Predicting Truck Crash Involvement: 2022 Update

October 2022

Prepared by the American Transportation Research Institute

ATRI American Transportation Research Institute

Predicting Truck Crash Involvement: 2022 Update

October 2022

Abbigail Markus
Research Analyst
American Transportation Research Institute
Minneapolis, MN

Dan Murray
Senior Vice President
American Transportation Research Institute
Minneapolis, MN

Atlanta, GA • Minneapolis, MN • New York, NY • Sacramento, CA

TruckingResearch.org

ATRI BOARD OF DIRECTORS

Judy McReynolds
Chairman of the ATRI Board
Chairman, President and Chief Executive Officer
ArcBest Corporation

Andrew Boyle
Co-President
Boyle Transportation

Hugh Ekberg
President and CEO
CRST International, Inc.

Darren D. Hawkins
Chief Executive Officer
Yellow

Derek Leathers
President and CEO
Werner Enterprises

Robert E. Low
President and Founder
Prime Inc.

Benjamin J. McLean
Chief Executive Officer
Ruan Transportation Management Systems

Dennis Nash
Executive Chairman of the Board
Kenan Advantage Group

Brenda Neville, CAE
President and CEO
Iowa Motor Truck Association

Srikanth Padmanabhan
President, Engine Business
Cummins Inc.

James D. Reed
President and CEO
USA Truck

Lou Rivieccio
President, Corporate Transportation
UPS

John A. Smith
President and CEO
FedEx Ground

Rebecca Brewster
President and COO
ATRI

Chris Spear
President and CEO
American Trucking Associations

ATRI RESEARCH ADVISORY COMMITTEE

Shawn R. Brown, RAC
Chairman
Vice President, Safety
Cargo Transporters

Michael Ahart
VP, Regulatory Affairs
Omnitracs

Ben Banks
Vice President, Operations
TCW, Inc.

Hayden Cardiff
CEO and Founder
Idelic

Joe Darby
Director, Safety and Risk Control, Transportation and Logistics Practice
Aon

Bob Elkins
Senior Vice President, Industry Vertical Operations
Ruan Transportation Management

Gary Falldin
Sr. Director, Industry Solutions
Trimble

Melanie Feeley
Account Manager
Pilot Company

James P. Fields
Chief Operating Officer
Pitt-Ohio, LLC

Rickey Fitzgerald
Manager, Freight and Multimodal Operations
Florida Department of Transportation

Steven Garrish, CDS
Vice President, Safety and Compliance
Old Dominion Freight Line

Rob Haddock
Group Director, Planning and Logistics
Coca-Cola North America

Glen Kedzie
Vice President, Energy and Environmental Affairs Counsel
American Trucking Associations

Kevin Lhotak
President
Reliable Transportation Specialists

Mike Ludwick
Chief Administrative Officer
Bison Transport

Steve Olson
President and Chief Underwriting Officer
Great West Casualty Company

Clay Porter
Attorney
Porter, Rennie, Woodard, Kendall, LLP

Dustin Ragon
Lieutenant Commercial Carrier
Wyoming Highway Patrol

Jeremy Reymer
Founder and CEO
DriverReach

Rob Rhea
Senior Vice President and General Counsel
FedEx Freight

Amanda Schuier
Director of Employee Engagement
Jetco Delivery

Joe Sculley
President
Motor Transport Association of Connecticut

Shelly Seaton
Vice President, Loss Prevention
Landstar

Russ Simpson
America's Road Team Captain
Yellow

Monique Stinson
Computational Scientist
Argonne National Laboratory

Daniel Studdard
Principal Planner, Transportation Access and Mobility Division
Atlanta Regional Commission

Randy Vernon
Chief Executive Officer
Big G Express

Doug Voss
Arkansas Highway Commission Endowed Chair
University of Central Arkansas

Tom Weakley
Director of Operations
Owner-Operator Independent Drivers Association Foundation

John Whittington
Vice President, Legislative Affairs
Grammer Logistics

ACKNOWLEDGEMENTS

The American Transportation Research Institute (ATRI) would like to thank Dr. Brenda Lantz for her important contribution to the driver data analysis. Dr. Lantz is a specialist in commercial vehicle safety research, and she currently serves as the Associate Director of the Upper Great Plains Transportation Institute at North Dakota State University. ATRI would also like to express appreciation to the numerous State Trucking Association executives and Commercial Vehicle Safety Alliance (CVSA) staff who were interviewed for this study.

TABLE OF CONTENTS

TABLES AND FIGURES

LIST OF ACRONYMS

ATRI	American Transportation Research Institute
BASIC	Behavior Analysis and Safety Improvement Categories
BLS	Bureau of Labor Statistics
CDL	Commercial Driver's License
CDLIS	Commercial Driver's License Information System
CMV	Commercial Motor Vehicle
CMVSA	Commercial Motor Vehicle Safety Act
CRSS	Crash Report Sampling System
CSA	Compliance, Safety, and Accountability
CVSA	Commercial Vehicle Safety Alliance
ELD	Electronic Logging Device
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GES	General Estimates System
GVWR	Gross Vehicle Weight Rating
HOS	Hours-of-Service
ISS	Inspection Selection System
LED	Light Emitting Diode
MCMIS	Motor Carrier Management Information System
NHTSA	National Highway Traffic Safety Administration
OOS	Out-of-Service
RAC	Research Advisory Committee
SEA	Safety Evaluation Area
SMS	Safety Measurement System
STA	State Trucking Association
TACT	Ticketing Aggressive Cars and Trucks
UGPTI	Upper Great Plains Transportation Institute
U.S. DOT	United States Department of Transportation
VMT	Vehicle Miles Traveled
WIT	Women in Trucking

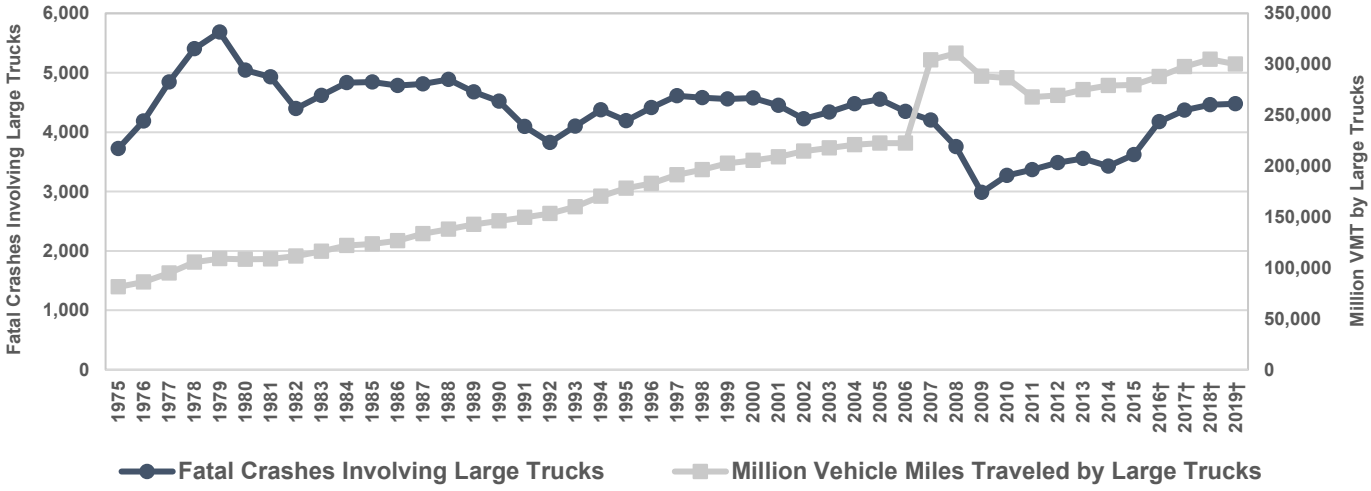
INTRODUCTION

Safety is the top priority in the trucking industry, with motor carriers, professional drivers, and myriad government agencies all focused on reducing truck-involved crashes. The industry's efforts have generally shown promise: from 2005 – 2010, fatal truck-involved crashes decreased significantly by 24.8 percent.[1] Unfortunately, recent upticks in truck crashes may negate the long-term progress.

The Federal Motor Carrier Safety Administration (FMCSA) reports statistics on large truck and bus crashes. The current data includes statistics from 1975 – 2019. When examining the relationship between fatal crash trends and total vehicle miles traveled (VMT) by trucks, it would be anticipated that crashes would increase at the same rate as VMT. However, that is not the case. Figure 1 shows steady VMT growth while total fatal truck-involved crashes remained relatively stable.[2] In fact, the average annual number of fatal truck-involved crashes between 1975 and 2019 was 4,334. In 2019, a total of 4,479 fatal truck-involved crashes were reported. Since 2016, fatal truck-involved crashes have increased by 7.2 percent. Additionally, the number of fatal truck crashes per 100 million VMT has seen an increase of 2.8 percent.

There are two items worth noting. VMT in 2007 and fatal crashes in 2016 both experienced abnormal shifts. This is due to new methodologies being implemented by the U.S. Department of Transportation (U.S. DOT).[3] Looking specifically at data between 2008 and 2015, where the methodology remained consistent for both metrics, the maximum VMT was 311 billion miles in 2008. In 2009, the lowest number of fatal crashes (2,983) occurred.

Figure 1: Fatal Crashes Involving Large Trucks and Million VMT by Large Trucks, 1975 – 2019



[1] "Trends Table 4. Large Truck Crash Statistics, 1975 – 2019," *Large Truck and Bus Crash Facts 2019*, FMCSA (October 2021).
[2] Ibid.
[3] The Federal Highway Administration (FHWA) implemented new methodology in 2007. The estimations for registered vehicles and VMT by vehicle type were impacted due to this. The reported numbers vary drastically from previous years, which is likely the cause of this substantial growth in VMT. FMCSA utilizes data from the National Highway Traffic Safety Administration (NHTSA). In 2017, NHTSA replaced their General Estimates System (GES) with the Crash Report Sampling System (CRSS). While both are samples of police-reported crashes, CRSS includes a more efficient and flexible sample by utilizing traffic and demographic information. The † denoted next to 2016 – 2019 in Figure 1 indicate this change in methodology.

Since 2011, both fatal crashes involving large trucks and total truck VMT have seen an increase. Identifying crash causal factors can assist industry and government in determining and implementing preventative measures and regulatory changes.

To target the recent increase in truck-involved crashes, the American Transportation Research Institute (ATRI) has updated its Crash Predictor research, first published in 2005.[4] The concept of the Crash Predictor report originated in 2004 with ATRI's Research Advisory Committee (RAC) members, who identified the need for an analytical tool that could predict the future likelihood of truck crash involvement based on inspection data.[5]

In 2005, ATRI partnered with the North Dakota State University Upper Great Plains Transportation Institute (UGPTI) and the Commercial Vehicle Safety Alliance (CVSA) to pursue the RAC's identified research objectives and complete the first iteration of the Crash Predictor report. In this first report, statistical methods were utilized to accurately develop a model for predicting future crash involvement. To do this, ATRI analyzed several truck driver-specific data sets in order to establish a relationship between previous driver crashes, violations, convictions, and future likelihood of crashes. Beyond this model, the research described effective enforcement and industry countermeasures to provide insight into what problem behaviors to monitor to avoid future crash involvement.

Recognizing the changes in enforcement strategies, safety technology adoption, regulatory environment, and industry practices, ATRI updated the Crash Predictor report in 2011 and 2018.[6] Like the original 2005 report, individual driver behaviors were again statistically analyzed to produce accurate risk assessments. While numerous behaviors in the 2011 and 2018 reports remained statistically significant, there was a general decrease in the strength of the driver history and crash relationship in 2011; this was likely due to the changes in the industry's safety landscape. The 2018 study saw an increase in strength in the relationship between driver history and crashes, closer to the trends seen in the 2005 report. The 2018 study also included an in-depth analysis of the relationship between age and gender with the probability of crash involvement, violations, and convictions.[7]

Four years have passed since the release of the last Crash Predictor report. Since then, the trucking industry has experienced substantial changes in the regulatory environment, technology adoption, safety performance and working conditions. Similar to previous iterations, this Crash Predictor update includes the crash likelihood increase model utilizing previous violations, convictions and crashes. In addition, this report will explore recent regulatory changes and their impacts on violations, younger driver safety, gender inspection trends and the relationship between crashes and traffic enforcement inspections. Finally, the time periods used in this report generally precede the COVID pandemic. Accordingly, it provides a useful baseline assessment for future analyses relating to truck crashes under post-pandemic conditions.

[4] Daniel Murray, Brenda Lantz, and Stephen Keppler, *Predicting Truck Crash Involvement: Developing a Commercial Driver Behavior-Based Model and Recommended Countermeasures*, ATRI (October 2005).
[5] ATRI's RAC is comprised of industry stakeholders representing motor carriers, trucking industry suppliers, federal government agencies, labor and driver groups, law enforcement, and academia. The RAC is charged with annually recommending a research agenda for the Institute.
[6] Micah D. Lueck and Daniel Murray, *Predicting Truck Crash Involvement: A 2011 Update,* ATRI (April 2011).
[7] Caroline Boris and Dan Murray, *Predicting Truck Crash Involvement: 2018 Update*, ATRI, (July 2018).

BACKGROUND

The main research objective of ATRI's inaugural Crash Predictor report in 2005 was to determine whether a driver performance-based indicator with significant safety-based correlational and predictive ability could be developed. Various studies prior to the initial 2005 *Predicting Truck Crash Involvement* report were carrier performance-based rather than driver performance-based. These studies laid the groundwork for the development of ATRI's initial Crash Predictor study.

Several foundational truck safety studies were analyzed for the first Crash Predictor report and are described below.

The Driver/Carrier Data Relationship (1996) project examined 1994 traffic citation data. However, at the time, most states did not identify carriers when issuing citations, so it was difficult to track the relationship between driver and carrier safety. The data utilized was from Indiana and Michigan because state police in these two states did identify the carrier when issuing citations. The primary research finding was that driver citation rates significantly differ among carriers. In addition, there was a positive correlation between driver citation rates for a carrier and crash rates for that carrier. In summation, the higher a carrier's citation rate, the higher its crash rate.[8]

Without national traffic citation data nor a reporting standard among state databases, identifying higher risk motor carriers nationwide based on citation data was not feasible. It requires that state police officers record U.S. DOT carrier numbers on traffic citations for accurate motor carrier identification.

In 1998, North Carolina ranked fourth in the nation for the number of trucks involved in fatal crashes. The University of North Carolina Highway Safety Research Center released research examining the effectiveness of state enforcement efforts. Utilizing carrier data, the research found that "serious driving violations" were strong predictors of crashes, and that fatal truck-involved crashes were reduced between 1995 and 1998 through an increase in commercial motor vehicle (CMV) enforcement.[9]

In 2001, UGPTI and FMCSA published *An Analysis of Commercial Vehicle Driver Traffic Conviction Data to Identify High Safety Risk Motor Carriers*. The investigation involved 13,829 carriers with a total of 64,711 drivers. This study created a carrier-driver-conviction measure and found that the average number of driver convictions associated with the carriers was significantly correlated with the carriers' out-of-service (OOS) rates, crash rates, and SafeStat Safety Evaluation Area (SEA) scores. It was concluded that by linking drivers' conviction data to their employer, motor carriers were more likely to have crashes could be identified.[10]

A subsequent study was published in 2006. *Development and Implementation of a Driver Safety History Indicator into the Roadside Inspection Selection System* found that a company's lack of driver safety management culture was an indicator of poor overall safety performance.

[8] AAMVAnet, Inc. and Keane Federal Systems, "Driver/Carrier Data Relationship Project," FMCSA (formerly the Office of Motor Carriers, Federal Highway Administration) (September 1996), https://rosap.ntl.bts.gov/view/dot/5298.
[9] Ronald G. Hughes, "Truck Safety in North Carolina: Effectiveness of NCDMV Enforcement Efforts in FY99," The University of North Carolina at Chapel Hill, Highway Safety Research Center Publications (2000).
[10] Brenda Lantz and Michael Blevins, "An Analysis of Commercial Vehicle Driver Traffic Conviction Data to Identify High Risk Motor Carriers" (September 2001), https://www.ugpti.org/research/details.php?id=7.

Additionally, the research sought to develop a new Inspection Selection System (ISS) algorithm to account for driver convictions associated with specific motor carriers.[11]

FMCSA's *Large Truck Crash Causation Study,* also published in 2006*,* examined large truck fatal and injury crashes between 2001 and 2003 in 17 states. The results of this study showed that driver factors played a critical role in 88 percent of fatal and injury crashes. The study also found that the most common associated factors recorded for both fatal and injury crashes were traveling too fast for conditions, making illegal maneuvers, illegal drug use, unfamiliarity with the roadway, and driver fatigue.[12]

[11] Brenda Lantz, *Development and Implementation of a Driver Safety History Indicator into the Roadside Inspection Selection System,* FMCSA (April 2006), https://www.ugpti.org/research/downloads/ISS-DFinalReport.pdf.

[12] Marc Starnes, *Large Truck Causation Study: An Initial Overview*, FMCSA (March 2006), https://rosap.ntl.bts.gov/view/dot/61143.

METHODOLOGY

The methodology in the Crash Predictor reports was originally designed around statistical analyses of driver and crash data. With three previous Crash Predictor reports released in 2005, 2011 and 2018, the core analysis has undergone little variation. All four reports have included a chi-square analysis as the primary statistical test for identifying key "crash predictors." The original report released in 2005 did an additional stepwise logistic regression analysis. The stepwise logistic regression created a model based on the relationship and significance of different behaviors, unlike the chi-square analysis, where the behaviors are independent of one another. This report repeats the same statistical analyses to determine what shifts may have occurred over a longer period of time. A breakdown of the four Crash Predictor reports' primary statistical tests is shown in Table 1.

Table 1: Primary Statistical Tests Used in ATRI Crash Predictor Reports

Primary Tool Used	2005	2011	2018	2022
Chi-square Analysis	Yes	Yes	Yes	Yes
Stepwise Logistic Regression	Yes	No	No	Yes

The chi-square analysis assesses whether there is a significant probability of future crash rates for truck drivers – based on past violation, conviction and/or crash data. This test of independence analyzes the difference between observed frequency (drivers with a violation, conviction or crash) in the sample versus the expected probability of crashes in the larger population. By first establishing the existence of a relationship, and then the strength of the significance, this analysis documents which driving behaviors are more likely to result in a future crash. All data that were used, and the resulting chi-square analysis results, can be found in Appendix A.[13]

This latest Crash Predictor update is once again utilizing a stepwise logistic regression analysis. This creates a predictive model with the non-continuous dependent variable of future crash involvement. The stepwise logistic regression creates an ordered model of joint violations, convictions and crashes beginning with the most significant. This is done by comparing neighboring models in the sequence, and then terminating when the model appears superior to its "neighbors" by considering different statistical properties. This particular model is useful for examining drivers with multiple violations, convictions and/or crashes.

The chi-square analysis, which is the core statistical test used to develop the top Crash Predictor list, is appropriate because it looks at each violation, conviction and crash separately; each output has its own identifiable significance. Whereas the stepwise logistic regression looks at a combination of significant behaviors – how different violations / behaviors may significantly impact one another. In stepwise logistic regression, a combination of forward and backward selection is utilized in order to build a model that accounts for significance with all the variables. The most significant behavior is added to the model first, then the second with the first selected behavior already included. Each time a behavior is added, the behaviors in the model are reevaluated to ensure significance is still present. The model is complete once all significant behaviors are included.

[13] Data used for the 2005, 2011 and 2018 Crash Predictor analyses can be found in their respective reports, available online at www.TruckingResearch.org.

Both serve their own purpose but together help provide context to driver behaviors and crash risk on the road.

Data Collection and Analysis

In order to commence the chi-square analysis and stepwise logistic regression, driver-specific data were obtained from both the Motor Carrier Management Information System (MCMIS) and the Commercial Driver's License Information System (CDLIS).

The main dependent variable of interest is a measure of "safety" for drivers. For this study, safety is defined primarily by crash involvement. The driver-specific crash data used in this analysis are readily available through MCMIS.

The independent variables for this study are any driver-specific performance indicators that can be mined from sample data. These include specific violations identified during roadside inspections (driver, vehicle, or moving violations, available through MCMIS); driver traffic conviction information (available through CDLIS); as well as any past crash involvement information (available through MCMIS).

The violations used in this Crash Predictor analysis arise from roadside inspections. Roadside inspection data, including all violations, are maintained in the MCMIS database. If a roadside inspection is associated with a traffic enforcement stop, the traffic enforcement-related violations noted on the inspection report are also maintained in MCMIS. A traffic enforcement violation may also result in a citation (e.g. speeding ticket).

Nationwide, every month there are approximately 200,000 unique drivers involved in a roadside or traffic enforcement inspection. Over a one-year period, there are approximately 2 to 2.5 million unique drivers identified in MCMIS through inspections. Consistent with the 2005, 2011 and 2018 studies, this analysis created an initial driver database comprised of drivers who had received an inspection during the three months of January through March 2019. A total of 583,805 unique U.S.-based truck drivers were identified, on which this year's analysis is based. It should be noted that MCMIS and CDLIS do not have all of the same variables. Therefore, the exact amount of data differs between crash-based analyses and inspection-based analyses.

MCMIS Inspection Data

MCMIS is an FMCSA-maintained database of carrier-based information regarding crashes and roadside inspections of CMVs and drivers. Most crash and inspection reports in MCMIS identify both the truck driver and the motor carrier that the truck driver was working for at the time of the crash or inspection. There are approximately 3.5 to 4 million roadside inspections, and 150,000 crashes reported each year. MCMIS also contains census information regarding each motor carrier (i.e., address, number of power units, number of drivers, cargo carried, etc.).

The 583,805 drivers had a total of 1,276,839 Level I, II, III, or IV roadside inspections between January 1, 2017 and December 31, 2018. Table 2 breaks down the results from the inspection types conducted during this time-period. The number of inspections that resulted in one or more vehicle and driver violations is included along with the number of trucks and drivers placed

OOS.[14] If inspections had occurred uniformly throughout the year, approximately 8.3 percent of the total inspections would occur each month. More than 9 percent of each year's inspections occurred in August or October. January and February experienced the lowest percentage of inspections in both years at approximately 7.5 percent on average.

Table 2: Inspections by Level, Driver Impact and Vehicle Impact

Inspection Classification	Count	Percentage
Level of Inspection		
Level I	392,030	30.7%
Level II	451,996	35.4%
Level III	432,027	33.8%
Level IV	786	0.10%
Driver Inspections		
Driver Violation	297,655	23.3%
Driver OOS	54,753	4.3%
Vehicle Inspections		
Vehicle Violation	450,848	53.4%
Vehicle OOS	166,556	19.7%

There were 1,785,056 specific violations associated with these inspections. Table 3 shows the top 20 violations based on frequency of occurrence. These 20 violations account for 94.7 percent of all violations issued. A full list of violations can be found in Appendix B. The violations indicated with an asterisk are driver behavior violations (vs vehicle violations), which are the primary focus of ATRI's Crash Predictor analyses. Of the 1,785,056 total violations, only 515,650 (28.9%) are driver behavior violations. In the 2018 study, truck driver behavior violations accounted for 29.0 percent of total violations, maintaining a highly consistent rate over time.

[14] The percentages calculated under Vehicle Inspections exclude Level III inspections (Driver / Credential / Administrative Inspection Procedure); "All Inspection Levels," CVSA, https://www.cvsa.org/inspections/all-inspection-levels/.

Table 3: Top 20 Most Frequently Occurring Violations

Violation Description	Frequency	Percent
Lighting	290,899	16.3%
All Other Vehicle Defects	249,700	14.0%
Brakes - All Others	237,853	13.3%
All Other Hours-Of-Service (HOS)*	116,902	6.5%
All Other Driver Violations*	112,850	6.3%
Tires	106,194	5.9%
Brakes - Out of Adjustment	91,302	5.1%
Size And Weight*	84,190	4.7%
Speeding*	51,703	2.9%
Emergency Equipment	50,317	2.8%
Windshield	47,528	2.7%
Periodic Inspection	45,134	2.5%
No Log Book - Log Not Current*	41,750	2.3%
Load Securement	39,136	2.2%
Wheels – Studs – Clamps	27,645	1.5%
10/15 Hours*	21,933	1.2%
Suspension	21,385	1.2%
False Log Book*	20,645	1.2%
Failure To Obey Traffic Control Device*	17,763	1.0%
Seat Belt*	15,317	0.9%
Total	**1,690,146**	**94.7%**

*Driver Behavior Violation

MCMIS Crash Data

Between January 1, 2017 and December 31, 2018, the 583,805 truck drivers had 38,797 crashes reported to FMCSA, with the majority (65.6%) being towaway crashes (Figure 2).

Figure 2: Crashes by Type [15] [16]

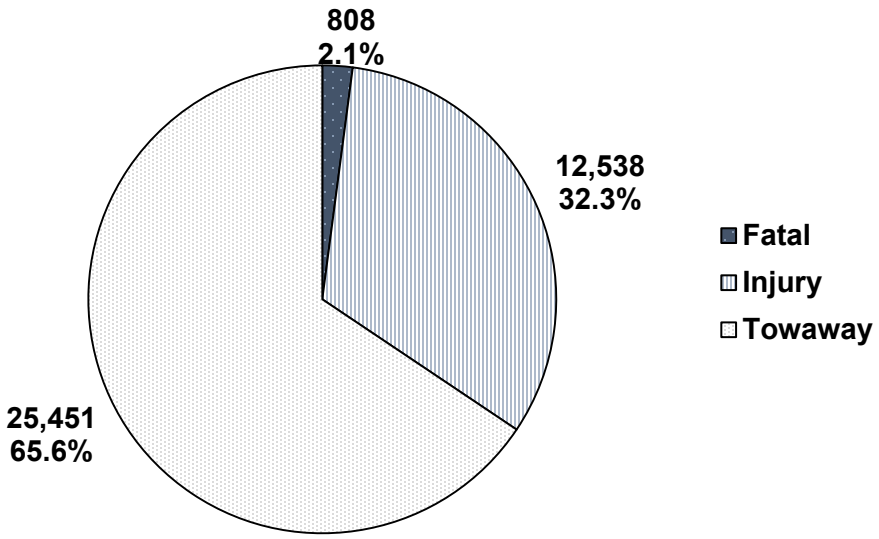


Table 4 illustrates the number of crashes each driver was involved in between January 1, 2017 and December 31, 2018. Over 90 percent of the 583,805 drivers in this analysis were not involved in any crashes. Approximately 34,117 (5.8%) were involved in one crash, and 1,881 (0.32%) were involved in two crashes. Only 89 drivers (0.01%) were involved in three or more crashes.

Table 4: Driver Crash Involvement

Number of Crashes	Number of Drivers	Percent
0	547,717	93.8%
1	34,117	5.8%
2	1,881	0.32%
3	81	0.01%
4	6	0.00%
5	2	0.00%

[15] For fatal crashes, a large truck is defined as a truck with a gross vehicle weight rating (GVWR) greater than 10,000 pounds. For injury and towaway crashes, a large truck is defined here as a truck, used for commercial purposes, with a GVWR or gross combination weight rating greater than 10,000 pounds, or any vehicle carrying hazardous material that requires placarding, regardless of weight. Injury crashes are defined here as crashes that resulted in at least one injury involving immediate medical attention away from the crash scene. Note that this definition of an injury crash is not the same as that used in the Crash Report Sampling System injury estimates presented in other tables of this report. Towaway crashes are defined here as crashes in which at least one vehicle was disabled as a result of the crash and transported away from the crash scene.

[16] "Truck and Bus Crashes Reportable to FMCSA," FMCSA (October 2021), https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Truck_and_Bus_Crashes_Reportable_to_FMCSA.pdf.

CDLIS Conviction Data

CDLIS was created out of the passage of the Commercial Motor Vehicle Safety Act (CMVSA) of 1986. It is the only existing nationwide source of commercial driver's license (CDL) traffic conviction data. Sometimes described as a "pointer system," CDLIS is a distributed relational database that provides a linkage between the various state driver records systems using a central index. CDLIS has been in full operation since April 1992. The central index serves as a clearinghouse for the 51 jurisdictions (the 50 states and the District of Columbia) to check information before issuing a CDL to ensure that no other state has issued a vehicle license in any other jurisdiction. It also assists states in reporting out-of-state convictions to the licensing state so they can be added to the truck driver's record.

CDLIS is used in the ATRI analysis for driver conviction records, date of birth, gender and CDL class.

Truck drivers in the ATRI analysis were first identified through roadside inspections in January, February, and/or March 2019. This resulted in 583,805 unique drivers. The CDLs for these drivers were then queried through CDLIS. Crash, violation, and conviction data were collected for the drivers between January 1, 2017 and December 31, 2018.

As displayed in Table 5, 38,336 drivers had one or more convictions, and 451,985 drivers had no convictions during this period. This data set also included 93,484 drivers who did not have matching results in the CDLIS database; this is deemed to be a normal return rate due to errors in data entry or system downtime.

Table 5: CDLIS Conviction Data Breakdown of the Total 583,805 Drivers Inspected

At Least One Conviction		No Convictions		Not Matched	
38,336	6.6%	451,985	77.4%	93,484	16.0%

The type of CDL for each driver is identified in CDLIS. While multiple vehicle configurations are inspected, it does focus heavily on tractor-trailer combinations. In this report, "truck driver" refers to an individual who holds either a Class A, B, or C CDL (as all three are subject to an inspection). Of the 394,447 drivers matched in this analysis, 363,021 drivers held a Class A CDL (92.0%).

FINDINGS: CHI-SQUARE ANALYSIS

Table 6 contains a summary of the Crash Predictor chi-square analysis. The list is rank ordered by the percentage increase in future crash probability, based on specific violations, convictions and prior crashes.

Table 6: Crash Predictor Analysis

Driver Behavior	Future Crash Likelihood Increase	Sig
A Failure to Yield Right-of-Way violation	141%	***
A Failure to Use / Improper Signal conviction	116%	***
A Past Crash	113%	***
A Reckless Driving violation	104%	*
A Failure to Obey Traffic Sign conviction	85%	**
A Failure to Keep in Proper Lane conviction	78%	**
An Improper or Erratic Lane Changes conviction	77%	***
A Reckless / Careless / Inattentive / Negligent Driving conviction	62%	***
An Improper Lane / Location conviction	61%	***
A Failure to Obey Traffic Signal / Light conviction	55%	***
A Disqualified Driver violation	53%	***
A False or No Log Book violation	49%	***
A Speeding 1 to 15 Miles Over Speed Limit conviction	48%	***
An HOS violation	47%	***
A Speeding violation	47%	***
Any conviction	46%	***
An Improper Turn conviction	45%	*
A Following Too Close violation	44%	***
Any Moving violation	43%	***
A Speeding More Than 15 Miles Over Speed Limit conviction	40%	***
An Improper Lane Change violation	39%	**
A Failure to Obey Traffic Control Device violation	34%	***
A Size and Weight violation	31%	***
Any OOS violation	29%	***
A Driving Too Fast for Conditions conviction	27%	*
A Failure to Obey Warning Light / Flasher conviction^	243%	*
An Improper Pass conviction		ns
A Following Too Closely conviction		ns
An Improper Passing violation		ns
An Improper Turns violation		ns
A Failure to Yield Right-of-Way conviction		ns
A Failure to Obey Yield Sign conviction		ns

*** Significant at $p < 0.001$
** Significant at $p < 0.01$
* Significant at $p < 0.05$
^ Chi-square test not reliable due to small sample size
ns Not Significant, $p \geq 0.05$

A Failure to Yield Right-of-Way violation, Failure to Use / Improper Signal conviction and Reckless Driving violation were strong indicators of future crash likelihood. All three increased crash likelihood by more than 100 percent. Comparing findings from the 2018 Crash Predictor report to this year's analysis:

- A Failure to Yield Right-of-Way violation increased crash likelihood by 141 percent, a 39.6 percent increase from 2018 to 2022;
- A Failure to Use / Improper Signal conviction increased crash likelihood by 116 percent, a 41.5 percent increase from 2018 to 2022;
- Reckless Driving violation increased crash likelihood by 104 percent, an 8.8 percent decrease from 2018 to 2022.

Prior crash involvement has consistently been a strong indicator of future crash involvement across all previous iterations of the ATRI Crash Predictor model. This latest analysis found that prior crash involvement had a 113 percent increased likelihood of a future crash, 28.4 percent higher than previous reports.

Nine other violation categories had a statistically significant relationship with future crashes, with increased crash likelihoods between 31 and 53 percent. Twelve other conviction categories had a statistically significant relationship with future crashes, with the majority above 50 percent increased likelihood of a future crash.

Drivers with any OOS violation were 29 percent more likely than their peers to be involved in a future crash, and drivers with a moving violation were 43 percent more likely to be involved in a future crash. Lastly, any conviction increased future crash likelihood by 46 percent.

Comparing Findings Across Four Crash Predictor Studies

ATRI's research has documented that crash involvement is associated with a variety of driver behaviors. While there has been some variation in the strength of predictability of future crashes, several behaviors have consistently ranked high in ATRI's reports. Table 7 shows the top 10 predictors of future crash risk across the four Crash Predictor reports. Appendix C has a comparison of all driver behaviors.

An Improper or Erratic Lane Changes conviction and Past Crash have been in the top 10 rankings for all four iterations, while several others were top-10 ranked behaviors in three of the four studies

Table 7: Comparison of Top 10 Predictors of Future Crash Involvement Across All Four ATRI Crash Predictor Models

Rank	Driver Behavior and Associated Increase in Future Crash Probability			
	2005	2011	2018	2022
1	A Reckless Driving violation (325%)	A Failure to Use / Improper Signal conviction (96%)	A Reckless Driving violation (114%)	A Failure to Yield Right-of-Way violation (141%)
2	An Improper Turn violation (105%)	A Past Crash (88%)	A Failure to Yield Right-of-Way violation (101%)	A Failure to Use / Improper Signal conviction (116%)
3	An Improper or Erratic Lane Changes conviction (100%)	An Improper Pass violation (88%)	A Failure to Keep in Proper Lane conviction (83%)	A Past Crash (113%)
4	A Failure to Yield Right-of-Way conviction (97%)	An Improper Turn conviction (84%)	A Failure to Use / Improper Signal conviction (82%)	A Reckless Driving violation (104%)
5	An Improper Turn conviction (94%)	An Improper or Erratic Lane Changes conviction (80%)	A Past Crash (74%)	A Failure to Obey Traffic Sign conviction (85%)
6	A Failure to Keep in Proper Lane conviction (91%)	An Improper Lane / Location conviction (68%)	An Improper Lane / Location conviction (72%)	A Failure to Keep in Proper Lane conviction (78%)
7	A Past Crash (87%)	A Failure to Obey Traffic Sign conviction (68%)	An Improper Pass conviction (70%)	An Improper or Erratic Lane Changes conviction (77%)
8	An Improper Lane Change violation (78%)	A Speeding More Than 15 Miles Over Speed Limit conviction (67%)	A Reckless / Careless / Inattentive / Negligent Driving conviction (69%)	A Reckless / Careless / Inattentive / Negligent Driving conviction (62%)
9	A Failure to Yield Right-of-Way violation (70%)	Any conviction (65%)	An Improper or Erratic Lane Changes conviction (66%)	An Improper Lane / Location conviction (61%)
10	A Driving Too Fast for Conditions conviction (62%)	A Reckless / Careless / Inattentive / Negligent Driving conviction (64%)	An Improper Lane Change violation (63%)	A Failure to Obey Traffic Signal / Light conviction (55%)

In Top 10 in 4 ATRI Crash Predictor Models

In Top 10 in 3 ATRI Crash Predictor Models

Table 8 displays the top five stable predictors of crash risk, based on a comparative assessment of the four ATRI Crash Predictor reports calculated using the median likelihood value from the four studies.

Table 8: Top Five Stable Predictors of Crash Risk

Violation / Conviction / Crash Type	Median Crash Likelihood Across All Four ATRI Crash Predictor Models
Reckless Driving violation	114%
Failure to Use / Improper Signal conviction	89%
Past Crash	88%
Failure to Yield Right-of-Way violation	85%
Improper or Erratic Lane Changes conviction	79%

FINDINGS: STEPWISE LOGISTIC REGRESSION

Logistic regression is a statistical modelling technique that uses potential explanatory variables to predict a binary outcome. For this study, the outcome is whether or not an individual truck driver is involved in a crash, and the potential explanatory variables include if the driver had a prior crash, particular inspections, moving violations, and/or driving convictions.

A stepwise procedure is useful when there are a large number of potential explanatory variables. The procedure first analyzes every variable and determines the one that is most significant in predicting the outcome. It then analyzes the remaining variables to determine the next one that is most significant, adding to the model given the first variable already included. As each new variable is entered into the model, the procedure will verify if all variables are still significant. If one is no longer significant, it will be removed from the model. The procedure continues until there are no more variables that are significant in predicting the outcome, given the variables already in the model. The final model is used to assess the probability that a driver will be involved in a future crash based on his/her combination of past behaviors.

For example, in both the 2005 iteration and again in this report, a False / Log Book violation entered the model first. Both a Past Crash and an Hours-of-Service violation were in the top five behaviors to enter the model. Finally, four other behaviors were also in the 2005 Crash Predictor Report: a Size and Weight violation (entered the model 7th); Speeding violation (8); Failure to Obey Traffic Control Device violation (13); and Failure to Yield Right-of-Way violation (14).

Every independent variable in Table 7 was included in the initial model with 217,815 available drivers. The research used a stepwise logistic regression procedure to determine the variables that, when combined into one overall model, were most significant. Unlike in the chi-square analysis, these behaviors are not independent. Table 9 displays the overall model, listed in order of the most significant variable.

Parameter estimates measure the impact of each safety infraction on a crash outcome in the model. Estimates are translated into an odds ratio: the increased likelihood that a driver who committed that infraction will be involved in a subsequent crash. So, for example, a driver involved in a past crash is 1.48 times more likely to have a future crash than a driver without a past crash.

Table 9: Overall Stepwise Regression Model

Parameter	Estimate	Standard Error	Wald Chi-Square	Probability > Chi Sq	Odds Ratio
Intercept	-3.0504	0.0116	69374.529	<0.0001 ***	
False or No Log Book violation	0.1478	0.0197	56.5095	<0.0001 ***	1.16
A Past Crash	0.3894	0.0365	113.6926	<0.0001 ***	1.48
Speeding violation	0.2302	0.0262	77.275	<0.0001 ***	1.26
Hours-of-Service violation	0.1228	0.0149	67.6663	<0.0001 ***	1.13
Size and Weight violation	0.1072	0.0165	42.3807	<0.0001 ***	1.11
Speeding More Than 15 Miles Over Speed Limit conviction (Serious)	0.2254	0.0364	38.3025	<0.0001 ***	1.25
Failure to Obey Traffic Sign conviction	0.3774	0.104	13.1745	0.0003 ***	1.46
Failure to Yield Right-of-Way violation	0.7596	0.2053	13.6954	0.0002 ***	2.14
Failure to Obey Traffic Control Device violation	0.1546	0.048	10.3852	0.0013 **	1.17
Improper or Erratic Lane Changes conviction (Serious)	0.3372	0.1054	10.2411	0.0014 **	1.40
Failure to Obey Warning Light / Flasher conviction	1.7931	0.669	7.1842	0.0074 **	6.01
Failure to Use / Improper Signal conviction	0.6618	0.2362	7.8465	0.0051 **	1.94
Failure to Obey Traffic Signal / Light conviction	0.2875	0.1024	7.8773	0.005 **	1.33
Improper Lane / Location conviction	0.2414	0.1018	5.6271	0.0177 *	1.27

ADDITIONAL ANALYSES

Violation Trends

As noted, the Crash Predictor analysis looks exclusively at driver behaviors. An additional analysis was done to compare the change in MCMIS violations from the 2018 report to this year's analysis. Additional insight into shifts in the frequency of violation distribution over the four years was provided through stakeholder interviews.

The frequency at which violations are issued can change over time. Stakeholder interviewees indicated that this may be the result of changing traffic enforcement strategies, changes in statewide traffic safety programs or funding, and/or more local efforts focusing on specific roadways, corridors or geographic regions.

One key benefit of ATRI's Crash Predictor research is to help law enforcement officers, safety inspectors and trucking industry personnel focus mitigation efforts on those truck driver behaviors that have the greatest nexus to crashes.

Table 10 displays the number of violations from the 2018 and 2022 reports, as well as the percentage change between these two time periods. Only violations with a count difference greater than 1,000 are included in this table. Three violations that are statistically significant predictors of future crash likelihood are not included in this table, based on their extremely low counts within the overall data set:

- Reckless Driving – 0.01 percent of 2022 violations;
- Failure to Yield Right-of-Way – 0.03 percent of 2022 violations; and
- Following Too Close – 0.19 percent of 2022 violations.

Table 10: Violation Percentage Changes from 2018 to 2022

Description	2018 Count	2022 Count	Percentage Change
Violations Increasing Over Time			
Traffic Enforcement	1,107	4,299	288.3%
Unknown	5,019	11,519	129.5%
Vehicle Suspension	9,483	21,385	125.5%
Wheels - Studs – Clamps	20,406	27,645	35.5%
Failure To Obey Traffic Control Device	13,502	17,763	31.6%
Periodic Inspection	39,766	45,134	13.5%
Load Securement	35,613	39,136	9.9%
Size And Weight	77,104	84,190	9.2%
Seat Belt	14,083	15,317	8.8%
Speeding	47,832	51,703	8.1%
Violations Decreasing Over Time			
State/Local HOS*	7,291	911	-87.5%
60/70/80 Hours*	3,374	1,383	-59.0%
10/15 Hours*	44,467	21,933	-50.7%
Exhaust Discharge	14,540	8,750	-39.8%
No Log Book - Log Not Current*	61,214	41,750	-31.8%
Improper Lane Change	3,805	2,609	-31.4%
Steering Mechanism	17,877	12,572	-29.7%
Medical Certificate	17,511	12,576	-28.2%
Tires	136,599	106,194	-22.3%
Lighting	352,928	290,899	-17.6%
Brakes - Out Of Adjustment	107,799	91,302	-15.3%
Frames	11,339	9,733	-14.2%
False Log Book*	23,090	20,645	-10.6%
All Other HOS*	129,364	116,902	-9.6%
All Other Vehicle Defects	270,951	249,700	-7.8%
Brakes - All Others	253,504	237,853	-6.2%
Emergency Equipment	52,613	50,317	-4.4%
Windshield	49,555	47,528	-4.1%

* Hours-of-Service (HOS) violation

As previously noted, ATRI's crash predictor analyses focused on driver behavior violations and convictions, rather than vehicle-related violations. However, there are changes in mechanical violations that are worth noting. Both brake and lighting violations decreased over time between 2018 and 2022.

One theory for the decrease in brake violations is the increased adoption of disc brakes by the trucking industry. During an industry interview, one brake engineer noted that there is strong evidence that inspectors are not able to conduct thorough inspections on disc brakes with the wheels in place. Without visible pads, it is difficult to determine if the brakes are out of adjustment – even though disc brakes are often described as "self-adjusting."

One theory for the reduction in lighting violations is the increased use of light-emitting diode (LED) lights. LEDs last considerably longer than incandescent lights, and one-piece wiring harnesses are utilized, creating less opportunity for corrosion. When it comes to distributing citations, the existing guidance to CVSA inspectors is limited. The regulation FMVSS108 declares a light must be visible from 500 feet to be legal.[17] However, during an interview an inspector surmised that most inspectors do not walk back the required 500 feet to check visibility, partially because they do not typically measure out 500 feet.

Examining the Relationship Between the Electronic Logging Device (ELD) Mandate and Crash Rates

The ELD mandate was designed to improve compliance with the Hours-of-Service (HOS) rules and as a result, reduce fatigue-related crashes.[18] This analysis compared the MCMIS crash and HOS violation data from the 2018 report and the data for this analysis to explore whether a decrease in crashes occurred. As a reminder, the 2018 report utilized data from 2013-2014, and the MCMIS data in this analysis is from 2017-2018, when mandate first went into effect.

Since 1988, CVSA has conducted its annual International Roadcheck. The International Roadcheck inspectors conduct compliance, enforcement and education initiatives targeted at various elements of motor carrier, vehicle and driver safety, and they typically are focused on a pre-determined issue or violation.[19] This 72-hour International Roadcheck is intensive; 67,603 inspections were conducted in 2018, equating to 15.6 inspections a minute.[20] As a reminder, the 2022 report examined data from 2017 – 2018, during the early-implementation of the ELD mandate. Consequently, the 2018 CVSA International Roadcheck had a focus on HOS compliance.

The data identifies a decrease in the number of HOS violations since the implementation of the ELD mandate. Prior to the ELD mandate, it was ostensibly easier to manipulate paper logbook records, or maintain multiple log books.

[17] "Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices, and Associated Equipment, Adaptive Driving Beam Headlamps," Federal Register (February 2022), https://www.federalregister.gov/documents/2022/02/22/2022-02451/federal-motor-vehicle-safety-standards-lamps-reflective-devices-and-associated-equipment-adaptive.
[18] "ELD Fact Sheet – English Version," FMCSA (October 2017), https://www.fmcsa.dot.gov/hours-service/elds/eld-fact-sheet-english-version.
[19] "International Roadcheck," CVSA, https://www.cvsa.org/programs/international-roadcheck/.
[20] "CVSA Releases 2018 International Roadcheck Results," CVSA (September 11,2018), https://www.cvsa.org/news/2018-roadcheck-results/.

Table 11 shows the trend line changes in crashes and HOS violations from the 2018 report to the 2022 report. The number of drivers that experienced a crash decreased by 7.0 percent and the total number of HOS-related violations decreased by 16.8 percent. .

Table 11: Comparing Crashes and Violations Before and After ELD Implementation

Categories	2018 Report Count	2018 Report Percentage	2022 Report Count	2022 Report Percentage	Percentage Change
Drivers Involved in Crash	31,098	7.1%	38,797	6.6%	-7.0%
Total Drivers in Sample	439,260		583,805		
HOS Violations	268,801	13.7%	203,532	11.4%	-16.8%
Total Violations	1,966,976		1,785,056		

This research was not designed to link correlations or causation between the ELD mandate and driver-fatigue crashes. Currently, there is little research that correlates the empirical relationship between ELD utilization and fatigue-related crashes, although one study conducted by the University of Arkansas offers research with results that conflict with those in presented in Table 11.[21] In addition, results from recent CVSA International Roadchecks indicate consistently high numbers of HOS violations, despite the fact that ELDs are intended to reduce HOS violations.

The University of Arkansas research found that in an attempt to comply with HOS regulations, drivers may be sacrificing other safety practices. For example, one metric documented that single-truck carriers had 43 percent fewer HOS violations, but a 26 percent increase in unsafe driving violations.

The 2021 CVSA International Roadcheck once again focused on HOS compliance. During the 72-hour period, over 40,000 inspections were conducted placing 6,710 CMVs and 2,080 drivers OOS. Of the 2,898 OOS driver violations issued during the 2021 International Roadcheck, over 40 percent were HOS violations.[22] HOS violations are commonly a result of false logs, which accounted for 35.5 percent of the HOS violations during the 2021 International Roadcheck.

One variable likely contributing to the high HOS violation count is the misuse of personal conveyance. Personal conveyance, as defined by FMCSA, "is the movement of a CMV for personal use while off duty."[23] One example of misuse of personal conveyance includes a truck bypassing available resting locations in order to get closer to an unloading point.

Based on the 2021 CVSA International Roadcheck results and FMCSA crash trends presented in Figure 1, crashes continue to go up and HOS violations continue to be frequently distributed despite the ELD mandate. More detailed research and analysis into HOS and ELD technologies should be conducted to understand the relationship between ELDs, HOS and truck-involved crashes.

[21] Andrew Balthrop, Jason W. Miller, and Alex Scott, "Unintended responses to IT-enabled monitoring: The case of the electronic logging device mandate," *Journal of Operations Management* (July 2020), https://onlinelibrary.wiley.com/doi/abs/10.1002/joom.1110.
[22] "CVSA Releases 2021 International Roadcheck Results," CVSA (August 3, 2021), https://www.cvsa.org/news/2021-roadcheck-results/.
[23] "Personal Conveyance," FMCSA (February 2019), https://www.fmcsa.dot.gov/regulations/hours-service/personal-conveyance.

Compliance, Safety and Accountability (CSA) and Crash Likelihood

As was done in the 2011 report, ATRI's Crash Predictor research attempted to find associations between FMCSA's CSA program scores and safety. CSA focuses on safety compliance and enforcement in an effort to statistically link motor carrier and driver safety actions with safety scoring. Both carriers and truck drivers are impacted by CSA, although CSA scores are not available to the public.

As background, a motor carrier's safety data is recorded in FMCSA's Safety Measurement System (SMS). The system considers number of safety violations and inspections, severity of safety violations and crashes, when safety violations occurred (with recent events carrying a heavier weight), the number of trucks/buses a carrier operates along with VMT, and the acute and critical violations found during investigations. FMCSA organizes the SMS data into seven Behavior Analysis and Safety Improvement Categories (BASICs).[24]

Table 12 includes the SMS Violation Severity Weight associated with each violation.[25] Since the Crash Predictor analysis focuses on driver behaviors, only four of the seven BASICs are included. The BASIC severity weights are another methodology for estimating crash risk. Most of the violations that fit into a BASIC violation are statistically significant in increasing crash likelihood in this analysis.

Table 12: CSA BASIC vs. ATRI Crash Likelihood Model

Violations	SMS Violation Severity Weight	Increase in Crash Likelihood
Unsafe Driving BASIC		
Reckless Driving violation	10	104%
Failure to Yield Right-of-Way violation	5	141%
Speeding violation	5	47%
Following Too Close violation	5	44%
Improper Lane Change violation	5	39%
Failure to Obey Traffic Control Device violation	5	34%
Improper Passing violation	5	ns
Improper Turns violation	5	ns
Crash Indicator BASIC		
Past Crash	*	113%
HOS Compliance BASIC		
False or No Log Book violation	7	49%
HOS violation	7	47%
Driver Fitness BASIC		
Disqualified Driver violation	8	53%

ns Not Significant
* Weights are assigned to crashes contingent on crash severity (fatal, injury and towaway)

[24] The seven categories include Unsafe Driving, Crash Indicator, HOS compliance, Vehicle Maintenance, Controlled Substances/Alcohol, Hazardous Materials Compliance and Driver Fitness.
[25] The violation severity weights in the tables that follow have been converted into a scale from 1 to 10, where 1 represents the lowest crash risk and 10 represents the highest crash risk relative to the other violations in the BASIC. *Safety Measurement System (SMS) Methodology: Behavioral Analysis and Safety Improvement Category Prioritization Status*, CSA (December 2021), https://csa.fmcsa.dot.gov/documents/smsmethodology.pdf.

Assessing Younger Truck Drivers

ATRI's original 2005 Crash Predictor study utilized data from 2001 – 2004, finding that the average age of truck drivers was 43 years old. Since that 2005 release, the average driver age in ATRI's data has increased to 46 years old. Recognizing that an aging workforce creates recruitment challenges, it is important for the industry to identify strategies for hiring younger employees to fill positions. ATRI's 2022 release of *Integrating Younger Adults into Trucking Careers* offered considerations for recruitment, training, and retention of younger truck drivers, and how they differ from traditional truck driver populations.[26]

Certain younger driver attributes can be problematic for safety, including perception, cognition, overestimation of driving skill, and their lack of ability to appreciate potential consequences and adjust actions. Fortunately, ATRI research suggests that safety outcomes can be reliably predicted by personality traits, health factors and cognitive characteristics.[27]

The 2018 Crash Predictor analyzed and confirmed the degree to which driver age influenced driver violations, convictions and crashes.[28] The youngest drivers, aged 20-24, had lower probabilities for future crashes (i.e. were safer) for seven of the 22 behaviors that were found to be significant, including having a past crash. Historically, previous crashes on a truck driver's record have been a relatively strong predictor of future crash involvement since. A past crash has been one of the top 10 predictors of future crash involvement in all four iterations of this report, as seen in Table 7.

New Apprenticeship Program

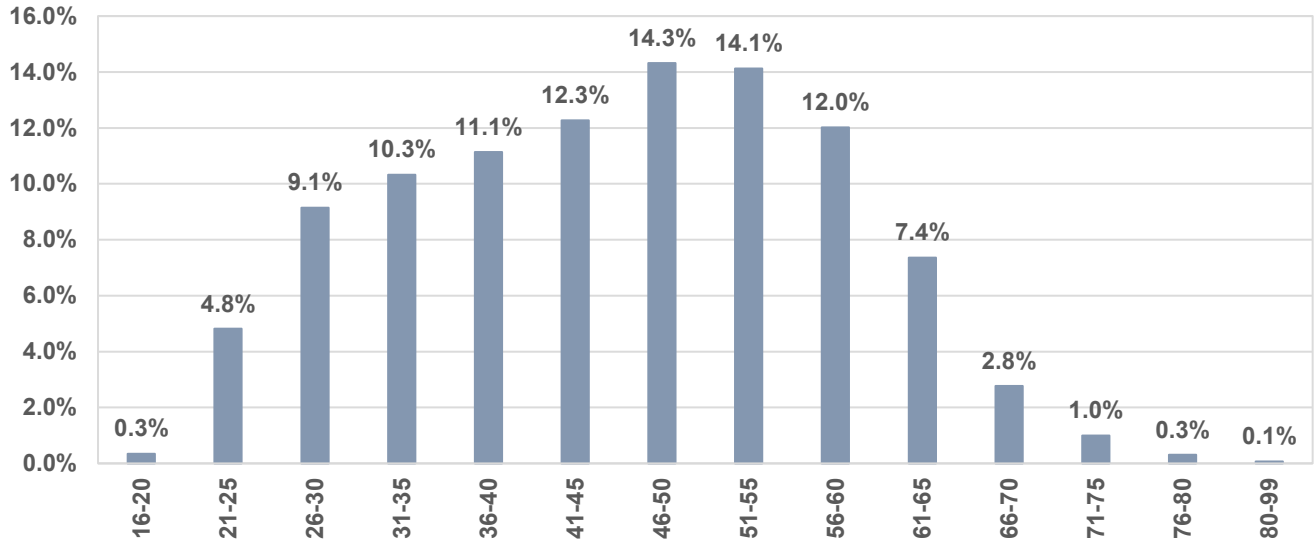
FMCSA established a pilot program that will allow fleets to establish an apprenticeship program for drivers aged 18 to 20 to operate a CMV in interstate commerce. Motor carriers who wish to participate in the Safe Driver Apprenticeship Pilot Program must complete an application for participation and submit monthly data on apprentice driver activity, safety outcomes and any additional supporting information.[29] FMCSA will monitor motor carrier and driver performance throughout the pilot program to ensure safety.

Younger Truck Driver Analysis

Using date of birth data from CDLIS, driver age was ascertained by subtracting the driver birth year from 2018. Next, driver ages were grouped into 5-year age categories. Figure 3 displays the distribution of driver age used in this analysis. On average, truck drivers in the analysis were 46.25 years of age (as compared to an average truck driver age of 43 in the original 2005 report). Of the 499,069 drivers included, 263,157 (52.7%) are ages 41 to 60.

[26] Alex Leslie and Danielle Crownover, *Integrating Younger Adults into Trucking Careers*, ATRI (July 2022), https://truckingresearch.org/2022/07/11/integrating-younger-adults-into-trucking-careers/.
[27] Rebecca Brewster, Dan Murray and Monica M. Luciana, *Developing a Younger Driver Assessment Tool Tech Memo: Phase 1 Beta Test – August 2021*, ATRI (August 2021), https://truckingresearch.org/2021/08/04/developing-a-younger-driver-assessment-tool-tech-memo-phase-1-beta-test-august-2021/.
[28] Caroline Boris and Dan Murray, *Predicting Truck Crash Involvement: 2018 Update*, ATRI (July 2018).
[29] "Safe Driver Apprenticeship Pilot Program To Allow Persons Ages 18, 19, and 20 To Operate Commercial Motor Vehicles in Interstate Commerce," Federal Register (January 14, 2022), https://www.federalregister.gov/documents/2022/01/14/2022-00733/safe-driver-apprenticeship-pilot-program-to-allow-persons-ages-18-19-and-20-to-operate-commercial.

Figure 3: Driver Age



Using the chi-square test, which is the basis for the overall Crash Predictor analysis, this particular analysis explored whether safety for drivers aged 18-20 differs from drivers 25 years and older. Drivers aged 21-24 were excluded in order to create a discrete barrier between the two age categories.

Table 13 shows the crash count and total driver population by each age category. Note that the sample size is substantially smaller for drivers under the age of 21 and should therefore be interpreted with caution.

Table 13: Crash Count by Age Category

	Under 21 Years Old	Over 24 Years Old
Crash Count for Age Category	42	32,557
Total Drivers in Age Category	1,723	475,052
Percentage of Age Category Involved in Crash	2.4%	6.9%

The null hypothesis for a chi-square test of independence assumes there is not a relationship between the two variables. In order to reject this hypothesis, a *p*-value of less than 0.05 must be returned.

- A chi-square value of 52.5519 was returned with a *p*-value less than 0.0001.

The *p*-value returned is well below the standard threshold for statistical significance of 0.05. Therefore, the null hypothesis can be rejected as there is a statistically significant relationship between age and crash involvement. Drivers less than 21 years old have statistically fewer crashes than those older than 24. Due to the small sample size of drivers under the age of 21, however, further research on young driver safety is necessary.

Driver Gender Trends

In 2018, the ATRI research team investigated the relationship between driver gender and the likelihood of safety events (violations, convictions and crash involvement). The events were evaluated by:

1. Calculating the increase in likelihood of safety behaviors for males relative to females; and
2. Examining the statistical significance of the relationship of gender and safety behaviors using a chi-square test.

Based on new analyses conducted in this 2022 Crash Predictor update, males continue to be more likely than females to have violations, convictions and crash involvement for all statistically significant events. These findings are displayed in Table 14.

Table 14: Summary of Crash, Violation and Conviction Likelihood Trends by Gender

Event	2018 Report		2022 Report	
	Relative to Females, Likelihood for Males Increased by	Sig	Relative to Females, Likelihood for Males Increased by	Sig
Significant in both the 2018 and 2022 Updates				
Medical Certificate violation	61%	***	91%	***
Seat Belt violation	78%	***	76%	***
Failure to Obey Traffic Sign conviction	34%	*	51%	*
HOS violation	60%	***	42%	***
Failure to Obey Traffic Signal or Light conviction	73%	***	39%	*
Any OOS violation	45%	***	34%	***
False / No Log Book violation	46%	***	33%	***
Failure to Obey Traffic Control Device violation	23%	*	29%	*
Any conviction	40%	***	23%	***
Speeding More Than 15 Miles Over Speed Limit conviction	43%	***	19%	***
A Crash	20%	***	14%	**
Only Significant in 2022 Update				
Improper Lane conviction		ns	221%	*
Driving Too Fast for Conditions conviction		ns	57%	**
Only Significant in 2018 Update				
Reckless / Careless / Negligent Driving conviction	88%	**		ns
Speeding 1 to 15 Miles Over Speed Limit conviction	70%	**		ns
Following Too Closely conviction	59%	*		ns
Improper Lane or Location conviction	53%	**		ns
Speeding violation	15%	**		ns
Any Moving violation	11%	***		ns

*** Significant at $p < 0.001$
** Significant at $p < 0.01$
* Significant at $p < 0.05$
ns Not Significant, $p \geq 0.05$

From 2018 to 2022, males continued to be significantly more likely than females to commit 11 behaviors predictive of future crash involvement. Of these behaviors, three experienced an increased likelihood larger than in 2018. These three behaviors include a Medical Certificate violation (up 49.2% from 2018), Failure to Obey Traffic Sign conviction (up 50% from 2018), and Failure to Obey Traffic Control Device violation (up 26.1% from 2018). The remaining eight behaviors, while still more likely among males than females, had a lower increased likelihood in 2022 than in 2018. These eight behaviors include: a Seat Belt violation (down 2.6% from 2018); HOS violation (down 30.0% from 2018); a Failure to Obey Traffic Signal or Light conviction

(down 46.6% from 2018); Any OOS violation (down 24.4% from 2018); False / No Log Book violation (down 28.3% from 2018); Any conviction (down 42.5% from 2018); Speeding More Than 15 Miles Over Speed Limit conviction (down 55.8% from 2018); and a Past Crash (down 30.0% from 2018).

As of 2022, two new behaviors experienced a statistically significant increase in likelihood for males. Those events include an Improper Lane conviction (221% more likely) and Driving Too Fast for Conditions conviction (57% more likely).

Males experienced an increase in likelihood for six different behaviors in 2018 that no longer hold significance. The six events that lost significance include: a Reckless / Careless / Negligent Driving conviction; Speeding 1 to 15 Miles Over Speed Limit conviction; Following Too Closely conviction; Improper Lane or Location conviction; Speeding violation; and Any Moving violation.

All other violations and convictions not listed in Table 14 were analyzed and had no significant relationship with gender. These violations and convictions include: Failure to Yield Right-Of-Way conviction; Failure to Use or Improper Signal conviction; Reckless Driving conviction; Improper or Erratic Lane Changes conviction; Improper Turn conviction; Failure to Keep in Proper Lane conviction; Following Too Close violation; Disqualified Drivers violation; Size and Weight violation; Failure to Obey Warning Light or Flasher conviction; Failure to Obey Yield Sign conviction; and Improper Lane Change violation.

Gender: The Disconnect Between Inspections and Driver Populations

The 2018 Crash Predictor was the first to examine driver crash and safety data by gender. Table 15 outlines the driver gender percentages in the 2018 report and this year's analysis.

Table 15: Driver Gender in 2018 and 2022 Crash Predictor Reports

Gender	2018 Count	2018 Percent	2022 Count	2022 Percent
Men	428,484	97.6%	485,784	97.3%
Women	10,741	2.5%	13,448	2.7%

According to the Bureau of Labor Statistics (BLS), females represented 6.7 percent of the truck driver workforce in 2019 (the year of inspection data collection), yet females represented only 2.7 percent of the 2019 driver inspection data being used for this year's analysis.[30] The 2018 gender-related findings derived from a data sample of 439,225 unique truck driver records, of which 10,741 or 2.5 percent were women. According to BLS, there were 3.5 million truck drivers in 2015, of which 5.1 percent, or approximately 176,900, were estimated to be women.[31] Given the percentage of female drivers in the industry at the time, the number of inspections where the driver was female should have been much higher than the 10,741 in the data (Table 16).

[30] "Labor Force Statistics from the Current Population Survey," BLS, https://www.bls.gov/cps/aa2019/cpsaat11.htm.

Table 16: Estimated Female Truck Drivers and Estimated Females Inspected

Year	Estimated Female Truck Drivers per BLS Data	Females Inspected Per MCMIS and CDLIS
2015	5.1%	2.5%
2019	6.7%	2.7%

To better understand this disconnect across gender data sets, ATRI identified several hypotheses to explore and various technical approaches were implemented when testing the hypotheses, including:

- In collaboration with the Women in Trucking (WIT) Association, a survey was disseminated to gain anecdotal insights from both male and female truck drivers on this finding.
- A comparison of ISS scores by gender was developed and reviewed.
- Interviews were conducted with trucking industry stakeholders.
- Analyses of the data by region and the role of probable cause on inspections were considered.

While ATRI research corroborates that female truck drivers are safer, there is no clear basis for female truck drivers being inspected less frequently than male truck drivers – as is shown in this latest Crash Predictor data. ATRI developed several new research tasks in an attempt to explain the delta between the number of female truck drivers and the number of female truck drivers being inspected. After completing several gender-related data analyses, the research team scheduled multiple interviews and/or facility site visits to obtain insights and ground-truthing from subject-matter experts. Working with a variety of industry stakeholders, ATRI developed and tested six primary hypotheses.

Hypothesis I: Female drivers work for safer motor carriers.

ATRI collaborated with the Women in Trucking Association to gather anecdotal insights into truck drivers' perspective on why female truck drivers are inspected less. ATRI received 113 completed surveys, 92 from female drivers and 21 from male truck drivers. The survey included representation from 30 different states and 30 different carriers, with 85.8 percent being employee drivers. Additionally, a variety of age groups, driving experience, and fleet sizes were represented in the responses. A breakdown of survey responses is included in Appendix D.

- When asked what gender gets inspected more, 58.4 percent of driver respondents believe no difference exists. However, 35.4 percent believe that men are inspected more frequently.
- Drivers were also asked if they believe working for a safe carrier is a *higher* priority for women than men. A large majority (65.5%) of respondents believe this to be true. Over half of the male truck driver respondents also believe this to be true.

The research team developed a research design to test this hypothesis. "Safer" carriers were defined as carriers with a better (lower) ISS score. As background, ISS is a safety rating system used by the enforcement and inspection community to assess a carrier's level of safety. Scores range between 1 and 100.

- Pass: ISS scores between 1 and 49 recommend the truck to pass through, for companies with good safety performance.
- Optional: ISS scores between 50 and 74 recommend the inspection to be optional, for companies that have neutral safety performance.
- Inspect: Scores between 75 and 100 recommend an inspection, for companies with poor safety performance or that have little to no safety data.

The numbers are based on the companies that drivers were employed with in 2019 when the inspections were conducted. Table 17 includes a breakdown of drivers included in this analysis. The research team pulled employer data for both male and female truck drivers and ran ISS scores to compare the relationship between ISS scores and gender. A total of 383,275 drivers were associated with a company that had an ISS score.

Table 17: ISS Score by Gender

Recommendation (Score)	Males		Females		Total
Pass (1 – 49)	207,275	55.5%	4,813	47.9%	212,088
Optional (50 – 74)	79,949	21.4%	2,524	25.1%	82,473
Inspect (75 – 100)	86,004	23.0%	2,710	27.0%	88,714

If this hypothesis were true, the percentage of females associated with companies with a "Pass" recommendation would be higher than that of the males. However, this was not the case. This sample included 55.5 percent of males associated with a company with a "Pass" recommendation where only 47.9 percent of females were associated with a company with a "Pass" recommendation.

The ISS score is not the deciding factor in determining whether to conduct the inspection or not. When trucks approach or enter a weigh station, a series of criteria are assessed manually and/or automatically (e.g., weigh-in-motion). It was determined during a site visit to a Minnesota weigh station that trucks may be examined based on over-weight, over-height, axle weight distribution, or by random selection.[32] While these values may be an indicator of safety performance, other immediate factors are considered at a weigh station.

Hypothesis II: Female truck drivers are waved through more frequently than male truck drivers.

This hypothesis was rejected based on inspector interviews and facility visits, where it was determined that the automation of the weigh station selection process cannot be linked to the driver's gender independently, nor can inspectors see a driver's gender at the point an inspection decision is made.

The driver survey introduced in Hypothesis I included open-ended responses regarding this finding from 8.8 percent of drivers. Specifically, the drivers indicated that inspectors see trucks long before they see the truck driver; that a driver's gender is not typically identifiable until a truck gets pulled aside to get inspected.

[32] The system used by this Minnesota weigh station selects a random truck between 11 percent to 13 percent of the time to be weighed again.

Hypothesis III: Females drive newer, cleaner and/or better maintained trucks.

This hypothesis generated from the survey responses. Female drivers believe they are more conscientious about clean and well-maintained trucks.

- 19.6 percent of females highlighted the value of in-depth pre- and post-trip inspections for ensuring that the vehicle is well maintained and in a condition that reduces the likelihood of an inspection and/or citation.
- 23.9 percent of female drivers acknowledged that a clean truck with a clear dashboard is beneficial. Respondents assumed inspectors would favor a truck that is clean and well maintained.

Each inspector focuses on different aspects of trucks when inspecting. While standards exist, each inspector will follow their own individualized routine in their inspection process. Based on the inspector interviews and site visits, inspectors generally look for damage, cleanliness, odd driving behaviors, CVSA decals or simply experience with particular carriers – beyond the use of ISS scores.[33] An inspector may experience the same inspection result with a carrier, and in turn they may broadly associate those results with every truck from that fleet.

Some states require probable cause in order to conduct an inspection. Inspectors in states that do not require probable cause may still look for reasons to conduct an inspection, rather than stopping trucks that do not clearly warrant an inspection.

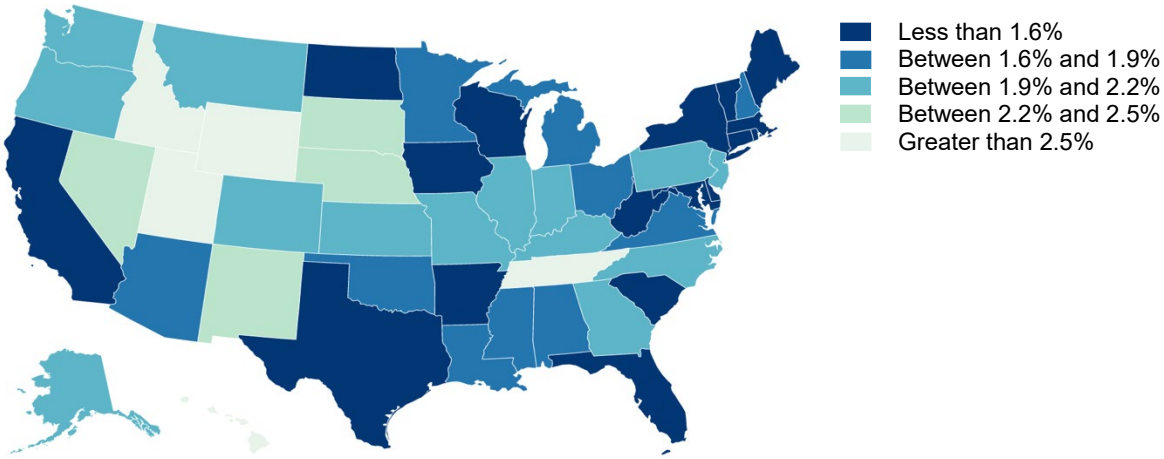
Hypothesis IV: Females avoid driving in winter conditions.

One inspector hypothesized that females may drive less during winter months to avoid dangerous weather conditions. While the MCMIS and CDLIS data derives from 2017 – 2018, this data is pulled based on the individuals who received an inspection between January 1 and March 31 of 2019. January through March is widely considered the slowest season for truck operations and their requisite inspections.[34]

The data collection design in this report may impact inspection outcomes by gender due to the time frame only including winter months. Figure 4 displays the percentage of inspections that occurred for females from January 1, 2017 to December 31, 2018. The darker the color, the lower the percentage of female truck drivers that were inspected.

[33] Steve Vaughn, "Improve Inspector Relationships Improve Truck Inspection Results," webinar from *Transport Topics* (March 18, 2022), https://www.youtube.com/watch?v=AkSE0v1IVyY.
[34] "Is the Trucking Business Slowing Down or Growing," TRUCKSTOP (July 2022), https://truckstop.com/blog/trucking-business-slow/.

Figure 4: Percentage of Inspections involving a Female Truck Driver



Across all states, the percentages of inspections involving a female truck driver do not differ greatly by state or region, with the exception of the northeast region which has a sizeable number of states with less than 1.6 percent of inspections involving females. Due to this regional imbalance, an additional analysis would need to be conducted to further understand the role that weather and time of year play on inspections.

Hypothesis V: Female drivers tend to be more cautious

Based on survey response theories, female truck drivers overwhelmingly believed that safe driving behaviors are more prevalent among female drivers.

- Sixty-three percent of female truck drivers described women with least one of the following adjectives: cautious (30.4%); careful (13.0%); patient (6.5%); risk averse (6.5%); or better aware of surroundings (5.7%).

> *"From my own driving experience, I believe women are more observant, maintain safe speeds, pay attention more to details (i.e., signs, construction) and are less aggressive than our counterparts."*

- Eleven percent of women mentioned nurturing qualities; the motivation of driving safe to get home to and providing for family. This may include thinking about the outcomes of every decision.

> *"Most of us operate with a maternal instinct and think 10 times over before making a choice on whether it's safe to do something or not."*

- Six and a half percent of the women surveyed emphasized having to prove themselves. A handful of men even mentioned this in their responses. As minorities in the industry, women may feel more pressure regarding the repercussions of their actions.

> *"Women have more to prove than men in this industry, and we have an image to uphold, so we have to make sure our record is clear."*

Research conducted by Quality Planning in 2008 found that female drivers are safer.[35] The study concluded that males were three times more likely to receive a Reckless Driving violation, a DUI and a Seatbelt violation.

Nearly 20 percent of female drivers stressed the importance of obeying laws and speed limits diligently. The 2022 Crash Predictor study found that males were 76 percent more likely to receive a Seat Belt violation, 57 percent more likely to receive a Driving Too Fast for Conditions conviction, 19 percent more likely to receive a Speeding More Than 15 Miles Over Speed Limit conviction and 14 percent more likely to be involved in a Crash.

All that said, there is no discernable way to translate these qualitative perspectives to fewer inspections, particularly based on the inspector interviews.

Hypothesis VI: The definition of "Truck Driver" is not consistent between sources.

The BLS Employment and Earnings database estimated 6.7 percent of truck drivers to be female in 2019, the same year as the MCMIS and CDLIS data used in this study.[36] This statistic represents "Driver / Sales Workers and Truck Drivers," defined as follows: "Drive truck or other vehicle over established routes or within an established territory and sell or deliver goods, such as food products, including restaurant take-out items, or pick up or deliver items such as commercial laundry. May also take orders, collect payment, or stock merchandise at point of delivery."[37]

While it is somewhat anecdotal, it appears that the disparity between inspection data involving female drivers and their requisite percentage within the overall truck driver population can be explained by the CDL class they possess, and vehicle configurations they operate. For example, in 2019 BLS reported that females made up 6.7 percent of U.S truck drivers. Since ATRI's inspection data analysis only categorizes female truck drivers at 2.69 percent, the "missing" 4.01 percentage points are likely female truck drivers who do not operate on roadways involving inspection stations.

Table 18 shows the gender count for each class of CDL examined. As mentioned previously, 92.0 percent of all truck drivers hold a Class A CDL. While 7.8 percent of men in this dataset hold a Class B or Class C driver's license, 15.3 percent of women do.

[35] "Men Break More Traffic Laws, Drive More Dangerously Than Women, Concludes QPC Study," Quality Planning (November 13, 2008), https://www.globenewswire.com/news-release/2008/11/13/1207833/0/en/Men-Break-More-Traffic-Laws-Drive-More-Dangerously-Than-Women-Concludes-QPC-Study.html.
[36] "Occupational Employment and Wages, May 2021," BLS, https://www.bls.gov/oes/current/oes533031.htm.
[37] Ibid.

Table 18: Driver CDL Classes by Gender

Gender	Class A Count	Class A %	Class B Count	Class B %	Class C Count	Class C %	Total Count	Total %
Men	354,179	97.6%	28,856	94.9%	974	95.7%	384,009	97.4%
Women	8,842	2.4%	1,552	5.1%	44	4.3%	10,438	2.6%
Total	363,021	100.0%	30,408	100.0%	1,018	100.0%	394,447	100.0%

Additionally, ATRI's inspector interviews revealed that the one facility sees approximately 10 female over-the-road truck drivers per week, while on average they have approximately 21,000 trucks through the weigh station on a weekly basis. The inspectors interviewed for this study have worked at the weigh station for 7+ years and reported a slight increase in female drivers over the years. In addition, they noted that more local agriculture vehicles and dump trucks driven by females pull through multiple times every day.

As a number of female drivers mentioned in their survey responses, women tend to be more inclined to pursue jobs where they can be home at the end of the day. This may motivate them toward Class B and Class C licenses, shorter trip lengths, and straight truck configurations.

This appears to be a primary explanation of the difference between females in the overall truck driver population versus females inspected at roadside facilities – an inspection model that focuses primarily on Class A drivers and vehicles.

TOP TIER STATES – SAFETY DATA ANALYSIS

The final investigation in this report implements an ATRI-designed formula that has been a part of the Crash Predictor report for all four iterations. The formula examines the relationship between crashes and traffic enforcement inspections for each of the 51 United States jurisdictions. The investigation in this section includes a snapshot of 2017 and 2018 MCMIS data.[38]

Based on the data and formula, states receive a ranking based on the percentage of traffic enforcement inspections and total fatal and non-fatal crashes that take place in their state.

State Ranking = (Percent of Traffic Enforcement Inspections) – (Percent of Crashes)

To further understand why some states have stayed consistent in their rankings or have seen significant shifts, ATRI interviewed both public and private sector stakeholders to ascertain why crashes or traffic enforcement inspections experienced a shift.

Data from the 2013 FMCSA Roadside Intervention Effectiveness Model confirms that traffic enforcement inspections tend to be about 3.1 times more effective from a safety standpoint than roadside vehicle inspections.[39] For this reason, traffic enforcement inspections are used for state rankings instead of roadside vehicle inspections.

The State Ranking proceeds from the state with the highest relationship between traffic enforcement inspections and crashes to the lowest. The larger the difference, the more traffic enforcement inspections and crashes deviate from one another. Using this methodology, ten top tier states were identified (Table 19). These numbers include crash and inspection data from both 2017 and 2018. A full breakdown of all 51 United States jurisdictions can be found in Appendix E.

[38] Data Source: FMCSA MCMIS data snapshot as of 5/28/2021, including current year-to-date information for CY 2021.
[39] Suzanne Horton, Eran Segev and Neil Meltzer, "FMCSA Safety Program Effectiveness Measurement: Roadside Intervention Effectiveness Model, Fiscal Year 2013," FMCSA (August 2017), https://rosap.ntl.bts.gov/view/dot/32506.

Table 19: Top Tier States

State	Rank	Number of Inspections	% of Total	Number of Traffic Enforcement Inspections	% of Total	Number of Crashes	% of Total	Safety Metric (Percentage Difference)
WA	1	200,227	2.98%	57,286	5.13%	4,396	1.24%	3.89%
IN	2	147,461	2.20%	72,251	6.47%	10,710	3.01%	3.46%
NM	3	191,487	2.85%	41,007	3.67%	1,806	0.51%	3.16%
AZ	4	102,559	1.53%	39,382	3.53%	5,663	1.59%	1.93%
MA	5	52,377	0.78%	28,810	2.58%	3,646	1.03%	1.55%
GA	6	185,258	2.76%	55,869	5.00%	12,735	3.58%	1.42%
PA	7	222,725	3.32%	64,625	5.79%	15,579	4.38%	1.41%
IL	8	177,715	2.65%	61,349	5.49%	15,138	4.26%	1.24%
CA	9	1,158,812	17.27%	97,037	8.69%	26,590	7.48%	1.21%
MI	10	106,911	1.59%	45,661	4.09%	10,669	3.00%	1.09%

A number of the top tier states have consistently ranked in the top ten based on this ATRI formula. Washington, Indiana, New Mexico and California have ranked in the top 10 since the initial report in 2005. Georgia, Pennsylvania and Massachusetts joined the top ten for the first time in this year's analysis, while Iowa dropped out of the top ten for the first time. Table 20 examines the top tier states from the four different Crash Predictor reports. A complete breakdown of rankings from the four reports can be found in Appendix F.

Table 20: Top Tier States for all Crash Predictor Studies

Rank	2022		2018		2011		2005	
	State	Safety Metric	State	Safety Metric	State	Safety Metric	State	Safety Metric
1	WA	3.89%	IN	4.86%	IN	4.42%	WA	8.37%
2	IN	3.46%	NM	3.18%	NM	3.76%	TN	4.62%
3	NM	3.16%	WA	2.61%	WA	3.06%	IA	3.07%
4	AZ	1.93%	CA	2.32%	CA	2.25%	NM	2.73%
5	MA	1.55%	MD	1.99%	AZ	1.56%	CA	2.56%
6	GA	1.42%	IA	1.34%	MI	1.33%	MI	2.48%
7	PA	1.41%	NV	1.11%	KY	1.30%	IN	2.46%
8	IL	1.24%	AZ	0.99%	IA	1.26%	IL	2.00%
9	CA	1.21%	KY	0.98%	MD	0.87%	KS	1.83%
10	MI	1.09%	IL	0.75%	NV	0.77%	LA	1.71%

The 2018 study, which accounted for only one year of data, had a total of 139,863 crashes, whereas this 2022 report includes a total of 355,638 crashes over two years of data; when the 2022 data is annualized there was a 27.1 percent increase in truck crashes.

Additionally, the 2018 study included 372,569 total traffic enforcement inspections, whereas the 2022 report includes a total of 1,116,648. When annualized, 2022 traffic enforcement inspections saw an increase of 49.9 percent. Both crashes and enforcement inspections have been on the rise, which accounts for the larger numbers when compared to previous years. While crashes are on the rise, an increase in traffic enforcement inspections could be viewed as an emerging countermeasure to that trend.

Table 21 presents the top tier states by changes in crashes and traffic enforcement trends within each state. A full breakdown of this can be found in Appendix G, which uses a mean calculation of two years of data.

Table 21: 2022 Top Tier States – Individual Trends

State	Percent Growth Crashes 2018 to 2022	Percent Growth Traffic Enforcement Inspections 2018 to 2022
Average	*26.3%*	*63.1%*
WA	35.3%	103.7%
IN	10.9%	16.4%
NM	24.6%	48.6%
AZ	20.3%	97.2%
MA	18.0%	141.3%
GA	44.1%	233.3%
PA	27.6%	97.6%
IL	6.9%	41.5%
CA	23.6%	30.0%
MI	14.5%	57.0%

Massachusetts, Georgia and Pennsylvania – new to the top tier list – all saw a dramatic increase in traffic enforcement inspections. Respectively, the state increases were 141.3 percent, 233.3 percent and 97.6 percent relative to the data collected for the 2018 report. For context, the national average increase was 63.1 percent.

New Mexico, Indiana and California experienced little growth in traffic enforcement inspections, likely a result of maintaining consistently high relative traffic enforcement inspections. It is quite noteworthy that Washington State has ranked in the top three places in all four ATRI reports. In the 2022 report, while Washington State experienced a truck crash increase 9 percentage points higher than the national average, its growth in traffic enforcement inspections rose 40.6 percentage points higher than the national average.

As previously demonstrated in Figure 1, the U.S. has experienced an increase in total truck-involved crashes. Only four states – Alaska, North Dakota, Vermont and Wyoming – decreased in total truck-involved crashes between the 2018 and 2022 reports. To combat the rise in crashes, it would be advantageous for states to increase traffic enforcement inspections. For the most part, this is corroborated in the data, as only ten states saw a decrease in traffic enforcement inspections. Those states include Hawaii, Alaska, South Dakota, Montana, New Hampshire, Kentucky, Connecticut, Missouri, New York and Maryland. Alaska was the only state to experience a decrease in both crashes and traffic enforcement inspections.

As was done in Table 21 with the top tier states, Table 22 compares the percentage change in traffic enforcement inspections and crashes between the MCMIS data for the 2018 Crash Predictor and 2022 Crash Predictor report between these 13 states that saw a decrease in either crashes or traffic enforcement inspections. These states were highlighted to demonstrate the correlation between traffic enforcement inspection and crashes and descend by crash percent increase.

Table 22: Traffic Enforcement Inspections and Crash Negative Correlation 2018 to 2022

State	Traffic Enforcement Inspections % Change	Crashes % Change
CT	-11.3%	135.7%
MD	-0.10%	69.0%
HI	-98.4%	67.2%
NY	-9.8%	66.9%
MO	-10.4%	63.5%
NH	-13.7%	36.9%
MT	-30.7%	15.3%
KY	-12.5%	15.2%
SD	-31.7%	3.5%
WY	108.2%	-6.4%
VT	76.5%	-12.0%
ND	167.3%	-28.9%

The established relationship between traffic enforcement inspections and crashes is reinforced by the values presented in Table 22. The inverse relationship existing between states that experienced a decrease in traffic enforcement inspections and increase in crashes corroborates that traffic enforcement inspections are valuable preventative measures to improve roadway safety.

Law Enforcement Perspectives on Top Tier Activities

Based on the top tier state trends over time, ATRI established a list of states where crash and traffic enforcement inspection activities stood out. ATRI then interviewed law enforcement and State Trucking Association (STA) executives in those states. The objective of these interviews was to identify priority, policy and/or funding changes or strategies that led to fewer crashes and increased traffic enforcement. From interviews with multiple association executives and enforcement personnel, a number of strategies were identified.

- It is important to establish a strong relationship between the STA and the state police. States that have consistently ranked high in the Top Tier Analysis and states that have risen in the ranking prioritize partnership activities between the STA and state police.
- Conduct joint seminars on the latest state and federal industry regulations.
- Educate local and non-CMV law enforcement on Federal Motor Carrier Safety Regulations and the trucking industry.
- Make "education a precursor to enforcement." Educating and training motor carriers and drivers on regulatory areas of confusion and traffic enforcement priorities prior to a CVSA International Roadcheck was described as a win-win model.
- The public/private CMV safety partnership is a resource for everyone. Associations typically make safety training available to members and non-members alike.
- Expand traffic enforcement beyond the interstates, and ensure all roads are safe was a key responsibility identified in one state.
- Place increased emphasis on construction/work zone safety. With road projects increasing everywhere, this focus is low-hanging fruit for increasing awareness and reducing truck-involved crashes.
- Implement and expand programs like Ticketing Aggressive Cars and Trucks (TACT), which increase enforcement presence and hold all drivers accountable for CMV safety.[40]
- Implement mock Level I inspections into entry-level driver training. This provides early exposure to inspection requirements and expectations. Truck drivers are better prepared and safer when they have a strong understanding of driver and vehicle inspection expectations.

[40] The Ticketing Aggressive Cars and Trucks (TACT) program Selective Traffic Enforcement (STEP) Program. The goal of TACT is to deter unsafe driving behaviors by passenger vehicle (PV) and commercial motor vehicle (CMV) drivers when they interact to share the road. "TACT Overview: A High Visibility Enforcement Program," FMCSA (February 25, 2014), https://www.fmcsa.dot.gov/safety/tact-overview-high-visibility-enforcement-program.

CONCLUSION

With the recent unexpected increase in truck-involved crashes in the U.S., it becomes more important than ever to understand both the underlying causes and attributes of these crashes, as well as targeted strategies for mitigating the crashes. This 2022 Crash Predictor report provides important insight into truck driver behaviors and violations that generate a statistically significant likelihood of a future crash. Further, the research identifies additional driver and crash attributes such as age and gender that allow industry stakeholders to better target crash causes before they occur.

This updated 2022 analysis compares findings with the previous Crash Predictor reports to improve understanding of positive and negative crash prediction trends over time. The analysis found that driver behavior continues to be one of the most important statistically significant predictors of future crash risk. The predictors have experienced variability over time, however eight different predictors ranked in the top 10 predictors of future crash involvement in at least three of the four Crash Predictor reports. Those include:

- Improper or Erratic Lane Changes conviction
- Past Crash
- A Failure to Keep in Proper Lane conviction
- Reckless Driving violation
- Failure to Yield Right-of-Way violation
- Failure to Use / Improper Signal conviction
- Improper Lane / Location conviction
- Reckless / Careless / Inattentive / Negligent Driving conviction

This analysis also expanded on the previous 2018 analyses focused on gender and age, including the safety data of 18- to 20-year-old truck drivers, and why female truck drivers experience dramatically fewer roadside inspections relative to both male truck drivers and relative to their market share in the overall truck driver population. A series of site visits and expert interviews helped elucidate why these real-world differences exist.

The 2022 research wraps up with the standard Top Tier States, which uses a weighted formula of traffic inspections and crash rates to identify leading states focused on trucking industry safety.

Overall, the Crash Predictor analysis provides an important safety tool for motor carriers and enforcement agencies. The Crash Predictor supports these efforts by providing statistically sound and reproducible data on what violations and convictions increase the likelihood that a truck driver will be involved a future crash.

Similarly, the Crash Predictor helps motor carriers identify and focus limited resources on those truck driver behaviors that are closely associated with crashes in the future. Safety training that centers on Crash Predictor behaviors can help reduce truck-involved crashes for entry-level drivers and indicate targeted remedial training opportunities for veteran drivers.

This 2022 report used the traditional chi-square analysis to identify truck driver behaviors most closely associated with increased crash risk. Additionally, a stepwise regression was utilized to document changes in violation groups, and the results were compared to stepwise regression results from 2005.

Table 23 shows the key findings from each of the 2022 Crash Predictor report sections.

Table 23: Key Findings

Focus Area	Key Findings
Data Collection	• In general, the truck driver data sample used in this 2022 analysis ranged from 490,300 to 583,800 truck drivers. • The top 20 driver and vehicle violations represent 94.7 percent of all violations issued. • While the Crash Predictor analysis focuses on truck driver behaviors and violations, more than 73 percent of all violations were associated with the equipment. • Among the 38,797 crashes that the ATRI truck driver sample had across 2017 and 2018, 65.6 percent of crashes were towaway. Slightly more than 93 percent of truck drivers had zero crashes in the 2-year time period analyzed.
Crash Predictor Trends	• The top crash predictor was Failure to Obey Warning Lights / Flasher conviction – generating a 243 percent increase in future crash probability; however, only 23 truck drivers received this conviction. • Failure to Yield Right-of-Way violation, Failure to Use / Improper Signal conviction and Reckless Driving violation were all strong indicators of future crash likelihood; all increase crash likelihood by more than 100 percent. • Simply having a prior crash on a truck driver's record increased the probability of a future crash by 113 percent – 28.4 percent higher than any previous Crash Predictor report. • An Improper or Erratic Lane Changes conviction and Past Crash have been among the top 10 predictors of future crashes in all four Crash Predictor reports. • The top five most stable predictors of future crashes across all four reports, according to their median increased likelihood of a future crash, were: Reckless Driving violation (114%); Failure to Use / Improper Signal conviction (89%); a Past Crash (88%); Failure to Yield Right-of-Way violation (85%); and Improper or Erratic Lane Changes conviction (79%).
Younger Driver Investigation	• A chi-square analysis comparison between drivers under the age of 21 and over the age of 24 found an existing relationship between age and crashes. Drivers younger than 21 years old have statistically fewer crashes than those 24 years and older. However, it should be noted that the sample size is substantially smaller for drivers under the age of 21 and should therefore be interpreted with caution.
Driver Gender	• Based on investigations conducted in the 2022 Crash Predictor update, males continue to be more likely than females to have violations, convictions and crash involvement for all statistically significant events. • As of 2022, two new events experienced a statistically significant increase in likelihood for males. Those events include an Improper Lane conviction (221%) and Driving Too Fast for Conditions conviction (57%).

Focus Area	Key Findings
	• Males are 14 percent more likely to be involved in a crash than females – a 30.0 percent decrease from the 2018 report.
Gender: The Disconnect Between Inspections and Driver Populations	• According to the Bureau of Labor Statistics, females represented 6.7 percent of the truck driver workforce in 2019, yet female truck drivers represented only 2.7 percent of the 2019 driver inspection data being used for this analysis. • The disparity between inspection data involving female drivers and their requisite percentage within the overall truck driver population can be explained by the CDL class they possess and vehicle configurations they operate.
Top Tier State Trends	• ATRI established a safety relationship in the original 2005 Crash Predictor report that evaluates states' traffic enforcement inspections and crashes. Each report includes a top tier state list, to highlight a focus on trucking industry safety. In all four reports, Washington, Indiana, New Mexico and California have been included in the top tier list. • Three states joined the top tier list for the first time. Those states are Massachusetts, Georgia, and Pennsylvania.

APPENDIX A: 2022 CHI-SQUARE ANALYSIS

Past Crash Analysis Results

There was a total of 583,805 U.S. drivers in our sample. Out of this total, there were 16,960 drivers who had a crash between 1/1/2017 and 12/31/2017, and 20,345 drivers who had a crash between 1/1/2018 and 12/31/2018.

566,845 drivers did not have a crash between 1/1/2017 and 12/31/2017
Of these, 19,128 (3.37%) had a crash between 1/1/2018 and 12/31/2018

16,960 drivers had a crash between 1/1/2017 and 12/31/2017
Of these, 1,217 (7.18%) had a crash between 1/1/2018 and 12/31/2018

** 113.1% increase in the likelihood of a crash
[Chi-square value 707.4370, p-value < 0.0001]

Inspection Analysis Results

There were 237,500 drivers in the sample that had a roadside inspection between 1/1/2017 and 12/31/2017. Of these, 12,251 drivers had a crash between 1/1/2018 and 12/31/2018.

Any Out-of-Service violation

164,871 drivers had zero (0) OOS violations
Of these, 7,823 (4.74%) had a crash

72,629 drivers had one or more OOS violations
Of these, 4,428 (6.10%) had a crash

** 28.7% increase in the likelihood of a crash
[Chi-square value 188.3298, p-value < 0.0001]

Medical Certificate violation

232,817 drivers did not have this violation
Of these, 12,076 (5.19%) had a crash

4,683 drivers had this violation
Of these, 175 (3.74%) had a crash

** No increase in the likelihood of a crash

False or No Log Book violation

212,974 drivers did not have this violation
Of these, 10,456 (4.91%) had a crash

24,526 drivers had this violation
Of these, 1,795 (7.32%) had a crash

** 49.1% increase in the likelihood of a crash

[Chi-square value 260.9421, p-value 0.0001]

Hours-of-Service violation

206,137 drivers did not have this violation
Of these, 10,016 (4.86%) had a crash

31,363 drivers had this violation
Of these, 2,235 (7.13%) had a crash

** 46.7% increase in the likelihood of a crash
[Chi-square value 286.0428, p-value 0.0001]

Disqualified Driver violation

235,158 drivers did not have this violation
Of these, 12,067 (5.13%) had a crash

2,342 drivers had this violation
Of these, 184 (7.86%) had a crash

** 53.2% increase in the likelihood of a crash
[Chi-square value 35.1996, p-value 0.0001]

Any Moving violation

185,849 drivers had zero (0) moving violations
Of these, 8,773 (4.72%) had a crash

51,651 drivers had one or more moving violations
Of these, 3,478 (6.73%) had a crash

** 42.6% increase in the likelihood of a crash
[Chi-square value 334.8289, p-value 0.0001]

Failure to Obey Traffic Control Device violation

230,193 drivers did not have this violation
Of these, 11,753 (5.11%) had a crash

7,307 drivers had this violation
Of these, 498 (6.82%) had a crash

** 33.5% increase in the likelihood of a crash
[Chi-square value 42.3139, p-value 0.0001]

Following Too Close violation

236,036 drivers did not have this violation
Of these, 12,143 (5.14%) had a crash

1,464 drivers had this violation
Of these, 108 (7.38%) had a crash

** 43.6% increase in the likelihood of a crash
[Chi-square value 14.8228, p-value 0.0001]

Improper Lane Change violation

236,343 drivers did not have this violation
Of these, 12,168 (5.15%) had a crash

1,157 drivers had this violation
Of these, 83 (7.17%) had a crash

** 39.2% increase in the likelihood of a crash
[Chi-square value 9.6533, p-value 0.0019]

Improper Passing violation

237,364 drivers did not have this violation
Of these, 12,239 (5.16%) had a crash

136 drivers had this violation
Of these, 12 (8.82%) had a crash

** 70.9% increase in the likelihood of a crash
[Chi-square value 3.7366, p-value 0.0532]

Reckless Driving violation

237,405 drivers did not have this violation
Of these, 12,241 (5.16%) had a crash

95 drivers had this violation
Of these, 10 (10.53%) had a crash

** 104.1% increase in the likelihood of a crash
[Chi-square value 5.5978, p-value 0.0180]

Speeding violation

217,181 drivers did not have this violation
Of these, 10,774 (4.96%) had a crash

20,319 drivers had this violation
Of these, 1,477 (7.27%) had a crash

** 46.6% increase in the likelihood of a crash
[Chi-square value 202.3520, p-value 0.0001]

Improper Turns violation

237,261 drivers did not have this violation
Of these, 12,232 (5.16%) had a crash

239 drivers had this violation
Of these, 19 (7.95%) had a crash

** 54.1% increase in the likelihood of a crash
[Chi-square value 3.8106, p-value 0.0509]

Size and Weight violation

211,345 drivers did not have this violation
Of these, 10,547 (4.99%) had a crash

26,155 drivers had this violation
Of these, 1,704 (6.52%) had a crash

** 30.7% increase in the likelihood of a crash
[Chi-square value 110.5811, p-value 0.0001]

Failure to Yield Right-of-Way violation

237,274 drivers did not have this violation
Of these, 12,223 (5.15%) had a crash

226 drivers had this violation
Of these, 28 (12.39%) had a crash

** 140.6% increase in the likelihood of a crash
[Chi-square value 24.1779, p-value 0.0001]

Conviction Analysis Results

There were 490,321 U.S. drivers in the sample with results returned from CDLIS. The following analysis represents drivers with and without the particular conviction between 1/1/2017 and 12/31/2017, and then whether these drivers had a crash between 1/1/2018 and 12/31/2018.

Any conviction

451,985 drivers had zero (0) of the convictions analyzed
Of these, 16,583 (3.67%) had a crash

38,336 drivers had one or more of the convictions analyzed
Of these, 2,050 (5.35%) had a crash

** 45.8% increase in the likelihood of a crash
[Chi-square value 272.3519, p-value 0.0001]

Speeding More Than 15 Miles Over Speed Limit conviction (Serious)

466,013 drivers had zero (0) of this type of conviction
Of these, 17,367 (3.73%) had a crash

24,308 drivers had one or more of this type of conviction
Of these, 1,266 (5.21%) had a crash

** 39.7% increase in the likelihood of a crash
[Chi-square value 138.6945, p-value 0.0001]

Following Too Closely conviction (Serious)

489,120 drivers had zero (0) of this type of conviction
Of these, 18,587 (3.80%) had a crash

1,201 drivers had one or more of this type of conviction
Of these, 46 (3.83%) had a crash

** 0.8% increase in the likelihood of a crash
[Chi-square value 0.0030, p-value 0.9566 – Not Significant]

Improper or Erratic Lane Changes conviction (Serious)

488,395 drivers had zero (0) of this type of conviction
Of these, 18,504 (3.79%) had a crash

1,926 drivers had one or more of this type of conviction
Of these, 129 (6.70%) had a crash

** 76.8% increase in the likelihood of a crash
[Chi-square value 44.4102, p-value 0.0001]

Reckless Driving conviction (Serious)

489,936 drivers had zero (0) of this type of conviction
Of these, 18,620 (3.80%) had a crash

385 drivers had one or more of this type of conviction
Of these, 13 (3.38%) had a crash

** No increase in the likelihood of a crash

Failure to Obey Traffic Signal / Light conviction

487,896 drivers had zero (0) of this type of conviction
Of these, 18,491 (3.79%) had a crash

2,425 drivers had one or more of this type of conviction
Of these, 142 (5.86%) had a crash

** 54.6% increase in the likelihood of a crash
[Chi-square value 28.1661, p-value 0.0001]

Failure to Obey Traffic Sign conviction

488,506 drivers had zero (0) of this type of conviction
Of these, 18,506 (3.79%) had a crash

1,815 drivers had one or more of this type of conviction
Of these, 127 (7.00%) had a crash

** 84.7% increase in the likelihood of a crash
[Chi-square value 50.9352, p-value 0.0001]

Failure to Obey Warning Light / Flasher conviction

490,298 drivers had zero (0) of this type of conviction
Of these, 18,630 (3.80%) had a crash

23 drivers had one or more of this type of conviction
Of these, 3 (13.04%) had a crash

** 243.2% increase in the likelihood of a crash
[Chi-square value 5.3756, p-value 0.0204]
Warning: 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Failure to Obey Yield Sign conviction

490,299 drivers had zero (0) of this type of conviction
Of these, 18,632 (3.80%) had a crash

22 drivers had one or more of this type of conviction
Of these, 1 (4.55%) had a crash

** 19.7% increase in the likelihood of a crash
[Chi-square value 0.0334, p-value 0.8549 - Not Significant]

Improper Lane / Location conviction

488,355 drivers had zero (0) of this type of conviction
Of these, 18,513 (3.79%) had a crash

1,966 drivers had one or more of this type of conviction
Of these, 120 (6.10%) had a crash

** 60.9% increase in the likelihood of a crash
[Chi-square value 28.6527, p-value 0.0001]

Failure to Keep in Proper Lane conviction

489,906 drivers had zero (0) of this type of conviction
Of these, 18,605 (3.80%) had a crash

415 drivers had one or more of this type of conviction
Of these, 28 (6.75%) had a crash

** 77.6% increase in the likelihood of a crash
[Chi-square value 9.8662, p-value 0.0017]

Improper Pass conviction

489,975 drivers had zero (0) of this type of conviction
Of these, 18,616 (3.80%) had a crash

346 drivers had one or more of this type of conviction
Of these, 17 (4.91%) had a crash

** 29.2% increase in the likelihood of a crash
[Chi-square value 1.1735, p-value 0.2787 – Not Significant]

Reckless / Careless / Inattentive / Negligent Driving conviction

489,032 drivers had zero (0) of this type of conviction
Of these, 18,554 (3.79%) had a crash

1,289 drivers had one or more of this type of conviction
Of these, 79 (6.13%) had a crash

** 61.7% increase in the likelihood of a crash
[Chi-square value 19.1697, p-value 0.0001]

Failure to Yield Right-of-Way conviction

489,820 drivers had zero (0) of this type of conviction
Of these, 18,609 (3.80%) had a crash

501 drivers had one or more of this type of conviction
Of these, 24 (4.79%) had a crash

** 26.1% increase in the likelihood of a crash
[Chi-square value 1.3452, p-value 0.2461 – Not Significant]

Failure to Use / Improper Signal conviction

489,992 drivers had zero (0) of this type of conviction
Of these, 18,606 (3.80%) had a crash

329 drivers had one or more of this type of conviction
Of these, 27 (8.21%) had a crash

** 116.1% increase in the likelihood of a crash
[Chi-square value 17.4865, p-value 0.0001]

Improper Turn conviction

489,741 drivers had zero (0) of this type of conviction
Of these, 18,601 (3.80%) had a crash

580 drivers had one or more of this type of conviction
Of these, 32 (5.52%) had a crash

** 45.3% increase in the likelihood of a crash
[Chi-square value 4.6832, p-value 0.0305]

Speeding 1 to 15 Miles Over Speed Limit conviction

489,040 drivers had zero (0) of this type of conviction
Of these, 18,561 (3.80%) had a crash

1,281 drivers had one or more of this type of conviction
Of these, 72 (5.62%) had a crash

** 47.9% increase in the likelihood of a crash
[Chi-square value 11.6430, p-value 0.0006]

Driving Too Fast for Conditions conviction

488,661drivers had zero (0) of this type of conviction
Of these, 18,553 (3.80%) had a crash

1,660 drivers had one or more of this type of conviction
Of these, 80 (4.82%) had a crash

** 26.8% increase in the likelihood of a crash
[Chi-square value 4.7321, p-value 0.0296]

APPENDIX B: VIOLATIONS COUNT AND PERCENT

Violation Description	Count	Percent
Lighting	290,899	16.3%
All Other Vehicle Defects	249,700	14.0%
Brakes - All Others	237,853	13.3%
All Other HOS	116,902	6.5%
All Other Driver Violations	112,850	6.3%
Tires	106,194	5.9%
Brakes - Out of Adjustment	91,302	5.1%
Size And Weight	84,190	4.7%
Speeding	51,703	2.9%
Emergency Equipment	50,317	2.8%
Windshield	47,528	2.7%
Periodic Inspection	45,134	2.5%
No Log Book - Log Not Current	41,750	2.3%
Load Securement	39,136	2.2%
Wheels - Studs – Clamps	27,645	1.5%
10/15 Hours	21,933	1.2%
Suspension	21,385	1.2%
False Log Book	20,645	1.2%
Failure To Obey Traffic Control Device	17,763	1.0%
Seat Belt	15,317	0.86%
Medical Certificate	12,576	0.70%
Steering Mechanism	12,572	0.70%
Unknown	11,519	0.65%
Frames	9,733	0.55%
Exhaust Discharge	8,750	0.49%
Disqualified Drivers	5,317	0.30%
Traffic Enforcement	4,299	0.24%
All Other HM Violations	3,751	0.21%
Fuel Systems	3,619	0.20%
Following Too Close	3,414	0.19%
Coupling Devices	3,168	0.18%
Improper Placarding	2,916	0.16%
Shipping Paper	2,738	0.15%
Improper Lane Change	2,609	0.15%
60/70/80 Hours	1,383	0.08%
Emergency Response	1,101	0.06%
State/Local HOS	911	0.05%
Improper Blocking And Bracing	733	0.04%
Radar Detectors	633	0.04%
Alcohol	613	0.03%
Failure To Yield Right-of-Way	545	0.03%
Improper Turns	498	0.03%
No Retest and Inspection (Cargo Tank)	320	0.02%
Drugs	302	0.02%
Improper Passing	296	0.02%
Accepting Shipment Improperly Marked	287	0.02%
Reckless Driving	193	0.01%
Use Of Non-Specification Container	71	0.00%
No Remote Shutoff Control	35	0.00%
15/20 Hours	8	0.00%
Total	**1,785,056**	**100.0%**

APPENDIX C: 2005, 2011, 2018 AND 2022 FUTURE CRASH LIKELIHOOD COMPARISONS

Event	2022 Report		2018 Report		2011 Report		2005 Report	
	+	Sig	+	Sig	+	Sig	+	Sig
A Failure to Yield Right-of-Way violation	141%	***	101%	***		ns	70%	***
A Failure to Use / Improper Signal conviction	116%	***	82%	**	96%	**		ns
A Past Crash	113%	***	74%	***	88%	***	87%	***
An Improper or Erratic Lane Changes conviction	77%	***	66%	***	80%	***	100%	***
A Reckless / Careless / Inattentive / Negligent Driving conviction	62%	***	69%	***	64%	***	53%	***
An Improper Lane / Location conviction	61%	***	72%	***	68%	***	47%	***
A Failure to Obey Traffic Signal / Light conviction	55%	***	20%	*	56%	***	29%	*
A Disqualified Driver violation	53%	***	44%	***		ns	51%	***
A False or No Log Book violation	49%	***	45%	***	42%	***	56%	***
A Speeding 1 to 15 Miles Over Speed Limit conviction	48%	***	38%	**	40%	**	26%	**
An HOS violation	47%	***	50%	***	45%	***	41%	***
A Speeding violation	47%	***	45%	***	38%	***	35%	***
Any conviction	46%	***	43%	***	65%	***	56%	***
A Following Too Close violation	44%	***		ns	41%	***	40%	***
Any Moving violation	43%	***	35%	***	29%	***	41%	***
A Speeding More Than 15 Miles Over Speed Limit conviction	40%	***	40%	***	67%	***	56%	***
A Failure to Obey Traffic Control Device violation	34%	***	30%	***	21%	***	30%	***
A Size and Weight violation	31%	***	20%	***	18%	***	21%	***
Any OOS violation	29%	***	29%	***	26%	***	16%	***
A Failure to Obey Traffic Sign conviction	85%	**	25%	**	68%	***	24%	*
A Failure to Keep in Proper Lane conviction	78%	**	83%	**		ns	91%	***
An Improper Lane Change violation	39%	**	63%	***	41%	***	78%	***
A Failure to Obey Warning Light / Flasher conviction^	243%	*		ns		ns		ns
A Reckless Driving violation	104%	*	114%	**		ns	325%	***
An Improper Turn conviction	45%	*	49%	*	84%	**	94%	***
A Driving Too Fast for Conditions conviction	27%	*	25%	*	56%	***	62%	***
An Improper Passing violation		ns		ns	88%	**		ns
An Improper Turns violation		ns		ns		ns	105%	***
An Improper Pass conviction		ns	70%	*		ns		ns
A Failure to Yield Right-of-Way conviction		ns		ns		ns	97%	***
A Failure to Obey Yield Sign conviction		ns		ns		ns		ns
A Following Too Closely conviction		ns	46%	**	36%	*	50%	***
A Medical Certificate violation	NA	x		ns		ns	18%	***
A Reckless Driving conviction - Serious	NA	x		ns		ns		ns

\+ Increase in future crash likelihood
*** Significant at $p < 0.001$
** Significant at $p < 0.01$
* Significant at $p < 0.05$
^ Chi-square test not reliable due to low sample size
ns Not Significant, $p \geq 0.05$

APPENDIX D: INSPECTION SURVEY RESPONSES BREAKDOWN

Driver Age	21 – 34	35 – 44	45 – 54	55 and Older
	12.5%	16.9%	31.3%	39.3%
Years Driving	**Less than 1**	**1 – 5**	**6 – 15**	**16 or Higher**
	17.7%	29.2%	27.4%	25.7%
Fleet Size (# of Trucks)	**Less than 20**	**20 – 100**	**101 – 500**	**More than 500**
	8.6%	0.0%	29.5%	61.9%

QUESTIONS

1. Who do you think gets inspected more frequently? Why?

Driver Gender	Women	%	Men	%	No Difference	%	Total	%
Women	7	7.6%	32	34.8%	53	57.6%	92	81.4%
Men	0	0%	8	38.1%	13	61.9%	21	18.6%
Total	7	6.2%	40	35.4%	66	58.4%	113	100%

2. Are there any extra steps or precautions you take because of your gender that might improve safety and/or reduce your inspection frequency?

3. Do you think working for a safe carrier is a higher priority for women than men? Why?

Driver Gender	Yes	%	No	%	No Preference	%	Total	%
Women	62	67.4%	6	6.5%%	24	26.1%	92	81.4%
Men	12	57.1%	1	4.8%	8	38.1%	21	18.6%
Total	74	65.5%	7	6.2%	32	28.3%	113	100%

4. Previous ATRI research found that women truck drivers have fewer violations, convictions, and crashes than their men. Additionally, in all statistically significant categories in predicting future crash likelihood, women were found to be safer. How would you explain this finding?

APPENDIX E: 2022 ENFORCEMENT ANALYSIS

Rank	State	Number of Inspections	%	Number of Traffic Enforcement Inspections	%	Number of Crashes	%	Safety Metric (% Difference)
1	WA*	200,227	2.98%	57,286	5.13%	4,396	1.24%	3.89%
2	IN*	147,461	2.20%	72,251	6.47%	10,710	3.01%	3.46%
3	NM*	191,487	2.85%	41,007	3.67%	1,806	0.51%	3.16%
4	AZ*	102,559	1.53%	39,382	3.53%	5,663	1.59%	1.93%
5	MA	52,377	0.78%	28,810	2.58%	3,646	1.03%	1.55%
6	GA	185,258	2.76%	55,869	5.00%	12,735	3.58%	1.42%
7	PA	222,725	3.32%	64,625	5.79%	15,579	4.38%	1.41%
8	IL*	177,715	2.65%	61,349	5.49%	15,138	4.26%	1.24%
9	CA*	1,158,812	17.27%	97,037	8.69%	26,590	7.48%	1.21%
10	MI	106,911	1.59%	45,661	4.09%	10,669	3.00%	1.09%
11	NV*	65,916	0.98%	13,911	1.25%	1,458	0.41%	0.84%
12	OR	65,760	0.98%	20,090	1.80%	3,568	1.00%	0.80%
13	IA*	106,265	1.58%	21,755	1.95%	4,115	1.16%	0.79%
14	TN	148,456	2.21%	34,599	3.10%	8,299	2.33%	0.76%
15	ME	29,858	0.45%	11,039	0.99%	1,829	0.51%	0.47%
16	CO	108,008	1.61%	17,720	1.59%	3,960	1.11%	0.47%
17	NE	56,589	0.84%	12,808	1.15%	2,539	0.71%	0.43%
18	WY	24,971	0.37%	9,887	0.89%	1,796	0.51%	0.38%
19	MD*	234,768	3.50%	25,919	2.32%	7,041	1.98%	0.34%
20	MN	74,678	1.11%	20,268	1.82%	5,254	1.48%	0.34%
21	ND	27,733	0.41%	7,196	0.64%	1,214	0.34%	0.30%
22	WV	35,175	0.52%	10,041	0.90%	2,135	0.60%	0.30%
23	ID	22,990	0.34%	7,999	0.72%	1,717	0.48%	0.23%
24	VT	12,975	0.19%	4,016	0.36%	454	0.13%	0.23%
25	DC	10,230	0.15%	2,903	0.26%	454	0.13%	0.13%
26	RI	6,180	0.09%	2,158	0.19%	421	0.12%	0.07%
27	SD	56,819	0.85%	2,832	0.25%	712	0.20%	0.05%
28	AK	15,651	0.23%	244	0.02%	77	0.02%	0.00%
29	NH	20,287	0.30%	3,043	0.27%	1,005	0.28%	-0.01%
30	DE	15,818	0.24%	3,989	0.36%	1,343	0.38%	-0.02%
31	KS	90,273	1.35%	10,390	0.93%	3,449	0.97%	-0.04%
32	KY*	160,143	2.39%	19,465	1.74%	6,458	1.82%	-0.07%
33	HI	6,163	0.09%	6	0.00%	291	0.08%	-0.08%
34	CT	34,381	0.51%	8,183	0.73%	3,205	0.90%	-0.17%
35	MT	60,619	0.90%	2,265	0.20%	1,432	0.40%	-0.20%
36	UT	74,255	1.11%	7,884	0.71%	3,393	0.95%	-0.25%
37	WI	75,176	1.12%	16,925	1.52%	6,322	1.78%	-0.26%
38	MS	119,183	1.78%	9,011	0.81%	3,802	1.07%	-0.26%
39	AR	72,408	1.08%	13,493	1.21%	5,384	1.51%	-0.31%
40	OK	63,905	0.95%	17,427	1.56%	6,811	1.92%	-0.35%
41	SC	76,975	1.15%	16,622	1.49%	6,997	1.97%	-0.48%
42	LA	99,077	1.48%	19,013	1.70%	7,879	2.22%	-0.51%
43	OH	174,291	2.60%	33,981	3.04%	15,196	4.27%	-1.23%
44	VA	66,710	0.99%	8,644	0.77%	8,464	2.38%	-1.61%
45	AL	77,144	1.15%	8,582	0.77%	8,574	2.41%	-1.64%
46	MO	194,538	2.90%	10,356	0.93%	11,007	3.10%	-2.17%
47	NY	232,778	3.47%	23,057	2.06%	15,299	4.30%	-2.24%
48	NC	189,525	2.83%	23,646	2.12%	15,628	4.39%	-2.28%
49	NJ	82,560	1.23%	11,671	1.05%	12,756	3.59%	-2.54%
50	FL	215,312	3.21%	31,215	2.80%	19,080	5.37%	-2.57%
51	TX	858,740	12.80%	29,118	2.61%	37,888	10.65%	-8.05%

*One of the 10 "Top Tier" States in 2018

APPENDIX F: 2005, 2011, 2018 AND 2022 ENFORCEMENT ANALYSIS COMPARISONS

State	2022 Report		2018 Report		2011 Report		2005 Report	
	Rank	% Difference	Rank	% Difference	Rank	% Difference	Rank	% Difference
WA	1	3.89%	3	2.61%	3	3.06%	1	8.37%
IN	2	3.46%	1	4.86%	1	4.42%	7	2.46%
NM	3	3.16%	2	3.18%	2	3.76%	4	2.73%
AZ	4	1.93%	8	0.99%	5	1.56%	40	-1.14%
MA	5	1.55%	14	0.50%	37	-0.36%	24	-0.04%
GA	6	1.42%	45	-0.91%	44	-0.91%	37	-0.73%
PA	7	1.41%	24	0.02%	49	-2.08%	48	-2.11%
IL	8	1.24%	10	0.75%	45	-1.23%	8	2.00%
CA	9	1.21%	4	2.32%	4	2.25%	5	2.56%
MI	10	1.09%	12	0.57%	6	1.33%	6	2.48%
NV	11	0.84%	7	1.11%	10	0.77%	32	-0.39%
OR	12	0.80%	39	-0.43%	13	0.56%	20	0.01%
IA	13	0.79%	6	1.34%	8	1.26%	3	3.07%
TN	14	0.76%	19	0.15%	36	-0.20%	2	4.62%
ME	15	0.47%	37	-0.29%	33	-0.06%	33	-0.40%
CO	16	0.47%	33	-0.17%	19	0.27%	38	-0.95%
NE	17	0.43%	15	0.44%	18	0.29%	30	-0.26%
WY	18	0.38%	31	-0.05%	30	-0.01%	36	-0.66%
MD	19	0.34%	5	1.99%	9	0.87%	13	0.54%
MN	20	0.34%	42	-0.52%	12	0.70%	41	-1.25%
ND	21	0.30%	35	-0.25%	35	-0.14%	14	0.46%
WV	22	0.30%	32	-0.06%	11	0.77%	34	-0.41%
ID	23	0.23%	13	0.55%	16	0.35%	22	-0.03%
VT	24	0.23%	21	0.12%	20	0.17%	16	0.33%
DC	25	0.13%	22	0.08%	22	0.08%	18	0.03%
RI	26	0.07%	18	0.16%	31	-0.02%	26	-0.05%
SD	27	0.05%	16	0.31%	15	0.37%	12	0.80%
AK	28	0.00%	25	0.00%	42	-0.90%	19	0.03%
NH	29	-0.01%	17	0.21%	25	0.04%	17	0.11%
DE	30	-0.02%	26	0.00%	26	0.04%	23	-0.04%
KS	31	-0.04%	34	-0.18%	32	-0.05%	9	1.83%
KY	32	-0.07%	9	0.98%	7	1.30%	28	-0.08%
HI	33	-0.08%	28	-0.01%	24	0.05%	21	-0.01%
CT	34	-0.17%	11	0.75%	17	0.34%	29	-0.16%
MT	35	-0.20%	29	-0.01%	23	0.07%	27	-0.07%
UT	36	-0.25%	27	0.00%	34	-0.12%	39	-1.00%
WI	37	-0.26%	38	-0.37%	21	0.17%	43	-1.35%
MS	38	-0.26%	43	-0.76%	41	-0.73%	46	-1.76%
AR	39	-0.31%	36	-0.27%	38	-0.36%	15	0.38%
OK	40	-0.35%	41	-0.46%	28	0.02%	25	-0.05%
SC	41	-0.48%	23	0.04%	27	0.02%	11	1.33%
LA	42	-0.51%	30	-0.01%	39	-0.49%	10	1.71%
OH	43	-1.23%	48	-2.10%	48	-1.62%	47	-1.90%
VA	44	-1.61%	47	-1.67%	46	-1.42%	45	-1.73%
AL	45	-1.64%	46	-1.52%	43	-0.90%	44	-1.67%
MO	46	-2.17%	44	-0.85%	14	0.47%	49	-3.09%
NY	47	-2.24%	20	0.15%	40	-0.50%	42	-1.26%
NC	48	-2.28%	50	-2.44%	47	-1.55%	31	-0.37%
NJ	49	-2.54%	49	-2.22%	50	-3.59%	50	-4.13%
FL	50	-2.57%	40	-0.43%	29	0.01%	35	-0.50%
TX	51	-8.05%	51	-8.16%	51	-9.00%	51	-8.27%

APPENDIX G: 2022 TRAFFIC ENFORCEMENT INSPECTIONS AND CRASH ANALYSIS

State	2018 Crashes	2018 Traffic Enforcement Inspections	2022 Crashes	2022 Traffic Enforcement Inspections	% Growth Crashes	% Growth Traffic Enforcement Inspections
AK	92	246	39	122	-58.15%	-50.41%
AL	3,539	3,751	4,287	4,291	21.14%	14.40%
AR	2,209	4,876	2,692	6,747	21.87%	38.36%
AZ	2,353	9,985	2,832	19,691	20.34%	97.21%
CA	10,755	37,318	13,295	48,519	23.62%	30.01%
CO	1,966	4,620	1,980	8,860	0.71%	91.77%
CT	680	4,614	1,603	4,092	135.66%	-11.32%
DE	485	1,283	672	1,995	38.45%	55.46%
FL	5,960	14,293	9,540	15,608	60.07%	9.20%
GA	4,420	8,380	6,368	27,935	44.06%	233.35%
HI	87	190	146	3	67.24%	-98.42%
IA	1,794	9,795	2,058	10,878	14.69%	11.05%
ID	652	3,795	859	4,000	31.67%	5.39%
IL	7,080	21,673	7,569	30,675	6.91%	41.53%
IN	4,833	31,023	5,355	36,126	10.80%	16.45%
KS	1,600	3,601	1,725	5,195	7.78%	44.27%
KY	2,802	11,118	3,229	9,733	15.24%	-12.46%
LA	3,430	9,099	3,940	9,507	14.85%	4.48%
MA	1,545	5,969	1,823	14,405	17.99%	141.33%
MD	2,083	12,967	3,521	12,960	69.01%	-0.06%
ME	743	902	915	5,520	23.08%	511.92%
MI	4,659	14,540	5,335	22,831	14.50%	57.02%
MN	2,350	4,335	2,627	10,134	11.79%	133.77%
MO	3,366	5,779	5,504	5,178	63.50%	-10.40%
MS	1,535	1,264	1,901	4,506	23.84%	256.45%
MT	621	1,635	716	1,133	15.30%	-30.73%
NC	6,154	7,299	7,814	11,823	26.97%	61.98%
ND	854	1,346	607	3,598	-28.92%	167.31%
NE	1,041	4,403	1,270	6,404	21.95%	45.45%
NH	367	1,762	503	1,522	36.92%	-13.65%
NJ	4,886	4,731	6,378	5,836	30.54%	23.35%
NM	725	13,800	903	20,504	24.55%	48.58%
NV	360	5,105	729	6,956	102.50%	36.25%
NY	4,583	12,780	7,650	11,529	66.91%	-9.79%
OH	6,266	8,846	7,598	16,991	21.26%	92.07%
OK	3,200	6,815	3,406	8,714	6.42%	27.86%
OR	1,469	2,319	1,784	10,045	21.44%	333.16%
PA	6,106	16,349	7,790	32,313	27.57%	97.64%
RI	178	1,070	211	1,079	18.26%	0.84%
SC	2,584	7,039	3,499	8,311	35.39%	18.07%
SD	344	2,074	356	1,416	3.49%	-31.73%
TN	3,142	8,929	4,150	17,300	32.07%	93.75%
TX	15,020	9,546	18,944	14,559	26.13%	52.51%
UT	1,138	3,026	1,697	3,942	49.08%	30.27%
VA	3,626	3,420	4,232	4,322	16.71%	26.37%
VT	258	1,138	227	2,008	-12.02%	76.45%
WA	1,624	14,058	2,198	28,643	35.34%	103.75%
WI	2,370	4,932	3,161	8,463	33.38%	71.58%
WV	970	2,357	1,068	5,021	10.05%	113.00%
WY	959	2,374	898	4,944	-6.36%	108.24%

ATRI American Transportation Research Institute

Atlanta, GA • Minneapolis, MN • New York, NY • Sacramento, CA

(770) 432-0628

ATRI@Trucking.org

TruckingResearch.org