% of drivers reported having one crash, 6% of drivers reported having two crashes, 3% of drivers reported having three crashes, and 2% of drivers reported having four or more crashes.

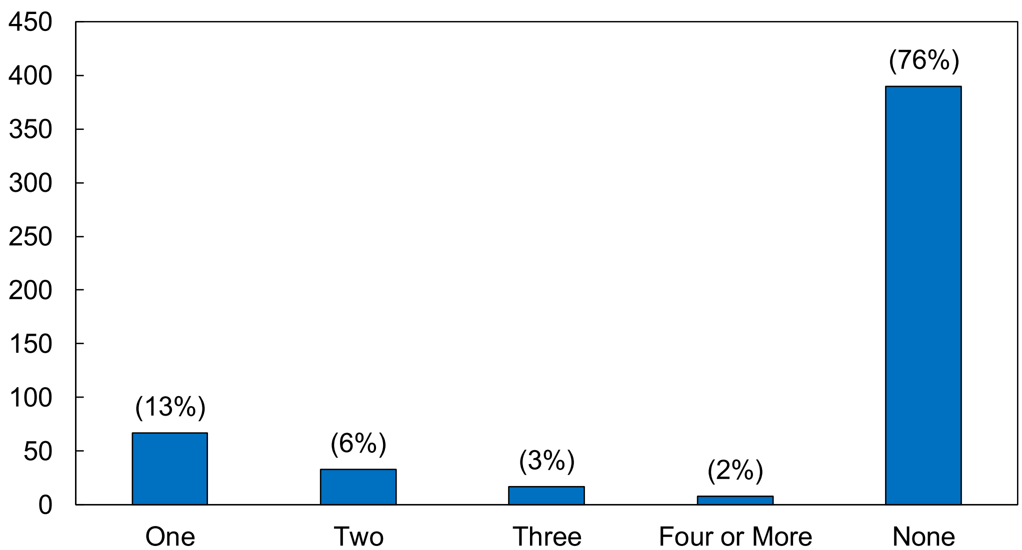


Figure 4.35: Distribution of surveyed drivers by number of crashes in last five years

4.1.5.11 If involved in at Least One Crash in the Last Five Years, Did This Crash/s Not Involve Other Vehicles (e.g., You Ran off the Road/Hit Something on the Road)?

To determine if the crashes reported by the surveyed drivers were multi-vehicle crashes, Figure 4.36 is presented. As seen, 58% of drivers involved in at least one crash in the last five years reported that the crash(s) did not involve other vehicles. However, 42% of drivers involved in at least one crash in the last five years reported that the crash(s) did involve at least one other vehicle.

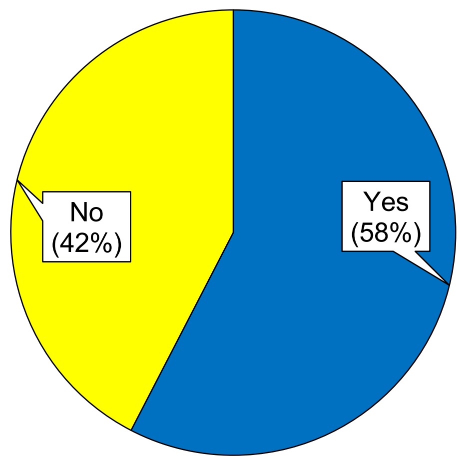


Figure 4.36: Proportion of surveyed drivers involved in crashes with no other vehicles

4.1.5.12 Thinking of the Last Crash You Had, Was Your Truck Loaded or Unloaded at the Time of the Crash?

As shown in Figure 4.37, 27% of drivers involved in at least one crash reported that their truck was empty at the time of their last crash, 42% reported that their truck was partially loaded, 30% reported their truck was fully loaded, and 1% reported that they did not recall how their truck was loaded at the time of their last crash.

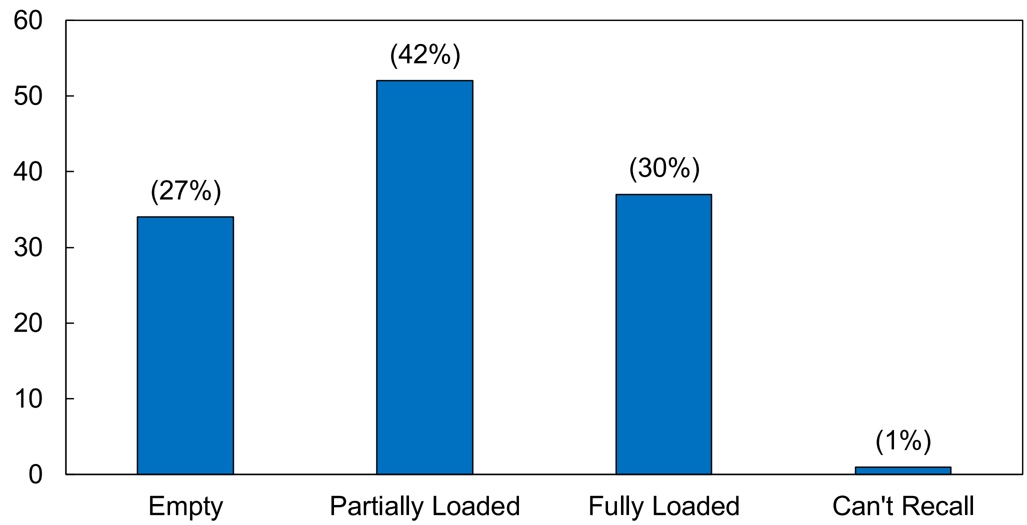


Figure 4.37: Proportion of trucks involved in at least one crash by load

4.1.5.13 Roughly, How Far Had You Driven Before You Had That Crash?

Referring to Figure 4.38, more than one-quarter (26%) of drivers involved in at least one crash reported having driven less than 50 miles before the crash had happened. Of the remaining drivers involved in at least one crash, 15% reported driving between 51 miles and 100 miles before the crash occurred, 9% reported driving between 101 miles and 500 miles, and 6% reported driving for more than 500 miles. In addition, a large proportion of drivers (44%) reported that they could not recall how far they had driven before the crash occurred. The average reported distance driven before being involved in their last crash was 5,763 miles, with a standard deviation of 41,904 miles.

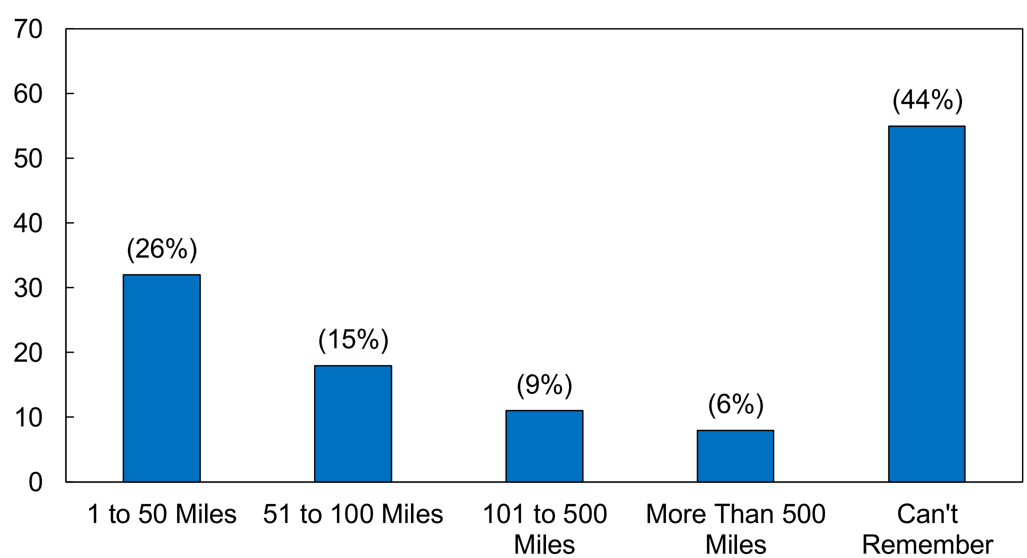


Figure 4.38: Miles driven before involved in last crash

4.1.5.14 Which Road Type Were You Driving On During Your Last Crash?

Figure 4.39 shows roadway types in which their last crash occurred. Referring to Figure 4.39, 62% of drivers reported that their last crash happened on a highway, 22% of drivers reported that their last crash occurred on a rural road, and 16% of drivers reported that their last crash took place on a city road.

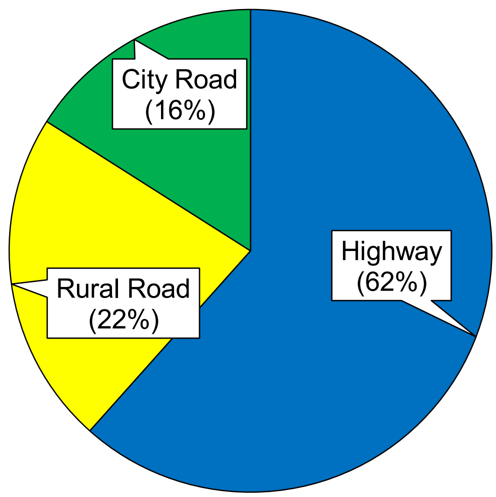


Figure 4.39: Proportion of roadway types in which crashes last occurred

4.1.5.15 What Weather Conditions Were Present at the Time of the Crash?

Weather conditions in which large truck crashes occurred, based on responses from the surveyed drivers, are presented in Figure 4.40. The majority of drivers involved in at least one crash reported that the weather was clear (34%) or cloudy (32%) at the time of their last crash. Also accounting for a large proportion, 25% of drivers reported that their last crash occurred in rainy weather. As for fog and snow, 6% and 4% of drivers reported these as the weather conditions at the time of their last crash, respectively.

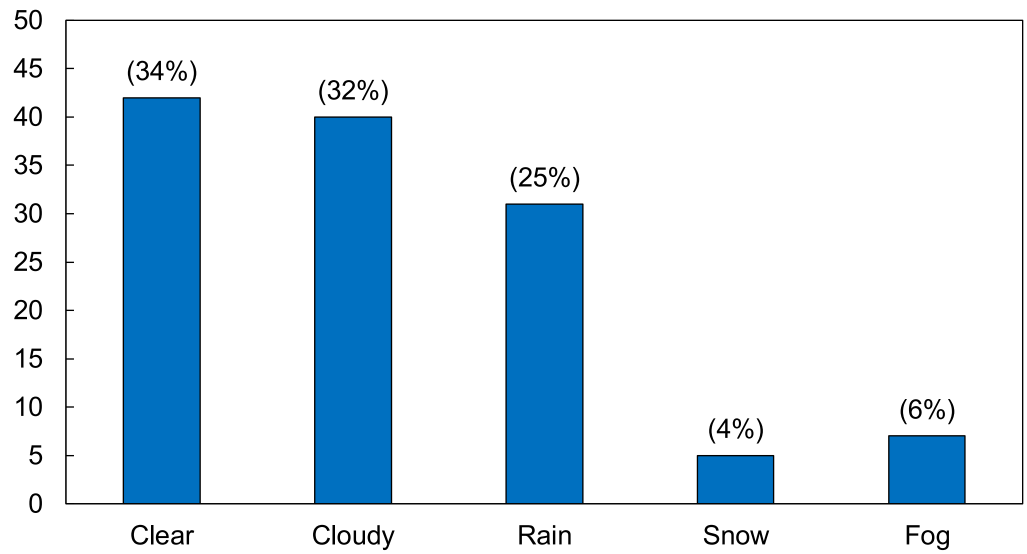


Figure 4.40: Distribution of crashes of surveyed drivers by weather condition

4.1.5.16 What Time-of-Shift Did Your Crash Occur?

Figure 4.41 shows the time of the driver's shift in which the crash occurred. As shown, the majority of drivers (46%) reported that their last crash occurred near the middle of their shift. As it pertains to beginning of shift and near the end of shift, 32% of drivers reported that their last crash occurred at the beginning of their shift and 22% of drivers reported that their crash occurred near the of their shift.

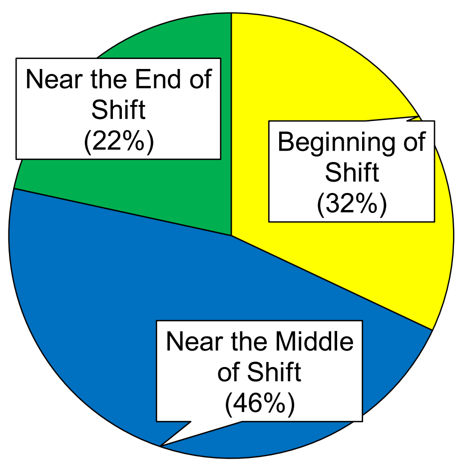


Figure 4.41: Proportion of reported crashes by time-of-shift

4.1.5.17 How Much Time Had Passed Since Your Last Break Before the Crash Occurred?

As illustrated in Figure 4.42, 40% of drivers reported that two to three hours had passed since their last break before the crash occurred and 23% of drivers reported that one to two hours had passed. The remaining proportion of driver responses are: 9% of drivers reported that less than one hour had passed since their last break, 17% of drivers reported that four to five hours had passed since their last break, and 12% of drivers reported that more than five hours had passed since their last break.

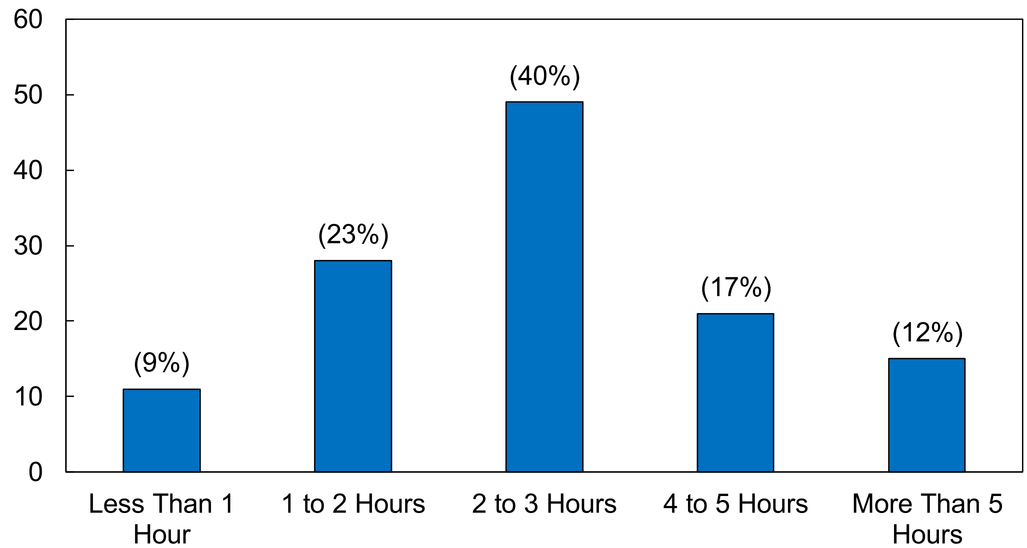


Figure 4.42: Distribution of time passed since last break before crash occurred

4.1.5.18 Do You Feel Operating Trucks in Mixed Traffic Poses Any Safety Hazard to You?

Drivers' perception of safety hazards due to operating trucks in mixed traffic is shown in Figure 4.43. As shown in Figure 4.43, 57% of driver reported that operating a truck in mixed traffic does pose a safety hazard to them. Of the remaining surveyed drivers, 33% reported that operating a truck in mixed traffic does not pose a safety hazard and 10% reported that they are unsure if operating a truck in mixed traffic poses a safety hazard.

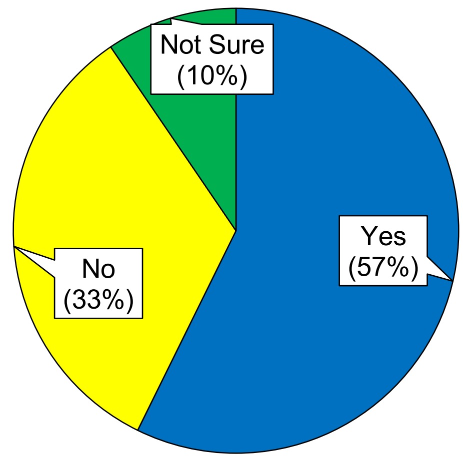


Figure 4.43: Proportion of surveyed drivers who feel operating trucks in mixed traffic poses a safety hazard

4.1.5.19 What Time-of-Day do You Think is the Safest Time to Drive Your Truck?

Figure 4.44 illustrates the distribution of time-of-day that drivers perceive to be the safest time to drive their truck. Referring to Figure 4.44, the majority of drivers (36%) reported early morning (midnight to 5:59 a.m.) as the safest time to driver their truck. Also with significant proportions, 24% of drivers reported midday (10:00 a.m. to 3:59 p.m.) as the safest time and 22% of drivers reported morning (6:00 a.m. to 9:59 a.m.) as the safest time. The smallest proportion of drivers (4%) reported evening as the safest time to driver their truck and 13% reported night (9:00 p.m. to 11:59 p.m.) as the safest time.

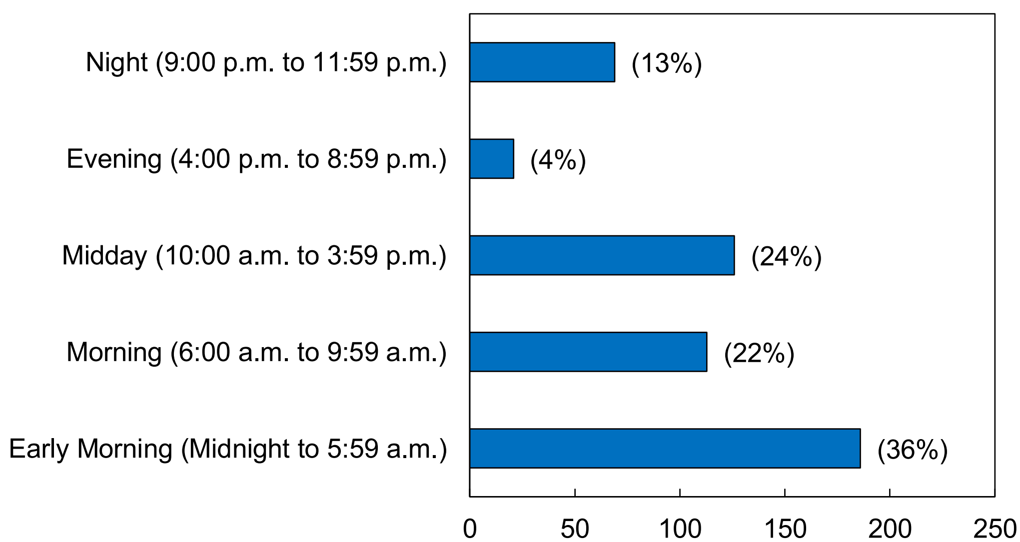


Figure 4.44: Distribution of surveyed drivers by perceived safest time to drive their truck

4.1.6 Parking-Related Characteristics

The next set of questions are designed to obtain information regarding parking behavior and opinions of the driver of the commercial motor vehicle.

4.1.6.1 When Required to Rest, Have you experienced any Problems Finding a Safe and Adequate Location to Park Your Truck?

Driver responses to whether they have experienced any problems finding a safe and adequate location to park their truck is shown in Figure 4.45. More than half of the surveyed drivers (55%) reported that they have experienced problems finding a safe and adequate location to park their truck and 45% of drivers reported they have not experienced any problems.

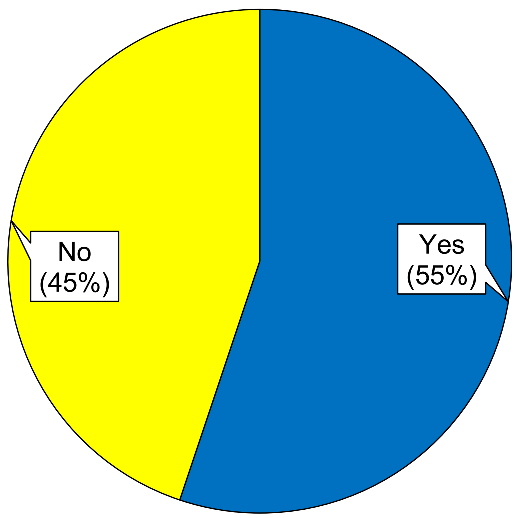


Figure 4.45: Proportion of surveyed drivers who reported problems when finding a safe and adequate location to park their truck

4.1.6.2 When it comes to Deciding Where to Stop and Park…

When it comes to deciding where to stop to park, Figure 4.46 shows that 78% of drivers reported making their own parking decisions and 21% of drivers reported that their company makes the decision when it comes to parking. In addition to these two choices, 1% of drivers reported ‘Other’ and provided their reasoning:

- One driver stated that her and her husband decide where to park.
- One driver stated that traffic conditions and size of the streets make their parking decision.

- One driver indicated that they routinely stop at specific stops along a given route.
- One driver stated they only make short-haul trips and are not required to park.
- One driver stated they have a co-driver and do not need to park.

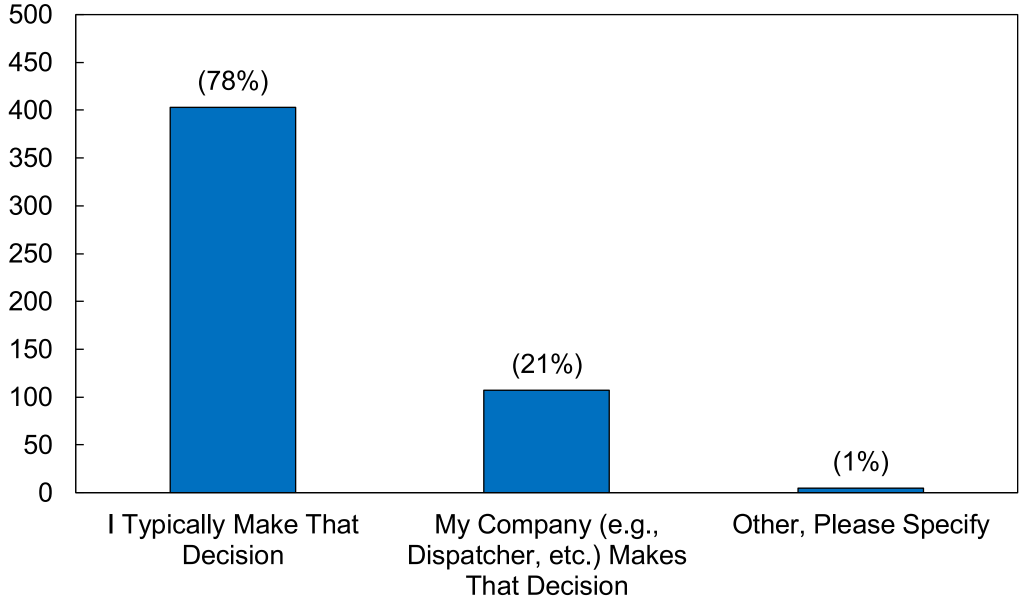


Figure 4.46: Distribution of surveyed drivers by parking decisions

4.1.6.3 In Your Experience, What Time-of-Day Have You Found to be the MOST Difficult in Finding Safe Truck Parking (Select All That Apply)?

For this question, drivers were asked to select all that apply; therefore, a total of 709 responses were recorded for this question. The presented percentages, both in the discussion and in Figure 4.47, are based on the number of drivers surveyed (515); hence, the percentages will not sum to 100%. With that in mind, the time-of-day selected by the highest percentage of surveyed drivers (45%) is evening (4:00 p.m. to 8:59 p.m.). Also selected by a large proportion of drivers are night (9:00 p.m. to 11:59 p.m.) and midday (10:00 a.m. to 3:59 p.m.) at 29% and 25% of the total responses, respectively. Morning and early morning times were selected by 18% and 15% of drivers, while 6% of drivers reported having no difficulty finding safe truck parking.

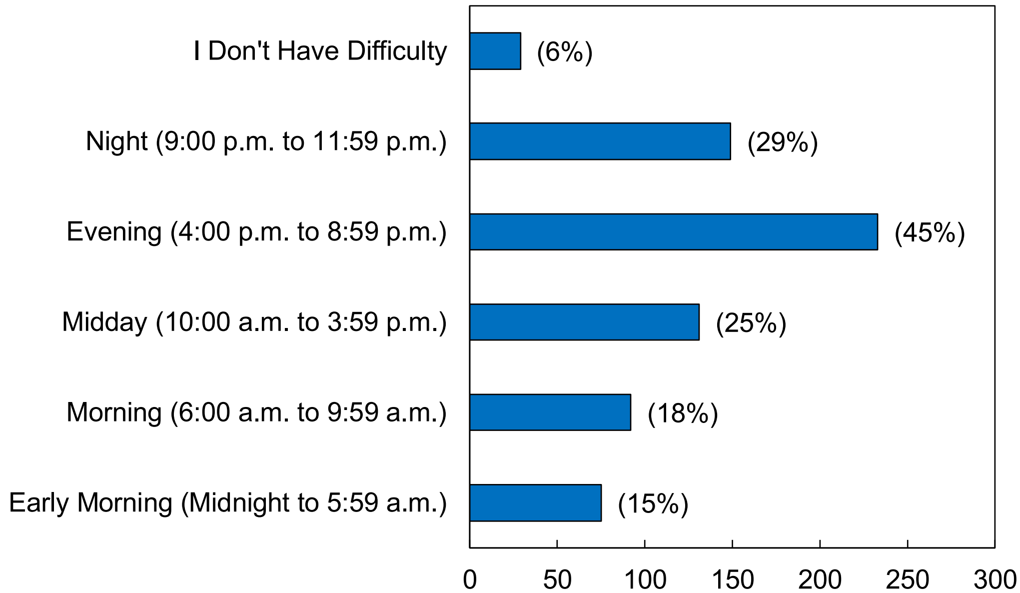


Figure 4.47: Distribution of surveyed drivers by time-of-day and perceived difficulty finding safe truck parking

4.1.6.4 In Your Experience, What Day of the Week Have You Found to be the MOST Difficult in Finding Safe Truck Parking (Select All That Apply)?

For this question, drivers were asked to select all that apply; therefore, a total of 1,241 responses were recorded for this question. The presented percentages, both in the discussion and in Figure 4.48, are based on the number of drivers surveyed (515); hence, the percentages will not sum to 100%. As seen in Figure 4.48, three days received responses from larger percentages of drivers: Friday, Monday, and Saturday. Specifically, 50% of the surveyed drivers reported Friday as being the most difficult day of the week to find safe truck parking, 39% reported Monday, and 36% reported Saturday. Of the remaining days of the week, 27% of drivers reported having experienced difficulty finding safe truck parking on Sunday and Tuesday, 26% of drivers reported Wednesday, and 24% of drivers reported Thursday. Lastly, of the 515 surveyed drivers, 11% reported not having difficulty finding safe truck parking.

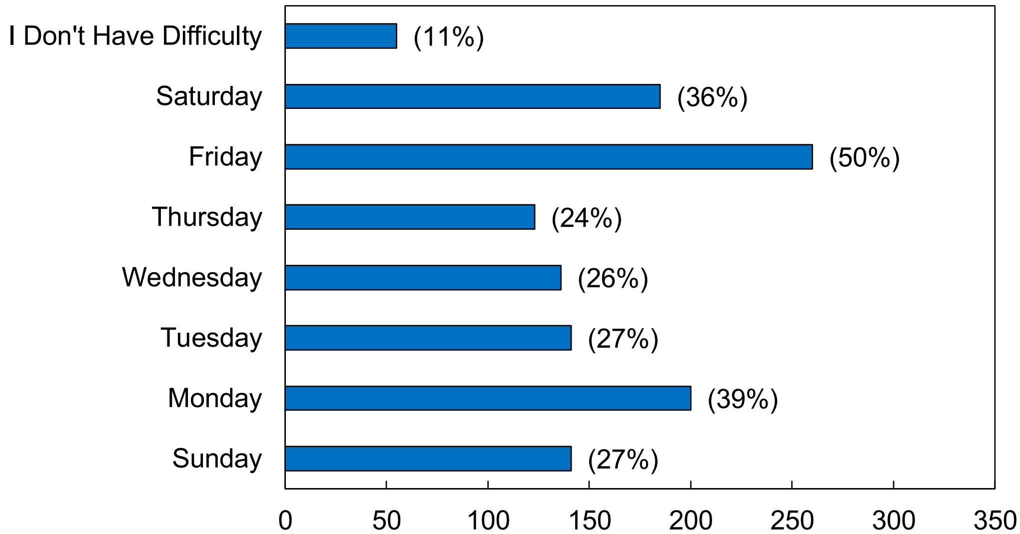


Figure 4.48: Distribution of surveyed drivers by day of the week and perceived difficulty finding safe truck parking

4.1.6.5 Which Months of the Year Have You Found to be the MOST Difficult in Finding Safe Truck Parking (Select All That Apply)?

For this question, drivers were asked to select all that apply; therefore, a total of 1,521 responses were recorded for this question. The presented percentages, both in the discussion and in Figure 4.49, are based on the number of drivers surveyed (515); hence, the percentages will not sum to 100%. As seen in Figure 4.49, more than one-half (51%) of surveyed drivers reported December as the most difficult month to find safe truck parking. Also a winter months, 35% of drivers reported January as the most difficult month to find safe truck parking and 24% of drivers reported February as the most difficult. Other notable months include the summer months of June, July, and August. Specifically, 29% of drivers reported June as the most difficult month to find safe truck parking, 34% of drivers reported July as the most difficult, and 23% reported August as the most difficult. Other than November (28% of drivers reported this as the most difficult month), the spring and fall months are reported to be the most difficult by a substantially smaller proportion of surveyed drivers.

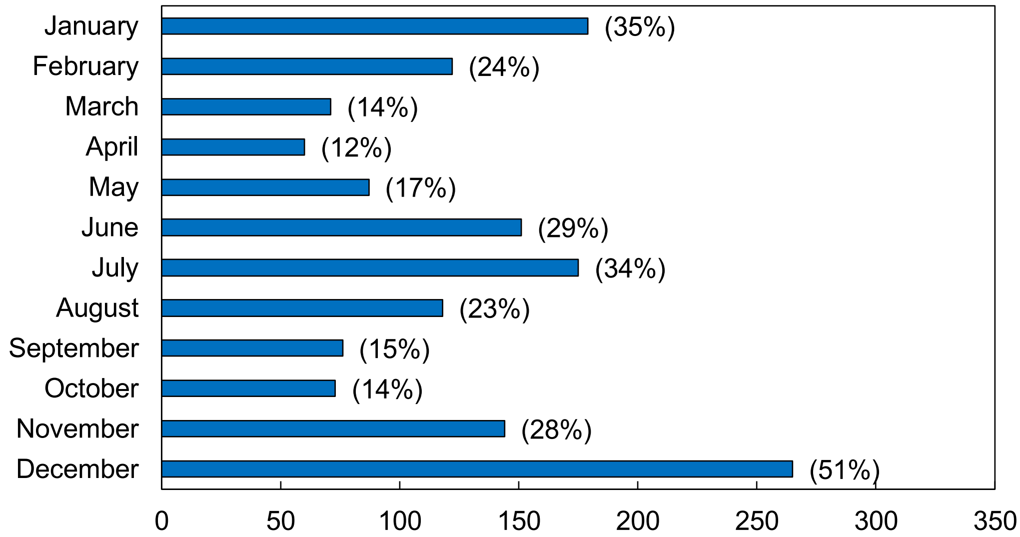


Figure 4.49: Distribution of surveyed drivers by month and perceived difficulty finding safe truck parking

4.1.6.6 How Often Does the Lack of Available Parking Cause Problems With Adhering to the Hours-of-Service Limitations?

To determine whether a lack of available parking causes problems with adhering to the hours-of -service (HOS) limitations, from the perspective of the surveyed drivers, this question was asked. Referring to Figure 4.50, 56% of drivers reported that a lack of available parking sometimes causes problems adhering to HOS limitations, 15% reported that it frequently causes problems, and 6% reported that it almost always causes problems. However, 23% of drivers reported almost never having problems adhering to HOS limitations as a result of inefficient truck parking.

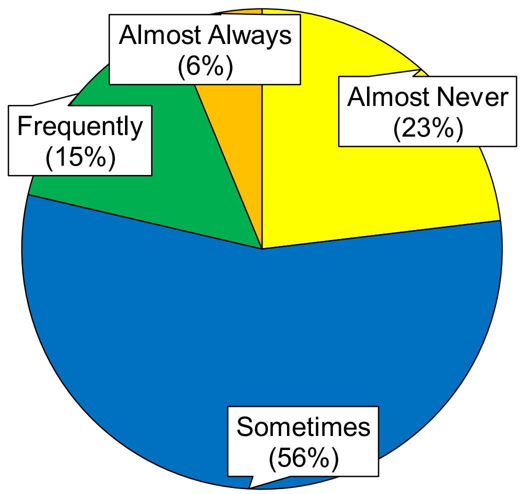


Figure 4.50: Proportion of surveyed drivers who perceive problems adhering to hours-of-service as a result of inefficient parking

4.1.6.7 Does Your Routing Software Accurately Provide You With the Location of Truck Parking on Routes?

As shown in Figure 4.51, 76% of drivers reported that their routing software accurately provides locations of truck parking on routes. The remaining drivers, however, reported that their routing software does not provide accurate locations of truck parking.

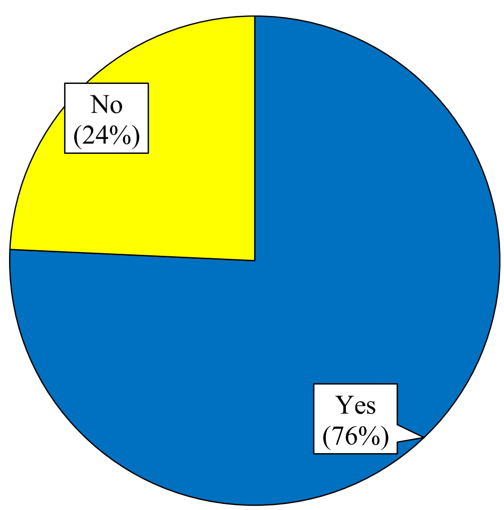


Figure 4.51: Proportion of surveyed drivers and routing software accurately providing parking locations

4.1.7 Fatigue-Related Characteristics

The next set of questions are designed to obtain information regarding fatigue-related characteristics of the driver of the commercial motor vehicle and the company the driver works for.

4.1.7.1 Does Your Company Monitor Levels of Fatigue in Drivers?

Figure 4.52 shows the proportion of drivers who reported working for a company that does, or does not, monitor levels of fatigue in their drivers. As seen, 61% of drivers reported that their company does monitor level of fatigue in their drivers and 39% of drivers reported that their company does not. In addition, 3 drivers selected other (this account for essentially 0%) and reported the following:

1. I actually ride along while my husband does the driving and he stops for coffee if he gets really sleepy, or he chews gum.

2. We are told to be aware of fatigue.

3. I am the owner.

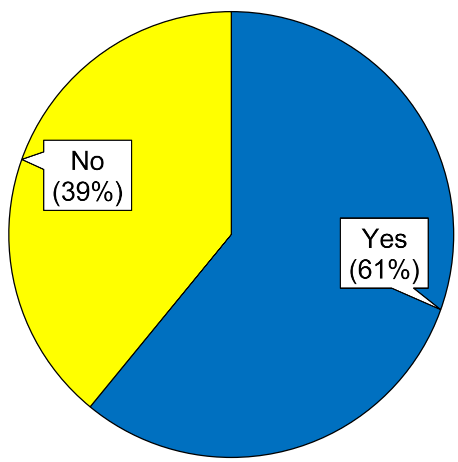


Figure 4.52: Proportion of surveyed drivers and companies monitoring level of driver fatigue

4.1.7.2 When Managing Drivers Working Hours, Does Your Company Put a Restriction on Any of the Following?

For this question, drivers were asked to select all that apply; therefore, a total of 799 responses were recorded for this question. The presented percentages, both in the discussion and in Figure 4.53, are based on the number of drivers surveyed (515); hence, the percentages will not sum to 100%. Referring to Figure 4.53, 54% of surveyed drivers reported that their company manages the number of hours worked in a day and 49% of drivers reported that their company manages the number of hours worked in a week. Also with a relatively large proportion of surveyed drivers, 37% of drivers reported that their company manages the number of continuous days worked. In regards to managing the number of nights drivers can work in a week, just 16% of drivers reported that their company manages this.

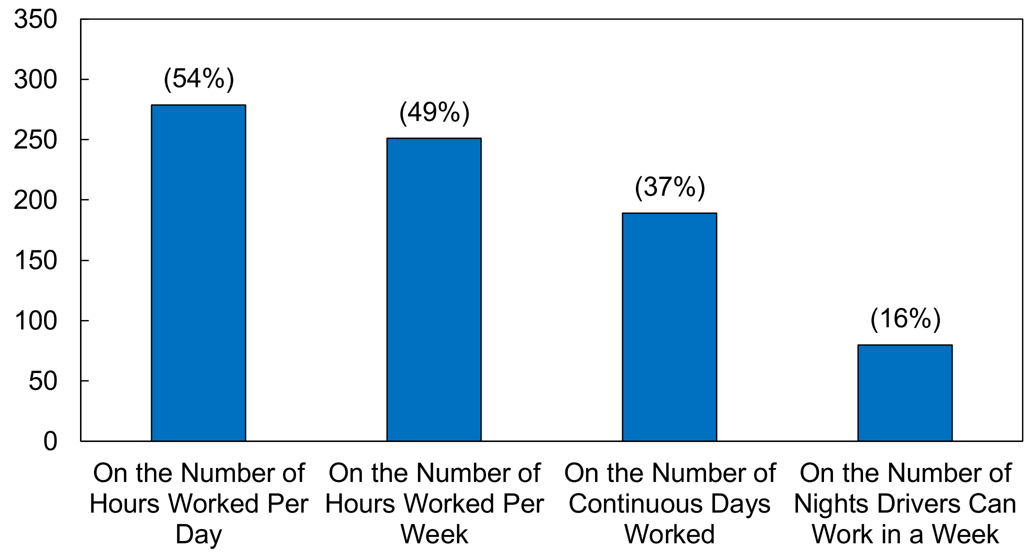


Figure 4.53: Distribution of surveyed drivers by company restrictions

4.1.7.3 How Does Your Company Monitor Driver Fatigue?

For this question, drivers were asked to select all that apply; therefore, a total of 799 responses were recorded for this question. The presented percentages, both in the discussion and in Figure 4.54, are based on the number of drivers surveyed (515); hence, the percentages will not sum to 100%. As observed in Figure 4.54, more than half of the surveyed drivers (55%) reported that their company monitors fatigue by reviewing driver log books. Of the remaining monitoring methods, 42% of drivers reported that their company asks drivers how they felt during their trip, 36% of drivers reported that their company reviews truck computer records, 33% of drivers reported that their company uses monitoring devices, and 27% of drivers reported that their company reviews crashes and incidents. Of the drivers that reported other, the reasons are as follows:

- One driver stated that their company uses e-logs.
- 12 drivers reported that their company does not monitor driver fatigue.
- One driver reported that they monitor their own fatigue.
- One driver reported that their company holds frequent meetings.
- One driver stated that they do not know how their company monitors fatigue.

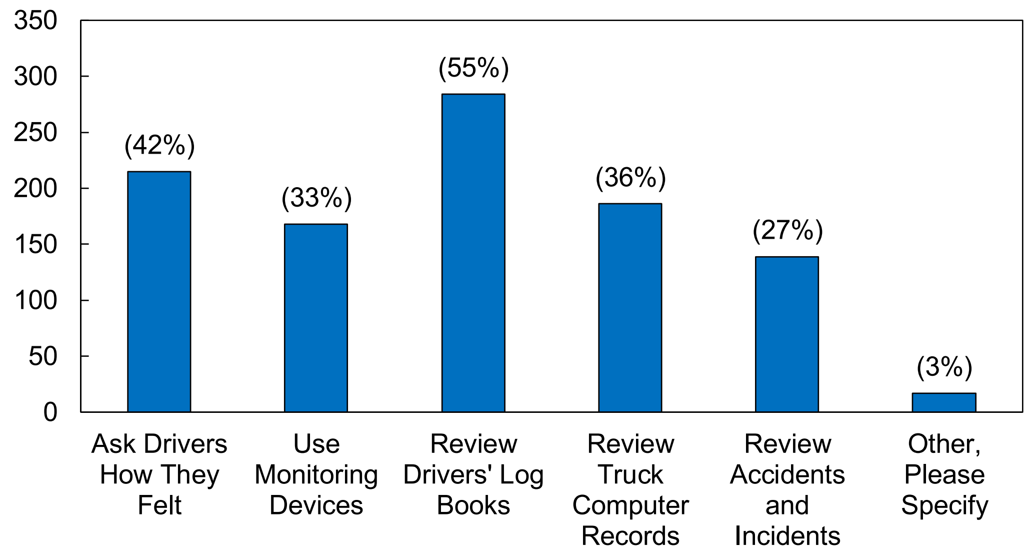


Figure 4.54: Distribution of surveyed drivers and company monitoring driver fatigue

4.1.7.4 How is Fatigue Managed?

The distribution of responses as it pertains to fatigue management is shown in Figure 4.55. In regards to strongly agreeing, the highest percentage of drivers (43%) strongly agreed with management encouraging them to take breaks from driving whenever needed. Also with higher proportions of drivers strongly agreeing is schedules imposed by companies to make taking breaks easy (29%) and drivers being allowed sufficient time to reach their destination (23%).

As for agreeing, no less than 31% of drivers agreed with each statement, where schedules imposed to make taking breaks easy and being allowed sufficient time to reach their destination had the highest percentage of responses at 41% and 44%, respectively.

Pertaining to disagreeing, rarely feeling the need to take breaks while driving long distances (26%) and preferring to carry on driving rather than stopping (23%) have the highest percentage of drivers that disagree. For strongly disagreeing, all aspects had a low percentage of responses, with preferring to carry on driving being the largest (9% of surveyed drivers).

Figure 4.55 can be seen on the following page.

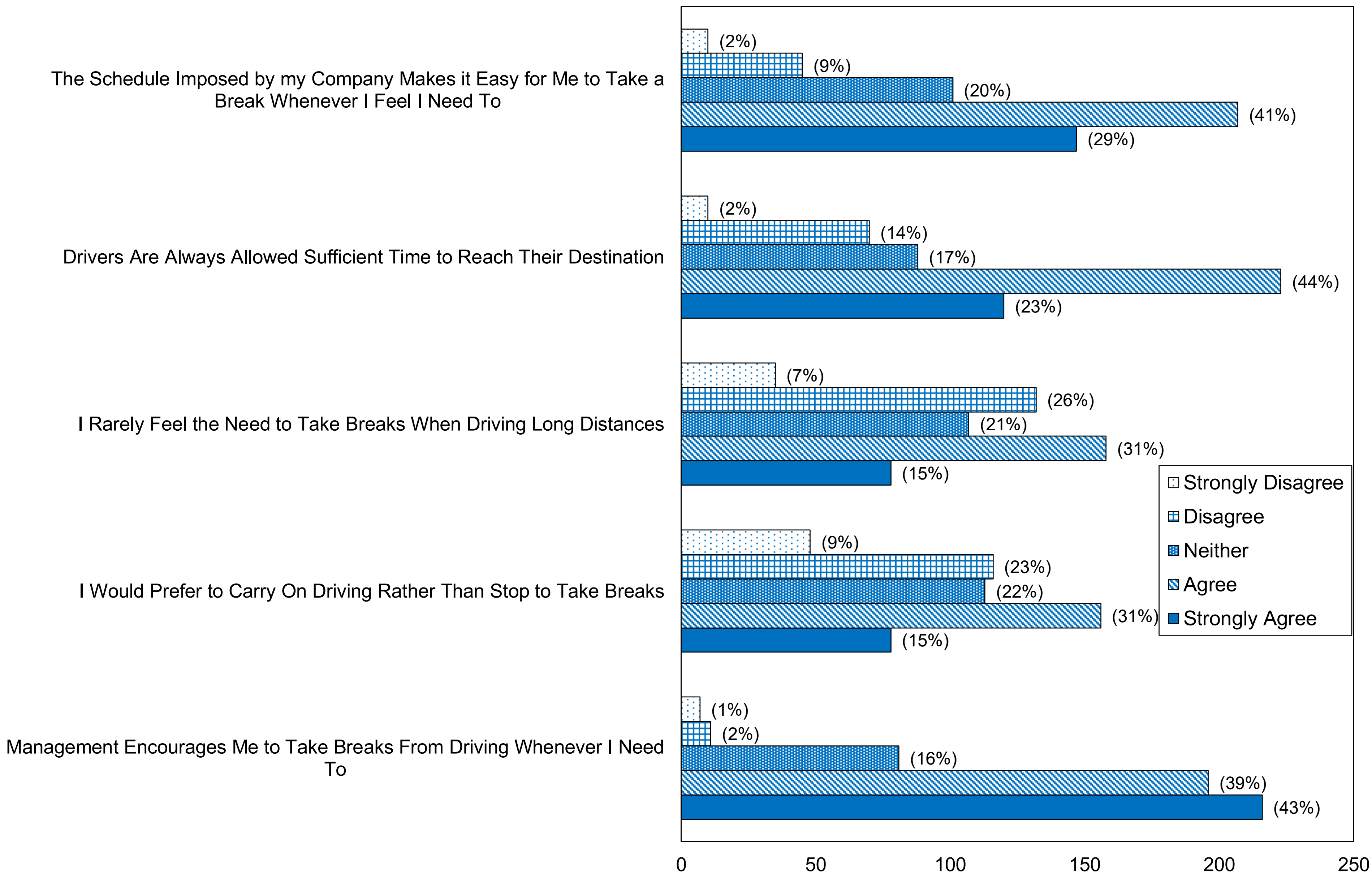


Figure 4.55: Distribution of surveyed drivers and how fatigue is managed

4.1.7.5 *How Well Do You Feel Fatigue is managed in the Industry Now?*

Driver opinions on how well fatigue is managed in the industry is presented in Figure 4.56. The majority of drivers (38%) reported that fatigue is managed quite, with 20% of drivers reporting that fatigue is managed very well. However, 25% of drivers reported that fatigue is managed quite badly and 9% reported that it is managed extremely badly. Of the surveyed drivers, just 8% reported that they do not have an opinion in this regard.

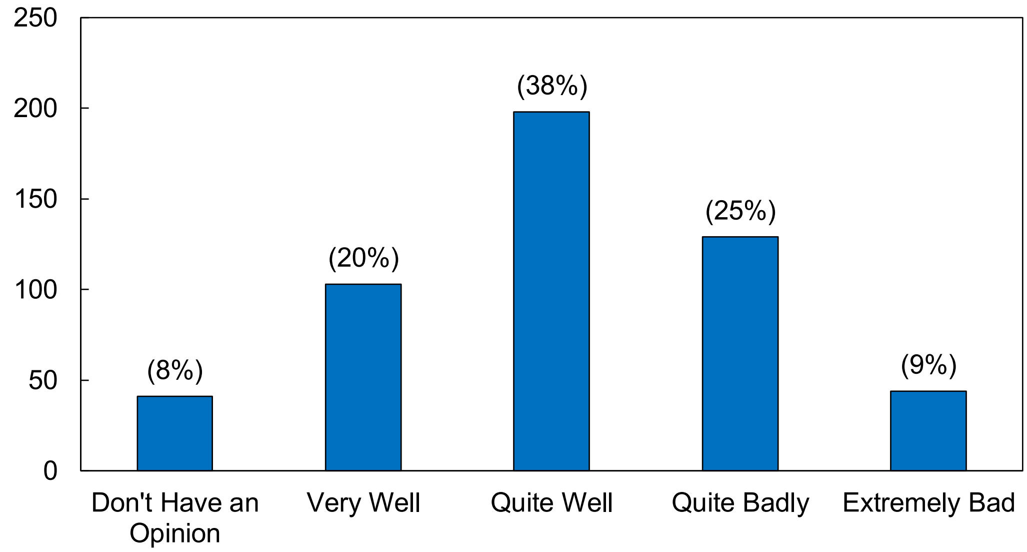


Figure 4.56: Distribution of surveyed drivers and how well fatigue is managed

4.1.7.6 *How often do you Drive When Tired?*

Figure 4.57 shows the driver distribution in regards to reporting driving when tired. As observed, the majority of drivers (38%) reported sometimes driving when tired. Regarding not driving when tired, 30% of drivers reported rarely driving when tired and 8% of drivers reported that they never drive when tired. On the other hand, 14% of drivers reported that they drive when tired quite often and 9% reported that they drive when tired very often.

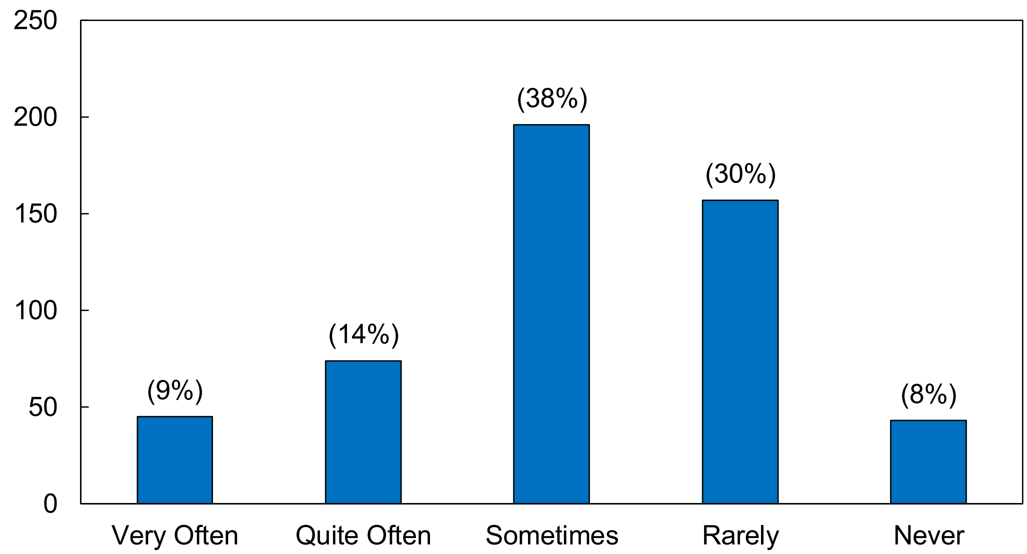


Figure 4.57: Distribution of surveyed drivers and driving when tired

4.1.7.7 Do You Feel You Get Enough Time to Stop to Rest When you Feel Tired?

Figure 4.58 shows the proportion of drivers regarding time to rest. As shown, 80% of drivers reported getting enough time to stop to rest when they feel tired. However, 20% of drivers reported not getting enough time to stop to rest when they feel tired.

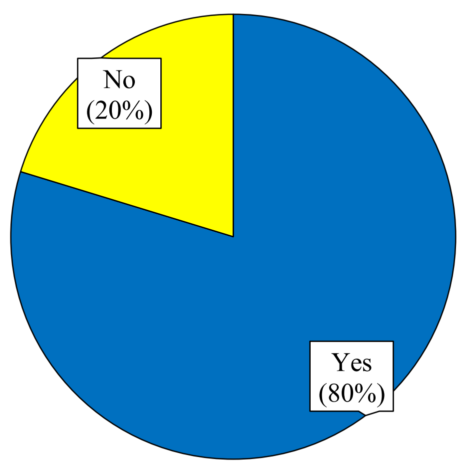


Figure 4.58: Proportion of surveyed drivers and time to rest

4.1.7.8 When You Are Making a Longer Trip, How Often do You Stop?

To help understand how drivers deal with fatigue while driving, they have been asked how often they stop when making a longer trip. Referring to Figure 4.59, the majority of drivers (27%) reported stopping every three to four hours. Also with higher proportions of driver responses, 21% of drivers reported stopping every four to five hours and 19% of drivers reported stopping every two to three hours. Of note, 2% of drivers reported they try not to stop at all and 12% of drivers reported they only stop when they feel tired.

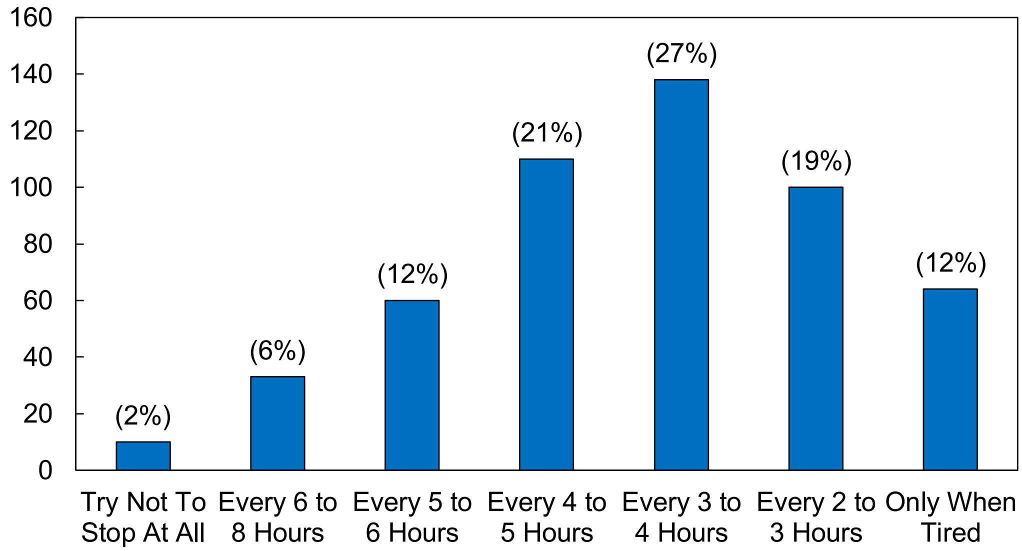


Figure 4.59: Distribution of surveyed drivers and stops on longer trips

4.1.8 Technology-Related Characteristics

The next set of questions are designed to obtain information regarding impacts of new technologies in the freight industry.

4.1.8.1 If Trucks Are Required to Have Electronic Logging Devices Installed That Have the Capability to Monitor Truck Operations and Movement, Will That Impact Your Driving/Operations Decisions?

As shown in Figure 4.60, the same proportion of drivers (38%) reported that electronic logging devices would impact driving/operations decisions and that they potentially could (i.e., maybe). Based on survey responses, 24% of the drivers reported that a mandate for electronic logging devices would not impact their driving/operations decisions.

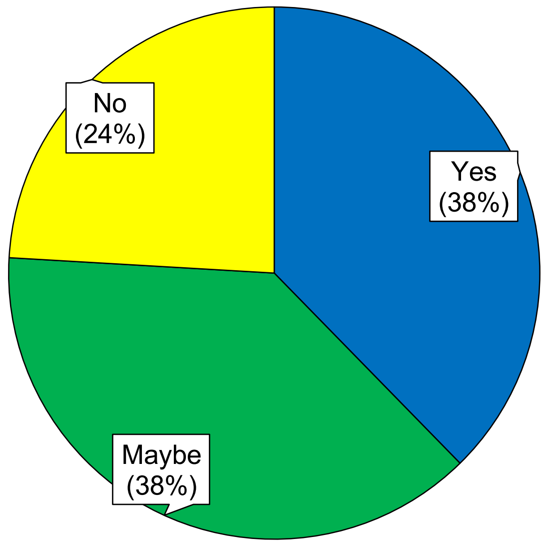


Figure 4.60: Proportion of surveyed drivers and impact of electronic logging devices on driving/operations decisions

4.1.8.2 If Trucks Are Required to Have Electronic Logging Devices Installed, Would the Amount of Time You Spend Driving Change?

As shown in Figure 4.61, drivers have differing opinions towards the impact of electronic logging devices on the amount of time spent driving. The majority of drivers, 46%, reported that the installation of electronic logging devices would have no change on their drive time. As it pertains to decreasing drive time, 28% of drivers reported that installing electronic logging devices would result in a small decrease in drive time and 10% reported they would result in a large decrease. For increases in drive time, 11% of drivers reported that installing electronic logging devices would result in a small increase in drive and 5% reported the would result in a large increase.

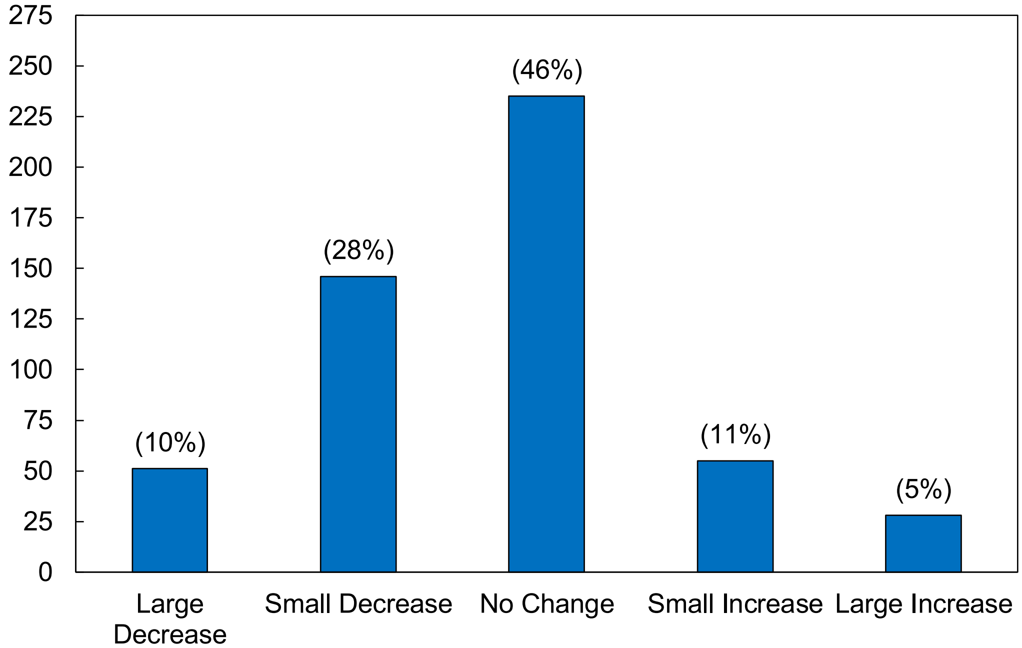


Figure 4.61: Distribution of surveyed drivers and impact of electronic logging devices on drive time

4.1.9 Configuration-Related Characteristics

The final set of questions are designed to obtain information regarding opinions on specific loading characteristics, such as the number of trailers or the length of the trailers being hauled.

4.1.9.1 How Often do You Drive a Tractor With Two Trailers?

The distribution of drivers and frequency of driving a tractor with two trailers is shown in Figure 4.62. The majority of drivers do not drive a tractor with two trailers often, as 28% of drivers reported they almost never drive a tractor with two trailers, 21% reported they rarely do, and 27% of drivers reported they sometimes do. Of the remaining proportion of drivers, 13% reported that they drive a tractor with two trailers quite often and 10% reported they driver a tractor with two trailers very often.

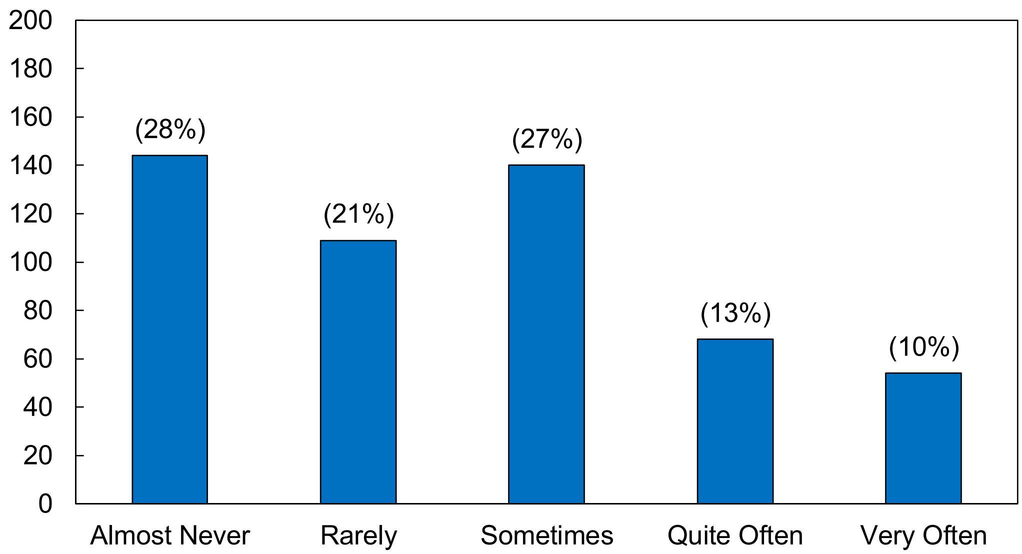


Figure 4.62: Distribution of surveyed drivers and operating a tractor with two trailers

4.1.9.2 Is Driving and Operating a Tractor With Two Trailers More Challenging Than a Tractor With One Trailer?

As presented in Figure 4.63, 68% of drivers reported that driving and operating a tractor with two trailers is more challenging than a tractor with one trailer. Notably, 20% of drivers reported that driving and operating a tractor with two trailers is not more challenging than a tractor with one trailer. The final proportion of drivers (12%) reported that driving and operating a tractor with two trailers might be more challenging that a tractor with one trailer.

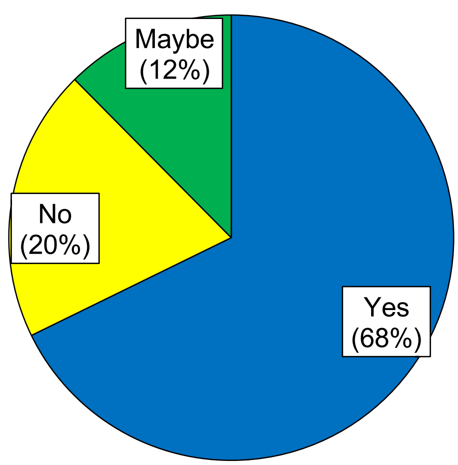


Figure 4.63: Proportion of surveyed drivers and challenges with two trailers

4.1.9.3 Would Driving a Tractor With Two 33 ft. Trailers be More Challenging or Dangerous Than a Tractor With Two 28 ft. Trailers?

In terms of driver perspective toward the potential safety hazards and challenges associated with different trailer lengths, drivers were asked about two specific trailer types. Specifically, Figure 4.64 shows the proportion of drivers who reported yes, no, or maybe, to two 33 ft. trailers being more challenging to drive with than two 28 ft. trailers. Survey results show that 60% of drivers reported that driving two 33 ft. trailers would be more challenging or dangerous, 26% of drivers reported that driving two 33 ft. trailers would not be more challenging or dangerous, and 14% of drivers reported that they did not know.

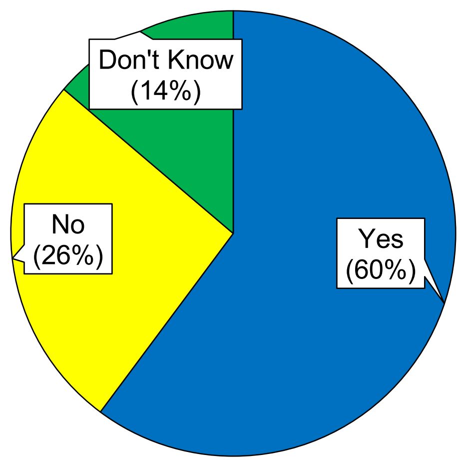


Figure 4.64: Proportion of surveyed drivers and challenges with different size trailers

4.2 SUMMARY

A representative stated-preference survey was designed and distributed to commercial motor vehicle drivers who were destined for or who originated from the Pacific Northwest (i.e., drivers that use Oregon's highway system). The stated-preference survey was administered through the Qualtrics platform at Oregon State University. The survey was conducted over 16 consecutive days between August 17, 2017 and September 1, 2017. To eliminate the possibility of multiple entries from the same participant, IP addresses and user IDs were collected. The representative sample consisted of 515 adequate and usable survey responses from a total of 1,919 participants (a 27% response rate). The survey was conducted to help understand driver behavior and potential factors leading to truck at-fault crashes. Drivers of large trucks in the Pacific Northwest were asked several questions, thereby providing their opinions of factors that may influence the occurrence of truck at-fault crashes.

As stated previously, participants were required to be truck drivers, to hold a commercial driver's license, to be at least 18 years old, and to be destined for or to originate from the Pacific

Northwest. The survey was composed of several sections: (1) driver characteristics, (2) company characteristics, (3) trip characteristics, (4) driving characteristics, (5) safety characteristics, (6) parking characteristics, (7) fatigue characteristics, (8) technology characteristics, and (9) truck configuration characteristics. For driver characteristics, participants were asked to provide demographic information such as age, gender, income, marital status, education, payment method, and driving experience.

The second section, company characteristics, asked questions related to industry type and company operational characteristics. The driving characteristics section asked participants questions on their ability and confidence regarding driving a semi-truck, how many years they have been driving a truck, what type of roads they typically drive on, and if they participate in team driving. For safety characteristics, several questions were asked, including training, distraction, and potential hazards.

Male drivers account for 77% of the participants, whereas 23% are female. 60% of drivers are between 20 and 39 years. As for the type of shipment, 82% of drivers' reported trips are truckload shipments. In terms of number of years the surveyed drivers have been driving large trucks, two-thirds (66%) of drivers have been driving a truck for 10 years or less. 43% of drivers reported that they learned how to driver a semi-truck in driving school. Further, the majority of have had a particular road safety training (87% of the respondents). In regard to team driving, the majority of drivers sometimes, rarely, and never participate in team driving (31%, 29%, and 23%, respectively).

Drivers' history of crashes have also been examined by asking them to report how many crashes they have been involved in during the last five years. 76% of drivers reported that they were not involved in a crash. In regards to actions that may distract drivers and alter their attention away from driving, 45% of drivers reported using their cell phone while driving.

5.0 DATA ANALYSIS

Being that data from ODOT's enforcement pilot program was provided, this became the primary focus for the data analysis. Although other data was collected, it will be used primarily for succeeding tasks. However, traffic volumes and historical crash are used to supplement the preliminary results of the pilot program.

The enforcement pilot program began in September 2016, and is expected to continue through 2020. As part of the pilot program, trucks that have committed a traffic violation are pulled over by local police and an inspection is administered. Data collected include the traffic violation that led to the enforcement stop, location of the violation (including county and highway number), and whether the inspection resulted in a warning or citation. Therefore, at the time of this memorandum, these data have been compiled from September, 2016, to June, 2018.

A key component of this analysis is to prepare for a safety benefit (cost) analysis based on the collected data. The aforementioned pilot program offers a unique opportunity to assess a countermeasure that is currently underway. As such, in addition to collecting and inventorying the necessary data for the upcoming analyses, this will focus on the data and a preliminary analysis of the enforcement pilot program.

The remainder of this chapter presents summary statistics of the enforcement program to-date, the number of truck at-fault crashes on specific highway segments in Oregon (truck at-fault crashes as defined by ODOT Motor Carrier), then a relationship between truck at-fault crashes and inspection frequency is presented.

5.1 OREGON MOTOR CARRIER SAFETY ACTION PLAN

In support of Oregon's MCTD safety goal of reducing truck and bus fatalities, and the CVSP, the Oregon MCTD began a pilot program: Oregon Motor Carrier Safety Action Plan (OMCSAP). The pilot program began in July, 2016 and will continue through the 2019-21 biennium.

The goal of OMCSAP is to reduce truck driver-at-fault crashes in Oregon. This is accomplished by focusing on and addressing unsafe truck driver behavior, as the drivers are shown to be at-fault for greater than 90% of truck at-fault crashes. For program implementation, the Oregon MCTD provided state funds to increase North American Standard Level 2 (Level 2) truck inspections by partnering with local law enforcement agencies. The result of enhanced level of roadside inspection activity by law enforcement agencies stemmed from identifying unsafe driving behaviors (e.g., speeding, following too close, etc.), which proceeded to the Level 2 safety inspection. Essentially, when a truck driver exhibited unsafe driver behavior in the presence of law enforcement, the officer performed a traffic enforcement stop followed by a Level 2 inspection.

Partnership with local law enforcement agencies was done through Inter Governmental Agreements allowing Level 2 inspection to take place upon observation of unsafe driving behaviors. Law enforcement agencies who partnered for the program are summarized in **Error! Reference source not found.** and locations can be viewed via Figure 5.1. As observed, all law enforcement agency partners with the exception of Salem Police Department, Scappoose Police Department, and Stanfield Police Department, are located in the Portland Metropolitan area.

Table 5.1: Participating Law Enforcement Agencies

Agency	Location
Clackamas County Sheriff's Office	Clackamas County, OR
West Linn Police Department	Clackamas County, OR
Oregon City Police Department	Clackamas County, OR
Scappoose Police Department	Columbia County, OR
Marion County Sheriff's Office	Marion County, OR
Salem Police Department	Marion County, OR
Multnomah County Sheriff's Office	Multnomah County, OR
Portland Police Bureau	Multnomah County, OR
Stanfield Police Department	Umatilla County, OR
Washington County Sheriff's Office	Washington County, OR
Tigard Police Department	Washington County, OR

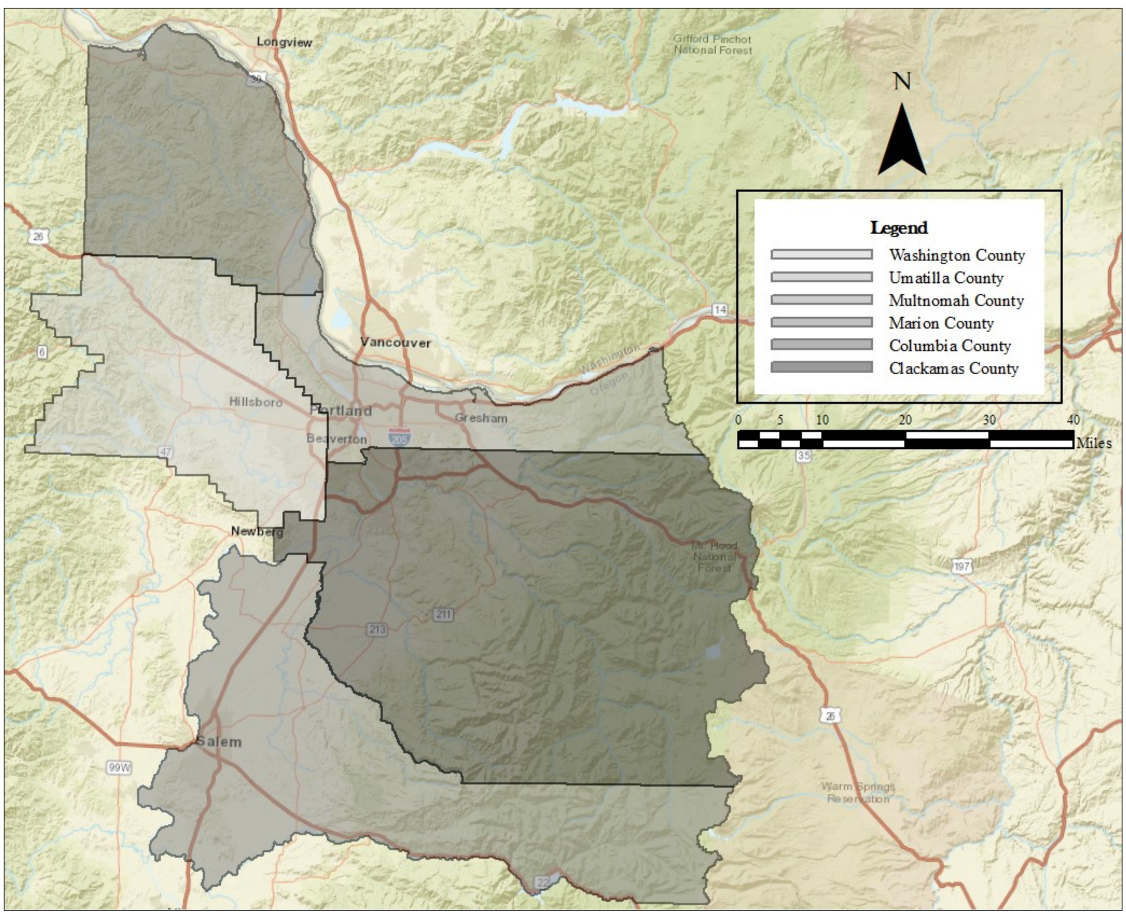


Figure 5.1: Locations of participating law enforcement agencies

5.2 INSPECTION DATA

As stated previously, if a truck driver exhibits unsafe driving behavior (e.g., speeding, following too close, unsafe lane change, etc.), in the presence of a law enforcement officer, the officer performs a traffic enforcement stop followed by a Level 2 inspection. From the start of the program (July, 2016) through December, 2018, there were a total of 4,210 Level 2 inspections resulting from unsafe driving behavior. The unsafe driving behavior that led to the inspection is recorded in the data, as shown in Figure 5.2[1] Of the unsafe driving behaviors, two account for the majority: speeding and lane restriction violation. Nearly 66% of all inspections resulted from drivers who were speeding and about 19% of inspections resulted from lane restriction violations.

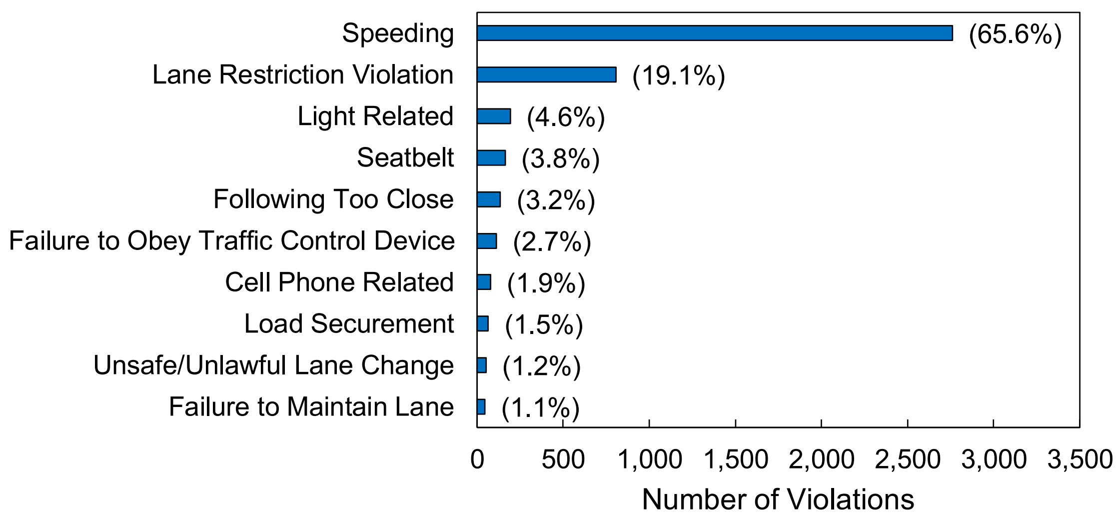


Figure 5.2: Frequency of most occurring unsafe driving behaviors

Vehicle lighting-related violations refer to any violation related to lighting attributes of the truck, ranging from no headlights or taillights to prohibited lighting.

The locations of the 4,210 Level 2 inspections are shown in Figure 5.3 and the frequency of inspections by highway are shown in Figure 5.4.[2] Referring to Figure 5.3, the majority of inspections took place on I-205, I-84, and I-5. As discussed later, this is likely due to resources and roadway geometry (i.e., is there sufficient shoulder space for a truck to safely park). Specifically, referring to Figure 5.4, approximately 61% of inspections occurred on I-205, 10% on I-84, and 10% on I-5.

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[1] In some instances, multiple unsafe driving behaviors were recorded. Therefore, the percentages in Figure 5.2 do not necessarily sum to 100%. If speeding and following to close were recorded as the unsafe driving behavior, it goes to the counts for speeding and to the counts for following too close.

[2] Violations resulting in inspections occurred on various roadways; however, only the highways where inspections were overrepresented are shown in Figure 5.4.

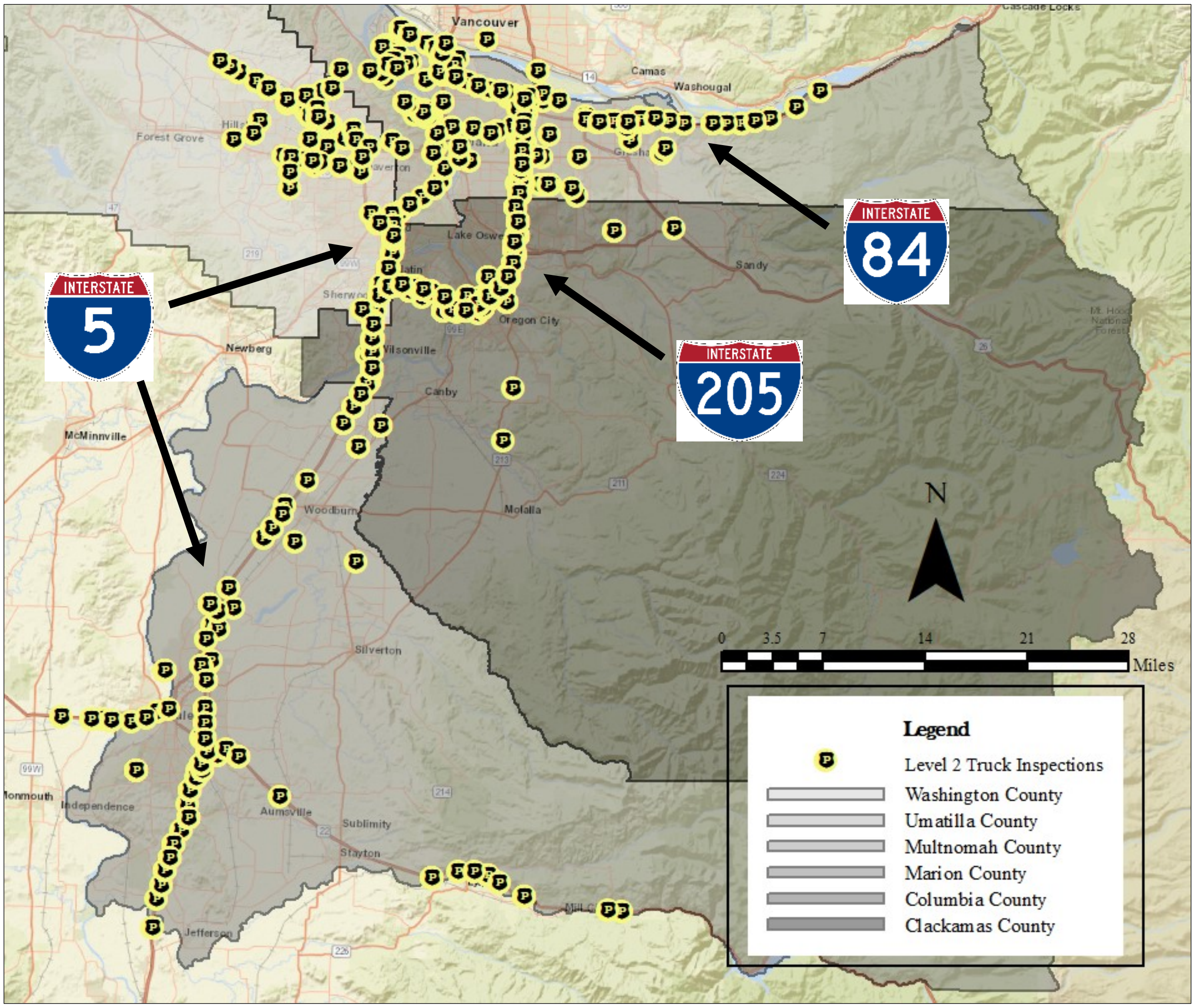

Figure 5.3: Locations of level 2 truck inspections

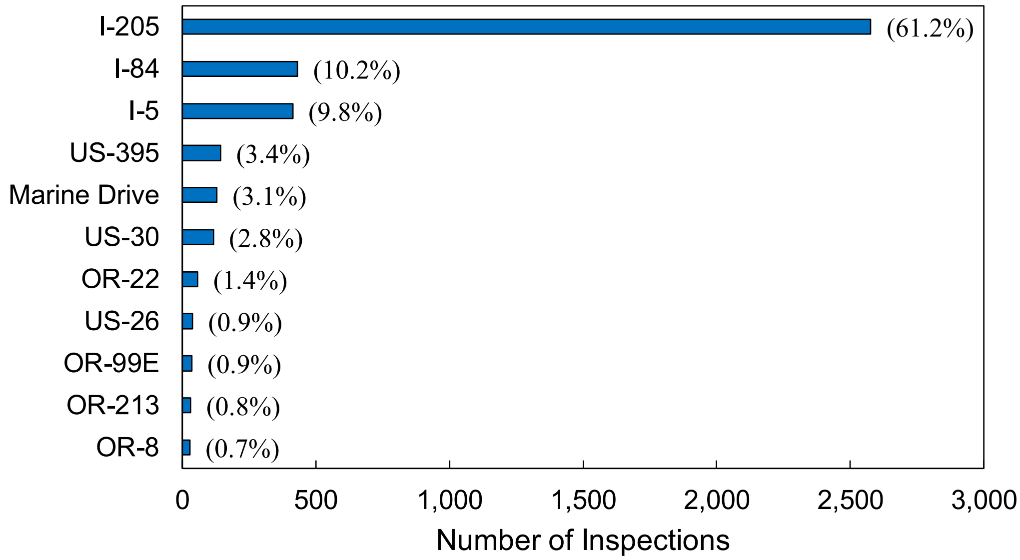

Figure 5.4: Frequency of inspections by highway

Temporal trends of inspections are shown in Figure 5.5. As observed, there are fluctuations in the number of inspections during the duration of the program. The outlier is July 2017, where the number of inspections substantially decreases as a result of Inter-Governmental Agreement renewals. In the following year, however, no substantial decrease is observed during this process. In general, the fall, winter, and spring months account for the most inspections, while summer months the least.

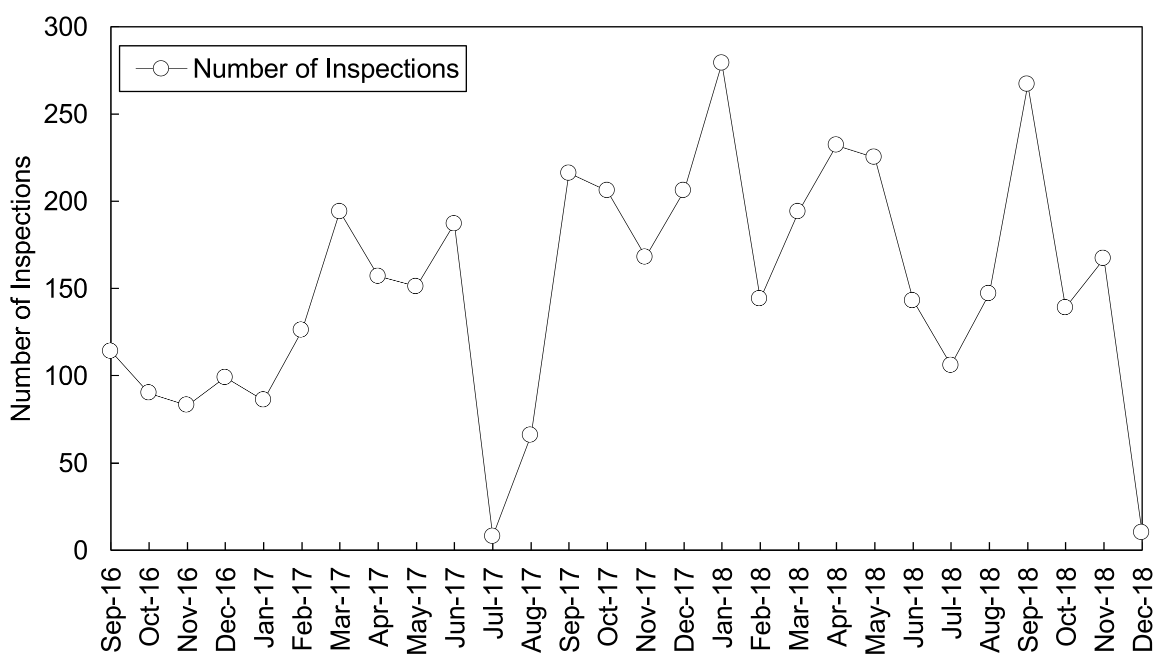

Figure 5.5: Number of inspections by month

5.3 TRUCK AT-FAULT CRASH DATA

To assess the effectiveness of the pilot program, crash data from the ODOT Transportation Development Division (TDD) was obtained. The crash data was compiled to consist of truck at-fault crashes, including driver-at-fault and mechanical-at-fault. Crash data for each of the highways in Figure 5.4 were provided.[3] Although the primary analysis focuses on I-205 due to the majority of inspections occurring along this corridor, the other highways are summarized.

Crash data of the highways shown in Figure 5.3 consisted of the years 2015 to 2018. As stated previously, the crash data was obtained via ODOT TDD. Using the data, the frequency of crash causes along these highways, holistically, is assessed. In the crash data provided, there were a total of 391 truck at-fault crashes. For crash cause frequencies that occurred most often, refer to Figure 5.6, while Table 5.2 summarizes all reported crash causes regardless of how often they occurred. As shown, mechanical-at-fault truck crashes account for approximately 5.4% of truck at-fault crashes. In other words, the driver was reported to be at-fault for 94.6% of truck at-fault crashes on the highways and years considered.

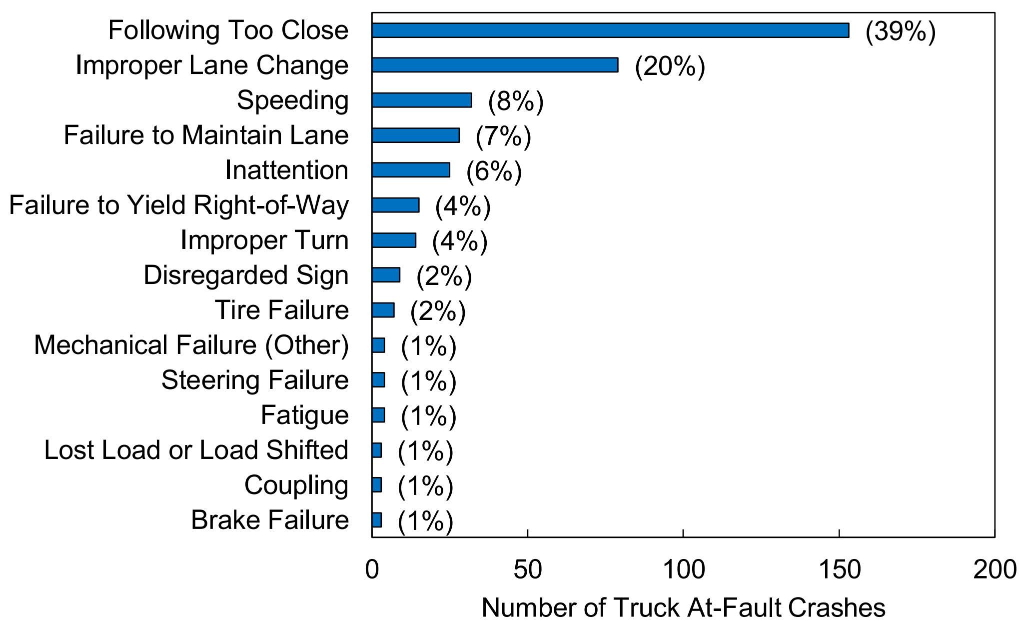

Figure 5.6: Reported cause for truck at-fault crashes

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[3] Based on Figure 5.3, specific segments of I-5, and I-84 were selected based on locations of inspections. For I-5, the defined segment is from Salem, OR to the Oregon-Washington border. On I-84, the defined segment runs from milepost marker 11 to milepost marker 30.

Table 5.1: Frequency of Reported Crash Causes for Truck At-Fault Crashes

Reported Crash Cause	Number of Crashes	Percent of Total
Following Too Close	153	39.1%
Improper Lane Change	79	20.2%
Speeding	32	8.2%
Failure to Maintain Lane	28	7.2%
Inattention	25	6.4%
Failure to Yield Right-of-Way	15	3.8%
Improper Turn	14	3.6%
Disregarded Sign	9	2.3%
Tire Failure	7	1.8%
Fatigue	4	1.0%
Steering Failure	4	1.0%
Mechanical Failure (Other)	4	1.0%
Brake Failure	3	0.8%
Coupling	3	0.8%
Lost Load or Load Shifted	3	0.8%
Failure to Maintain Control	2	0.5%
Improper Backing	2	0.5%
Vision Obscured	1	0.3%
Improper Pass	1	0.3%
Driving Under the Influence	1	0.3%
Failed to Avoid Vehicle Ahead	1	0.3%
Total	**391**	**100%**

To further assess truck at-fault crashes, the number of crashes and their associated reported crash causes by highway are evaluated. Based on Figure 5.7 and Table 5.3, greater than 50% of the crashes occurred on the segment of I-5, 20% took place on I-205, and 5% happened on US-30.

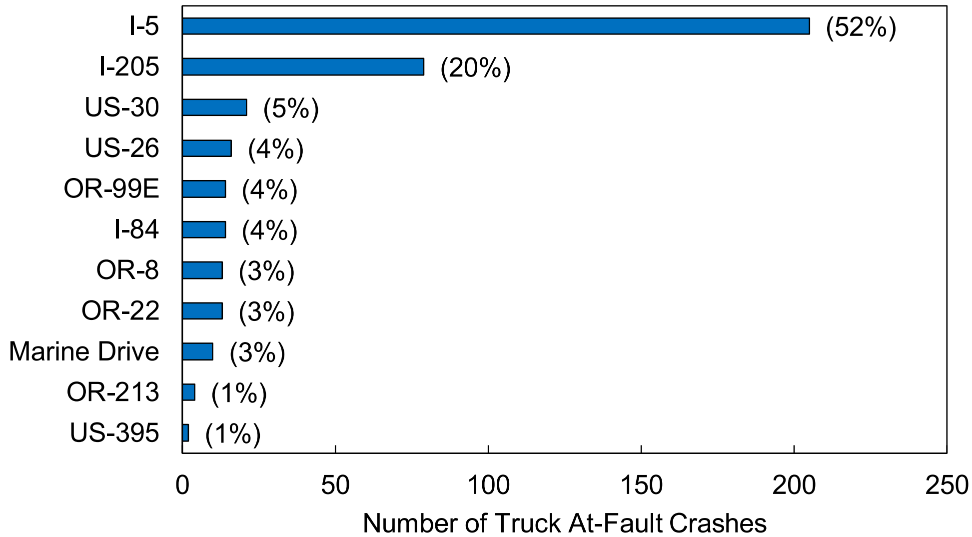

Figure 5.7: Frequency of truck at-fault crashes by highway

Table 5.2: Frequency of Truck At-Fault Crashes by Highway

Highway/Road	Number of Crashes	Percent of Total
I-5	205	52.4%
I-205	79	20.2%
US-30	21	5.4%
US-26	16	4.1%
I-84	14	3.6%
OR-99E	14	3.6%
OR-22	13	3.3%
OR-8	13	3.3%
Marine Drive	10	2.6%
OR-213	4	1.0%
US-395	2	0.5%
Total	**391**	**100%**

5.4 INSPECTION AND CRASH ANALYSIS

Using inspection data and Oregon crash data, relationships are identified. Summary of crash frequency and inspections are provided for each of the aforementioned highways. However, as stated previously, due to the large number of inspections on I-205, I-205 is the only corridor considered for further analysis and is the focal point of this chapter. To begin, summaries will be provided for the other highways.

5.4.1 Inspections and Crash Frequencies

As stated above, all highways (excluding I-205) will be summarized in terms of crash frequencies and number of inspections. This subchapter will summarize these corridors. Summaries begin on the following page.

5.4.1.1 Interstate 5

I-5 from Salem to the Oregon-Washington border, as shown in Figure 5.7, experienced the highest volume of crashes from 2015 to 2018. Although this segment experienced a large number of crashes, the relative number of inspections was low. Based on the limited number of participating law enforcement agencies, and the roadway geometries of I-5 through the Portland Metro area, the conditions for a truck to park on the shoulder are unfavorable. Referring to Figure 5.8, no significant change in crash frequency is observed in relation to the number of inspections. For instance, the number of inspections substantially increased from 2016 to 2017, with essentially no change in the number of truck at-fault crashes. These results are likely explained by the number of inspections, which are limited based on law enforcement resources along the corridor, corridor geometrics, etc.

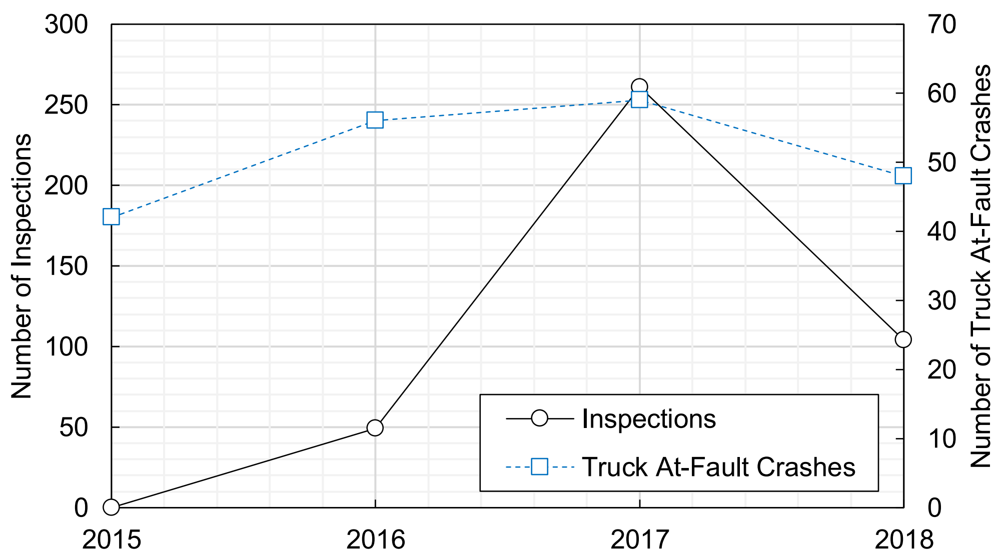

Figure 5.8: Number of inspections and truck at-fault crashes on I-5

5.4.1.2 US-30

Of the considered highways, US-30 accounts for approximately 5% of the truck at-fault crashes and 3% of the total number of inspections. For a comparison of inspections and crash frequency on US-30, refer to Figure 5.9. Although a small number of both inspections and at-fault crashes took place on US-30, the anticipated trend is observed. That is, as inspections increase, the number of truck at-fault crashes decrease. This suggests that around 48 inspections per year is adequate. However, this requires further analysis and observation to validate.

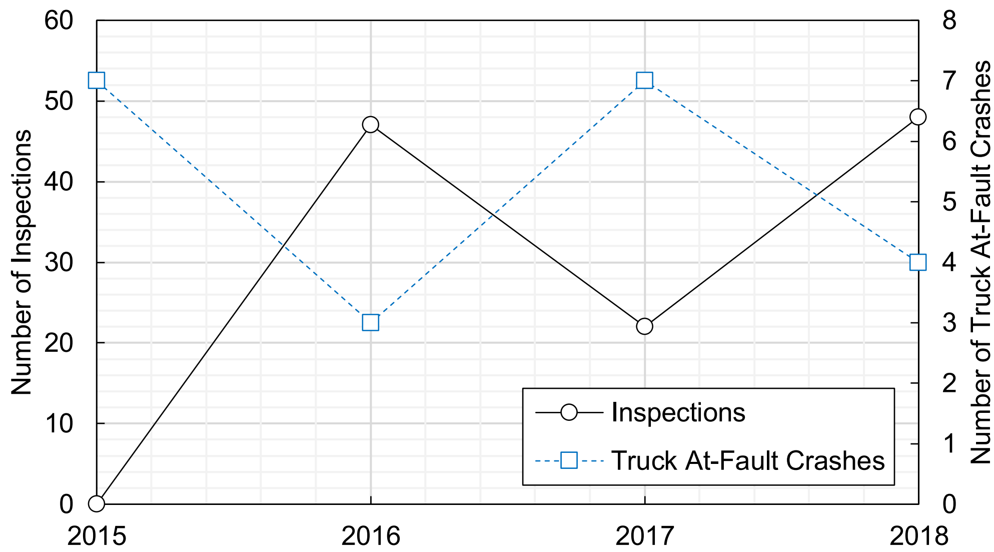

Figure 5.9: Number of inspections and truck at-fault crashes on US-30

5.4.1.3 US-26

US-26 accounts for approximately 4% of the truck at-fault crashes and 1% of the total number of inspections. For a comparison of inspections and crash frequency on US-26, refer to Figure 5.10. Similar results, in terms of few observations, are observed for US-26. As inspections decreased, the number of truck at-fault crashes increased.

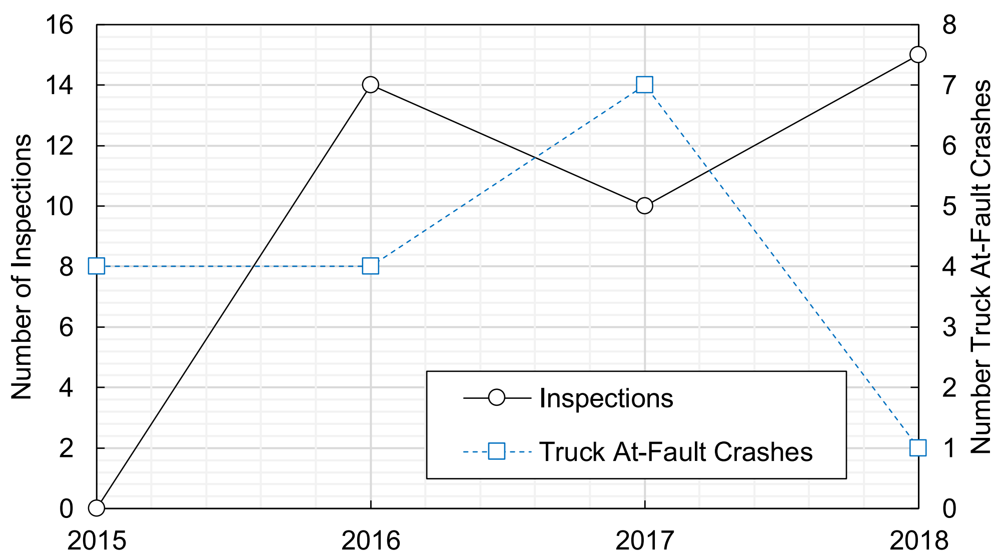

Figure 5.10: Number of inspections and truck at-fault crashes on US-26

5.4.1.4 OR-99E

OR-99E accounts for approximately 4% of the truck at-fault crashes and 1% of the total number of inspections. For a comparison of inspections and crash frequency on OR-99E, refer to Figure 5.11. Due to the small number of both inspections and crashes, no anticipated results are observed. Being that this segment is not prone to a high number of truck at-fault crashes, it may be not be a viable option for the program.

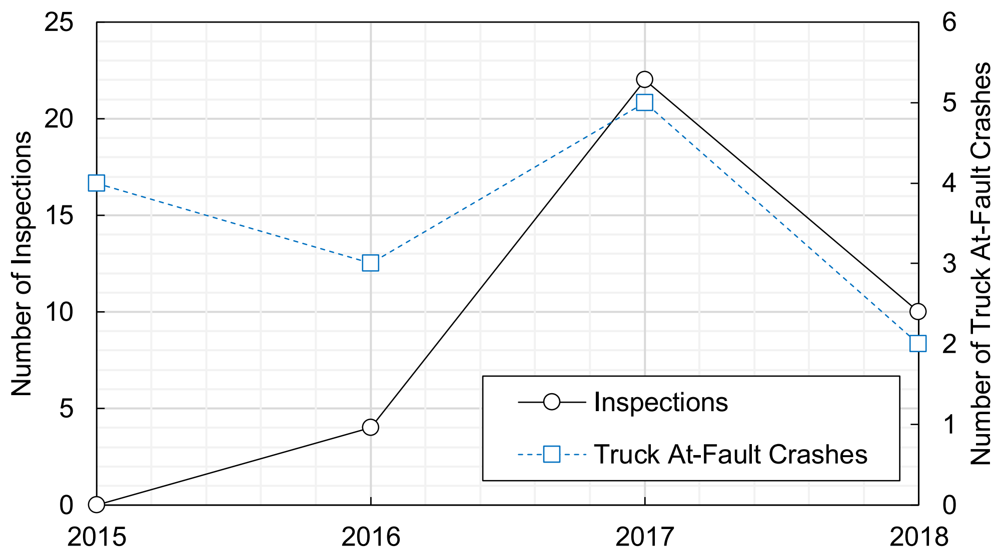

Figure 5.11: Number of inspections and truck at-fault crashes on OR-99E

5.4.1.5 Interstate 84

I-84 accounts for approximately 4% of the truck at-fault crashes and 10% of the total number of inspections. For a comparison of inspections and crash frequency on I-84, refer to Figure 5.12. Although the number of inspections is relatively large compared to other highways, the number of truck at-fault crashes along this segment of I-84 are not. When inspections increased, truck at-fault crashes decreased or remained the same. Due to the small number of truck at-fault crashes along this segment of I-84, it may not be a viable candidate for the program.

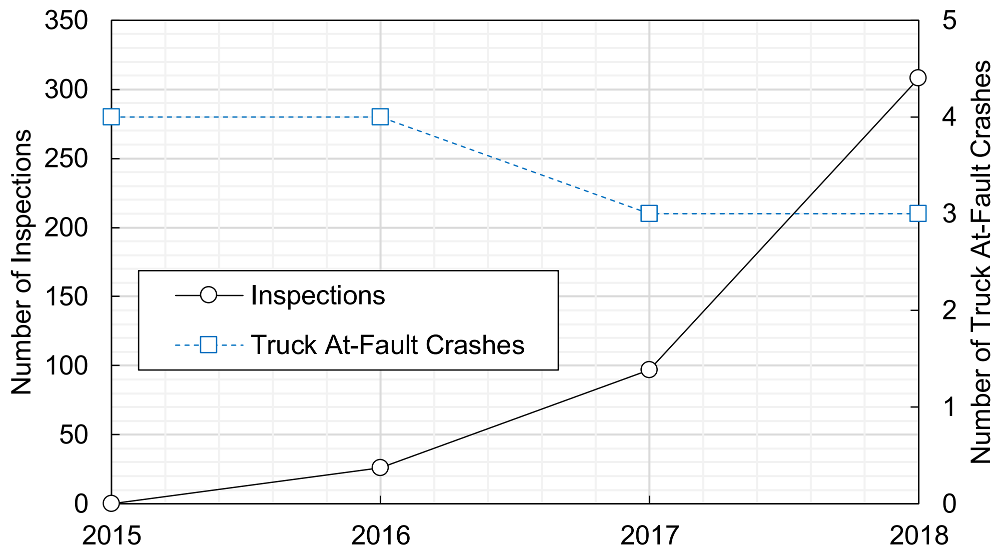

Figure 5.12: Number of inspections and truck at-fault crashes on I-84

5.4.1.6 OR-8

OR-8 accounts for approximately 3% of the truck at-fault crashes and 0.7% of the total number of inspections. For a comparison of inspections and crash frequency on OR-8, refer to Figure 5.13. The anticipated trends are observed from 2016 to 2017, but crashes remain the same thereafter with decreasing inspections. Due to the small number of truck at-fault crashes along this corridor, OR-8 may not be a viable corridor. In addition, many portions of OR-8 are in an urban environment with stop and go traffic and many signalized intersections. This section, in the main, is not a free-flowing corridor like most of the other corridors studied.

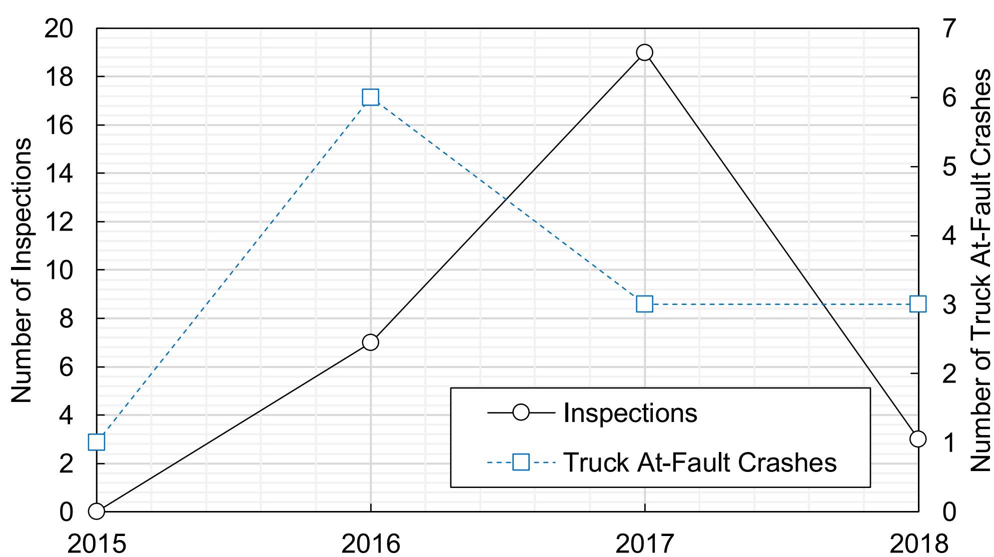

Figure 5.13: Number of inspections and truck at-fault crashes on OR-8

5.4.1.7 OR-22

OR-22 accounts for approximately 3% of the truck at-fault crashes and 1.4% of the total number of inspections. For a comparison of inspections and crash frequency on OR-22, refer to Figure 5.14. On OR-22, the anticipated results are observed (i.e., increasing inspections and decreasing truck at-fault crashes). However, the sample size is small, as are the crash numbers.

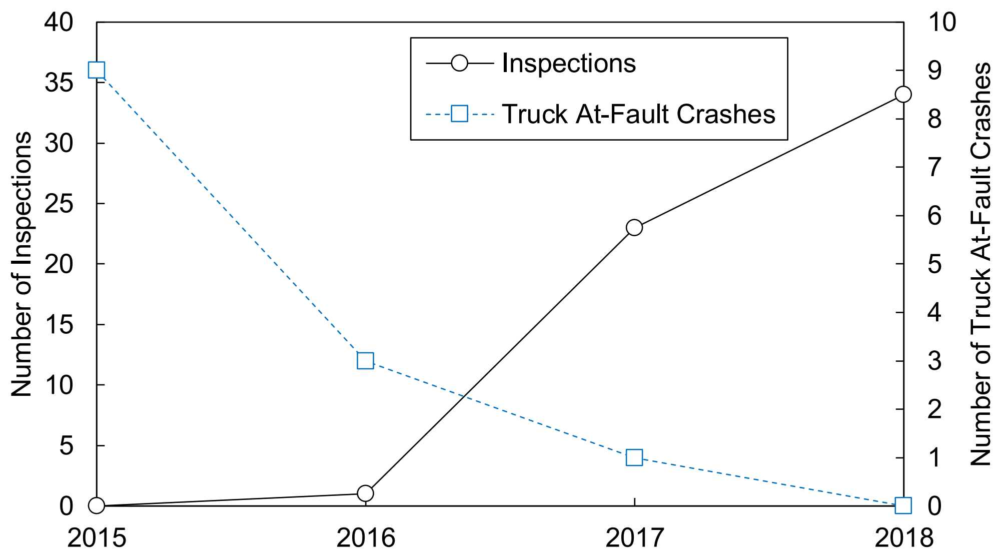

Figure 5.14: Number of inspections and truck at-fault crashes on OR-22

5.4.1.8 Marine Drive

Marine Drive accounts for approximately 3% of the truck at-fault crashes and 3% of the total number of inspections. For a comparison of inspections and crash frequency on Marine Drive, refer to Figure 5.15. On Marine Drive, the anticipated results are again observed (i.e., increasing inspections and decreasing truck at-fault crashes). However, the crash numbers along this corridor are already low.

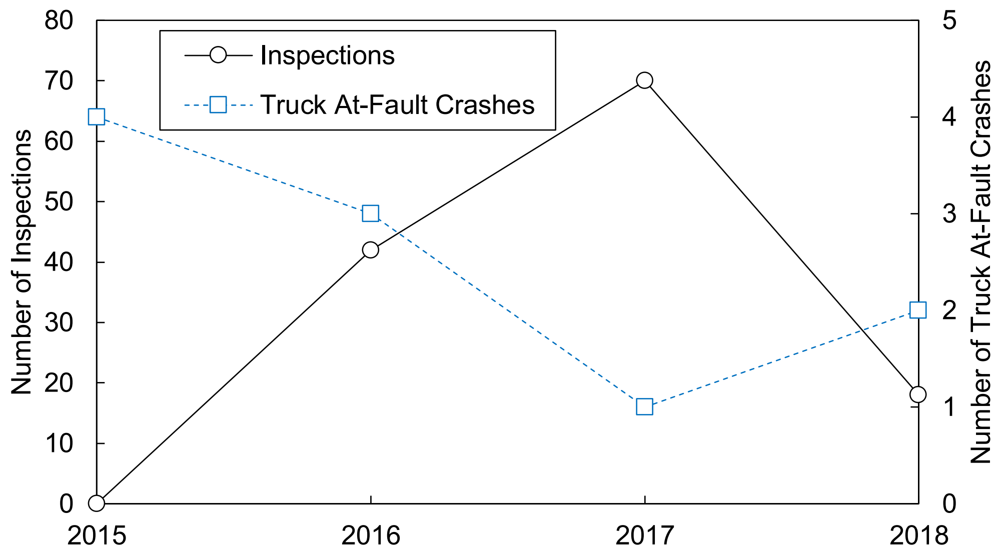

Figure 5.15: Number of inspections and truck at-fault crashes on Marine Drive

5.4.1.9 OR-213

OR-213 accounts for approximately 1% of the truck at-fault crashes and 0.8% of the total number of inspections. For a comparison of inspections and crash frequency on OR-213, refer to Figure 5.16. Once more, on a corridor with small sample sizes, anticipated results are observed; that is, increasing inspections and decreasing truck at-fault crashes.

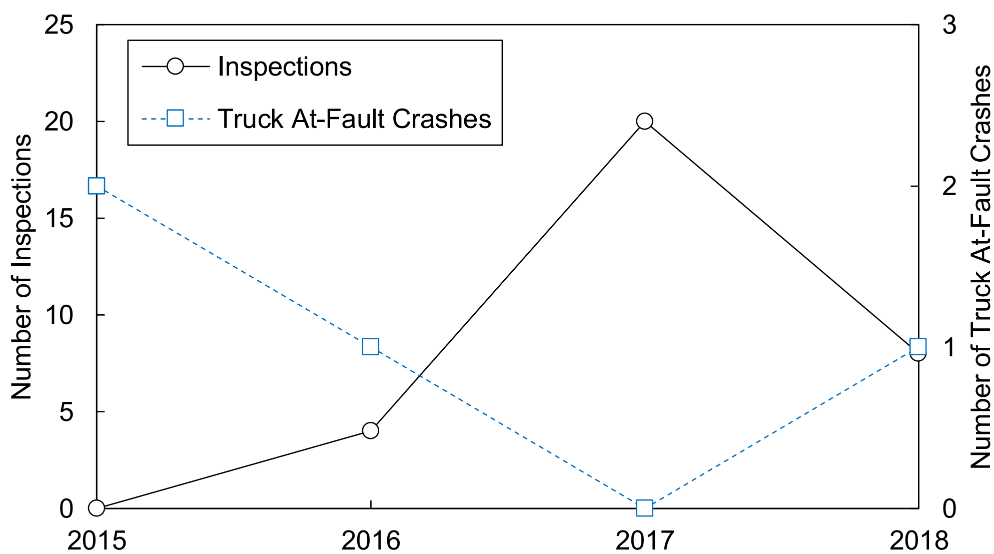

Figure 5.16: Number of inspections and truck at-fault crashes on OR-213

5.4.1.10 US-395

US-395 accounts for approximately 1% of the truck at-fault crashes and 3.4% of the total number of inspections. For a comparison of inspections and crash frequency on US-395, refer to Figure 5.17. The anticipated results on US-395 are observed. But, once more, the total number crashes along this corridor is low.

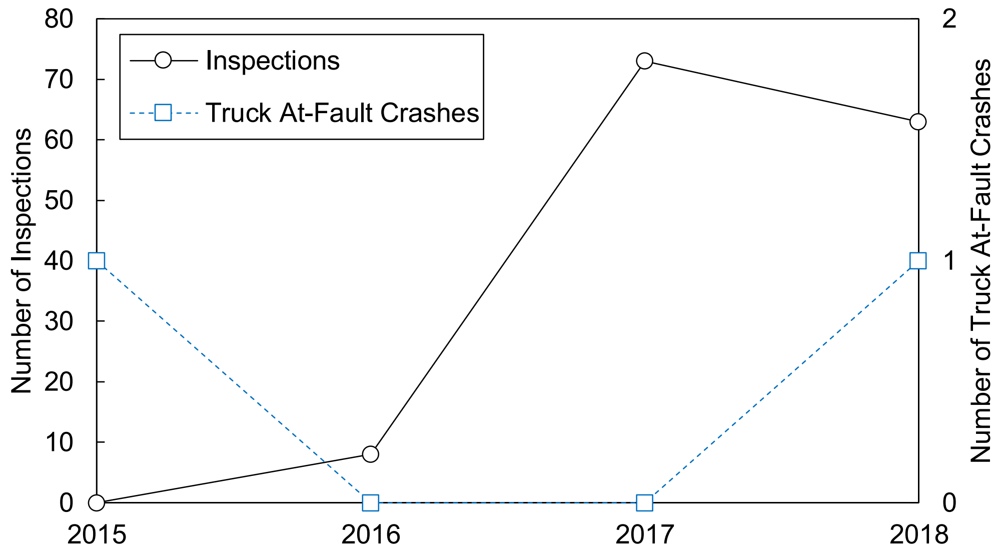

Figure 5.17: Number of inspections and truck at-fault crashes on US-395

5.5 INTERSTATE 205

With I-205 having the most inspections over the period of the program, I-205 will be the primary focus for a more in-depth analysis. In addition to analyzing inspections and crash frequency, crash rate (to account for traffic volumes) and a cost-benefit (or cost-effectiveness) analysis will be discussed.

Over the duration of the program, there have been 2,576 inspections on I-205. Also during this time period, there have been 79 truck at-fault crashes. Locations of inspections and truck at-fault crashes on I-205 can be seen in Figure 5.18. Based on records from ODOT Motor Carrier, the most occurring unsafe driving behaviors leading to inspections are shown in Figure 5.19 and the most occurring reported causes of truck at-fault crashes are shown in Figure 5.20. The total number of inspections by year and truck at-fault crashes by year are shown in Figure 5.21. Total number of inspections and truck at-fault crashes per 100-million VMT are shown in Figure 5.22.

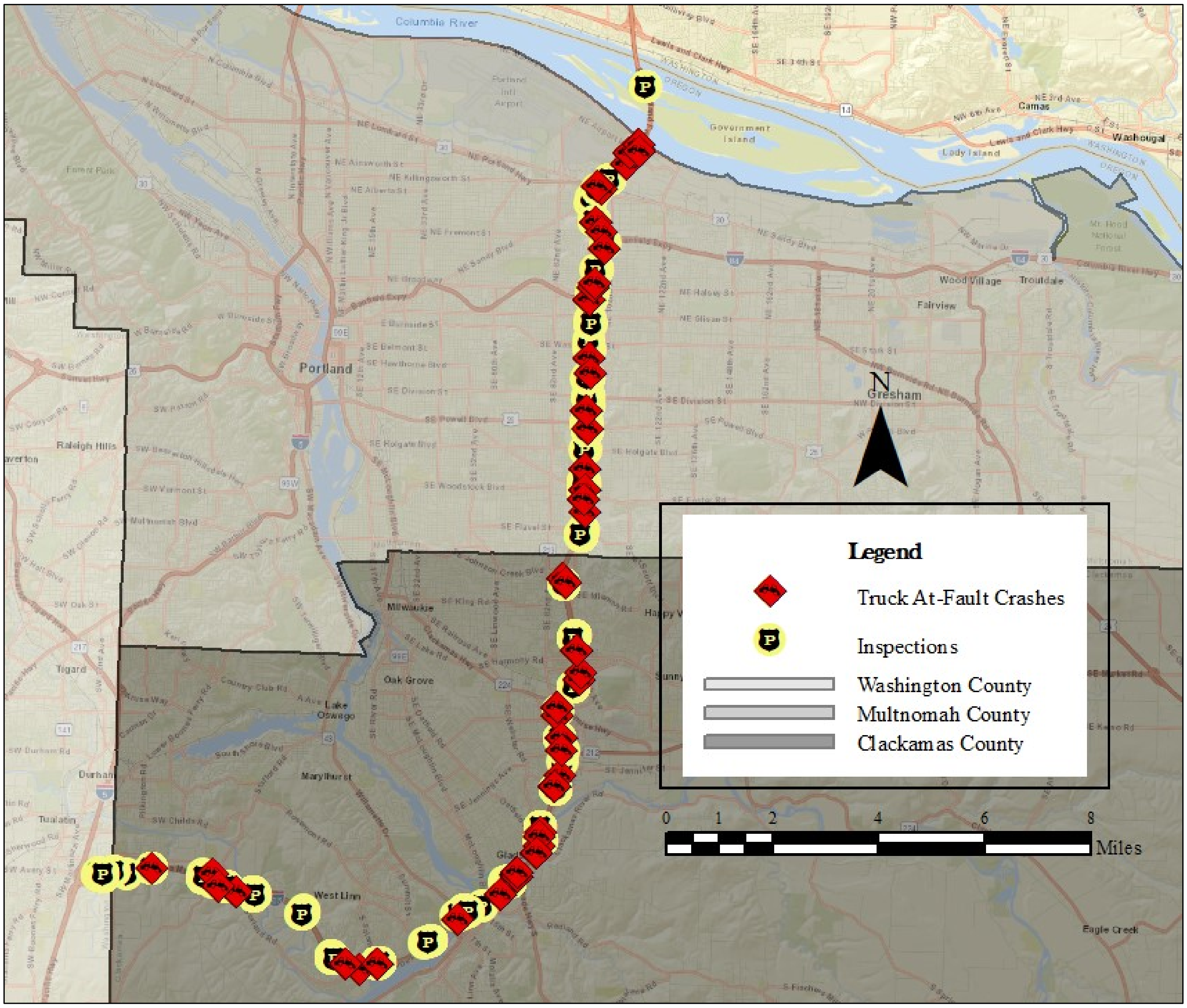

Figure 5.18: Inspections and truck at-fault crashes on I-205

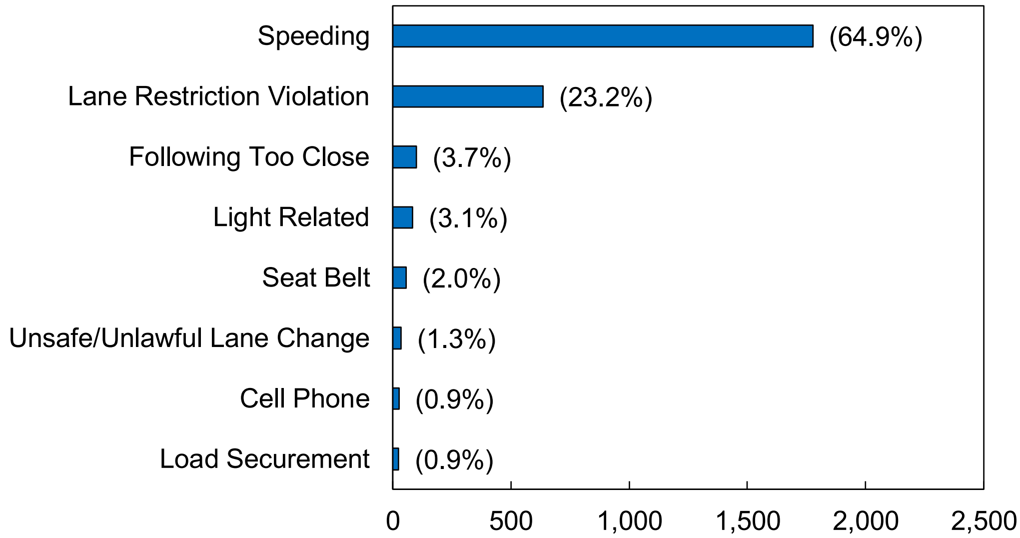

Figure 5.19: Most occurring unsafe driving behaviors leading to inspections

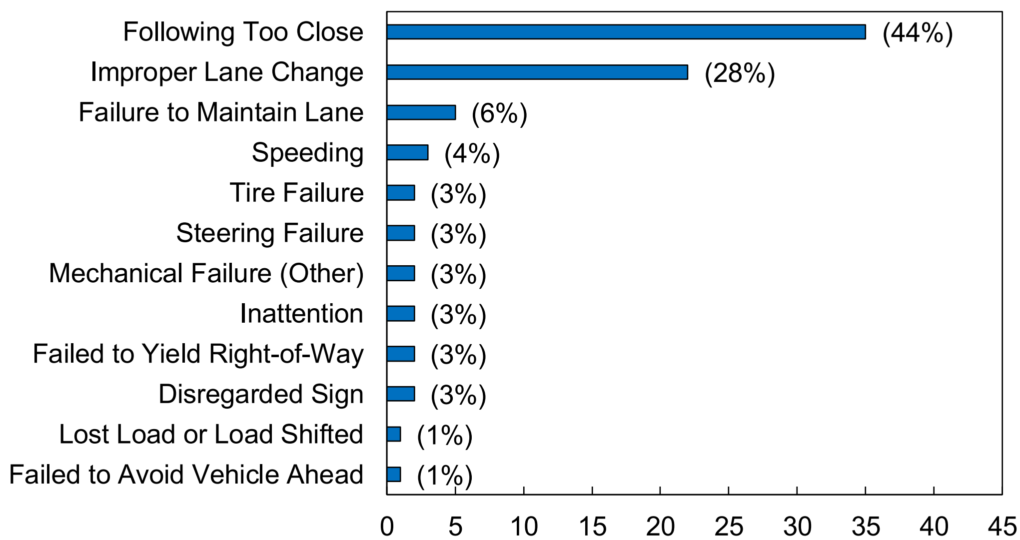

Figure 5.20: Frequency of reported causes for truck at-fault crashes on I-205

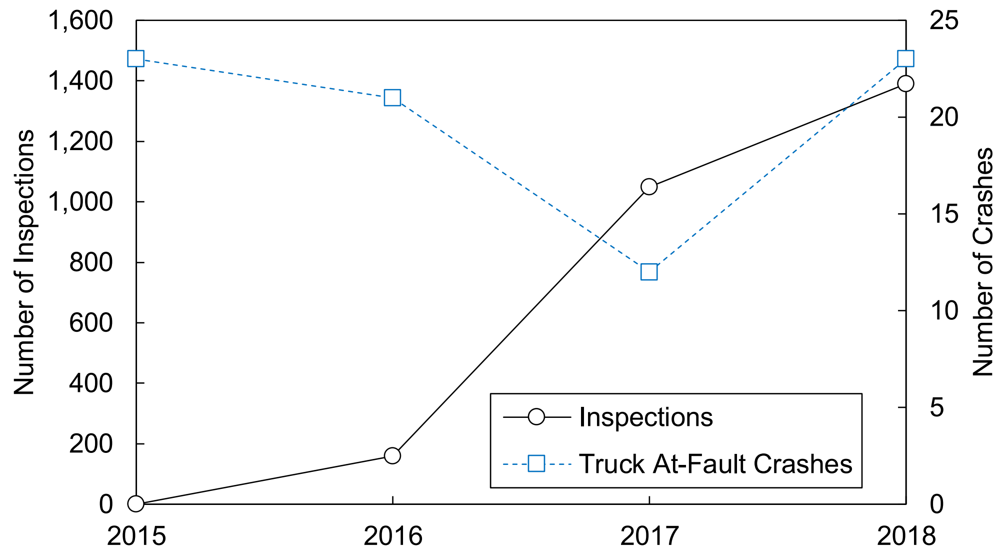

Figure 5.21: Number of inspections and truck at-fault crashes by year on I-205

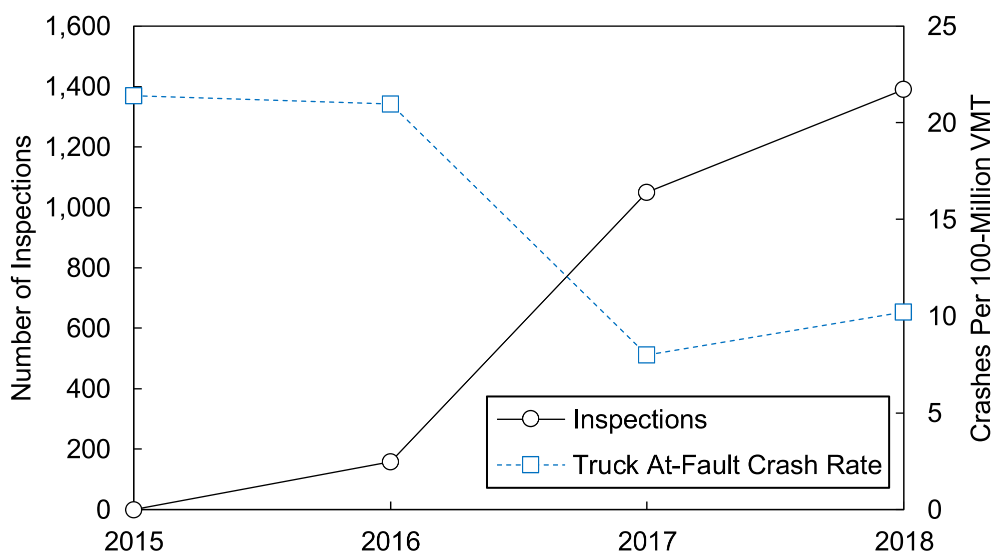

Figure 5.22: Number of inspections and truck at-fault crashes per 100-million VMT by year on I-205

Before any further analysis, any crash that occurred under congested conditions, or was caused by a mechanical failure, was omitted. This was done to account for crashes that increased law enforcement are unable to potentially mitigate. In other words, crashes that occur in extreme congestion (i.e., stop-and-go conditions) and crashes that occur due to mechanical failures have a low likelihood of being reduced as a result of increased law enforcement. Removal of these crashes are based on the crash reports as provided by ODOT Motor Carrier and the reported crash cause. As such, the new crash trends and the difference in crash totals are shown in Figure 5.23 and Table 5.3, respectively.

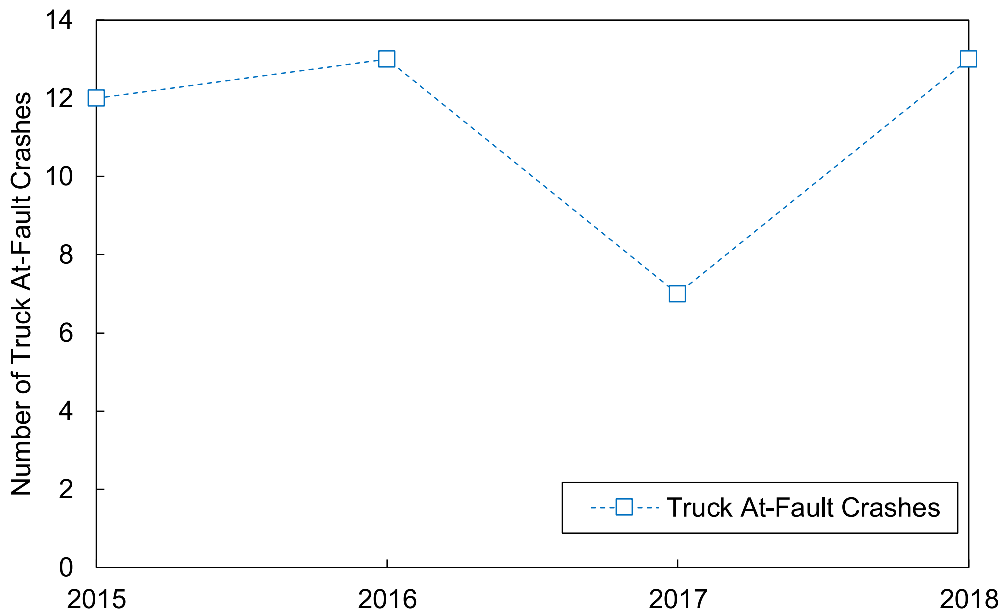

Figure 5.23: Driver-at-fault truck crashes in uncongested conditions on I-205

Table 5.3: Comparison of Crashes Based on Driver-at-Fault and Congestion

	All Crashes	**Driver-at-Fault Without Congestion**	**Percent Difference**
Year	**Number of Crashes**	**Number of Crashes**	
2015	23	12	-48%
2016	21	13	-38%
2017	12	7	-42%
2018	23	13	-44%

In addition to reported crashes, maximum crash severities were provided for I-205. Maximum crash severities are used to assess the average cost of the truck at-fault crash.[4] The frequency of crashes by maximum crash severity are shown in Figure 5.24. As observed, no fatal crashes occurred along I-205 during this time period, 24% of the crashes involved a non-fatal injury, and 76% resulted in no injury.

[4] Maximum crash severity refers to the most extreme injury sustained during the crash. For example, if both a non-fatal injury and a fatal injury occurred, the maximum crash severity would be recorded as fatal.

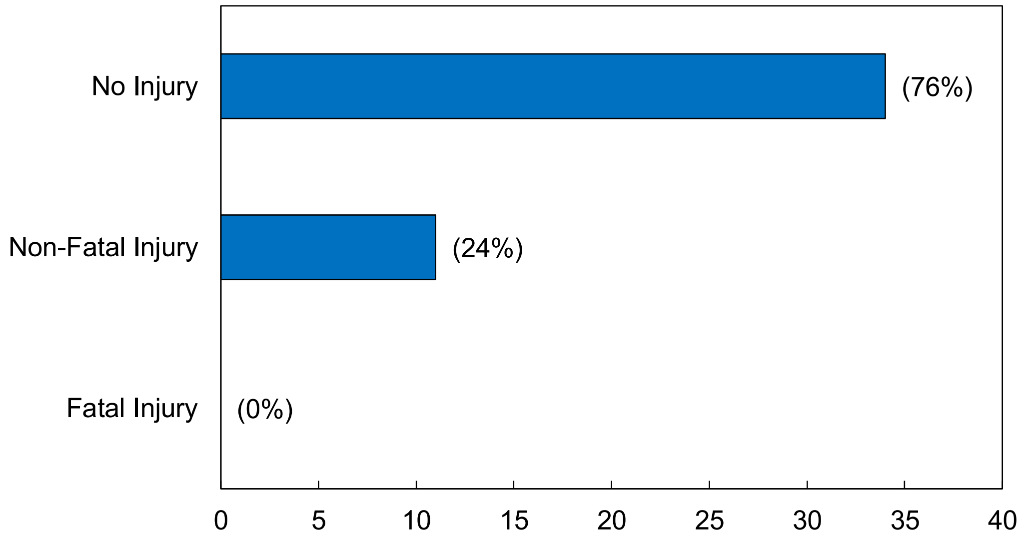

Figure 5.24: Number of crashes by maximum crash severity on I-205

The trend in no injury and non-fatal injury crashes along I-205 are shown in Figure 5.25. The number of injury crashes are decreasing, while the number of no injury crashes have increased over the last year.

To account for traffic volumes, the remaining plots are in terms of crash rate; specifically, the number of truck at-fault crashes per 100-million vehicle-miles-traveled (VMT). VMT is measured for trucks only. Figure 5.26 shows the trend in truck at-fault crashes in 2015. This is the year before the program started; therefore, the plot shows no inspections. Figure 5.27 shows the number of inspections and truck at-fault crashes by month for the first year of the program. The program started late in the year, which is depicted in the figure. Near the end of the year, a slight increasing/decreasing relationship between inspections and truck at-fault crashes is observed. In 2017, the first full year of the program, the relationship between inspections and truck at-fault crashes is anticipated for parts of the year (see Figure 5.28). This relationship is primarily observed in the late winter months and the summer months. Lastly, Figure 5.29 shows the relationship between inspections and truck at-fault crashes in 2018, the second year of the program. In 2018, the anticipated trends are observed throughout the year. In each case where inspections are increasing or decreasing, truck at-fault crashes are doing the opposite. In addition, as shown in Figure 5.25, if a crash does occur, they are resulting in more no injury crashes (i.e., injury crashes and fatal crashes are being reduced).

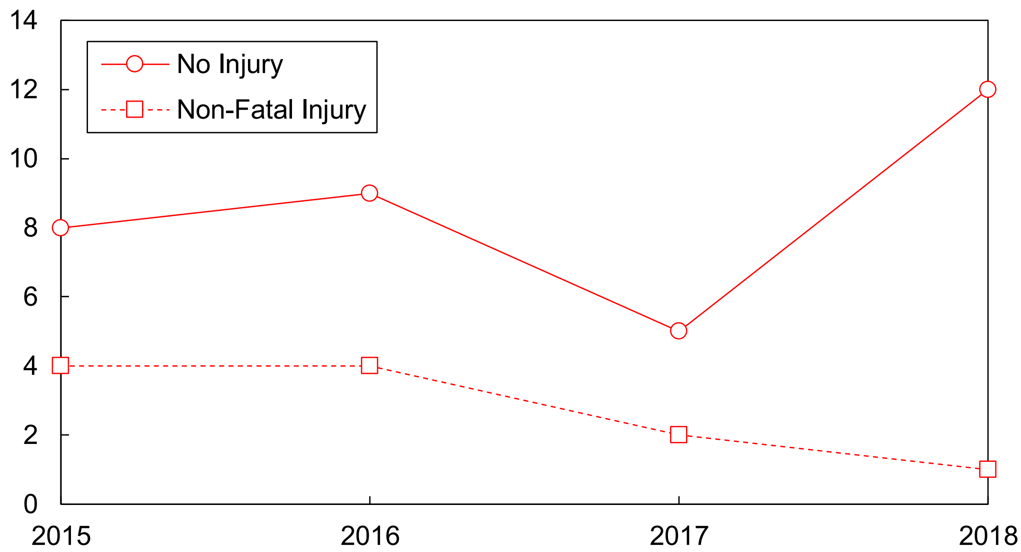

Figure 5.25: I-205 crashes by maximum crash severity on I-205

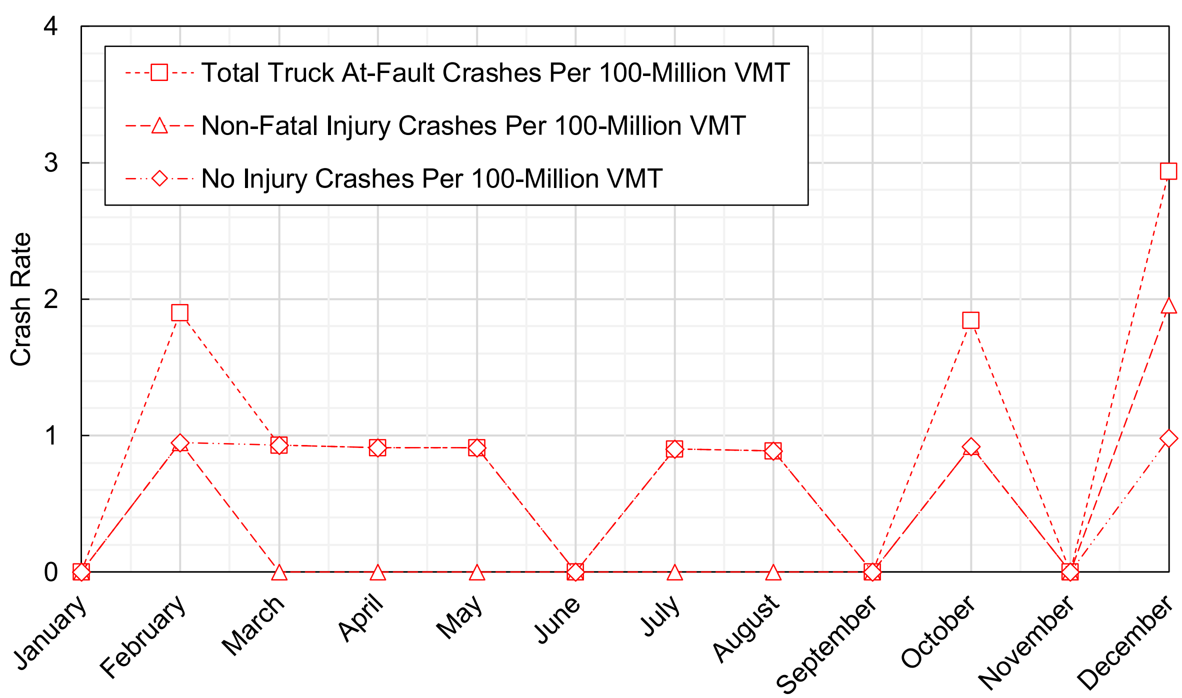

Figure 5.26: Truck at-fault crash rate in 2015 on I-205

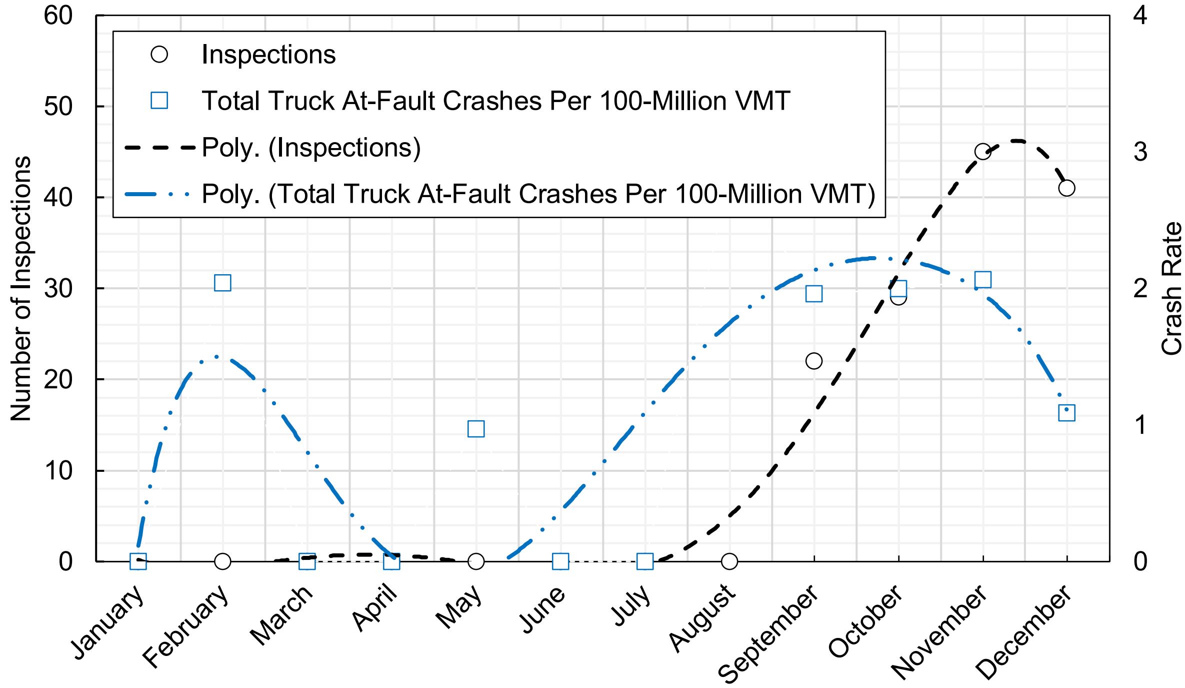

Figure 5.27: Number of inspections and truck at-fault crash rate in 2016 on I-205

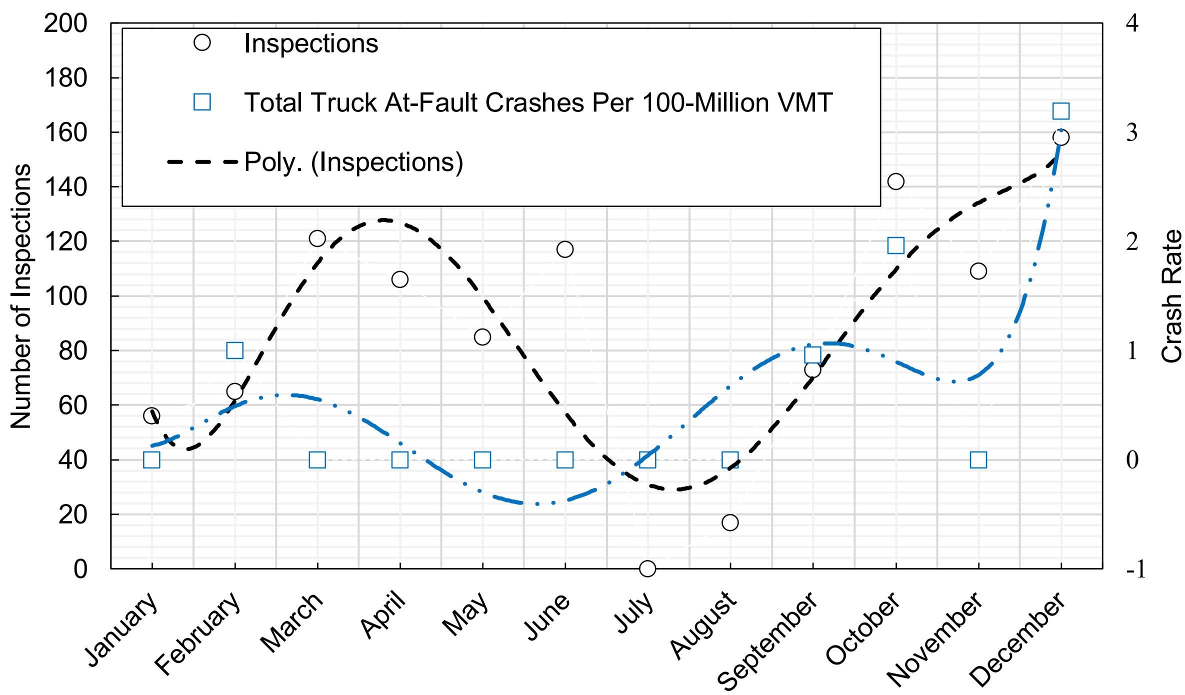

Figure 5.28: Number of inspections and truck at-fault crash rate in 2017 on I-205

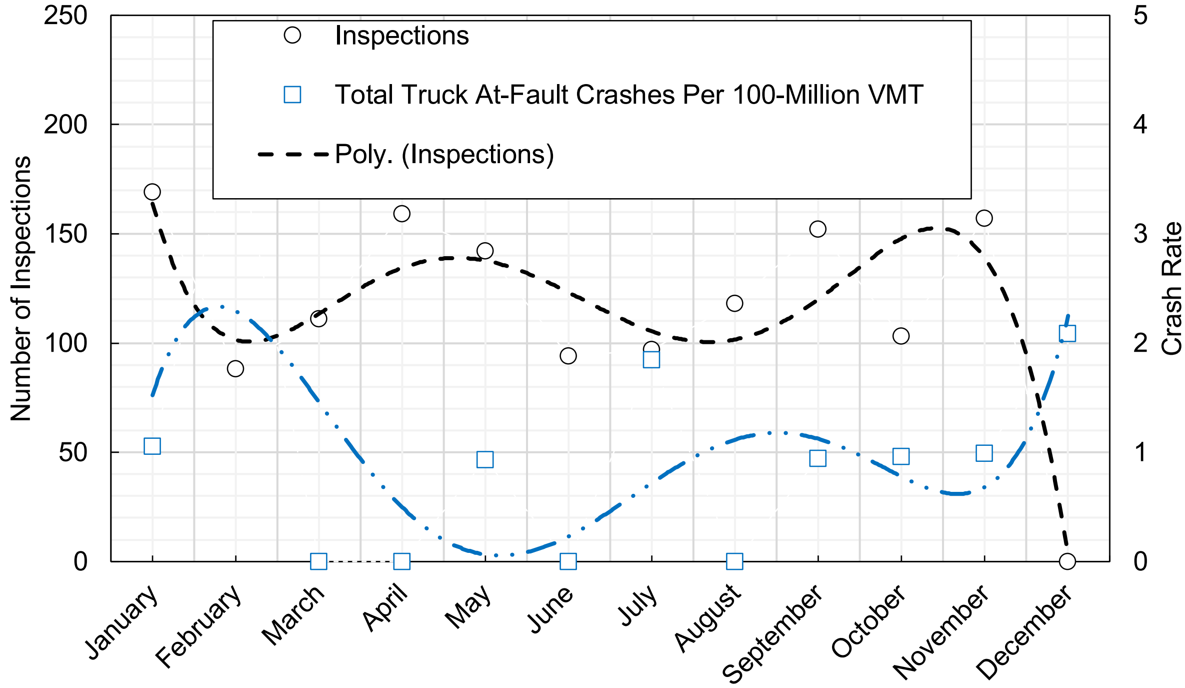

Figure 5.29: Number of inspections and truck at-fault crash rate in 2018 on I-205

6.0 CRASH DATA ANALYSIS

This chapter utilizes Oregon crash data to provide a method and results for identifying crash contributing factors. The method to accomplish this is a truck at-fault crash severity analysis.

For the crash severity analysis, a binary logit modeling framework is applied. The framework also accounts for a key limitation among crash datasets: unobserved heterogeneity.

6.1 CRASH SEVERITY ANALYSIS

The crash severity analysis identifies significant contributing factors to crash severity. Unlike injury severity, which is specific to each driver, crash severity refers to the maximum sustained injury in the crash. The maximum sustained injury could be sustained by the driver, but may also be referring to a driver or passenger in another vehicle. The use of crash severity, as opposed to injury severity, for the current project is based on two items:

- The number of observations by severity when considering truck at-fault driver-injury severities.
- The effects of truck at-fault crashes on crash severity, not just the effects on the driver of the truck.

On this premise, three years of crash data were used to model crash severity of truck at-fault crashes. In addition, each year of crash data is modeled separately to assess changes or similarities of contributing factors across years of crash data. This follows recent findings from Mannering (2018), in which aggregating several years of crash data can result in biased parameter estimates due to temporal instability (i.e., factors and their effects can change from year-to-year).

In regards to Oregon crash data, beginning in 2016, the Oregon Department of Transportation Crash Manual began to code various crash data variables as "unknown,", "NA,", etc., for crashes in which no injury was sustained. As a result, no injury crashes are unable to be accounted for when using 2016 or 2017 data. For example, driver-level crash cause is coded as "No cause associated at this level" for no injury crashes. This results in at-fault no injury crashes being coded as not at-fault. This is the case for all vehicle types. Therefore, to associate at-fault truck drivers and the corresponding crash severities, the three years of crash data used are 2013, 2014, and 2015.

Utilizing each year of crash data, three separate crash severity models were generated. In Oregon crash data, crash severity levels are defined as fatal, non-fatal injury, and no injury. Similar to driver-injury severities, fatal crash severities account for a small proportion of observations. As a result, to ensure there are adequate observations for all outcomes being considered, crash severity was dichotomized to a binary format. Specifically, injury crashes (fatal or non-fatal injuries) were coded as 1 and no injury crashes were coded as 0. Based on the nature of this variable, a binary logit model was applied to determine significant crash severity contributing factors.

6.2 CRASH SEVERITY METHODOLOGY

6.2.1 Random Parameters Logit Model

Logit models are an econometric method used to determine significant factors on outcome probabilities for a discrete outcome or event. Although an econometric method, logit models have been widely used for various types of data, including transportation safety analyses with state or federal crash data. In the case of the current project, this discrete outcome is whether the crash resulted in an injury/fatality or resulted in no injury. Logit models begin with the definition of the logit probability (McFadden, 1981; McFadden & Train, 2000; K. E. Train, 2009):

$$\boldsymbol{P_c(s) = \frac{e^{(\beta_c X_{cs})}}{\sum_{\forall c} e^{(\beta_c X_{cs})}}} \tag{6-1}$$

where $P_c(s)$ is the probability of crash c resulting in crash severity s (i.e., s takes on the value 1), β_c is a vector of parameters to be estimated corresponding to crash c, and X_{cs} is a vector of explanatory variables used to determine $P_c(s)$ (i.e., observable characteristics in the Oregon crash data). As part of logit modeling, the analyst must satisfy the alternative-specific-constant rule by normalizing one of the discrete outcomes (refer to Train (2009) for a full discussion on this rule and how it applies to logit modeling). In the case of two outcomes (e.g., injury and no injury), one is normalized to zero and the other remains to generate the following formulation (Greene, 2018; Hensher, Rose, & Greene, 2015; K. E. Train, 2009; Washington, Karlaftis, & Mannering, 2011):

$$\boldsymbol{P_c(s) = \frac{e^{(\dot{\beta})}}{1 + e^{(\dot{\beta})}}\text{, where } \dot{\beta} = \beta_0 + \beta_1 X_{1,c} + \cdots + \beta_s X_{s,c} + \varepsilon_{sc}} \tag{6-2}$$

Where:

> ε_{sc} is a Type I Extreme Value distributed error term and all other terms have been defined previously. This distribution of ε_{sc} is what makes this a logit model. For example, if utilities were scaled by 1 and ε_{sc} were to have a standard normal distribution, Eq. (6-2) would take the form of a binary probit model.

The purpose of the error term is to capture unobservables in the data being analyzed. Unobservables refer to attributes that are unobserved by the analyst; that is, variables/characteristics not included in the data or are not collected. In the context of the current project, each and every factor that contributes to crash severity are not present in the data. This primarily stems, in crash data, from data not being collected on crash report forms (they are not asked or required to be collected) or specific attributes simply being unknown/unavailable. These potential observable characteristics are now unobservables. These unobservables can result in a term known as unobserved heterogeneity, which if unaccounted for, can result in invalid model estimations. Unobserved heterogeneity can also be attributed to variations within observable data. In crash data, there could be variation in various variables, such as driver-related variables, seatbelt usage, if the crash occurred on a grade, etc. Referring to driver-related variables, gender and age are often known, but no other driver-specific information is known. With that in mind, physical and cognitive abilities often vary from driver-to-driver and can be a contributing factor in crash severity outcomes, but is unknown. This information may cause variation within the observable driver-related variables. In regards to seatbelt usage, it is known that seatbelts save lives, but can cause an injury in the process due to unobservables (e.g., speed at time of impact, driver physiology, etc.). Lastly, crash data often indicates if a crash occurred on a grade, but direction and percent grade are generally unknown.

Considering this limitation in crash data and the impact it can have on model estimations, the current project attempts to account for these unobservables (or unobserved heterogeneity) through the estimation of random parameters. In traditional modeling frameworks, coefficient estimates are assumed to have the same sign across all observations (i.e., the same effect). However, in the random parameters framework, coefficient estimates are allowed to vary across observations based on a distribution defined by the analyst. As a result, the coefficient estimate is now negative for a proportion of observations and positive for the remainder, or vice-versa. Therefore, the addition of a mixing distribution is applied to the binary logit formulation shown in Eq. (6-2) (McFadden & Train, 2000; K. E. Train, 2009; Washington et al., 2011):

$$\boldsymbol{P_c(s \mid \varphi) = \int_X \frac{e^{(\dot{\beta})}}{1 + e^{(\dot{\beta})}} f(\dot{\beta} \mid \varphi)\, d\dot{\beta}} \tag{6-3}$$

Where:

$P_c(s \mid \varphi)$ is the weighted outcome probability of $P_c(s)$ taking on the value 1 conditional on $f(\dot{\beta} \mid \varphi)$. This function, $f(\dot{\beta} \mid \varphi)$, is the density function of $\dot{\beta}$ and φ represents the distributional parameter. The density function allows parameter estimates to vary across crash observations and, therefore, allowing $\dot{\beta}$ to account for crash-specific variations of the effects of observable characteristics (i.e., X_{cs}) on $P_c(s)$ (Washington et al., 2011). The distribution of this density function is often chosen to be normally distributed and is the distribution applied in the current project.

As observed in Eq. (6-3), computing probabilities from such a formulation can be problematic. As such, a simulation-based approach is used to estimate parameters. In doing so, probabilities are approximated for any given value of φ. A value of $\dot{\beta}$ is drawn from $f(\dot{\beta} \mid \varphi)$ and the logit probability is calculated based on this value. This process is repeated many times and the results are averaged, where the average simulated probability is as follows (K. E. Train, 2009):

$$\breve{P}_c(s) = \frac{1}{R}\sum_{r=1}^{R}\frac{e^{(\dot{\beta}^r)}}{1 + e^{(\dot{\beta}^r)}}$$

(6-4)

Where:

R is the number of draws and $\breve{P}_c(s)$ is an unbiased estimator of $P_c(s)$.

As shown in previous work (Bhat, 2003; Halton, 1960; K. Train, 2000), Halton draws are the preferred type of draws for this process and are therefore used in the present study. The simulated probabilities from the Halton draws are then inserted into the following log-likelihood function to produce a simulated log-likelihood value (K. E. Train, 2009; Washington et al., 2011):

$$\mathbf{SSL} = \sum_{c=1}^{C}\sum_{s=1}^{S}\delta_{sc}\ln[P_c(s \mid \varphi)]$$

(6-5)

Where:

C is the total number of crashes, S is the total number of severity outcomes, δ_{sc} is equal to 1 if the observed outcome for crash c is severity s and zero otherwise, and all other terms have been defined previously.

Unlike traditional linear regression models, the parameter estimates of a logit model are not readily interpretable. In most instances, the use of marginal effects are used to interpret parameter estimates and determine the effects of variables on outcome probability. As such, the current study uses marginal effects as a means to interpret model estimations.

For continuous independent variables, marginal effects are computed as (Greene, 2016, 2018):

$$\frac{\partial P_c(s)}{\partial X_{sck}} = [1 - P_c(s)]P_c(s)\beta_{c(s)}$$

(6-6)

Where:

$\frac{\partial P_c(s)}{\partial X_{sck}}$ is the derivative of the probability of crash c resulting in severity s.

However, more commonly, indicator variables are used over continuous variables. In such a case, marginal effects are computed as the difference in probabilities when an indicator variable changes from zero to one (Greene, 2018):

$$M_{X_{sck}}^{P_c(s)} = \Pr[P_c(s) = 1 | X_{(X_{sck})}, X_{sck} = 1] - \Pr[P_c(s) = 1 | X_{(X_{sck})}, X_{sck} = 0]$$

(6-7)

Where:

$X_{(X_{sck})}$ is the mean of all other variables (i.e., the variables are held constant) while X_{sck} changes from zero to one.

6.2.2 Model Significance

To assess model significance of the random parameters binary logit model, two specific metrics are assessed: log-likelihood and McFadden Pseudo R^2 value. The log-likelihood assessment consists of a log-likelihood ratio test in which two log-likelihood values are compared to determine if the log-likelihood of the random parameters model is of more significance than its fixed parameters counterpart. The log-likelihood ratio is as follows (Washington et al., 2011):

$$\chi^2 = -2[LL(\beta_{\text{Fixed}}) - LL(\beta_{\text{Random}})]$$

(6-8)

Where:

$LL(\beta_{\text{Fixed}})$ is the log-likelihood at convergence of the fixed parameters model,
$LL(\beta_{\text{Random}})$ is the log-likelihood at convergence of the random parameters model, and
χ^2 is a chi-square statistic with degrees of freedom equal to the number of estimated random parameters.

This test the null hypothesis that the log-likelihood at convergence of the fixed parameters model is of more significance than that of the random parameters model. Therefore, if significant, the tests indicates that the random parameters model is the preferred estimation approach and the null hypothesis is rejected.

The second model assessment metric is the McFadden Pseudo R^2 value. This measures the model's fit using the log-likelihood at convergence and the log-likelihood of the model estimated with only a constant term. The McFadden Pseudo R^2 value is computed as (McFadden, 1973, 1977, 1981):

$$\text{McFadden Pseudo } R^2 = 1 - \frac{LL(\beta)}{LL(0)}$$

(6-9)

Where:

$LL(\beta)$ is the log-likelihood at convergence of the final model (i.e., the random parameters model) and $LL(0)$ is the log-likelihood of the model estimated with only the constant.

Values between 0.10 and 0.20 are considered to have adequate fit, while values of greater than 0.20 are considered to have “exceptional” fit (McFadden, 1973, 1977, 1981).

6.3 RESULTS

6.3.1 2015 Crash Severity Results

Summary statistics of significant variables are shown in Table 6.1 and final model specifications are shown in Table 6.2. As shown in Table 6.1, 11 factors were found to be statistically significant in determining crash severity probability. Of these 11 factors, 2 have heterogeneous effects across crash observations; that is, they have estimated random parameters. The significance of the random parameters is based on the estimated standard deviation, which if significant, indicates significant heterogeneous effects. The first of these parameters is related to posted speed limits. Specifically, the estimated parameter for posted speed limits of 50 mi/hr or 55 mi/hr was found to random and normally distributed with a mean of 0.31 and a standard deviation of 3.54. These estimates indicate that for 46.5% of crashes the estimated parameter mean is less than zero and for 53.5% of crashes the estimated parameter mean is greater than zero. In other words, if a truck at-fault crash occurred at a location with posted speed limits of 50 mi/hr or 55 mi/hr, 46.5% of the crashes are less likely to result in an injury and 53.5% are more likely to result in an injury. It is widely known that higher speeds are associated with crashes of a higher severity, while lower speed limits are associated with crashes of a lower severity. Therefore, the heterogenous nature observed may be a result of traffic conditions. For instance, if the truck at-fault crash occurred during congested conditions, speeds will be much less than the posted resulting in a likelihood of a less severe injury.

The second estimated random parameter is associated the truck’s movement at the time of the crash. In particular, the estimated parameter for trucks that were traveling straight at the end of the crash is random and normally distributed with a mean of 0.43 and a standard deviation of 2.41. Based on these estimations, 42.9% of truck at-fault crashes in which the truck was traveling straight at the time of the crash are less likely to result in an injury and 57.1% are more likely to result in an injury.

Of the remaining significant crash severity factors, various have substantial impacts on crash severity probability based on marginal effects. Marginal effects provide an absolute change in probability due to a one-unit increase (i.e., indicator variable changes from zero to one). For instance, marginal effects show that truck at-fault crashes that happened where the posted speed limit was 40 mi/hr or 45 mi/hr have a 0.22 higher probability of resulting in an injury. As stated previously, it is well known that higher speeds are associated with more severe crashes. Also with a considerable impact on crash severity are rear-end crashes. According to marginal effects, truck at-fault crashes that were rear-end crashes have a 0.40 higher probability of resulting in an injury. Again, with positive effects on crash severity probability, marginal effects show that truck at-fault crashes in which the cause at the driver-level was not yielding the right-of-way results in a 0.34 increase in probability of the crash having an injury. The final two variables with positive impacts on crash severity probability are foggy weather conditions and urban minor arterials. Referring to the former, marginal effects show that truck at-fault crashes that occurred under foggy conditions have a 0.18 higher probability of resulting in an injury. As for urban minor arterials, marginal effects show that truck at-fault crashes that happened on this roadway classification have a 0.14 increase in probability of resulting in an injury.

In regards to negative effects on crash severity probability, there are four factors. The first of these factors, also with the largest effects, is snowy weather. Specifically, truck at-fault crashes that occurred under snowy weather conditions have a 0.40 lower probability of resulting in an injury. This is in-line with several previous works, in which inclement weather conditions have shown a decrease in more severe outcomes. The next two factors have the same magnitude of change in probability on crash severity: crashes in which the truck was turning right and drivers aged 36 years to 45 years.[5] As it pertains to truck at-fault crashes where the truck was turning right, marginal effects show a 0.11 decrease in probability of resulting in an injury. For truck drivers aged 36 years to 45 years, marginal effects show a 0.11 lower probability of the crash resulting in an injury. The final factor with negative effects is time-of-day. In particular, truck at-fault crashes that happened between 10:00 a.m. and 4:00 p.m. have a 0.08 lower probability of resulting in an injury.

Table 6.1: Summary Statistics of Significant Variables in 2015 Crash Severity Model

Variable	Mean	Standard Deviation
Posted Speed Limit		
1 if 40 mi/hr or 45 mi/hr, 0 Otherwise	0.08	0.27
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	0.34	0.47
Crash Type		
1 if Rear-End Crash, 0 Otherwise	0.14	0.35
Weather Condition		
1 if Fog, 0 Otherwise	0.03	0.18
1 if Snow, 0 Otherwise	0.04	0.19
Vehicle Movement		
1 if Right Turn, 0 Otherwise	0.11	0.31
1 if Traveling Straight, 0 Otherwise	0.73	0.44
Driver-Level Crash Cause		
1 if Did Not Yield Right-of-Way, 0 Otherwise	0.06	0.24
Driver Age		
1 if 36 Years to 45 Years, 0 Otherwise	0.18	0.39
Time-of-Day		
1 if 10:00 a.m. to 4:00 p.m., 0 Otherwise	0.38	0.49
Roadway Classification		
1 if Urban Minor Arterial, 0 Otherwise	0.08	0.27

[5] Age categories are based on age categories used by NHSTA in several recent publications.

Table 6.2: Final Model Specifications for 2015 Crash Severity Analysis

Variable	Coefficient	Std. Error	*t*-statistic	Marginal Effects
Constant	-0.91	0.19	-4.78	
Posted Speed Limit				
1 if 40 mi/hr or 45 mi/hr, 0 Otherwise	0.91	0.26	3.54	0.22
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	0.31	0.18	1.78	0.08
(Standard Deviation, Normally Distributed)	*(3.54)*	*(0.36)*	*(9.73)*	
Crash Type				
1 if Rear-End Crash, 0 Otherwise	1.66	0.25	6.73	0.40
Weather Condition				
1 if Fog, 0 Otherwise	0.75	0.42	1.77	0.18
1 if Snow, 0 Otherwise	-1.64	0.46	-3.54	-0.40
Vehicle Movement				
1 if Right Turn, 0 Otherwise	-0.43	0.27	-1.60	-0.11
1 if Traveling Straight, 0 Otherwise	0.43	0.20	2.18	0.10
(Standard Deviation, Normally Distributed)	*(2.41)*	*(0.21)*	*(11.63)*	
Driver-Level Crash Cause				
1 if Did Not Yield Right-of-Way, 0 Otherwise	1.39	0.28	4.95	0.34
Driver Age				
1 if 36 Years to 45 Years, 0 Otherwise	-0.47	0.20	-2.35	-0.11
Time-of-Day				
1 if 10:00 a.m. to 4:00 p.m., 0 Otherwise	-0.31	0.15	-2.04	-0.08
Roadway Classification				
1 if Urban Minor Arterial, 0 Otherwise	0.57	0.27	2.11	0.14
Model Summary				
Number of Observations	851			
Log-Likelihood at Zero	-580.36			
Log-Likelihood at Convergence	-517.45			
McFadden Pseudo R-Squared	0.11			

6.3.2 2014 Crash Severity Results

Summary statistics of significant variables are shown in Table 6.3 and final model specifications are shown in **Error! Reference source not found.**. Referring to **Error! Reference source not fo und.**, 12 factors are found to statistically impact crash severity outcome. Of these 12 factors, three are found to have heterogeneous effects on crash severity outcomes. The first factor with varying effects is crash type. Specifically, truck at-fault rear-end crashes have a random and normally distributed estimated parameter with a mean of 0.77 and a standard deviation of 1.11. These estimates suggest that for 24.4% of truck at-fault rear-end crashes were less likely to result in an injury and 75.6% of truck at-fault rear-end crashes were more likely to result in an injury.

The next factor with heterogenous effects is associated with roadway surface conditions. With a mean of 0.54 and a standard deviation of 0.57, the estimated parameter for dry surface conditions is random and normally distributed. Based on these estimates, 17.2% of truck at-fault crashes that occurred on dry surface conditions are less likely to result in an injury and 82.8% of truck at-fault crashes are more likely to result in an injury.

The final factor in the 2014 crash data analysis with heterogenous effects is a roadway classification. In particular, urban interstates have a random and normally distributed estimated parameter with a mean of 0.19 and a standard deviation of 2.51. According to the normal distribution curve, these estimates indicate that 47% of truck at-fault crashes that happened on urban interstates were less likely to result in an injury and 53% of truck at-fault crashes that happened on urban interstates were more likely to result in an injury.

Of the remaining significant factors, several have considerable positive impacts on crash severity based on marginal effects. The factor with the largest positive effects is rainy weather. Referring to raining weather, marginal effects show that truck at-fault which occurred during raining weather have a 0.19 higher probability of resulting in an injury. Also within increase in injury probability is the indicator for gender. In particular, marginal effects show that male drivers in truck at-fault crashes have a 0.15 higher probability of resulting in an injury. With similar effects is a factor related to driver-level crash cause. According to marginal effects, truck at-fault crashes in which the truck driver-level crash cause was not yielding the right-of-way have a 0.14 higher probability of resulting in an injury.

In regards to factors with negative impacts on crash severity, there are three. The first of these factors is related to the truck's movement. Based on marginal effects, truck at-fault crashes in which the truck was backing up have a 0.25 lower probability of resulting in an injury. The second factor is associated with the speed limit at the location of the crash. Specifically, truck at-fault crashes that occurred at locations where the posted speed limit was 20 mi/hr or 25 mi/hr have a 0.16 lower probability of resulting in an injury. The final factor with negative effects on crash severity is associated with the type of median. According to marginal effects, truck at-fault crashes that happened at a location with a solid median have a 0.15 lower probability of resulting in an injury.

Table 6.3: Summary Statistics of Significant Variables in 2014 Crash Severity Model

Variable	Mean	Standard Deviation
Posted Speed Limit		
1 if 20 mi/hr or 25 mi/hr, 0 Otherwise	0.04	0.20
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	0.34	0.48
Crash Type		
1 if Rear-End Crash, 0 Otherwise	0.19	0.39
Weather Condition		
1 if Rain, 0 Otherwise	0.13	0.34
Road Surface Condition		
1 if Dry, 0 Otherwise	0.60	0.49
Vehicle Movement		
1 if Backing, 0 Otherwise	0.03	0.18
1 if Traveling Straight, 0 Otherwise	0.74	0.44
Driver-Level Crash Cause		
1 if Did Not Yield Right-of-Way, 0 Otherwise	0.05	0.23
Driver Age		
1 if 46 Years to 55 Years, 0 Otherwise	0.25	0.43
Driver Gender		
1 if Male, 0 Otherwise	0.90	0.30
Roadway Classification		
1 if Urban Interstate, 0 Otherwise	0.14	0.35
Median Type		
1 if Solid Median, 0 Otherwise	0.16	0.37

Table 6.4: Final Model Specifications for 2014 Crash Severity Analysis

Variable	Coefficient	Std. Error	*t*-statistic	Marginal Effects
Constant	-2.11	0.28	-7.62	
Posted Speed Limit				
1 if 20 mi/hr or 25 mi/hr, 0 Otherwise	-0.70	0.34	-2.05	-0.16
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	0.30	0.12	2.45	0.07
Crash Type				
1 if Rear-End Crash, 0 Otherwise	0.77	0.15	5.10	0.18
(Standard Deviation, Normally Distributed)	*(1.11)*	*(0.21)*	*(5.17)*	
Weather Condition				
1 if Rain, 0 Otherwise	0.84	0.20	4.30	0.19
Road Surface Condition				
1 if Dry, 0 Otherwise	0.54	0.13	4.07	0.13
(Standard Deviation, Normally Distributed)	*(0.57)*	*(0.11)*	*(5.35)*	
Vehicle Movement				
1 if Backing, 0 Otherwise	-1.08	0.55	-1.96	-0.25
1 if Traveling Straight, 0 Otherwise	0.42	0.16	2.74	0.10
Driver-Level Crash Cause				
1 if Did Not Yield Right-of-Way, 0 Otherwise	0.61	0.24	2.53	0.14
Driver Age				
1 if 46 Years to 55 Years, 0 Otherwise	0.42	0.13	3.32	0.10
Driver Gender				
1 if Male, 0 Otherwise	0.63	0.22	2.79	0.15
Roadway Classification				
1 if Urban Interstate, 0 Otherwise	0.19	0.21	0.92	0.04
(Standard Deviation, Normally Distributed)	*(2.51)*	*(0.40)*	*(6.20)*	
Median Type				
1 if Solid Median, 0 Otherwise	-0.65	0.18	-3.54	-0.15
Model Summary				
Number of Observations	940			
Log-Likelihood at Zero	-608.60			
Log-Likelihood at Convergence	-551.71			
McFadden Pseudo R-Squared	0.09			

6.3.3 2013 Crash Severity Results

Summary statistics of significant variables are shown in Table 6.5 and final model specifications are shown in Table 6.6. Table 6.6 shows that 10 factors are found to be statistically significant crash severity contributing factors, five of which have heterogeneous effects across crash observations. The first of these heterogeneous factors is a posted speed limit. With a mean of -0.11 and a standard deviation of 4.88, the estimated parameter for posted speed limits of 50 mi/hr or 55 mi/hr is random and normally distributed. These estimations indicate that 49.1% of truck at-fault crashes that occurred at a location with a posted speed limit of 50 mi/hr or 55 mi/hr were more likely to result in an injury and 50.9% were less likely.

The next factor with heterogenous effects is also related to posted speed limits. Specifically, with a mean of 0.15 and a standard deviation of 6.33, the estimated parameter for posted speed limits greater than or equal to 60 mi/hr was found to be random and normally distributed. Based on these estimates, 49% of truck at-fault crashes at locations with speed limits of 60 mi/hr or greater were less likely to result in an injury and 51% were more likely.

Two factors with heterogeneous effects on crash severity are associated with crash type. Truck at-fault rear-end crashes, with a mean of 1.48 and a standard deviation of 6.77, have a random and normally distributed estimated random parameter. Referring to the normal distribution curve, these estimates indicate that 41.4% of truck at-fault rear-end crashes were less likely to result in an injury and 58.6% of truck at-fault rear-end crashes were more likely to result in an injury. The other crash type, also with a random and normally distributed random parameter, is fixed-object. A mean of -0.95 and a standard deviation of 0.72 indicate that 9.4% of truck at-fault fixed-object crashes were likely to result in an injury and 90.6% of truck at-fault fixed-object crashes were less likely to result in an injury.

The final factor with varying effects across crash observations is the movement of the truck at-fault. With a mean of 0.68 and a standard deviation of 1.53, the estimated parameter for crashes in which trucks were traveling straight is random and normally distributed. These estimates indicate that 32.8% of truck at-fault crashes in which the truck was traveling straight were less likely to result in an injury and 67.2% were more likely.

In regards to factors with considerable positive impacts on crash severity, there are five according to marginal effects calculations. Of the five, the largest effects are related to gender. According to marginal effects, if the truck at-fault driver was male, there is a 0.32 higher probability of the crash resulting in an injury. The next factor is associated with truck driver-level crash cause. Based on marginal effects, truck at-fault crashes in which the truck driver-level crash cause was not yielding the right-of-way have a 0.19 higher probability of resulting in an injury. The third factor corresponds to the movement of the at-fault truck. Marginal effects show that truck at-fault crashes in which the truck was traveling straight have a 0.14 higher probability of resulting in an injury.

Just one factor has substantial negative impacts on crash severity, snowy weather. According to marginal effects, truck at-fault crashes that happened during snowy weather have a 0.24 lower probability of resulting in an injury.

Table 6.5: Summary Statistics of Significant Variables in 2013 Crash Severity Model

Variable	Mean	Standard Deviation
Posted Speed Limit		
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	0.40	0.49
1 if Greater Than or Equal to 60 mi/hr, 0 Otherwise	0.13	0.34
Crash Type		
1 if Turning Movement Crash, 0 Otherwise	0.17	0.38
1 if Rear-End Crash, 0 Otherwise	0.20	0.40
1 if Fixed-Object Crash, 0 Otherwise	0.22	0.42
Weather Condition		
1 if Snow, 0 Otherwise	0.04	0.20
Vehicle Movement		
1 if Traveling Straight, 0 Otherwise	0.73	0.44
Driver-Level Crash Cause		
1 if Did Not Yield Right-of-Way, 0 Otherwise	0.08	0.27
Driver Gender		
1 if Male, 0 Otherwise	0.90	0.30
Roadway Classification		
1 if Rural Principal Arterial, 0 Otherwise	0.16	0.37

Table 6.6: Final Model Specifications for 2013 Crash Severity Analysis

Variable	Coefficient	Std. Error	*t*-statistic	Marginal Effects
Constant	-3.01	0.45	-6.73	
Posted Speed Limit				
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	-0.11	0.22	-0.50	-0.02
(Standard Deviation, Normally Distributed)	*(4.88)*	*(0.51)*	*(9.61)*	
1 if Greater Than or Equal to 60 mi/hr, 0 Otherwise	0.15	0.35	0.43	0.03
(Standard Deviation, Normally Distributed)	*(6.33)*	*(0.97)*	*(6.51)*	
Crash Type				
1 if Turning Movement Crash, 0 Otherwise	0.54	0.28	1.93	0.11
1 if Rear-End Crash, 0 Otherwise	1.48	0.30	4.97	0.31
(Standard Deviation, Normally Distributed)	*(6.77)*	*(0.84)*	*(8.09)*	
1 if Fixed-Object Crash, 0 Otherwise	-0.95	0.25	-3.78	-0.20
(Standard Deviation, Normally Distributed)	*(0.72)*	*(0.29)*	*(2.48)*	
Weather Condition				
1 if Snow, 0 Otherwise	-1.14	0.47	-2.41	-0.24
Vehicle Movement				
1 if Traveling Straight, 0 Otherwise	0.68	0.28	2.46	0.14
(Standard Deviation, Normally Distributed)	*(1.53)*	*(0.19)*	*(8.08)*	
Driver-Level Crash Cause				
1 if Did Not Yield Right-of-Way, 0 Otherwise	0.89	0.25	3.55	0.19
Driver Gender				
1 if Male, 0 Otherwise	1.54	0.37	4.12	0.32
Roadway Classification				
1 if Rural Principal Arterial, 0 Otherwise	0.53	0.24	2.18	0.11
Model Summary				
Number of Observations	845			
Log-Likelihood at Zero	-550.27			
Log-Likelihood at Convergence	-503.16			
McFadden Pseudo R-Squared	0.09			

6.4 SUMMARY

Utilizing the three most recent years of crash data in which driver-level causes are provided for no injury crashes, a series of crash severity models were developed to identify contributing factors to truck driver-at-fault crash severity. To account for variation in the data due to unobservables, a random parameters binary logit model was applied. Additionally, to assess changes in the contributing factors across years, crash severity models were developed by year of crash data.

A full summary of contributing factors is provided in Table 6.7. Of particular interest in Table 6.7 are the factors that were found to be significant in each crash year model. The first of these factors is speed limit; specifically, posted speed limits of 50 m/hr or 55 mi/hr. In two of the years, 2013 and 2015, this posted speed limit had heterogeneous effects. The varying effects may be linked to traffic conditions, where several crashes occurred under congested conditions in which vehicle speeds were much lower than the posted speed limit. In 2014, the effect was homogenous, where there was an increase in crash severity across all crashes. Ultimately, although with varying effects for two of the years, higher posted speed limits are associated with an increase in crash severity for truck driver at-fault crashes.

The second factor found to be significant across all years was a crash type: rear-end crashes. Similar to the previous factor (posted speed limits of 50 mi/hr or 55 mi/hr), rear-end crashes were found to have heterogenous effects for two of the years, 2013 and 2014. This variation may also be linked with traffic conditions, as well as speed at the time of impact. Speed at the time of impact may be related to driver distraction. As for 2015, rear-end crashes were homogenous across crash observations and increased the likelihood of a more severe crash. Even with the heterogeneous effects in 2013 and 2014, the majority of crashes were more likely to result in an injury. Accompany this with all crashes in 2015, rear-end crashes consistently increased the likelihood of a more severe crash across the three years of crash data.

The third factor found to be significant across all years of crash data was vehicle movement; specifically, vehicles that were traveling straight. Once more, two of the years experienced heterogenous effects, while one year had homogeneous effects. In 2013 and 2015, truck at-fault crashes in which the truck was traveling straight had varying effects on crash severity; albeit, the majority of crashes were more likely to result in an injury crash. In 2014, all crashes were more likely to result in an injury. Therefore, across all years of crash data, truck at-fault crashes in which the truck was traveling straight consistently increased the likelihood of an injury crash. This, too, may be linked with speed and driver distraction.

The fourth, and final, factor found to be significant across all years of crash data was a driver-specific behavior: not yielding the right-of-way. Unlike the previous three factors, there were no heterogenous effects; that is, truck driver-at-fault crashes in which the driver was at-fault due to not yielding the right-of-way increased the likelihood of a more severe crash for each year of crash data for all crashes. Not yielding the right-of-way may be due to visibility issues, but may also be a result of driver distraction that led to the driver not yielding.

Table 6.7: Summary of Effects of Contributing Factors across Years

Variable	Year		
Posted Speed Limit	**2013**	**2014**	**2015**
1 if 20 mi/hr or 25 mi/hr, 0 Otherwise	-	↓	-
1 if 40 mi/hr or 45 mi/hr, 0 Otherwise	-	-	↑
1 if 50 mi/hr or 55 mi/hr, 0 Otherwise	↓↑	↑	↓↑
1 if Greater Than or Equal to 60 mi/hr, 0 Otherwise	↓↑	-	-
Crash Type			
1 if Turning Movement Crash, 0 Otherwise	↑	-	-
1 if Fixed-Object Crash, 0 Otherwise	↓↑	-	-
1 if Rear-End Crash, 0 Otherwise	↓↑	↓↑	↑
Weather Condition			
1 if Rain, 0 Otherwise	-	↑	-
1 if Fog, 0 Otherwise	-	-	↑
1 if Snow, 0 Otherwise	↓	-	↓
Road Surface Condition			
1 if Dry, 0 Otherwise	-	↓↑	-
Vehicle Movement			
1 if Backing, 0 Otherwise	-	↓	-
1 if Right Turn, 0 Otherwise	-	-	↓
1 if Traveling Straight, 0 Otherwise	↓↑	↑	↓↑
Driver-Level Crash Cause			
1 if Did Not Yield Right-of-Way, 0 Otherwise	↑	↑	↑
Driver Gender			
1 if Male, 0 Otherwise	↑	↑	-
Driver Age			
1 if 36 Years to 45 Years, 0 Otherwise	-	-	↓
1 if 46 Years to 55 Years, 0 Otherwise	-	↑	-
Time-of-Day			
1 if 10:00 a.m. to 4:00 p.m., 0 Otherwise	-	-	↓
Roadway Classification			
1 if Urban Interstate, 0 Otherwise	-	↓↑	-
1 if Rural Principal Arterial, 0 Otherwise	↑	-	-
1 if Urban Minor Arterial, 0 Otherwise	-	-	↑
Median Type			
1 if Solid Median, 0 Otherwise	-	↓	-

↓ Denotes a decrease in crash severity (i.e., no injury crashes are more likely)

↑ Denotes an increase in crash severity (i.e., injury/fatal crashes are more likely)

↓↑ Denotes heterogeneous effects (i.e., a decrease in crash severity for a proportion of crashes and an increase in severity for the remaining)

7.0 COST-BENEFIT

To assess the cost of inspections and crash costs, crash harm is used. Crash harm is a "*quantitative measure of the combined human and material losses from traffic crashes based on economic valuation*" (Knipling, 2009). These costs, or crash harm, are based on the maximum crash severity (i.e., the most severe injury sustained in the crash).

The most recent crash harm metrics are presented by Zaloshnja and Miller (2007). Included in the crash harm metric are monetary values related to the following:

- Medical costs.
- Emergency services costs.
- Property damage costs.
- Costs due to lost productivity.
- Value of pain and suffering.
- Value of quality of life that family loses due to death or injury.

Due to the crash harm metrics being presented in 2005 dollars, they are converted to 2018 dollars using consumer price index (CPI) inflation conversion factors (Bureau of Labor Statistics, 2019; Sahr, 2019):

$$\boldsymbol{C_{2018_s} = \frac{C_s}{CF}}$$

(7-1)

Where:

> C_{2018_s} is the average cost per crash for severity s in 2018 dollars, C_s is the average cost per crash for severity s in 2005 dollars, and CF is a conversion factor used to convert 2005 dollars to 2018 dollars.

In this case, the conversion factors is based on the final annual average CPI for 2018, resulting in a conversion factor of 0.746. Table 7.1 summarizes average truck-involved crash costs by severity.

Table 7.1: Summary of Truck-Involved Crash Costs

Crash Severity	Average Cost in 2005	Average Cost in 2018	Percent Change
No Injury	$15,114	$19,352	
Non-Fatal Injury	$195,258	$250,010	+28.04%
Fatal	$3,604,518	$4,615,260	

In terms of inspections, each inspection costs $113.75. Based on 2018 crash costs by maximum crash severity and inspection costs of $113.75 per inspection, Figure 7.1 shows a linear trend over the duration of the program. As more money is spent on inspections, costs due to truck at-fault crashes are decreasing. To quantify, see Table 7.2.

As observed in Table 7.2, there is a steady reduction in crash harm. Although the number of crashes is slightly up in 2018 compared to the previous year, the crash harm has decreased as a result of less severe crashes. Table 7.2 shows that since the beginning of the program, total crash cost has reduced by nearly 68%. This is due to a substantial decrease in the total number of crashes in 2017, as well as crashes that did occur in 2018 being primarily no injury crashes. In addition, the trend of inspections and crashes in 2018 is the anticipated result. The overall numbers may be a result of specific months in which crashes increased due to too few inspections (refer to Figure 5.29). As such, this particular month can inflate the year's crash numbers. Once more, refer to Figure 5.29 to observe the desired trend in truck at-fault crashes and the number of inspections. Ultimately, the data shows that the program is working, both in terms of reducing driver-at-fault crashes and associated severities. Figure 7.2 shows the trend in the relationship between crash cost and inspection cost. The first full year of the program has a steep slope, but following the first year of the program, the slope begins to flatten. It is anticipated that at some inspection cost, the line no longer decreases. The point of this behavior is expected to be obtained with the data still being collected. Therefore, the additional data from 2019, being that the program has been extended, can further substantiate these findings.

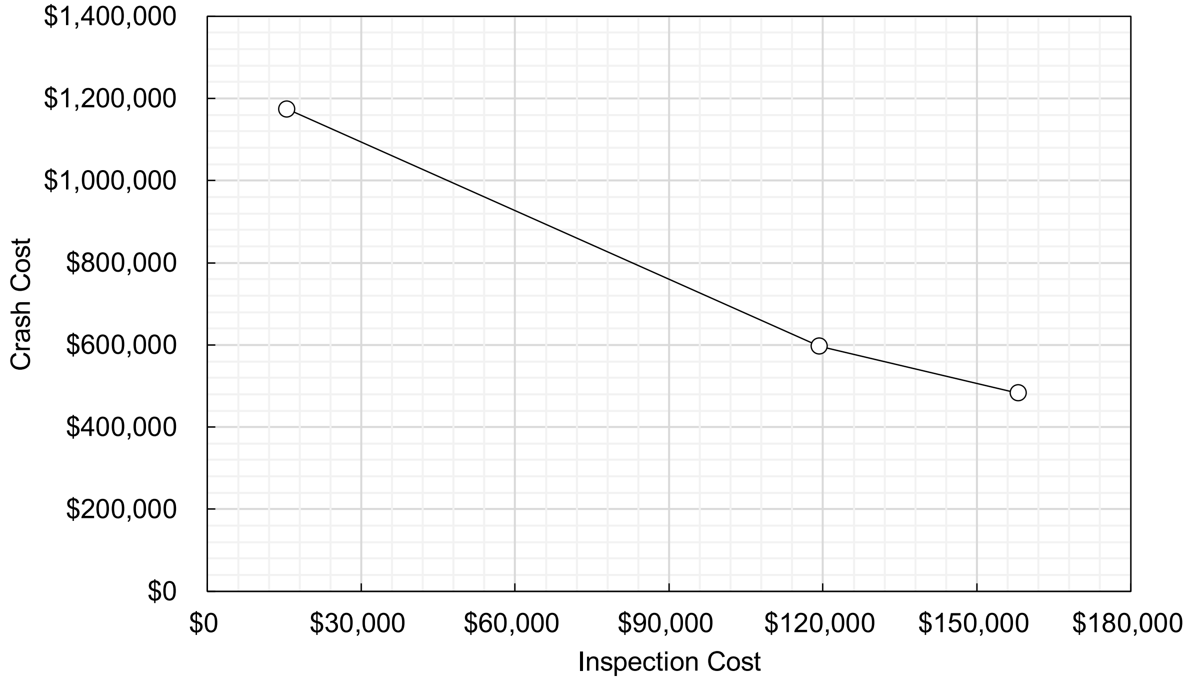

Figure 7.1: Crash cost and inspection cost

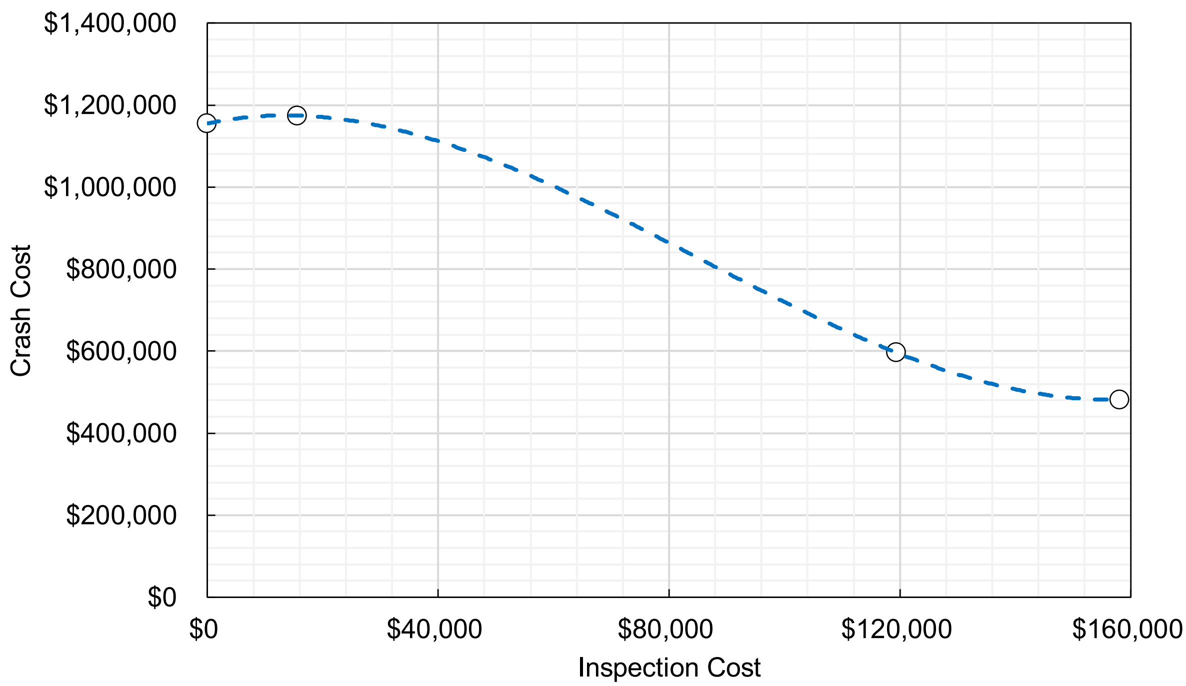

Figure 7.2: Trend in crash cost versus inspection cost

Table 7.2: Changes in Crash Cost and Inspection Costs

Year	Crash Cost	Inspection Cost	Change in Crash Cost	Change in Inspection Cost	Accumulated Percent Change in Crash Cost
2015	$1,154,858	$0	-	-	-
2016	$1,174,210	$15,584	↑ 1.7%	-	↑ 1.7%
2017	$596,781	$119,324	↓ 49.2%	↑ 665.68%	↓ 47.5%
2018	$482,236	$158,113	↓ 19.2%	↑ 32.51%	↓ 66.7%

Table 7.3: Changes in Truck VMT and Number of Crashes

Year	Truck VMT	Crashes	Injury Crashes	No Injury Crashes	Percent Change			
					VMT	Total	Injury	No Injury
2015	107,471,648	12	4	8	-	-	-	-
2016	100,091,285	13	4	9	-6.9%	8.3%	0.0%	12.5%
2017	102,093,111	7	2	5	2.0%	-46.2%	-50.0%	-44.4%
2018	104,134,973	13	1	12	2.0%	85.7%	-50.0%	140.0%

7.1 SUMMARY

Although various methods were tested to determine the cost-benefit of the program, the most reliable results were determined to be the accumulative savings in societal costs over the duration of the program based on the amount of data at the time of the project. Other method explored required additional after years (i.e., after the program implementation) of data to generate reliable cost-benefit estimates. Using the cost for inspections and the average cost for truck-involved crashes, the total change in costs due to crashes has decreased by over 65% since the start of the program. This clearly illustrates that the program to address truck driver behavior has promise.

Although this provides evidence of the program's effectiveness in addressing truck driver behavior and reducing crash costs, there is still more to be done. With continued data collection, additional aspects of this program, included a more detailed cost-benefit analysis as a result of additional data, is currently being addressed in an ODOT funding research study: SPR-828.

8.0 SUMMARY AND RECOMMENDATIONS

The objective of the current study was to provide a framework to evaluate the causes and effects of truck driver-at-fault crashes in Oregon. First, a comprehensive literature review on distracted truck driving and truck at-fault crashes was presented. Next, agency, both state and federal, representatives across the U.S. were surveyed. The intent was to gather opinions, concerns, and current mitigation efforts regarding truck driver behavior, distraction, and other factors that may lead to truck at-fault crashes. Following the agency survey, a survey was administered to truck drivers to gather opinions and concerns from the drivers' perspective. After the surveys a series of data analyses were conducted. The first of these utilized data from a pilot program aimed at addressed truck driver behavior and reducing truck driver-at-fault crashes. The second data analysis used three years of Oregon crash data to generate advanced crash severity models and identify crash severity contributing factors for truck at-fault crashes. The final data analysis looked at costs and benefits of the aforementioned pilot program aimed at addressing driver behavior and truck driver-at-fault crash reduction.

8.1 AGENCY SURVEYS

Of 303 contacted representatives, 24 completed the survey. Of the 24 that completed the survey, there were representatives from all over the U.S., ranging from the west coast, Midwest, and east coast. The split between state and federal agencies was comparable, with few respondents at the county-level. Additionally, a large proportion of the respondents were representatives from law enforcement. Respondents agreed that causes of truck at-fault crashes are most likely due to the driver, as well as truck driver distraction being a significant issue for their respective agency. In terms of effect mitigation efforts, the majority of respondents believe enforcement, fees/penalties, and legislation are likely to be most effective. As discussed in Chapter 8.6.1, due to there being just 24 respondents, there are recommendations to expand the sample size. Although the current project was to gather opinions, conducting statistical analyses and making statistical inference with a high level of confidence would require a substantially larger sample size.

8.2 TRUCK DRIVER SURVEYS

The truck driver surveys showed that the majority of surveyed drivers are long-haul, in that their shipments are consistently truckload shipments. In terms of years driving a truck, roughly two-thirds of the surveyed drivers indicated they have been driving a truck for 10 years or less. Less than 50% of the surveyed drivers stated they learned how to drive a truck in a formal driving school, while nearly 90% of drivers stated they have had some form of road safety training. Regarding crashes, over 75% of drivers reported not being involved in a crash in the last five years. But, nearly half of the drivers reported using their cell phone while driving.

8.3 OMCSAP DATA ANALYSIS

Using data from a pilot program aimed at addressing driver behavior and reduction in truck driver-at-fault crashes, information on truck inspections and crash data were used to identify the viability of the program. It was determined that due to participating law enforcement agencies and roadway geometry, I-205 was the primary location in which inspections were occurring as a result of driver traffic violations. Although other highways showed an inverse relationship between inspections and crashes, the number of observations were too low to make inference with any high level of confidence. Focusing on I-205, speeding and lane restriction violations were the most observed traffic violations leading to inspections, with following too close and light-related violations being the next highest at just over 3%. In terms of truck driver-at-fault crashes on I-205, following too close, improper lane changes, and failure to maintain lane were the leading causes. It was determined that by the second full year of the program, the anticipated behavior was being observed: increasing inspections leading to a decrease in truck driver-at-fault crashes.

8.4 CRASH DATA ANALYSIS

From the three crash severity models, various contributing factors were identified. Of all the contributing factors, four were found to be significant in each year of crash data and all increasing the likelihood of a more severe crash; albeit, some were found to be heterogeneous across crashes (i.e., increase for some, decrease for some). These factors were: (1) posted speed limits of 50 mi/hr or 55 mi/hr, (2) rear-end crashes, (3) crashes in which the truck was traveling straight, and (4) crashes that occurred due to the truck driver not yielding the right-of-way.

8.5 COST-BENEFIT

Utilizing the data from the pilot program, it was determined that the accumulated change in crash cost since the start of the program has reduced by more than 65%. It was also determined that a more detailed cost-benefit analysis required additional years of "after" data, which was not available at the time of the current study. This will be addressed in the coming recommendation section.

8.6 RECOMMENDATIONS AND FUTURE WORK

Based on analysis results, the research team has the following recommendations.

8.6.1 Agency and Truck Driver Surveys

In regards to the agency surveys, only 24 completed surveys were obtained. It is recommended that additional agency representatives be contacted to increase this sample size. It may also be advantageous to contract out the survey (e.g., Qualtrics) to obtain a much larger sample size. However, contracting out surveys may not be cost effective. Additionally, obtaining additional agency contacts recommended by motor carrier may increase the sample size. To arrive at a sample size in which inference with high levels of confidence can be made, additional contacts are needed, additional surveys should be sent out, and some consideration on contracting out the survey can be considered.

As for truck drivers, the response was great. However, there may be some concerns with self-response bias; that is, drivers who have been in a crash and did not report it in the survey. This can be hard to overcome, but survey-specific statistical approaches exist to address some of these limitations. It is recommended to apply statistical models to such surveys to get a better understanding of what factors lead to drivers' perceptions of specific situations (e.g., lane changing, cell phone use, etc.).

8.6.2 Crash Data Analysis

Due to the nature in which ODOT crash data is now reported, the most recent years of crash data were not used in model development. The most recent years of crash data were not used due to all no injury crashes being coded as "no associated cause." As a result, driver at-fault crashes are unidentifiable for no injury crashes. Therefore, it is recommended that ODOT continue, as in the past, coding driver-related causes with all severity levels. If this is not done, information on no injury crashes (even though the driver is at-fault) cannot be obtained. It is further recommended to assess the temporal stability of factors among years through additional statistical measures. Through future work, it also recommended that a crash rate analysis be conducted. Crash rate was explored in the current work, but model estimates were consistently unstable, requiring additional methods to be explored. Such an analysis would provide insight on exposure-based factors that contribute the number of crash per truck-miles-traveled.

8.6.3 Cost-Benefit

Unfortunately, the methods considered for use in the current project required additional data that was not yet available. On the fortunate side, this data has since been collected and a detailed cost-benefit analysis using such methods is currently underway has part of another ODOT funded project: *SPR-828 - Expanding the Motor Carrier Safety Action Plan*. Due to this, no additional recommendations regarding the cost-benefit analysis are made at this time.

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