Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths

Safety Study

NTSB/SS-13/01
PB2013-106637

National Transportation Safety Board

NTSB/SS-13/01
PB2013-13-106637
Notation 8492
Adopted June 17, 2013

Safety Study

Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths

National Transportation Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

National Transportation Safety Board. 2013. ***Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths.*** **Safety Study NTSB/SS-13/01. Washington, DC.**

Abstract: There are 8.22 million single-unit trucks registered in the United States, which travel more than 110.7 billion miles each year. Although single-unit trucks comprise three percent of registered motor vehicles and four percent of miles traveled, they are involved in nine percent of fatalities among passenger vehicle occupants in multivehicle crashes. Crashes involving single-unit trucks and passenger vehicles pose a hazard to passenger vehicle occupants due to the differences in weight, bumper height, and vehicle stiffness.

The NTSB undertook this study because of concerns about the safety record of single-unit trucks and an interest in identifying countermeasures to address the risks posed by these vehicles. One of the concerns is that single-unit trucks are excluded from some safety rules applicable to tractor-trailers. This study used a variety of data sources, including state records of police and hospital reports, federal databases, and case reviews of selected single-unit truck crashes. Risks were compared between single-unit trucks and tractor-trailers.

The study found that the adverse effects of single-unit truck crashes have been underestimated in the past because these trucks are frequently misclassified and thus undercounted in federal and state databases (approximately 20 percent in the case of fatalities). There are substantial societal impacts resulting from single-unit truck crashes, including deaths, non-fatal injuries, hospitalizations, and hospital costs.

Areas identified for safety improvements include the need to (1) enhance the ability of drivers of single-unit trucks to detect vulnerable road users such as pedestrians and cyclists, (2) prevent passenger vehicles from underriding the rears and sides of single-unit trucks, (3) improve conspicuity of single-unit trucks, (4) improve federal and state databases on large truck crashes, (5) continue the functions of databases vital for accurate fatality data or that link hospital data with police reports, (6) examine the frequency and consequences of single-unit truck drivers operating with an invalid license, and (7) research the potential benefits of expanding the commercial driver's licensure requirement to lower weight classes.

The National Transportation Safety Board (NTSB) is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

Recent publications are available in their entirety on the Internet at <http://www.ntsb.gov>. Other information about available publications also may be obtained from the website or by contacting:

National Transportation Safety Board
Records Management Division, CIO-40
490 L'Enfant Plaza, SW
Washington, DC 20594
(800) 877-6799 or (202) 314-6551

NTSB publications may be purchased, by individual copy or by subscription, from the National Technical Information Service. To purchase this publication, order report number PB2013-106637 from:

National Technical Information Service
5301 Shawnee Road
Alexandria, Virginia 22312
(800) 553-6847 or (703) 605-6000

Contents

Figures

Tables

Abbreviations and Definitions

BIFA Buses in Fatal Accidents

CDL commercial driver's license

CFR Code of Federal Regulations

CODES Crash Outcome Data Evaluation System

DOT Department of Transportation

ESC electronic stability control

FARS Fatality Analysis Reporting System

FHWA Federal Highway Administration

FMCSA Federal Motor Carrier Safety Administration

GES General Estimates System

GIS geographic information systems

GVWR gross vehicle weight rating

HPMS Highway Performance Monitoring System

HSIS Highway Safety Information System

IIHS Insurance Institute for Highway Safety

LTCCS Large Truck Crash Causation Study

MAIS Maximum Abbreviated Injury Scale
- MAIS 0 = no injury
- MAIS 1 = minor injury
- MAIS 2 = moderate injury
- MAIS 3 = serious injury
- MAIS 4 = severe injury
- MAIS 5 = critical injury
- MAIS 6 = maximum injury

NASS National Automotive Sampling System

NHTSA National Highway Traffic Safety Administration

NTSB National Transportation Safety Board

TIFA Trucks in Fatal Accidents

VIN vehicle identification number

VMT vehicle-miles of travel

Executive Summary

There are 8.22 million single-unit trucks[1] registered in the United States, which travel more than 110.7 billion miles each year. Although single-unit trucks comprise three percent of registered motor vehicles and four percent of miles traveled, they are involved in nine percent of fatalities among passenger vehicle occupants in multivehicle crashes. Crashes involving single-unit trucks and passenger vehicles pose a hazard to passenger vehicle occupants due to differences in weight, bumper height, and vehicle stiffness.[2]

The National Transportation Safety Board (NTSB) undertook this study because of concerns about the safety record of single-unit trucks and an interest in identifying countermeasures to address the risks posed by these vehicles. Single-unit trucks are excluded from some safety rules applicable to tractor-trailers. Single-unit trucks do not have to meet the requirements for improved rear underride guards (mandatory in 1998 for new trailers) and conspicuity treatments to enhance visibility (mandatory in 1993 for new trailers; in 1997 for new truck-tractors; and in 2001 for trailers manufactured before 1993). Further, in 2012, the National Highway Traffic Safety Administration (NHTSA) proposed mandating electronic stability control for tractor-trailers and motorcoaches but not for single-unit trucks.

Many studies of truck safety have examined fatalities as the sole outcome of interest. Tractor-trailers result in a larger proportion of fatal injuries from large truck crashes, which is one reason why some truck safety regulations have been limited to tractor-trailers and trailers. However, this study shows that there are substantial societal impacts resulting from non-fatal injuries arising from single-unit truck crashes. Emergency department visits, inpatient hospitalizations,[3] and hospital costs[4] that result from the crashes provide measures of the adverse effect of non-fatal injuries on the public. This study also shows that federal and state databases frequently misclassify single-unit trucks and thus undercount the total number of fatalities resulting from single-unit truck crashes by approximately 20 percent.

The primary focus of this study was on the risks of single-unit truck crashes, and these risks were compared with those of tractor-trailer crashes. This study used a variety of data sources. Crash Outcome Data Evaluation System (CODES) data, which links hospital discharge records with police accident reports, were obtained from five participating states (Delaware, Maryland, Minnesota, Nebraska, and Utah) and served as the primary source of data for injury severity and hospitalizations in

---

[1] Single-unit trucks are large trucks (gross vehicle weight rating over 10,000 pounds) with typically non-detachable cargo units that have all axles attached to a single frame. Tractor-trailers are defined as large trucks that have a connection enabling them to pull semi-trailers (no front axles). In this study, tractor-trailers refer to truck-tractors traveling without trailers, truck-tractors pulling semi-trailers, and truck-tractors pulling multiple trailers.

[2] Vehicle stiffness refers to the amount of force required to crush the front of a vehicle. Vehicle stiffness is independent from vehicle weight and affects the likelihood of injury in a crash.

[3] A trip to the hospital is counted as an emergency department visit if the visit ends when the person is discharged from the emergency department. Inpatient hospitalizations are counted separately and are defined as spending at least one night in the hospital following admission for medical treatment. Some fractures are treated by emergency departments rather than by hospitalizations. In this study, emergency department visits and inpatient hospitalizations are mutually exclusive.

[4] Hospital costs were based on what hospitals charged for individual patients and vary by hospital for similar treatments.

relation to truck and accident characteristics. Additional databases used include Trucks in Fatal Accidents (TIFA) and the Fatality Analysis Reporting System (FARS) (fatal crashes); the National Automotive Sampling System (NASS)/General Estimates System (GES) (national estimates of non-fatal injuries); and the Large Truck Crash Causation Study (LTCCS) (truck crash investigations with details not available from the other sources).

To improve the quality and accuracy of CODES data, the NTSB developed and used a program to decode truck vehicle identification numbers (VIN); this program was used in conjunction with VIN-derived gross vehicle weight ratings (GVWR) supplied by NHTSA. Additionally, the CODES staff used statistical procedures to impute missing values for critical variables in the data sent to the NTSB and thereby maximize the data available for analysis. This approach avoids the bias introduced by omitting records with missing values. This comprehensive approach resulted in a detailed characterization of single-unit truck crash types and the associated fatalities and injuries.

Recommended Safety Actions

In response to the findings of this study, the NTSB is issuing nine recommendations to NHTSA, four recommendations to the Federal Motor Carrier Safety Administration, one recommendation to the Federal Highway Administration, and two recommendations to the US Department of Transportation.

Recommendation areas include requiring modifications to enhance the ability of drivers of single-unit trucks to detect pedestrians and cyclists,[5] side underride protection systems for newly manufactured single-unit trucks, rear underride protection systems on newly manufactured single-unit trucks, and conspicuity treatments on the sides and rears of single-unit trucks.

The NTSB is also recommending improving federal and state data on large truck crashes (including the use of VINs to improve the coding of large trucks involved in crashes), continuing the functions that had been performed by the TIFA program and the CODES project, and examining the frequency and consequences of single-unit truck drivers operating with an invalid license.

This study reiterates previous recommendations to NHTSA to require front underride protection systems for large trucks and electronic stability control, adaptive cruise control, collision warning systems, and lane departure systems for large commercial vehicles.

[5] Cyclists are defined as bicyclists and other types of pedalcyclists (non-motorized).

What the NTSB Found in This Study

This study compared the accident characteristics of single-unit trucks with those of tractor-trailers over a five-year period during 2005–2009. Crashes involving single-unit trucks and passenger vehicles pose a hazard to passenger vehicle occupants due to differences in weight, bumper height, and vehicle stiffness. Study analyses resulted in the following conclusions regarding single-unit truck safety:

- The adverse effects of single-unit truck crashes have been underestimated in the past because these trucks are frequently misclassified in police accident reports and thus undercounted in federal and state databases.
- Single-unit trucks are involved in a disproportionate share of passenger vehicle occupant deaths in multivehicle crashes in relation to the number of registered vehicles and vehicle-miles of travel.
- Considerable societal impacts result from single-unit truck crashes as measured by fatalities, injuries, hospitalizations, and emergency department visits.
- Single-unit trucks should be subject to certain vehicle safety rules applicable to tractor-trailers.
- Additional vehicle-based countermeasures are needed to protect occupants of passenger vehicles and vulnerable road users.

This study quantified the numbers of fatal crashes, fatalities, and non-fatal injuries resulting from single-unit truck crashes during 2005–2009. National counts based on TIFA data show that an average of 1,662 single-unit trucks were involved in fatal crashes and 1,817 persons were fatally injured in these crashes nationwide each year. National estimates based on CODES data show that single-unit truck crashes resulted in 2,459 persons receiving serious or worse injuries, 5,720 hospitalizations, and 56,359 emergency department visits each year. Study analyses identified the following key issue areas.

Protection of Vulnerable Road Users

Vulnerable road users, defined as pedestrians and cyclists for this study, received non-fatal injuries more often from single-unit trucks than from tractor-trailers. However, single-unit truck crashes resulted in about 19 percent fewer pedestrian and cyclist fatalities than tractor-trailer crashes. Each year, an average of 145 pedestrians and 40 cyclists were fatally injured in single-unit truck crashes over the five-year study period, nationwide. During the same time period, an estimated 143 pedestrians/cyclists received serious or worse injuries each year. These numbers of fatalities and injuries indicate a need for countermeasures to protect vulnerable road users from single-unit truck crashes.

Side, Rear, and Front Underride

In the United States, an estimated annual average of 4,124 single-unit trucks and 8,726 tractor-trailers were involved in crashes in which a passenger vehicle collided with the sides of the trucks each year during 2005–2009. Average annual rates of serious injury per involved road user were highest in single-unit truck crashes in which passenger vehicles collided with the side of the single-unit truck and in sideswipes.[6] Side underrides in these crashes were common, based on a national sample of large truck crashes resulting in injuries or deaths.

According to national data, single-unit trucks were involved in 2,309 crashes in which passenger vehicles collided with the rears of these trucks each year during 2005–2009. Rear underrides occurred in more than 70 percent of passenger vehicle collisions with rears of single-unit trucks in which an injury or death occurred.

Truck frontal impacts pose a major hazard to passenger vehicle occupants and front underride contributes to the risk. Each year, front underride occurred in an estimated 608 crashes involving single-unit trucks colliding with the rear or sides of passenger vehicles, based on the LTCCS.

This study determined that side, rear, and front underride protection systems are needed to protect passenger vehicle occupants in collisions with single-unit trucks.

Conspicuity

An estimated 1,184 crashes involving single-unit trucks occurred on roads that were dark and unlit annually during 2005–2009. Crashes involving a passenger vehicle colliding with the side or rear of a single-unit truck on dark and unlit roads were more likely to result in a serious injury compared with those occurring during daylight.[7] This study determined that conspicuity improvements to single-unit trucks would be beneficial in low-light conditions and circumstances where other vehicles were traveling faster than the single-unit truck.

Electronic Stability Control

An estimated 201 single-unit trucks were involved in rollovers and an estimated 783 were involved in single-vehicle run-off-road crashes nationwide each year during 2005–2009. The NTSB previously recommended that large commercial vehicles be equipped with electronic stability control systems that would reduce rollovers and single-vehicle run-off-road crashes.

Misclassification of Large Trucks in Databases

Misclassification of large trucks in databases has resulted in a 19 percent undercount of single-unit trucks involved in fatal crashes, a 20 percent undercount of the fatalities, and an associated undercount of the injuries during 2005–2009. This misclassification is a consequence of relying solely upon vehicle body type codes from police accident reports to classify large trucks. This study developed and used a program to decode VINs to improve the accuracy of classification of both single-unit truck and tractor-trailer crashes. Using VINs results in a more accurate count of large trucks and is a method that should be widely applied to federal databases.

[6] Sideswipes are defined as collisions in which a vehicle strikes another vehicle along the side while traveling either in the same direction or opposite direction. This usually involves one vehicle encroaching upon the travel lane of the other vehicle.

[7] This increase was not statistically significant.

Crash Locations for Large Trucks

This study examined locations of crashes involving large trucks. Locations of fatal single-unit truck crashes follow the distribution of the general population, while locations of fatal tractor-trailer crashes tracked more closely with the network of the interstate highway system. This study also found a need to address the considerable state-by-state variation in the availability of geographic information for crashes.

Commercial Driver's Licenses

In fatal crashes during 2005–2009, six percent of drivers of single-unit trucks had invalid licenses compared with two percent of drivers of tractor-trailers. The majority of those single-unit truck drivers with invalid licenses were required to have a commercial driver's license but did not have one. The risks associated with invalid licensure remain unknown.

1. Introduction

1.1 Background

During 2005– 2009, 24,545 fatalities in crashes involving large trucks occurred on US public roads, averaging 4,909 per year (Jarossi et al. 2006; 2007; 2008).[8] In this same time period, the estimated number of people injured in large truck crashes ranged from 74,000 to 114,000 per year (NHTSA 2012c). Large trucks accounted for 4.3 percent of all registered vehicles and 9.7 percent of vehicle-miles of travel in 2010, and they were overinvolved in passenger vehicle occupant deaths relative to their numbers of vehicles and miles traveled (Federal Highway Administration (FHWA) 2012; Insurance Institute for Highway Safety (IIHS) 2010). Specifically, large trucks were reported as involved in 23 percent of passenger vehicle occupant fatalities in collisions involving two or more vehicles in 2010. Large trucks are overrepresented in fatal crashes involving passenger vehicles; one factor in this overrepresentation is the large weight disparity between the two types of vehicles (Braver and Kyrychenko 2004; Brumbelow 2012; Krusper and Thomson 2008; Krusper and Thomson 2012). Another contributing factor in large truck overrepresentation is the bumper height mismatch between large trucks and passenger vehicles, allowing passenger vehicles to go underneath large trucks, which is known as underride. Underride can be catastrophic to passenger vehicle occupants because it increases the risk of the truck structure intruding into the passenger compartment. Additionally, vehicle stiffness[9] is greater for large trucks than for passenger vehicles and increases the injury risk to passenger vehicle occupants in collisions with large trucks.

The US Department of Transportation (DOT) defines large trucks as trucks with a GVWR over 10,000 pounds. A GVWR is the maximum allowable weight specified by the vehicle manufacturer and combines the individual vehicle's unloaded weight with the weight that the vehicle may carry as cargo and anything else transported by the vehicle, such as occupants and fuel.[10] Single-unit trucks are a type of large truck that has a typically non-detachable, cargo-carrying unit (all axles are attached to a single frame). Tractor-trailers, another type of large truck, consist of cabs with engines[11] that have a connection such that they can pull a trailer without a front axle (semi-trailer).[12] GVWRs for large trucks fall into classes 3–8, with truck-tractors typically falling into class 8[13] and single-unit trucks falling into classes 3–8 (see figure 1, which depicts light trucks, single-unit trucks, truck-tractors, and trailers; single-unit trucks are shown in brown, and tractor-trailers in black). Single-unit trucks include medium/large pickup

[8] For 2009, the NTSB analyzed TIFA data to obtain the fatal crash statistics.

[9] See footnote 2.

[10] Trailers have separate GVWRs.

[11] The front cab that contains the engine is referred to as a power unit for both tractor-trailers and single-unit trucks. The power unit is called a truck-tractor for tractor-trailers.

[12] In this study, large trucks are classified by type of power unit, not by whether they are pulling a semi-trailer or full trailer. Tractor-trailers refer to truck-tractors traveling without trailers, truck-tractors pulling semi-trailers, and truck-tractors pulling multiple trailers.

[13] Some truck-tractors fall into class 7, including those that pull two or three trailers.

trucks, vans, dump trucks, flatbeds, garbage trucks, cement mixers, highway maintenance vehicles, and special work vehicles, among other vehicle body types (see figure 2 for photos of different types of single-unit trucks).

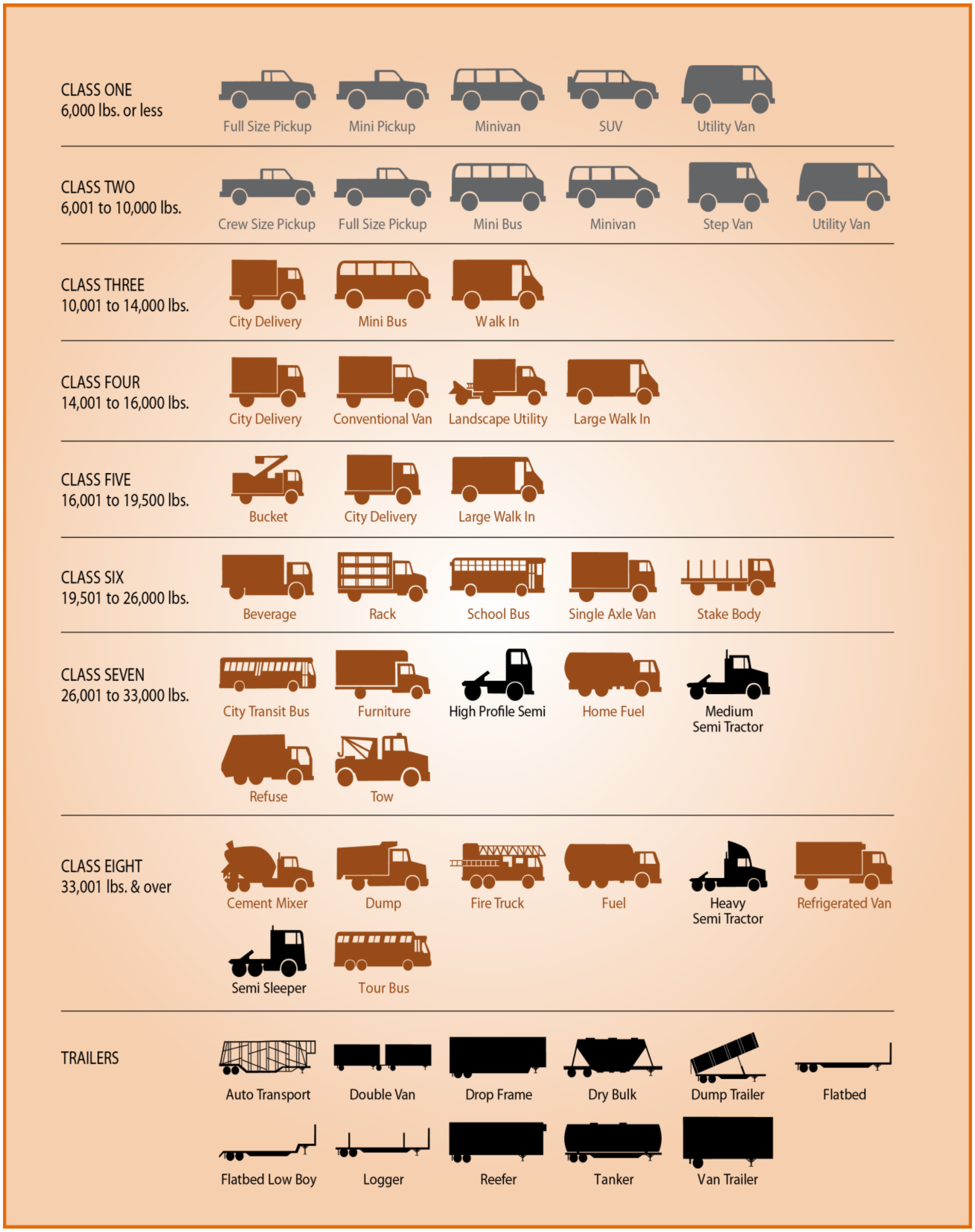


Figure 1. Illustration of truck GVWR classes, modified from Goodyear Tires, 2011.

Figure 2. Different types of single-unit trucks.

1.2 Objectives

This safety study aimed to improve understanding of the risks from crashes involving single-unit trucks, with a focus on those crashes resulting in deaths, non-fatal injuries, and hospital treatment. The objectives of this study were to:

1. Estimate the numbers of fatal injuries, non-fatal serious injuries, emergency department visits, and inpatient hospitalizations resulting from single-unit truck crashes versus those numbers resulting from tractor-trailer crashes.
2. Compare accident characteristics for these two categories of large trucks: single-unit trucks and tractor-trailers.
3. Identify safety problems involving single-unit trucks and vehicle safety countermeasures, including an examination of regulations that currently apply to tractor-trailers but not to single-unit trucks.

In 2010, about 8.22 million single-unit trucks and 2.55 million tractor-trailers were registered in the United States (FHWA 2012). However, in the same year, tractor-trailers accumulated more vehicle-miles of travel (VMT) (175,789 million) than single-unit trucks (110,738 million). Single-unit trucks tend to be used in short-haul operations, often by intrastate carriers, rather than long-haul interstate operations. Approximately 55 percent of single-unit trucks involved in fatal crashes were within 50 miles of their home base. Single-unit trucks have different travel patterns than tractor-trailers, with a lower percentage of VMT on rural or urban interstates and a correspondingly higher percentage of travel on non-divided rural and urban roads (Moonesinghe et al. 2003).[14] These differences in travel patterns expose single-unit trucks to more opportunities than tractor-trailers to collide with passenger vehicles and pedestrians and cyclists at intersections, on urban and suburban roads with non-divided opposing lanes of traffic, and on congested roads. As part of describing accident characteristics of single-unit trucks, this study estimated the frequency of crashes involving pedestrians and cyclists.

Safety regulations for tractor-trailers are generally less costly to implement nationwide than those for single-unit trucks because there are fewer tractor-trailers registered in the United States. Because tractor-trailers are reported to be involved in about 75 percent of fatalities involving large trucks, based on vehicle body type codes in FARS (IIHS 2010), cost-effectiveness estimates that rely mainly on fatalities show a higher cost-effectiveness for safety rules aimed at tractor-trailers than for single-unit trucks. Consequently, single-unit trucks are not included in some of NHTSA's safety regulations which apply to truck-tractors[15] and trailers.[16] For example, single-unit trucks do not have to meet the requirements for improved rear underride guards (mandatory in 1998 for new trailers) or the requirements for conspicuity treatments to enhance visibility (mandatory in 1993 for new trailers; in 1997 for new tractors; and in 2001 for all trailers on the road).[17,18] In 2012, NHTSA (2012a) proposed mandating electronic stability control for truck-tractors and motorcoaches but not for single-unit trucks. The proposed rule on electronic stability control pointed out that there are no electronic stability control systems available for hydraulically-braked trucks (which comprise most single-unit trucks); however, single-unit trucks with air brakes were also excluded from the proposal. During 2005–2009, 44 percent of single-unit trucks involved in fatal crashes had GVWRs in excess of 26,000 pounds, almost all of which had air brakes. Furthermore, based on information from brake manufacturers and the prior NTSB accident investigation in Glen Rock, Pennsylvania (2006), air brakes also were likely to have been present on a large proportion of the single-unit trucks with GVWRs of 19,501-26,000 pounds. Thus, about half of the single-unit trucks that were involved in fatal crashes during 2005-2009 had air brakes.

Research on single-unit trucks has not adequately described the crashes resulting in serious injuries, nor has it distinguished among the different types of single-unit trucks. This research is necessary for evaluating safety regulations for single-unit trucks, as well as determining whether other vehicle safety technologies would be beneficial. This study describes

---

[14] In 2010, about 56 percent of single-unit truck VMT was on urban roads compared with 44 percent of tractor-trailer VMT. A far lower proportion of single-unit truck VMT occurred on interstate highways than tractor-trailer VMT: 23 percent versus 48 percent.

[15] Truck-tractors are the power units (component with engines) of tractor-trailers.

[16] NHTSA. Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices, and Associated Equipment; Final rule. *Federal Register, Vol* 57, No. 238, p. 58406, December 10, 1992. NHTSA. Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection; Final rule. *Federal Register, Vol.* 61, No. 16, p. 2004, January 24, 1996.

[17] 49 CFR Part 571.223 and 571.224 (Federal Motor Vehicle Safety Standards: Rear Impact Guard and Rear Impact Protection) and 49 CFR Part 571.108 (Federal Motor Vehicle Safety Standards: Lamps, Reflective Devices, and Associated Equipment).

[18] Retroreflective tape is the most commonly used method for complying with conspicuity requirements. Specifically, red and white alternating tape is at least two inches high and six inches long. The markings on trailer sides are not required to be continuous but must cover half their length and be evenly distributed. Rear markings include upper corners and also cover the full width of the lower rear in addition to the underride guard.

the characteristics of single-unit truck crashes and quantifies the frequency of emergency department visits and hospitalizations due to these crashes.[19] Injuries that require hospital treatment can result in suffering and long-term disability, as well as substantial medical and other societal costs. Additionally, this study used an accident investigation database, as well as case studies, to add to knowledge regarding injury causation and to help identify potential vehicle-based countermeasures. Recommendations to improve the safety of single-unit trucks are presented.

This study also examined the accuracy of federal and state data with respect to coding single-unit truck crashes. The Fatality Analysis Reporting System (FARS) is the federal database for recording all crashes on US public roads in which a death occurs within 30 days of the crash. As a supplement to the FARS, the DOT funded the University of Michigan Transportation Research Institute (UMTRI) to collect additional data on fatal crashes involving large trucks for calendar years 1980–2010. This database, known as Trucks in Fatal Accidents (TIFA), has identified additional large trucks that were not classified as such in FARS, particularly single-unit trucks (Blower and Matteson 2002).

1.3 Previous Research

Moonesinghe et al. (2003) examined characteristics of fatal large truck crashes and concluded that single-unit trucks were less likely to be involved in fatal crashes than tractor-trailers. Their study showed that a large proportion of fatal truck crashes occurred on non-divided roads for both types of large trucks. Fatal single-unit truck crashes occurred more often in urban areas, during daylight, and at traffic-signal-controlled intersections. The most common types of two-vehicle fatal collisions involving single-unit trucks were trucks following straight paths and striking passenger vehicles, head-on collisions in the truck's lane, passenger vehicles striking the rears of single-unit trucks, passenger vehicles turning across the truck travel paths, and sideswipes (primarily those in which the passenger vehicle encroached on the truck's lane).

Wang et al. (1999) completed a comprehensive study comparing single-unit truck crashes with tractor-trailer crashes. Wang et al. estimated that combination truck (primarily tractor-trailer) crashes resulted in $10 billion in costs annually compared with $5 billion in costs[20] resulting from single-unit truck crashes. The most common single-unit truck crashes were single-vehicle roadway departures, backing crashes, lane change/merge crashes, and crashes in which the large truck struck the rear of a stopped or moving vehicle. The types of crashes resulting in the greatest number of serious injuries in single-unit truck crashes were

[19] Inpatient hospitalizations refer to patients who require admission to hospitals and stay at least one night rather than being sent home the same day that they are examined and treated.

[20] These costs included direct medical costs, direct societal costs, and intangible costs due to pain and suffering. The authors used estimated costs for each crash type and then multiplied those costs by the estimated annual frequency of the crash types for each type of vehicle. The total estimated cost for passenger car crashes was $147 billion.

single-vehicle run-off-road crashes, pedestrian/cyclist collisions, rear-end crashes, and opposite direction crashes.

Although Wang et al.'s study was useful, it did not research crashes in which the single-unit truck was struck in the rear or side; information on these types of crashes is helpful in determining the safety benefit of underride guards and conspicuity treatments. Additionally, the study did not have data on hospitalizations and length of hospital stay. The injury severity classifications were based on police reports, which do not have the detail and accuracy of hospital records; approximately half of the injuries coded as incapacitating[21] by police are minor (Farmer 2003).

The Large Truck Crash Causation Study (LTCCS), sponsored by the Federal Motor Carrier Safety Administration (FMCSA), collected a nationally representative sample of 963 crashes involving large trucks from April 2001 through December 2003 (FMCSA 2005). Of the 1,123 large trucks in the study, 297 were single-unit trucks. Knipling and Bocanegra (2008) used LTCCS data to compare crash types of single-unit trucks and tractor-trailers and reported that single-unit trucks were involved in fewer single-vehicle crashes than tractor-trailers. The study also found that, because of their different travel patterns, single-unit trucks tended to be involved in more intersection crashes and more crashes where the truck struck the rear of vehicles stopped in traffic. Finally, Knipling and Bocanegra found that approximately 13 percent of single-unit truck crashes occurred during conditions of darkness or dawn/dusk.

1.3.1 Large truck/passenger vehicle underride collisions

Figures 3 and 4 show photographs of a side underride collision and a rear underride collision, respectively. Brumbelow and Blanar (2010) observed that among the 22 single-unit trucks struck in the rear by passenger vehicles included in the LTCCS, 3 were not underridden, 11 (50 percent) passenger vehicles experienced slight to moderate underride, and 8 (36 percent) passenger vehicles experienced severe to catastrophic passenger vehicle underride.[22] The severity of the underride appeared to be related to the height of the truck chassis or underride guard, with less severe underrides occurring if the passenger vehicle bumper engaged the truck structure. The findings of IIHS's study suggest that improved rear underride guards would be beneficial for at least some single-unit trucks, and IIHS petitioned NHTSA to extend the underride guard regulation to single-unit trucks and to alter the requirements for the underride guards mandated in 1998 for trailers to make them more effective (IIHS 2012b). As of the time of this study, NHTSA has not formally responded to this petition, but sponsored research on rear underride (Blower and Woodrooffe 2013).

---

[21] Police use a KABCO scale to code injury severity, where K refers to fatal injuries; A refers to incapacitating injuries; B refers to non-incapacitating injuries; C refers to possible injuries such as complaints of pain; and O refers to people who were involved in the crash but uninjured (Rothenberg 2012).

[22] Slight underride was defined as the passenger vehicle going underneath up to one-half of the length of the hood; moderate underride was defined as the passenger vehicle receiving damage up to the base of the windshield; severe underride was defined as damage extending as far as the B-pillar (second pillar of the passenger vehicle); catastrophic underride was defined as having the entire front-row space compromised by passenger compartment intrusion.

Figure 3. Photos of a Side Underride from Case 884005705, Large Truck Crash Causation Study.

Figure 4. Photo of a Rear Underride of a Single-Unit Truck, January 2013.

Blower and Woodrooffe (2013) conducted a rear underride study based on TIFA data and reported that 977 large trucks were struck in the rear in fatal crashes during 2008–2009, constituting 13 percent of all large truck fatal involvements. The percentages of fatal rear crashes were the same for single-unit trucks and for tractor-trailers. Their research also found that 74 percent of fatal crashes in which the rear of a single-unit truck was struck by a passenger vehicle involved underride; the corresponding percentage for tractor-trailers was 78 percent.[23] Additionally, Vachal et al. (2009) examined North Dakota's agricultural fleet, which includes single-unit dump trucks and other rear-unloading single-unit trucks and trailers, and concluded that the public safety benefits from equipping and maintaining large agricultural trucks with rear underride guards would outweigh the costs of the equipment and maintenance.[24]

European regulations have addressed the problem of front and side underride, which are potential areas where truck safety could be improved in the United States. Countries in the European Union have mandated front underrun (underride) protection systems for newly manufactured large trucks beginning in August 2003 (Council of the European Union 2000). European countries and Japan have had a requirement for side underrun guards for large trucks since the 1990s (Patten and Tabra 2010; Council of the European Communities 1989); however, these guards are designed to protect pedestrians and cyclists from going beneath large trucks rather than to prevent side underrides of passenger vehicles (United Nations 1988). A 2009 project funded by the European Commission designed a side underride guard for large trucks meant to prevent passenger vehicle side underrides, together with testing requirements (Gugler 2009). Some European researchers have proposed systems that would modify frames of large trucks as an alternative to side underride guards and at least one manufacturer sells trailers with a protective frame that is designed to prevent both rear and side underride crashes (Brumbelow 2012).

Brumbelow (2012) used LTCCS data to examine crashes in which passenger vehicles had collided with the sides of large trucks to determine potential benefits of side underride guards. His study reported that side underride guards could have reduced the severity of 76 of the 143 crashes in which passenger vehicle occupant injuries were attributed primarily to the side impact with the large truck (either single-unit or tractor-trailer). When examining only crashes involving the sides of single-unit trucks, his study found that side underride guards could have mitigated 5 of the 38 crashes.

Blower and Woodrooffe (2013) studied side and front underrides, along with the frequency of passenger compartment intrusion,[25] in passenger vehicle collisions with large trucks included in the LTCCS. Side underride occurred in 53 percent of side impacts to single-unit truck cargo body areas and in 43.5 percent of side impacts to single-unit truck cabs. Side underride occurred in 69 percent of passenger vehicle collisions to the sides of trailers. Large

[23] The percentages of rear underrides excluded crashes in which the underride status could not be determined, about 10 percent of rear impacts in the study (Blower and Woodrooffe 2013).

[24] The rear-unloading trailers used for agricultural purposes fell under the federal mandate for rear underride guards; however, the state of North Dakota requested an exemption from the mandate for these trailers.

[25] Passenger compartment intrusion "was recorded if there was any deformation of the passenger compartment. . . such as the A-pillar being pushed back" (Blower and Woodrooffe 2013). Passenger compartment intrusion greatly increases that risk of occupants being fatally injured in underride collisions.

trucks that had cargo beds that extended below the tops of the tires had a lower percentage (30 percent) of side underride in truck side impacts than large trucks with cargo beds that were 50 inches above the ground or higher.

Front underride occurred in at least 72 percent of passenger vehicle impacts with the front of large trucks and 64.5 percent resulted in passenger compartment intrusion. Truck bumper height was an important determinant of front underride occurrence: 87 percent of front impacts resulted in underride when large trucks had high bumpers (defined as above their front axles) compared with 58 percent of front impacts when large trucks had low bumpers (below their axles).

1.3.2 Protection of Vulnerable Road Users

Pedestrians and cyclists are considered “vulnerable road users,” as they lack an external vehicular structure to protect them while on the road.[26] Methods of protecting these vulnerable road users are a growing subject of international and national interest (World Health Organization 2009; Williams 2013). In 2012, New York passed legislation requiring a cross over mirror[27] on the fronts of large trucks operating in cities with populations of at least one million and on highways other than limited access roads to reduce truck-pedestrian collisions; this mainly affected New York City (NYC DOT 2012). Europe also has requirements for enhanced mirrors on large trucks to reduce blind spots (European 2003, 2005).[28] In 2005, NHTSA published a proposed rule aimed at preventing backover pedestrian accidents involving single-unit trucks with GVWRs ranging from 10,001–26,000 pounds (NHTSA 2005). The proposal subsequently was withdrawn after NHTSA determined that very few backover pedestrian fatalities on private property involved single-unit trucks in this GVWR range (NHTSA 2008).[29] In 2010, 69 percent of pedestrian fatalities occurred during nighttime (NHTSA 2012d); advanced sensing technologies are not yet widely available to detect pedestrians and cyclists at night.

1.3.3 Previous NTSB Investigations, Safety Studies, and Recommendations

Most large truck crashes investigated by the NTSB have involved tractor-trailers. The NTSB’s safety recommendations based on tractor-trailer crashes have usually been written broadly to apply to all types of large trucks, including single-unit trucks. The NTSB (2006a,

[26] Motorcyclists also are considered vulnerable road users, but were not defined as such in this study.

[27] A cross over mirror is convex and is mounted on the front of the truck, which enables the driver to detect pedestrians.

[28] The European regulation refers to “Devices for indirect vision,” which allows for technology other than enhanced mirrors. The rule states that these are “devices to observe the traffic area adjacent to the vehicle which cannot be observed by direct vision. These can be conventional mirrors, camera-monitors or other devices able to present information about the indirect field of vision to the driver.”

[29] In 2008, Congress passed a law (K.T. Safety Act of 2007) mandating that NHTSA issue a rule to enable passenger vehicle drivers to detect small children and disabled people behind vehicles to prevent backover crashes (NHTSA 2008); large trucks were not included in NHTSA’s proposed rule.

1997) has completed two major investigations of accidents in which the primary focus was a single-unit truck; both involved crashes in which the trucks (one a dump truck, the other a cement mixer) were unable to stop due to maladjusted brakes. As a result of these investigations, the NTSB recommended revisions of procedures to ensure that air brakes are properly adjusted. A third investigation, which is ongoing, involved a collision between a roll-off truck (a single-unit truck that permitted containers to be lifted onto and rolled off a chassis) and a school bus at an intersection in Chesterfield Township, New Jersey, in 2012.

The NTSB (2002) issued a report in 2002 of intrastate trucking operations, which tend to have a large proportion of single-unit trucks in their fleets. Crash characteristics were similar between intrastate and interstate motor carriers. Intrastate carriers had higher rates of large trucks being placed out of service due to vehicle equipment defects (31 percent) than interstate carriers did (25 percent).

The NTSB has long advocated for research and implementation of vehicle- and infrastructure-based technologies to aid in the prevention and mitigation of large truck and bus collisions. The potential contributions of these technologies were described in several NTSB accident investigations (NTSB 2006b, 2010c, 2010a, 2011a) and a Special Investigation Report (NTSB 2001b). The NTSB (2001a, 2009, 2010b) has issued safety recommendations regarding electronic stability control, adaptive cruise control, collision warning and lane departure systems, and infrastructure-based technologies such as active (variable) message signs and driver notification of distant traffic queues. Additional recommendations have urged research and design enhancements to address heavy truck aggressivity, which refers to the high risk of serious injuries and deaths to occupants of passenger vehicles involved in collisions with large trucks due to the disparities in vehicle weights and other structural incompatibilities (NTSB 2006c).[30]

The NTSB has issued several safety recommendations regarding rear, front, and side underride. In 1971 and 1981, the NTSB made recommendations to NHTSA concerning the specifications for a rear underride guard (referred to as rear impact protection guard by NHTSA) for all large trucks.[31] NHTSA's 1996 final rule requiring improved rear underride guards applied only to full trailers and semi-trailers. Since then, the NTSB has not made any further recommendations about rear underride guards for large trucks.

In 1971, the NTSB (1971a) recommended that NHTSA "consider the desirability of adding the requirement for side underride protection." However, NHTSA has not issued regulations to address the problem of side underrides of large trucks, which prior research

---

[30] Safety Recommendation H-06-15 was classified "Closed—Acceptable Alternate Action" and H06-16 was classified "Closed—Unacceptable Action, Superseded by H-10-12."

[31] In 1971, the NTSB recommended that NHTSA establish performance requirements for "energy-absorbing underride and override barriers" (H-71-18). In 1981, the NTSB investigated a chain-reaction crash in which multiple fatalities occurred as a result of underride collisions with large trucks and pointed out that the types of rear underride guards mounted on the large trucks (per rules issued in 1953) were ineffective. Therefore, the NTSB recommended that NHTSA promulgate a rear underride guard standard that would permit no more than 18 inches of clearance between the ground and the guard (H-81-27). http://www.ntsb.gov/doclib/recletters/1981/H81_26_27.pdf

estimated as occurring more often than rear underrides and almost as often as fatal front underrides (Braver et al. 1997).

In 2006 and 2010, the NTSB issued recommendations to NHTSA to address structural incompatibility between large trucks and passenger vehicles and pointed out the need for front underride protection systems on large trucks.[32]

The NTSB issued safety recommendations relating to pedestrians in 1971. These safety recommendations addressed the need for coordination of efforts between different federal agencies, a need for increased funding of pedestrian safety programs, and a need for "pedestrian safety research and development," as well as "development of vehicle safety standards to reduce pedestrian accidents and injuries." Additionally, the NTSB (1971b) recommended that the FHWA consider what should be done to protect pedestrians from large trucks and buses, including issuing "motor carrier safety regulations to reduce pedestrian accidents."[33]

[32] Safety Recommendations H-10-12 (which superseded H-06-16) and H-10-13. Both are classified "Open—Acceptable Response."

[33] The NTSB issued Safety Recommendations H-71-54 through -56 to address pedestrain safety. In 1975, Safety Recommendations H-71-54 and H-71-56 were classified "Closed—Acceptable Action" and Safety Recommendation H-71-55 was classified "Closed—Acceptable Alternate Action."

2. Methods

This is a descriptive study that relied on multiple state and federal databases to examine characteristics of single-unit truck crashes and to estimate the magnitude of the injury problem arising from single-unit truck crashes. The databases complemented each other in meeting the study objectives. Figure 5 provides an overview of the data sources used in this study. This study also used case reviews to provide further insight into the circumstances of single-unit truck crashes and potential countermeasures. In many of the analyses, single-unit trucks are compared with tractor-trailers, the type of truck that is subject to more safety regulations. As mentioned in section 1.1, single-unit trucks are defined as a truck with a typically non-detachable cargo-carrying unit and a GVWR over 10,000 pounds.

2.1 Data Sources

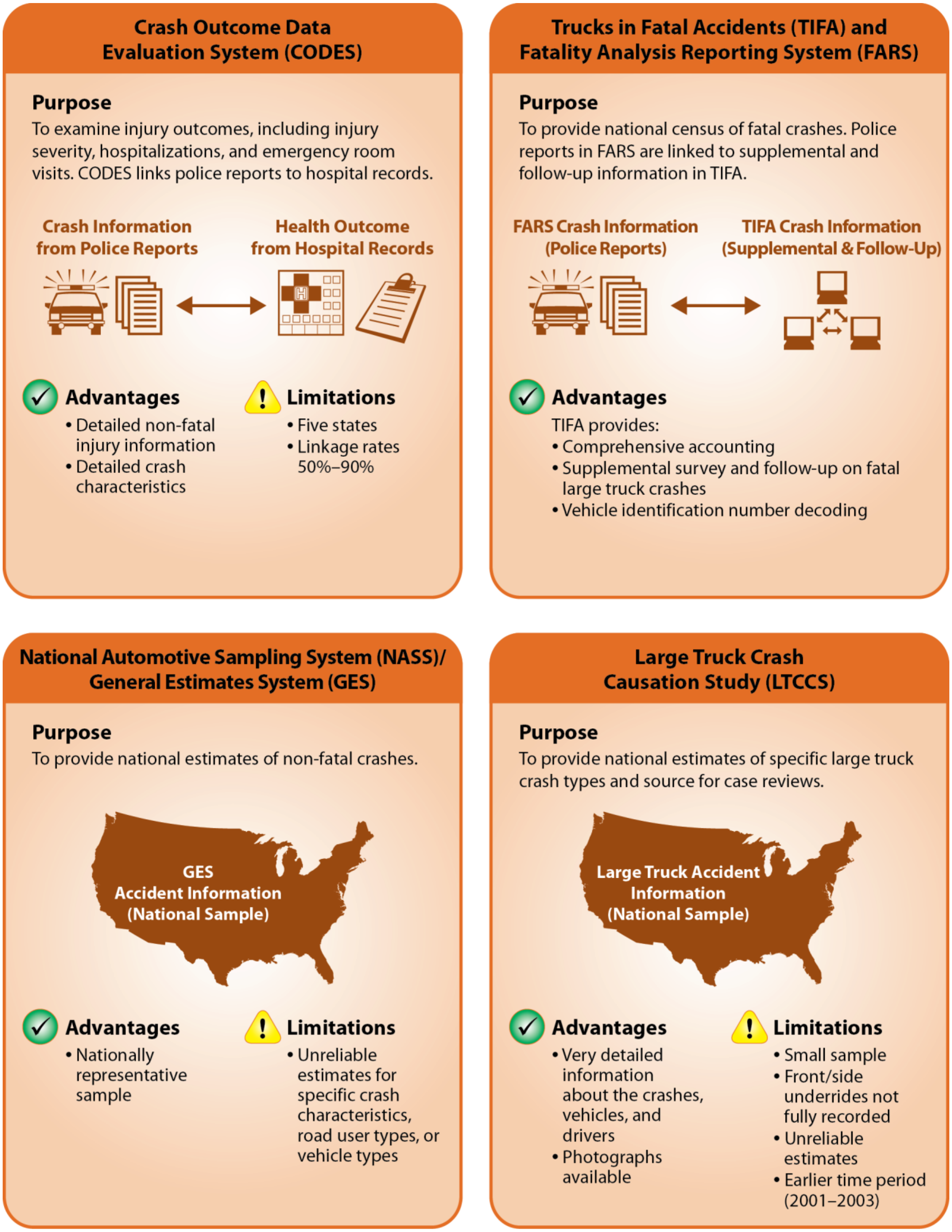


Figure 5. Overview of Data Sources (CODES, TIFA and FARs, GES, and LTCCS).

2.1.1 Crash Outcome Data Evaluation System (CODES)

The primary data source was CODES, a project in which 13 states link people hospitalized due to motor vehicle crashes to police reports; 5 of these states participated in this study. NHTSA has been providing partial subsidies to states and technical support to standardize the methods. The purpose of CODES is to study medical outcomes of people injured in motor vehicle crashes in relation to accident characteristics by linking hospital and police-reported accident data; this is done using probabilistic linkage.[34] Each participating state uses a standard protocol and the same software (CODES2000) (McGlincy 2004). CODES data included 50 to 90 percent of drivers[35] hospitalized within states as a result of motor vehicle crashes and provided detailed data on injury diagnoses, injury severity,[36] and hospital charges, in addition to crash characteristics available from police accident reports.[37] Fatalities in states were identified by using both the police accident reports and hospital data. Police accident reports generally include weather; lighting; surface conditions; VINs, which are unique 17-digit numbers mandated by NHTSA for each vehicle sold in the United States; initial impact point; most harmful event; and vehicle body type. Vehicle body types include motorcycles, passenger cars, minivans/vans, pickup trucks, single-unit trucks, tractor-trailers, and school buses. Different states have their own sets of vehicle body types and their own codes for categories within variables on police reports.[38]

NHTSA collaborated with the NTSB by coordinating the process of requesting and obtaining CODES data, supplying VIN-derived GVWRs, and providing technical advice and assistance. Five states (referred to in this study as the "participating states") participated in this collaboration: Delaware, Maryland, Minnesota, Nebraska, and Utah. The states' CODES organizations obtained permission from their CODES Board of Directors and Institutional Review Boards to release data and included the Delaware Department of Health and Social Services, the National Study Center for Trauma and Emergency Medical Systems at the University of Maryland, the Minnesota Department of Health, the Nebraska Department of Health and Human Services, and the University of Utah CODES Project. Each state's CODES

---

[34] Because unique personal identifiers are often removed from hospital discharge records to maintain privacy, the participating states use probabilistic linkage to match hospital discharges to police accident reports. Probabilistic linkage is a method that uses personal and event information common to a pair of records to estimate the probability that a police accident report and hospital record describe the same person and event. Linking information may include names, date of birth, sex, date and time, location, and the roles of people and vehicle types involved. This method results in multiple imputed datasets, each with the possibility of different links between police accident reports and hospital records. Analysis of multiple imputed datasets accounts for the uncertainty inherent in the linkage process (Cook et al. 2001). For each hospitalized road user, five potential links are generated (if all the data fields match, all five links may be to the same police report).

[35] Some states also include passengers and vulnerable road users in addition to drivers. Each state has different linkage rates.

[36] CODES states use the Abbreviated Injury Scale (AIS) to score injury severity as well as other methods; this study relied on AIS.

[37] Medical outcomes were derived from emergency department and hospital discharge databases and include billing information related to the visit, such as billed charges, length of stay, and discharge status.

[38] Coding is done for all types of records created by the state or other entities, including hospitals, as a way to summarize the information for electronic data files. Once data that have been coded are entered into electronic data files, the information from these files can be analyzed.

staff imputed linkages between hospital discharge records and police accident reports, compiled their state databases according to the NTSB's specifications, worked with the NTSB on individual variables, and provided advice on their databases. Maryland CODES at the University of Maryland also provided centralized injury severity coding to ensure consistency in addition to coordinating the work done by the states. [39] The University of Utah CODES Project staff worked closely with the NTSB in order to provide the agency with imputed missing values for each state and provided extensive statistical consultation concerning the correct methods for analyzing imputed data.

The study period for state data was 2005–2009; the participating states varied in their numbers of calendar years for which linked data were available. The states also varied in their numbers of police-reported motor vehicle crashes and the percentage of their population living in urban or rural areas. States use different criteria for what crashes must be reported to police, which can affect rates of injuries per person involved in large truck crashes. However, all state analyses were based on the combined state data and one state was not compared with another.

The participating states had a combined total of 16.9 million residents, or 5.6 percent of the US population (US Census Bureau 2010). This study generated national estimates for people receiving serious or worse injuries, emergency department visits,[40] and inpatient hospitalizations by using the rates per million population in the participating states combined with the US census population estimates for 2005–2009.

Missing data are a frequent occurrence in administrative databases such as hospital records and police accident reports, the sources for the CODES data. The CODES Technical Resource Center at the University of Utah performed all the imputations of missing data, using multiple imputation methods,[41,42] to maximize the numbers of records available for data analyses and minimize potential bias from missing data.[43] Multiple imputations, when done properly, are considered more statistically sound than either ignoring missing data or imputing only one potential value (Subramanian 2002). Both the University of Utah CODES Project and the NTSB used SAS statistical software (SAS 2004; 2012) for imputations.[44] The NTSB provided guidance to the University of Utah regarding which variables to use for each participating state when doing multiple imputations; this resulted in predictions of five different sets of plausible values

---

[39] The University of Maryland used a computer program, ICDMap-90, which converts hospital billing code data to injury severity scales.

[40] See footnote 3.

[41] Multiple imputations are a statistical method of reducing potential bias from missing values. SAS Institute has a useful explanation: "Multiple imputation does not attempt to estimate each missing value through simulated values. Instead, it draws a random sample of the missing values from its distribution. This process results in valid statistical inferences that properly reflect the uncertainty due to missing values—for example, confidence intervals with the correct probability coverage."

[42] Vehicle body types were assigned by the NTSB; missing values were not imputed for vehicle body types.

[43] Many studies have excluded individuals with missing data from statistical analyses, which can result in incorrect findings because people with missing values may be very different from those with complete records.

[44] Multiple imputations were done by using sequences of regression models implemented in IVEware and SAS software (Raghunathan et al. 2001; SAS Institute Inc. 2012). Analysts at the CODES Technical Resource Center at the University of Utah developed state-specific imputation models. Missing data from each of the five submitted state datasets were imputed separately.

for the missing data in the study populations for each state. The NTSB used standard statistical methods and procedures (Rubin 1987) for imputed data when analyzing the five different databases generated for each participating state by probabilistic linkage of hospital and police records and multiple imputation procedures. The summary statistics generated from CODES data were combined from the results of five imputations.

Based on the previously documented discrepancy between TIFA's and FARS's counts of single-unit trucks (Blower and Matteson 2002), relying solely on police-reported vehicle body type codes to identify single-unit truck crashes could have resulted in underestimates. Consequently, this study used VINs to supplement police report data.

Because no software was available to decode batches of truck VINs, the NTSB wrote a VIN-decoding SAS[45] program to identify single-unit trucks and tractor-trailers based on the printed booklets of large truck VINs produced every few years by the National Insurance Crime Bureau (NICB) (1990, 1995, 2000, 2005, 2010) for all truck manufacturers for model years 1987 through 2010. The methods for describing characteristics of large trucks through VINs vary by manufacturer and over time. After testing and revising this software program, the NTSB discovered that the VIN-derived GVWR was also needed to correctly classify large trucks, and NHTSA supplied the VIN-derived GVWR for each vehicle in the participating states' databases. However, even with the NTSB's VIN-decoding program, some truck types remained undefined, including those sold with a chassis that would allow them to be transformed into either a truck-tractor or single-unit truck.[46]

The NTSB developed an algorithm for each participating state to identify and classify large trucks as accurately as possible (see figure 6). First, the NTSB obtained all available vehicle records from each state's electronic data files. Delaware, Maryland, Nebraska, and Utah had VINs for more than 90 percent of the respective state's vehicles, while Minnesota had VINs for 76 percent of its vehicles. Of these available VINs across the participating states, 88 percent were valid; these were initially classified into single-unit trucks, tractor-trailers, gliders,[47] buses, or other vehicles (predominantly passenger vehicles). If valid VINs were unavailable, data from the police report served as the sole source for identifying the type of vehicle.

[45] SAS (formerly known as Statistical Analysis System) is statistical software produced by the SAS Institute, Inc. (2012). Users of SAS write programs to execute statistical procedures.

[46] Occasionally, single-unit trucks are subsequently converted into truck-tractors or vice versa, so the VIN could not classify correctly these particular large trucks.

[47] Gliders are large trucks manufactured with the frame, cab, steer axle and wheels. Customers purchase them and can turn them into either truck-tractors or single-unit trucks. In many instances, they are used to reconstruct existing trucks by using the engine, power train, and transmission from the older truck. In this study, they were assigned as unspecified large trucks.

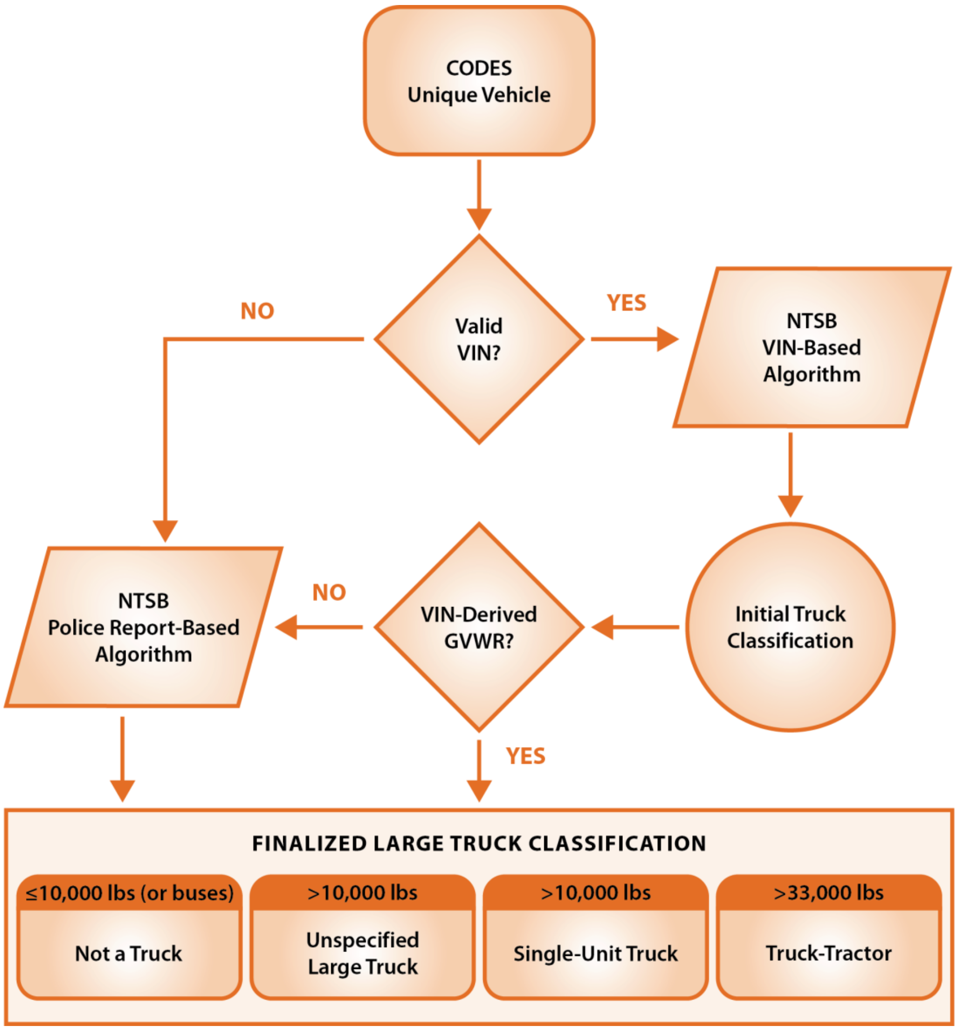


Figure 6. Flow chart for identifying and classifying large trucks in the participating states.

Second, to eliminate the possibility of misclassifying passenger vehicles as large trucks, the NTSB used the VIN-derived GVWR supplied by NHTSA to classify the large trucks by weight class. Class 0 refers to passenger cars, while Classes 1 and 2 refer to other passenger vehicles, including minivans, SUVs, and light pickup trucks. Classes 3 through 7 refer to single-unit trucks. The heaviest weight class, Class 8, contains both tractor-trailers and heavy single-unit trucks such as cement mixers and dump trucks.[48]

Finally, the NTSB used information from police reports to categorize vehicles that did not have VIN-derived GVWRs or where the GVWR was coded as 9 (unknown). Most of these were reclassified as passenger vehicles. Varying by state, the available variables from police reports included vehicle body type, whether the vehicle was towing a trailer, the cargo body style

[48] Some tractor-trailers fall into Class 7, but they are uncommon.

(e.g., the physical design of the vehicle, such as cement mixers, box trucks, and heavy pickups), vehicle configuration, and the type of cargo.

CODES data from the participating states had sufficient numbers to be valid because they included a complete set of state police-reported crashes involving large trucks and a high percentage of hospitalized drivers (50–90 percent).[49] The state data did not include detailed accident investigations apart from the police accident reports; consequently, some data drawn from police accident reports were missing or inaccurate. The participating states represented diverse geographic areas, with some states being primarily rural. The validity of the state findings was strengthened by the imputation of missing values. Furthermore, the accuracy and completeness of truck type classifications was improved in the participating states' data by supplementing vehicle body type codes with information from VINs.

The data from the participating states appear to be relevant to the nation as a whole as demonstrated by the following: (1) the state percentage (38 percent) of fatalities involving large trucks that occurred in single-unit truck crashes was similar to the national percentage of 37 percent, (2) state-based estimates of national large truck crash fatalities were close to the true number of fatalities involving large trucks in the United States, and (3) the participating states' rates of fatal single-unit truck involvements per million population were similar to the overall US annual rate of 6.14 fatal single-unit truck involvements per million. No definitive national data source exists on either non-fatal injuries or hospitalizations resulting from large truck crashes; therefore, this study was unable to evaluate how well its national estimates represented the nation as a whole. Nonetheless, this study's estimates constitute the best available data regarding the magnitude of non-fatal injuries and hospitalizations resulting from single-unit truck crashes.

Both state CODES data and national estimates derived from CODES underestimate the actual numbers of people injured in single-unit truck and tractor-trailer crashes. There are several reasons for this underestimation of non-fatal injuries:

- Ten percent of large trucks were of undefined types, so injury information could not be assigned to either single-unit truck or tractor-trailer crashes.
- About 10−50 percent of hospital records for drivers could not be linked to police reports.
- State police do not receive accident reports when crashes occur on federal property (e.g., national parks, military bases), nor do states receive data from military hospitals.
- Some crashes resulting in hospitalizations are not reported to police or by police.
- About 5−10 percent of hospitals in two of the participating states did not report discharge data to CODES.
- Hospitals can have incomplete discharge records.
- Motorists involved in crashes in one state may be hospitalized in another state (for example, about three percent of hospitalized motorists in Minnesota were involved in Wisconsin crashes).

[49] Motor vehicle crashes occurring on federal property, such as military bases or national parks, are not included in state police crash databases.

2.1.2 The Fatality Analysis Reporting System (FARS) and the Trucks in Fatal Accidents (TIFA) database

FARS, a database maintained by NHTSA, is a census of fatal motor vehicle crashes in the United States on public roads in which a fatality has occurred within 30 days of the crash (with the exception of documented suicides). FARS analysts in each state extract data from police reports, vehicle registration records, and driver history records. FARS decodes VINs but does not use them to correct vehicle body type codes that were incorrectly classified in the original police accident reports.[50]

The TIFA database is a supplement to FARS, which improves the accuracy of FARS data on fatal large truck crashes, as well as providing more detailed information on the involved large trucks, motor carriers, and sequence of events. To identify a complete set of large trucks, TIFA analysts decode information contained in the VIN to determine if the GVWR exceeds 10,000 pounds for vehicles involved in fatal crashes; this results in identifying more large trucks than are identified by the FARS vehicle body type variable. Additionally, TIFA analysts collect copies of the police reports and conduct interviews with the owners of the involved vehicles. If the owners cannot be reached, the interviewers try contacting the drivers, the investigating police officers, or the tow truck operators. In the absence of a knowledgeable respondent, the police report serves as the primary source of information about the large truck and the motor carrier. TIFA analysts code crash types and also decode the VINs to determine the type of large truck involved in the crash, its manufacturer, and other characteristics.

This study compared the counts of large trucks involved in fatal crashes by truck type between TIFA and FARS during 2005–2009. TIFA counts were considered the most definitive because prior research indicated that these counts are more complete and accurate (Blower and Matteson 2002). Additionally, TIFA provided data for this study on the commercial driver licensure status of drivers of large trucks involved in fatal crashes. Commercial driver's licenses are required for all tractor-trailer drivers but are not required for single-unit truck drivers unless they are operating a vehicle transporting hazardous materials or unless the vehicle has a GVWR over 26,000 pounds. Location data (latitude-longitude coordinates) were also drawn from TIFA to examine patterns of crash occurrence for single-unit trucks and tractor-trailers. Location data are relevant to the development of countermeasures.

2.1.3 National Automotive Sampling System (NASS) General Estimates System (GES)

The NASS GES (referred to in this study as GES) is maintained by NHTSA and is a database that consists of a nationally representative sample of police-reported motor vehicle crashes occurring on US public roads. These crashes encompass all severities of injury, including

[50] FARS contains a variable referred to as VIN Body Type that is based on decoding the vehicle identification number; however, it does not use the standard categories for passenger vehicles, motorcycles, large trucks, and buses. FARS also has a variable denoting VIN-derived GVWRs. However, official NHTSA reports rely on the vehicle body type variable (referred to as Body Type) and do not use the VIN-derived variables.

those that result in fatal and non-fatal injuries, as well as property-damage-only crashes. This database relies on information from police accident reports and includes about 50,000 crashes per year.

For this study, GES provided national estimates of people receiving non-fatal injuries in large truck crashes by type of truck during 2005–2009. This study also used GES to generate national estimates for crash types and other accident characteristics by truck type. VIN-derived GVWRs[51] were unavailable in GES, so this study could not apply the NTSB's VIN-decoding program.

GES, a database based on a national sample, had smaller than optimal numbers, resulting in uncertainties about weighted estimates for subcategories of variables. Missing and inaccurate data are also a limitation of GES because GES does not include detailed accident investigations. Weighted GES estimates were derived from 12,632 single-unit trucks and 22,400 tractor-trailers involved in crashes. In comparison with GES, this study's analysis of state data was based on a larger data record (52,051 single-unit trucks and 38,247 tractor-trailers in crashes) and was a census of police-reported crashes rather than a sample. Furthermore, because only police-reported vehicle body type codes could be used in GES rather than supplemental information from VINs to classify trucks, GES was subject to the same misclassifications and resulting undercounts of single-unit trucks observed in FARS. Some of the differences in findings between GES and state data may be due to this undercounting of single-unit trucks in GES.

2.1.4 Large Truck Crash Causation Study (LTCCS)

The LTCCS was a FMCSA-funded nationally representative study of police-reported large truck crashes resulting in injury from 2001–2003. The LTCCS included detailed investigations, truck inspections, driver interviews, use of federal and state records on motor carriers, and police reports. When possible, accident investigators arrived at the scene of the crash before the truck had been driven or towed away. The LTCCS also included photographs, which were taken of the crash scene and all of the involved vehicles. A total of 963 large truck crashes (297 of which were single-unit truck crashes) were included in this database. Although the data are older than the other data used in this study, the LTCCS contains valuable information that was not available elsewhere. Because underride is underreported and inconsistently coded by police reports used by FARS and other databases, the LTCCS provided a way to examine the occurrence of large truck underride crashes (Brumbelow and Blanar 2010; Brumbelow 2012; Blower and Woodrooffe 2013). The LTCCS also provided information on the use of conspicuity treatments on single-unit trucks.

LTCCS had smaller than optimal numbers, such that national estimates often were based on a very few crashes within a particular category. This resulted in considerable uncertainty

[51] GVWR appears as a variable in GES for 2011, but not for earlier years. It is unclear whether GES analysts are instructed to defer to police-reported vehicle body type codes when the VIN-derived GVWR contradicts such codes.

regarding national estimates derived from LTCCS. LTCCS had missing or inaccurate data for some variables.

2.2 Data Analysis Methods

2.2.1 Descriptive statistics

Generally, the analytical approach involved providing a comparison between single-unit trucks and tractor-trailers. This study produced statistics that were person-level (such as the number of persons involved, hospitalized, or injured) and vehicle-level (such as the number of single-unit trucks or large trucks involved). This study also examined characteristics of the accidents, such as the lighting condition, locations, and how colliding vehicles impacted one another. Analyses on collision characteristics were limited to two-vehicle collisions. To aid in interpretation of the results, row percentages showed the relative frequency of outcomes involving single-unit trucks versus tractor-trailers within each row of a table (referred to as “row %” in tables). When appropriate, column percentages were shown in each column of a table to examine the distribution of crash types (referred to as “column %” in tables). Rates per 1,000 involved persons were also presented in some tables; an involved person (or road user) was either an occupant of any type of vehicle involved in a collision with a large truck or was a vulnerable road user, such as a pedestrian. Depending on the table, the rates referred to all road users involved in single-unit truck crashes or tractor-trailer crashes or to particular categories of road users involved in large truck crashes (such as passenger vehicle occupants) or to road users involved in particular types of single-unit truck crashes (such as sideswipes).

As previously noted, the calendar years of data provided by each participating state varied. One participating state had data for all five calendar years (2005–2009), while other participating states contributed three or four years of data, depending on whether they had fully linked the hospital data to the police reports for those years. To ensure that the combined state data accurately represented the findings instead of tilting towards those states which had contributed more calendar years of data, this study computed average annual counts of crashes and crash outcomes for state-level analyses.[52]

The analytical approach to GES data was similar but with two main differences. First, GES data were national in scope and covered 2005–2009, so there was no need to compute yearly averages. Second, GES was based on samples and the results were presented as national estimates, not absolute counts.

[52] Yearly average counts for the five participating states were computed as follows.

(1) The yearly average crash count was calculated for each individual state. This was done by summing the crash counts for each year and then dividing the total crashes by the number of calendar years available for that state. For example, Minnesota had three years of crash data, so the crashes for all three years were summed and then divided by three to get Minnesota’s yearly average crash count.

(2) After computing the yearly average crash count for each state, these average counts were added together to come up with the average annual numbers of crashes for all participating states combined.

(3) This was computed for all outcomes of interest, including crashes, large trucks involved in crashes, fatalities, injuries, and hospital treatment.

2.2.2 Risk Ratio Comparison

This study compared injury and hospitalization outcomes of road users[53] involved in single-unit truck crashes versus outcomes in tractor-trailer crashes. For some comparisons, risk ratios were calculated along with their 95 percent confidence intervals (the ranges where the true values could fall) by using Poisson regression. Risk ratios estimate how strongly associated exposures are with outcomes of interest. They are used to find out whether an outcome of interest is more common in a group exposed to a potential hazard than in an unexposed group (Gerstman 2003). See figure 7 for an example.

	Outcome (Fatal injury)	Outcome (Not injured)	Groups
Exposed (Dark and unlit road)	A	B	N_1
Not exposed (Daylight)	C	D	N_2

$$\textbf{Risk ratio} = \frac{\left(\frac{A}{N1}\right)}{\left(\frac{C}{N2}\right)}$$

Figure 7. Example of a risk ratio comparing risk of death if in crash on dark and unlit road compared with risk of death if in crash on road during daylight.

In the above example, if the risk ratio for death in a single-unit truck crash on a dark and unlit road equals 2.0, this means that the chances of an involved person dying in such a crash were twice as high as the chances of an involved person dying in a single-unit truck crash that occurred during daylight.[54] If a risk ratio exceeds 1.0 and the lower bound of its 95 percent confidence interval also exceeds 1.0, this suggests that the exposure of interest increases the risk of the outcome. If both a risk ratio and the upper bound of its 95 percent confidence interval fall below 1.0, this suggests that the exposure may protect against the outcome. If a crash involved both a single-unit truck and a tractor-trailer, it was removed from risk ratio estimation. Poisson regression was used for each of the five sets of imputed data and then the analyses were combined to obtain risk ratios.[55]

---

[53] Road users include both occupants of vehicles and non-occupants involved in the crashes, such as drivers, passengers, pedestrians, cyclists, and motorcyclists.

[54] Note that this risk ratio refers only to crashes on dark and unlit roads relative to crashes occurring during daylight hours. It does not tell us about the risks associated with crashes on dark and lit roads, which would need to be calculated separately.

[55] Confidence intervals were obtained by taking the overall estimate plus or minus a number of standard errors, which were based upon the within-imputation variance and between-imputation variance. Detailed discussion can be found in Rubin (1987).

2.2.3 Geographical Analysis of Fatal Crash Involvements

This study constructed descriptive maps using the latitude and longitude coordinates attributed to fatal crashes involving single-unit trucks and tractor-trailers within the TIFA data. Truck involvement rates were computed per 100,000 population. Additionally, using Getis-Ord Gi* statistics,[56] this study performed hot spot and cold spot analyses to describe the variation in state involvement rates. For Maryland and Delaware, this study completed detailed analyses to illustrate clusters of fatal single-unit truck crashes and how they could be overlaid with existing information on urban versus rural populations and roadway networks.

2.2.4 Case Reviews

To supplement the database analyses and to gain more insight into what happens during single-unit truck crashes, this study included case reviews and chose cases to represent a variety of crash scenarios involving single-unit trucks where crash mitigation was a possibility. These cases included rear-end collisions, side-impact collisions, front-impact collisions, and pedestrian impacts. Eleven single-unit truck crashes were identified for review, 10 of which were from the LTCCS database. The other case was obtained from state police and was a recent (2013) rear-end collision involving a single-unit truck and a 2007 minivan with ratings of “good” for front and side impacts in crash tests conducted by IIHS (2012a). The case review team consisted of experts in the fields of vehicle dynamics, crash reconstruction, vehicle operations, and biomechanics. Vehicle equipment countermeasures were the main focus; traffic enforcement countermeasures were not considered. A detailed case review summary report is in the study docket (see Appendix A).

Limitations of the case review process included the small non-representative sample drawn from LTCCS and the limited ability to gain additional information on previously investigated cases. Further, although a comprehensive database, the LTCCS was conducted from 2001–2003 and, as a result, the passenger vehicle age placed some cases outside what may be considered a common vehicle in the fleet today.

[56] Getis-Ord Gi* statistics were used to identify hot and cold spots. Getis-Ord Gi* statistics is a commonly used statistical measure in spatial statistics. It is known as a local measure of spatial autocorrelation. In this analysis, for each state (excluding Alaska and Hawaii), the annual fatal single-unit truck crash involvement rate was analyzed, along with its neighboring states’ rates. Therefore, the analysis also captured the influence of involvement rates of the neighboring states. The Gi* statistics were conveniently expressed as Z-scores with their accompanying confidence levels indicated. For a description and history of the full range of measures and concepts in spatial autocorrelation, see Getis (2008). A detailed description of the use of Getis-Ord Gi* statistics within the GIS environment can be found at http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/How_Hot_Spot_Analysis_Getis_Ord_Gi_works/005p00000011000000/.

3. Results

3.1 Fatal Crashes

TIFA data were used to obtain national numbers of fatal crashes and fatalities. During 2005–2009, among the 23,444 large trucks involved in fatal crashes, 8,312 were single-unit trucks (35 percent) and 14,869 were tractor-trailers (63 percent) (see table 1).[57] TIFA identified 1,609 more single-unit trucks involved in fatal crashes than FARS (see figure 8). TIFA also identified 1,829 additional fatalities in large truck crashes than FARS over this five-year period (see table 2). This difference was largely due to misclassification of single-unit trucks, resulting in a 20 percent undercount of fatalities in single-unit truck crashes by FARS (see figure 9).

The numbers of fatalities were 9,084 (37 percent) in single-unit truck crashes and 15,876 (65 percent) in tractor-trailer crashes. Some crashes involved both types of trucks, so the two numbers and percentages do not add up to the total of 24,545 fatalities in all large truck crashes presented in table 2. Although single-unit trucks comprised three percent of registered motor vehicles and four percent of VMT during 2005–2009, they were involved in nine percent of fatalities among passenger vehicle occupants in multivehicle crashes.

[57] Two percent of large trucks involved in fatal crashes could not be assigned to a category.

Table 1. Large trucks involved in fatal crashes by truck type and data source, TIFA and FARS, 2005–2009.

	Single-unit trucks*		Tractor-trailers		Total†	
Year	**TIFA**	**FARS***	**TIFA**	**FARS**	**TIFA**	**FARS**
2005	1,879	1,502	3,452	3,442	5,343	4,952
2006	1,867	1,474	3,333	3,289	5,250	4,767
2007	1,803	1,412	3,235	3,208	5,049	4,633
2008	1,516	1,264	2,776	2,817	4,352	4,089
2009	1,247	1,051	2,073	2,155	3,450	3,211
Total	**8,312**	**6,703**	**14,869**	**14,911**	**23,444**	**21,652**

* Includes single-unit trucks pulling trailers, as well as large trucks of unknown type that were not coded as pulling trailers.

† Includes large trucks where the type was unknown.

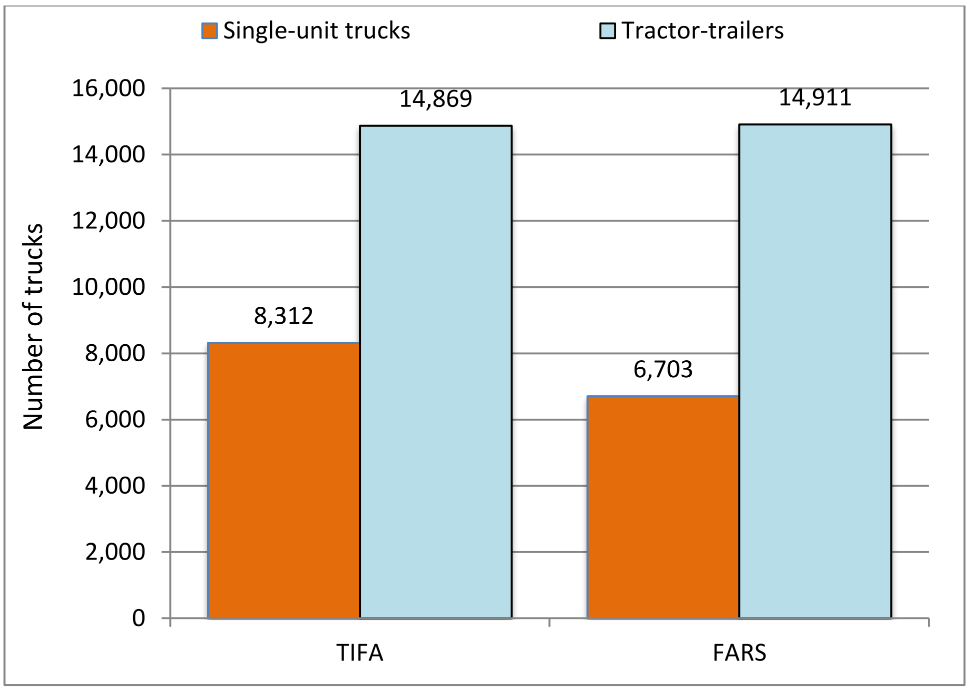


Figure 8. Comparison of TIFA and FARS counts of large trucks involved in fatal crashes, 2005–2009 combined.

Table 2. Fatalities in all large truck crashes by truck type, TIFA versus FARS, 2005–2009.

	Single-unit trucks*		Tractor-trailers*		Total	
Year	**TIFA**	**FARS**	**TIFA**	**FARS**	**TIFA**	**FARS**
2005	2,062	1,643	3,700	3,708	5,623	5,241
2006	2,021	1,581	3,604	3,539	5,537	5,028
2007	1,965	1,537	3,439	3,399	5,248	4,822
2008	1,656	1,387	2,931	2,965	4,508	4,245
2009	1,380	1,159	2,202	2,283	3,629	3,380
Total	**9,084**	**7,307**	**15,876**	**15,894**	**24,545**	**22,716**

* Fatalities in crashes involving both types of trucks are counted in both categories, but are counted only once in the total.

† Percentage differences were calculated by calculating (TIFA – FARS)/FARS.

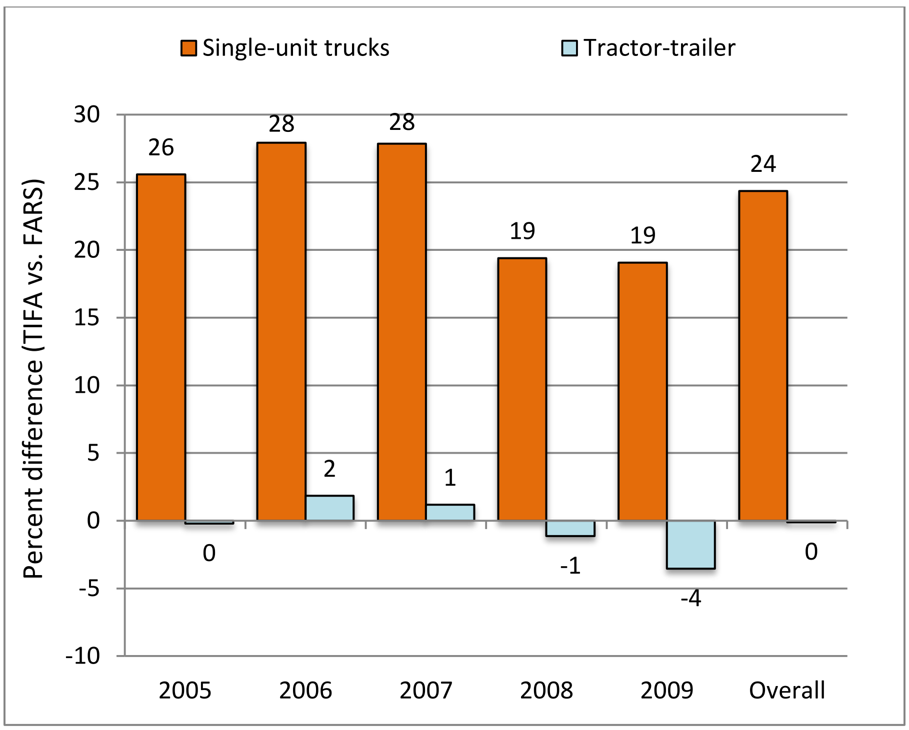


Figure 9. Percentage differences in TIFA compared with FARS fatality counts by truck type and year, 2005–2009.

Of pedestrian/cyclist fatalities in large truck crashes during 2005–2009, 928 involved single-unit trucks and 1,149 involved tractor-trailers. In single-vehicle crashes involving single-unit trucks, 613 pedestrians and 193 cyclists were fatally injured.[58] The fronts of the single-unit trucks made contact with 58 percent of the pedestrians and 48 percent of the cyclists who received fatal injuries. Cyclists were more likely than pedestrians to have an impact with the right side of single-unit trucks (35 percent).

Figure 10 shows the locations of fatal crashes involving single-unit trucks during the five-year period, and figure 11 shows tractor-trailers. Only three percent (627) of the crashes were not given latitude and longitude coordinates. Therefore, the maps are a good representation of the overall geographic distribution of their involvements. Locations of single-unit truck involvements follow the general population distribution. Outside of the major metropolitan areas, locations of single-unit truck fatal crashes were more dispersed compared with those involving tractor-trailers. The locations of fatal tractor-trailer crashes tracked very closely with the network of the interstate highway system.

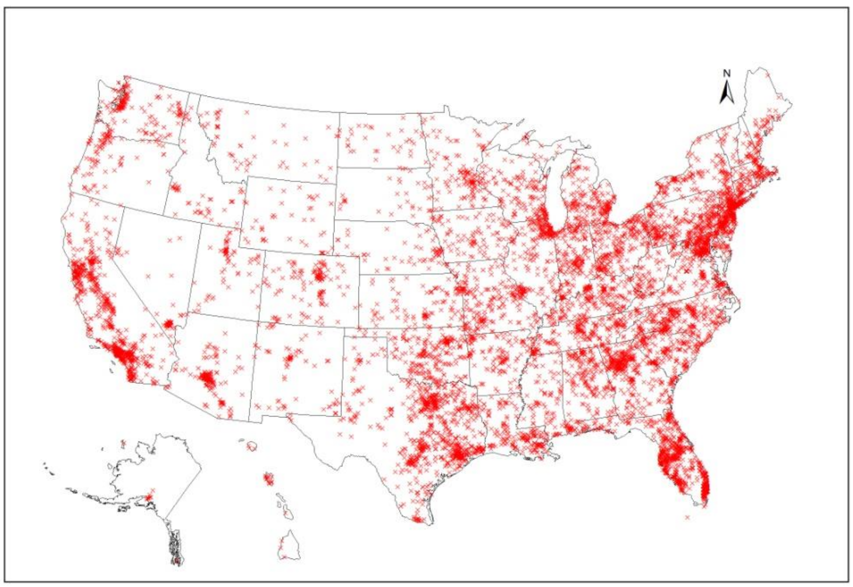


Figure 10. Locations of fatal crashes involving single-unit trucks, TIFA, 2005–2009.

[58] These fatality counts were limited to single-unit truck crashes involving only one truck and no other motor vehicle. The total pedestrian and cyclist fatality counts were 727 and 201, respectively, when multivehicle single-unit truck crashes were analyzed.

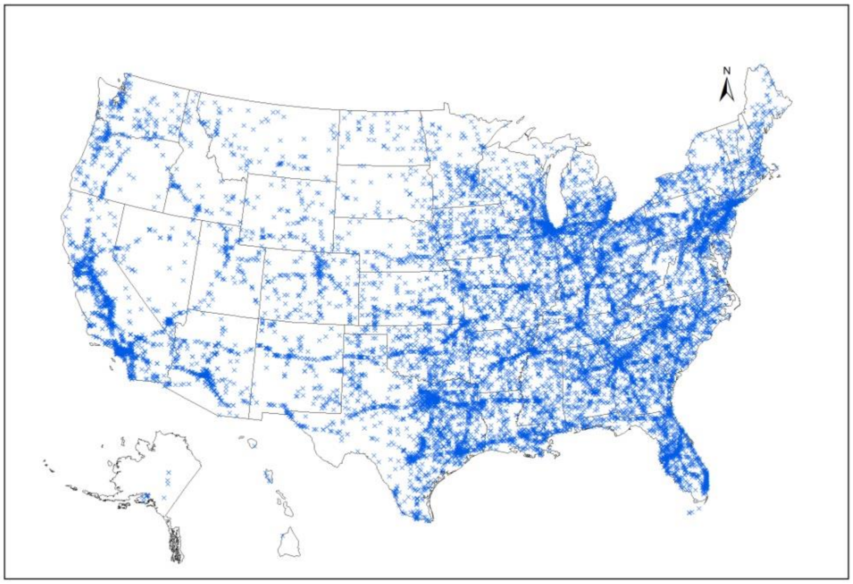


Figure 11. Locations of fatal crashes involving tractor-trailers, TIFA, 2005–2009.

Using TIFA's 2005–2009 data, this study also computed state-specific rates of fatal single-unit truck crash involvements per million people. The overall US annual rate was 6.14 fatal single-unit truck involvements per million people. State rates ranged from 2.11 (Massachusetts) to 16.06 (Wyoming) (see figure 12). The participating states ranked in the middle of all states, and their respective rates were Nebraska (6.50), Delaware (5.97), Maryland (5.55), Utah (4.94), and Minnesota (4.69). The states' rates were within half a standard deviation of the US annual rate of 6.14. Therefore, in terms of fatal single-unit truck involvement rates, the participating states are fairly similar to the rest of the United States. Hot and cold spots were identified based on these state-level single-unit truck fatal involvement rates using the Getis-Ord Gi* statistics. At the 95 percent confidence level, three hot spots of high involvement rates were identified. Figure 13 shows that the first hot spot consists of Montana and Wyoming (statistically significant at the 99 percent confidence level) and the second and third hot spots are Colorado and Arkansas. There is a large cold spot of low involvement rates that included eight states (Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, and New Hampshire).

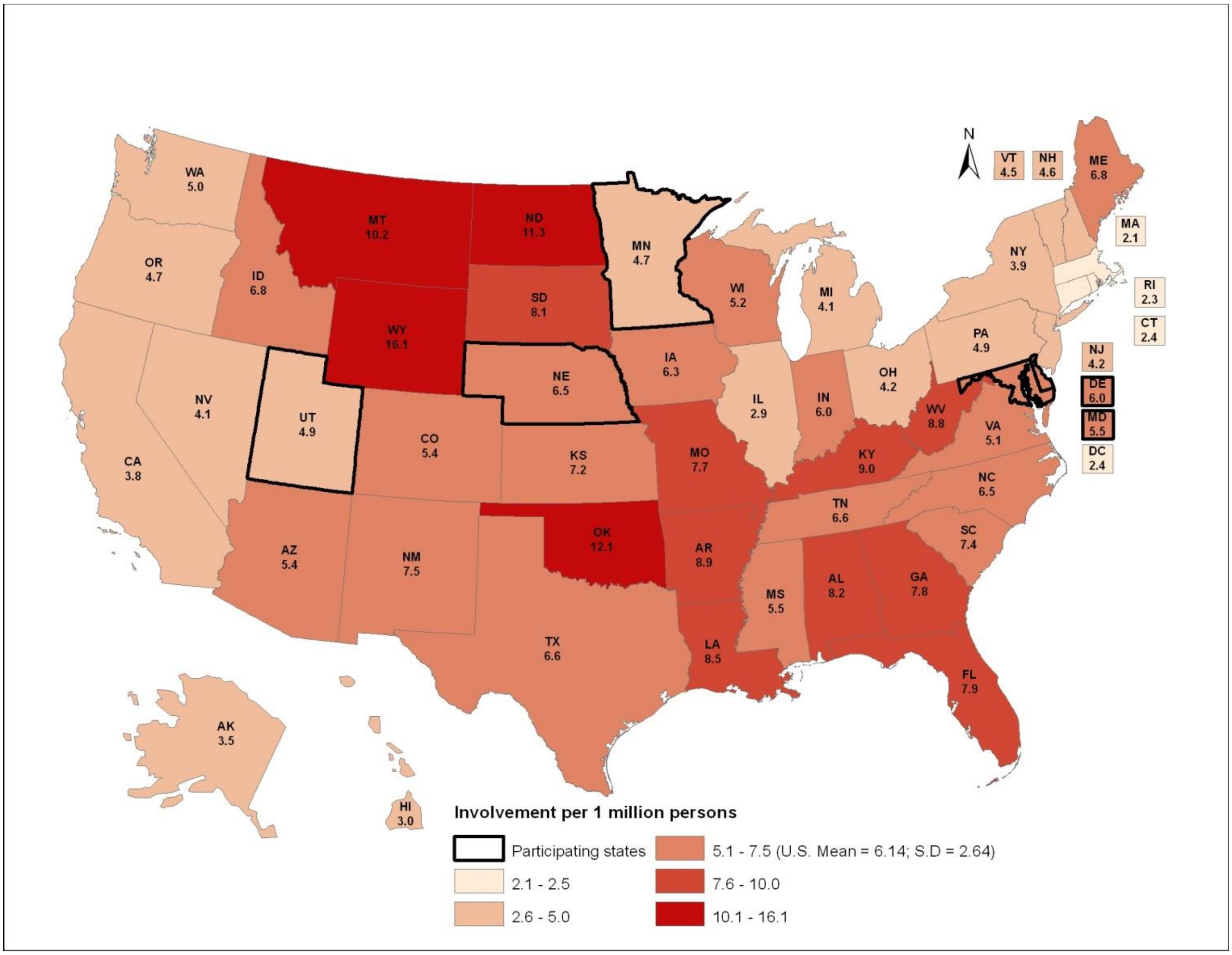


Figure 12. Annual single-unit truck fatal crash involvements per 1,000,000 persons by states, TIFA, 2005–2009.

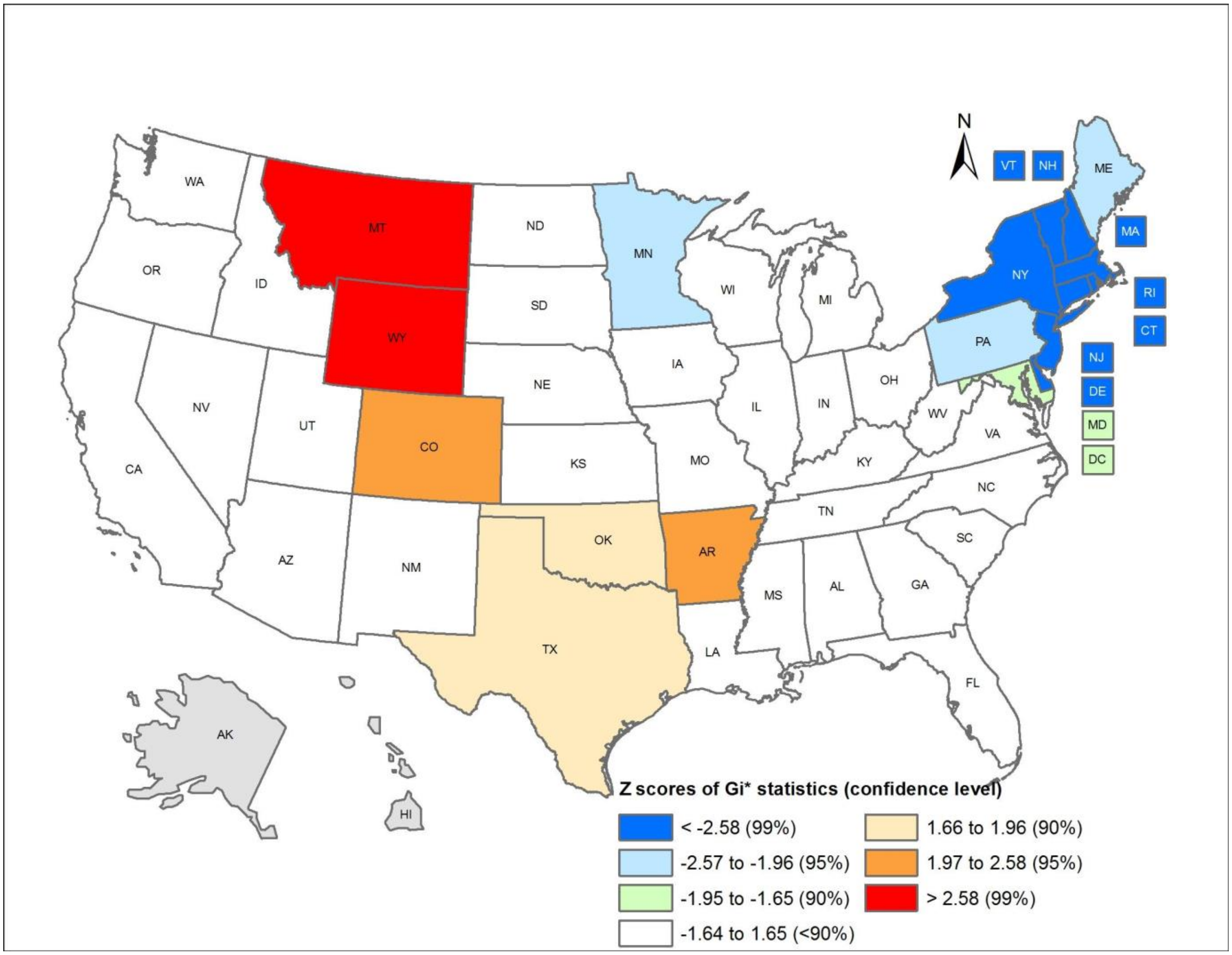


Figure 13. Hot and cold spots based on annual fatal single-unit truck crash involvement rate by states using Getis-Ord Gi* statistics (expressed in Z-scores), TIFA, 2005–2009.

Figure 14 provides a visualization of the distinct geographic patterns of fatal crashes by large truck types and lighting conditions. The map depicting fatal crashes involving tractor-trailers in dark conditions shows the strongest resemblance to a map of the US interstate network.

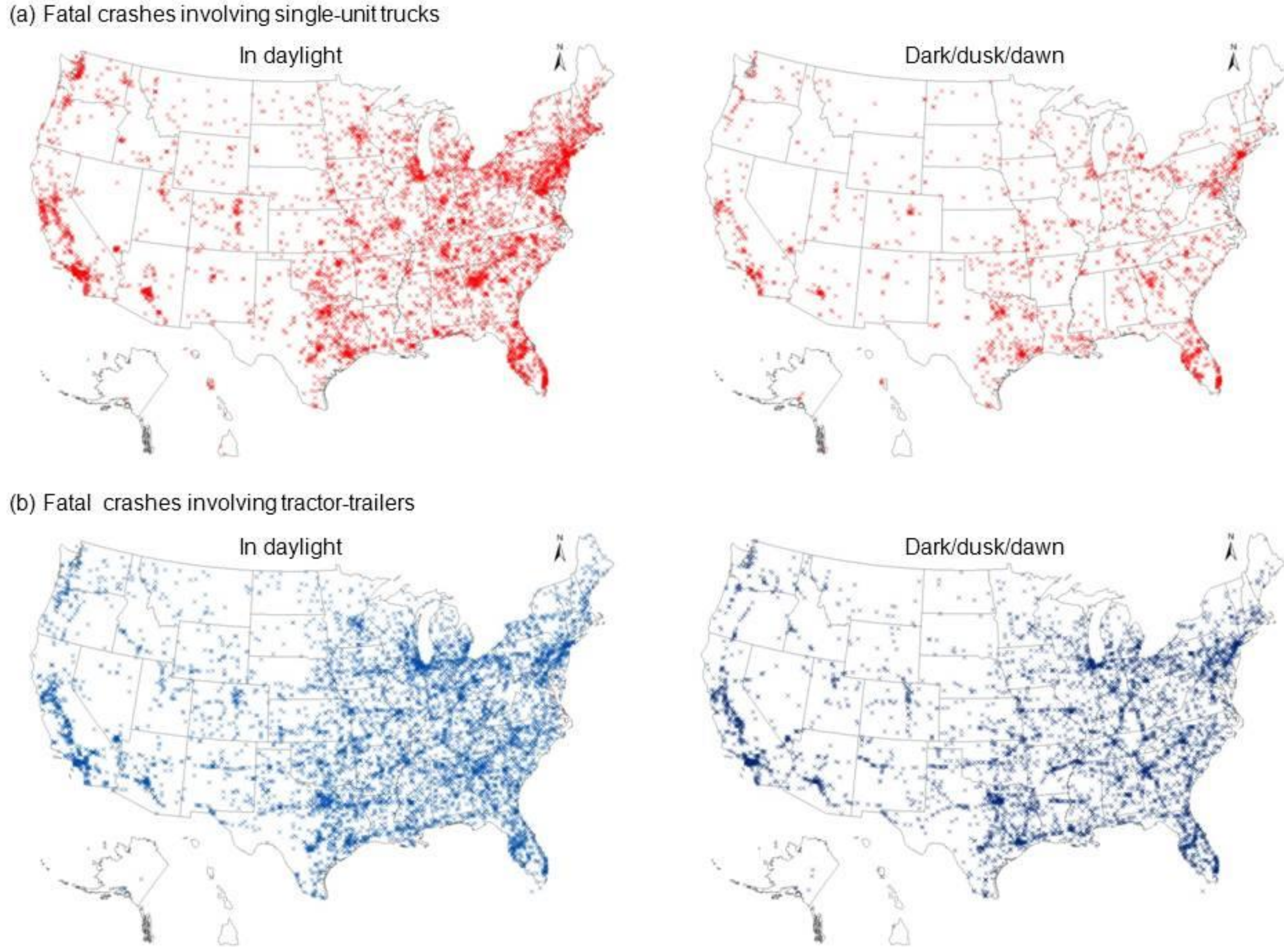


Figure 14. Fatal crash locations involving large truck by truck types and lighting conditions, TIFA, 2005–2009.

Overall, fatal single-unit truck crashes are more likely to occur in urban areas, more likely to occur on local roads, and less likely to occur on interstate highways compared with fatal tractor-trailer crashes. The analysis showed that 42 percent of all single-unit truck fatal crashes occurred in urbanized areas (densely populated; $\geq$ 50,000), with another 11 percent in urban clusters (2,500 to 50,000), compared with only 31 percent of fatal tractor-trailer crashes (US Census Bureau 2012). Eighteen percent of fatal single-unit truck crashes occurred on interstate highways compared with 39 percent of fatal tractor-trailer crashes. Similar percentages of single-unit truck (45 percent) and tractor-trailer (43 percent) crashes occurred on non-interstate highways (such as state highways). The remaining fatal crashes occurred largely on local roadways: 36 percent of fatal single-unit truck crashes and 19 percent of fatal tractor-trailer crashes.[59] Figure 15 uses Maryland and Delaware to illustrate the overlay process in which each fatal crash was shown in relation to highway networks and urban classifications.

[59] This study used GIS data obtained from the Bureau of Transportation Statistics (2012).

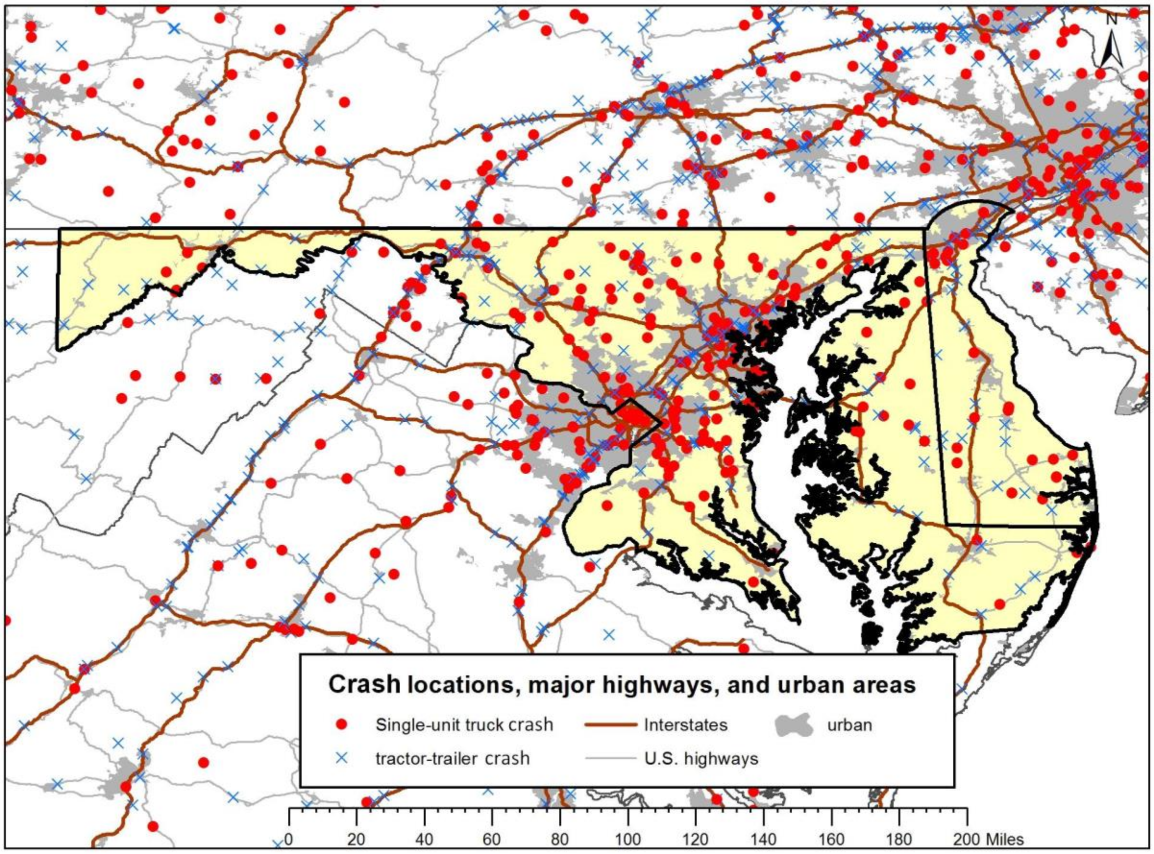


Figure 15. Distribution of fatal large truck crashes by truck type, urban/rural location, and roadway type, Maryland and Delaware, 2005–2009.

More detailed analyses at the state or local level were also performed. Figure 16 shows the crash density (per square mile) of fatal single-unit truck crashes in Maryland and Delaware (shown in contours) compared with the crash density for all fatal motor vehicle crashes (shown in shaded contours). Areas where more than 25 percent of all motor vehicle fatal crashes involved at least one single-unit truck were identified and areas with only one single-unit truck crash were eliminated. Five areas were identified as clusters in Maryland, as shown in orange polygons. These areas had two to five fatal single-unit truck crashes during 2005–2009 and were labeled A through E.

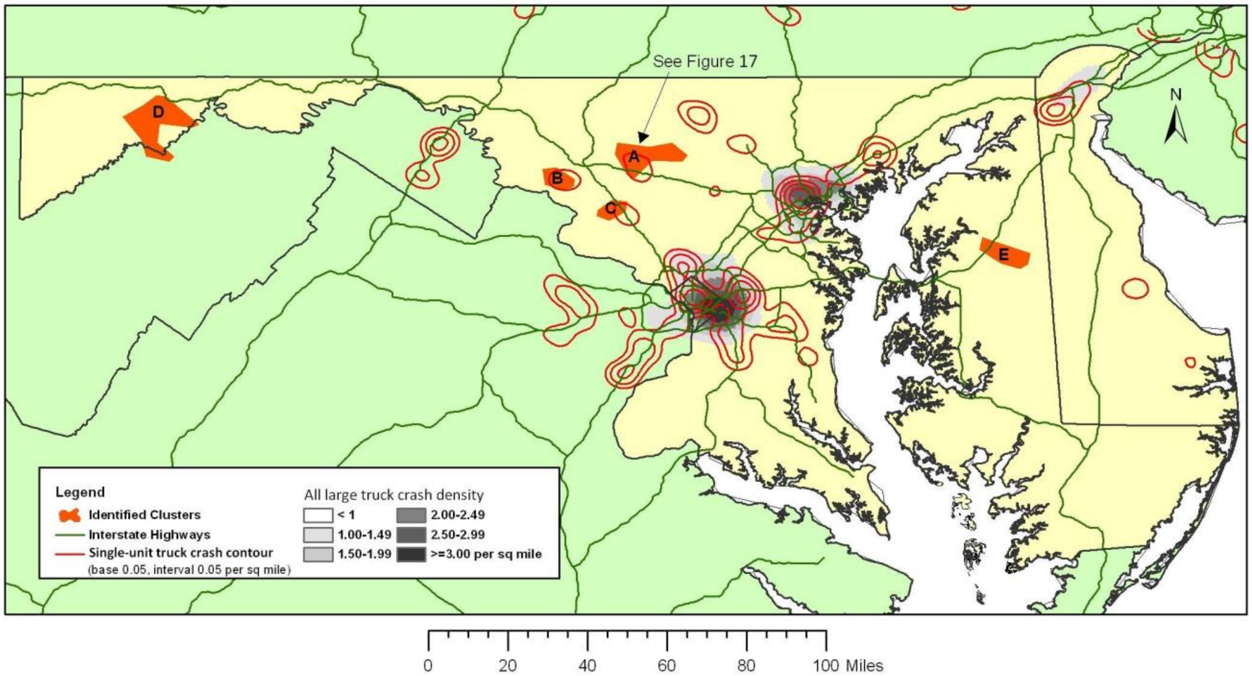


Figure 16. Geospatial analytical map of fatal single-unit truck crashes in Maryland and Delaware, TIFA, 2005–2009.

Cluster A included five fatal single-unit truck crashes, resulting in five fatalities, in 2005−2009. Figure 17 shows the actual locations of these crashes. Three fatal crashes occurred on a five-mile stretch of State Highway 75 (Green Valley Road), between New Market and Libertytown. This analysis illustrates that hot spots of single-unit truck fatal crashes can be quickly identified using fairly simple and standard geospatial techniques if crash locations are accurate and complete. In the five year period during 2005–2009, 97 percent of all fatal crashes in the US were reported with latitude and longitude coordinates in the FARS database. However, there was state variation. Twelve states had 100 percent availability whereas two states (Alaska and Virginia) had less than 90 percent availability. There is no repository of latitude and longitude information for the non-fatal crashes at the national level.

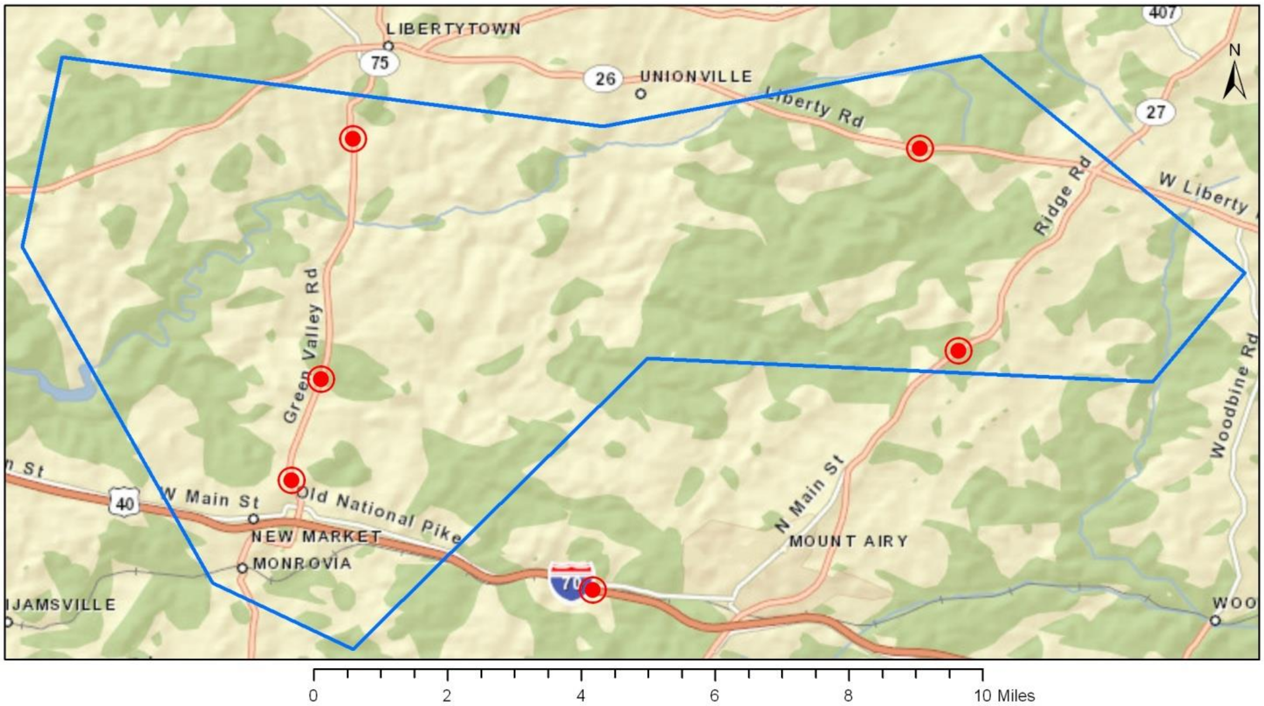


Figure 17. Locations of fatal single-unit truck crashes within Cluster A, TIFA, 2005–2009.

3.2 Injury Outcomes and Crash Characteristics

CODES state data were the primary source of data on injury severity, hospital treatment, and hospital costs[60] resulting from crashes involving single-unit trucks compared with those involving tractor-trailers. Analyses of data from the participating states accounted for the varying numbers of calendar years contributed by each of the participating states. One participating state had data for all five calendar years during 2005–2009 and the other participating states contributed three to four years of data during the same time period, depending on whether they had finished linking the hospital data to the police reports for those years (see table 3). To ensure that the combined state data were an accurate representation of the findings and not tilted toward those states that contributed more calendar years of data, this study computed average annual counts of crashes and crash outcomes.[61]

Among the participating states combined, 50 percent of crash-involved large trucks were single-unit trucks, 39 percent were tractor-trailers, and 10 percent could not be classified in either category. The participating states varied in the distribution of large trucks by truck type and in the percentages that could not be assigned to each category. In Maryland and Delaware, the highest percentages of crash-involved large trucks were single-unit trucks, while in Minnesota and Nebraska, the highest percentages of crash-involved large trucks were tractor-trailers. Utah had about the same percentages in each category. Police-reported crashes were provided by the states, and included fatal,

[60] Hospital costs were defined as hospital charges, which vary from hospital to hospital.
[61] See footnote 55.

injury, and property-damage-only crashes. The analysis encompassed all police-reported crashes in which a large truck was identified.

Table 3. List of participating states by calendar years of data available and average annual numbers of large trucks involved in police-reported crashes, state CODES.

State	2005	2006	2007	2008	2009	Average annual single-unit trucks	Row %	Average annual tractor-trailers	Row %	Average annual large trucks, undefined*	Row %	Average annual all large trucks	Row %
Delaware	n/a	Yes	Yes	Yes	n/a	728	52	547	39	138	10	1,413	100
Maryland	Yes	Yes	Yes	Yes	Yes	5,856	65	2,952	33	154	2	8,962	100
Minnesota	Yes	Yes	Yes	n/a	n/a	2,493	41	2,725	45	900	15	6,118	100
Nebraska	Yes	Yes	Yes	Yes	n/a	1,094	44	1,294	52	113	5	2,501	100
Utah	n/a	Yes	Yes	Yes	Yes	2,184	40	2,124	39	1,205	22	5,513	100
Total						**12,354**	**50**	**9,642**	**39**	**2,510**	**10**	**24,506**	**100**

* Large trucks with missing VINs or VIN-derived GVWRs or insufficiently descriptive information in police reports. Due to rounding, some of the row percentages do not sum to 100%.

3.2.1 Injury Outcomes

Single-unit trucks were involved in 38 percent[62] of fatalities in large truck crashes in the participating states (see table 4).[63] This was similar to the national percentage of 37 percent (see table 2).

Each year, single-unit truck crashes resulted in more than 130 non-fatal maximum abbreviated injury scale (MAIS) 3+ injuries (serious to maximum injury severity levels) and more than 300 inpatient hospitalizations (table 4).[64] About 15 percent of people hospitalized due to single-unit truck crashes were discharged to long-term care or rehabilitation facilities, which is one measure of long-term disability. Emergency department visits are another useful metric because they are costly and often involve treatment of non-fatal injuries that cause suffering and impair the quality of life. Single-unit trucks were involved in the majority (61 percent) of large truck crashes resulting in emergency department visits. Hospital charges averaged $14.3 million annually for single-unit truck crashes in the participating states.

[62] This is based on a row percentage (referred to as "row %" in the table) computed for single-unit trucks versus tractor-trailers.

[63] In Table 4 and subsequent tables that present annual average numbers, the averages are rounded to be whole numbers.

[64] MAIS denotes Maximum Abbreviated Injury Scale, an injury severity scoring system that refers to the most severe injury sustained across nine body regions. The values are: 0 = no injury; 1 = minor injury; 2 = moderate injury; 3 = serious injury; 4 = severe injury; 5 = critical injury; and 6 = maximum injury. Deaths were subtracted from the MAIS 2+ and 3+ categories. Injuries of MAIS 3+ severity almost always result in hospitalizations.

Table 4. Average annual numbers of fatalities, persons with non-fatal injuries, and hospital treatment resulting from large truck crashes by type of large truck, combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

	Single-unit trucks			Tractor-trailers			Comparison of tractor-trailers and single-unit trucks		
Outcomes	**Average**	**Row %***	**Rates per 1,000 involved persons†**	**Average**	**Row %***	**Rates per 1,000 involved persons†**	**Risk ratios§**	**95% confidence intervals**	**Average all large trucks‡**
Fatalities	93	38	2.5	153	62	7.0	3.14	1.88–5.26	254
Persons with serious injuries (MAIS 3+)‡	138	46	3.7	159	54	7.2	2.06	1.27–3.33	320
MAIS 2+‖	480	51	12.7	454	49	20.7	1.66	1.16–2.38	976
Hospitalizations (inpatient)	321	49	8.5	336	51	15.3	1.86	1.25–2.76	698
Emergency department visits	3,163	61	83.9	2,059	39	93.8	1.12	0.89–1.42	5,408
Long-term care/rehabilitation facility	56	45	1.5	68	55	3.1	2.15	1.17–3.95	131
Person-days in hospital	1,658	48		1,830	52				3,714
Hospital charges	$14.3 million	47		$16.15 million	53				32.3
Total persons involved	37,694	63		21,955	37				63,330

* Calculated only for single-unit trucks and truck-tractors.
† Rates were calculated separately per 1,000 persons involved in single-unit truck crashes and per 1,000 involved in tractor-trailer crashes. People were considered to be involved in crashes if they were occupants of any type of vehicle or if they were non-occupants, such as pedestrians.
§ Risk ratios and 95 percent confidence intervals were computed using the actual numbers, not the rates, so they may differ from rate patterns.
‡ Includes large trucks where the category could not be determined.
|| MAIS is an injury severity scoring system in which 0 = no injury; 1 = minor injury; 2 = moderate injury; 3 = serious injury; 4 = severe injury; 5 = critical injury; and 6 = maximum injury. Deaths were subtracted from the MAIS 2+ and 3+ categories.

In comparison with single-unit truck crashes, the following findings were observed for tractor-trailer crashes:

- More fatalities.
- More persons with MAIS 3+ injuries.
- Similar numbers of persons with MAIS 2+ injuries.
- Similar numbers of hospitalizations.
- More discharges to long-term care/rehabilitation facilities.
- Average annual hospital charges of $16.15 million.
- More person-days in the hospital.

In addition to determining the numbers of fatalities, injuries, and hospitalizations by type of large truck, this study also sought to determine whether people had similar risks when involved in a single-unit truck crash or a tractor-trailer crash. This was done by computing risk ratios, which measure the strength of a relationship between a hazard and an adverse outcome such as an injury. Risk ratios do not provide information on the frequency with which people were injured; instead, they provide information about the chances of injury when involved in a crash. This study calculated risk ratios for adverse outcomes in tractor-trailer crashes versus single-unit truck crashes. The risk ratios ranged from 1.66 (95 percent CI:[65] 1.16–2.38) for MAIS 2+ injuries to 3.14 (95 percent CI: 1.88–5.26) for fatalities (see table 4). These risk ratios indicated that people involved in tractor-trailer crashes had significantly higher risks for fatalities, MAIS 2+ injuries, and hospitalized patients being discharged to long-term care or rehabilitation facilities than people involved in single-unit truck crashes.

Data from the participating states show that single-unit truck crashes are neither as lethal nor as likely to cause the most severe injuries as compared with tractor-trailer crashes. Nonetheless, they show that single-unit truck crashes result in substantial proportions of the fatal and non-fatal injuries that arise from all large truck crashes:

- 38 percent of the fatalities.
- 46 percent of serious or worse injuries.
- 45 percent of hospital discharges to rehabilitation or long-term care facilities.
- 49 percent of inpatient hospitalizations.
- 61 percent of emergency department visits.

The non-fatal injuries from crashes involving single-unit trucks cause pain, suffering, disability, and costs to society in both direct medical care and lost productivity.

3.2.2 Road User Types and Injuries

This study examined the types of road users that sustained fatal or non-fatal injuries in large truck crashes in the participating states. For passenger vehicle occupants involved in large truck crashes, single-unit truck crashes resulted in 34 percent of fatalities, 49 percent of moderate injuries (MAIS 2), and 42 percent of crashes resulting in serious or worse non-fatal injuries (MAIS 3+).

---

[65] "95% CI" refers to 95 percent confidence intervals, which are measures of the range within which the true values are likely to fall.

The numbers of fatalities of vulnerable road users were similar for both single-unit truck crashes and tractor-trailer crashes in the participating states (see table 5). However, single-unit truck crashes were involved in the majority of large truck crashes that resulted in MAIS 2 (moderate) injuries and MAIS 3+ (serious to critical) injuries to occupants of large trucks, pedestrians/cyclists, and motorcyclists. This was especially pronounced for pedestrians/cyclists; at least 80 percent of large truck crashes where pedestrians/cyclists received MAIS 3+ injuries involved single-unit trucks.

Based on the risk ratios, all types of road users had significantly higher risks of death when involved in tractor-trailer crashes than when involved in single-unit truck crashes. In contrast, the findings for non-fatal injuries varied by road user type, with no significant differences by truck type observed for pedestrians or cyclists. Passenger vehicle occupants had a non-significant elevation in risk of receiving MAIS 3+ injuries when involved in tractor-trailer crashes.

3.2.3 Accident Characteristics

This study examined the characteristics of police-reported accidents, irrespective of whether an injury was reported. Among single-unit trucks, the most common types of police-reported two-vehicle collisions were:

- head-on collisions,
- the front of the truck striking the side of another vehicle, and
- a passenger vehicle striking the side of the truck (see table 6).

In comparison with tractor-trailers, single-unit trucks were involved in:

- more multivehicle crashes,
- more pedestrian/cyclist collisions,
- more urban crashes, including at intersections,
- more head-on collisions,
- more collisions in which they struck the rears and sides of other vehicles,
- more collisions in which passenger vehicles struck them in the rears or sides,
- fewer crashes on interstate roads, and
- fewer run-off-road crashes and rollovers.

In both types of large trucks, the vast majority of crashes occurred during daylight. Single-unit trucks had fewer crashes on dark and unlit roads than tractor-trailers.

Table 5. Road users: Average annual numbers of fatalities and persons with MAIS 2* and 3+ injuries by type of road user and truck type involved in crashes, combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

	Single-unit trucks			Tractor-trailers			Tractor-trailers/single-unit truck risk ratios		
Type of road user	**Average**	**Row %†**	**Rates per 1,000 involved persons§**	**Average**	**Row %‡**	**Rates per 1,000 involved persons§**	**Risk Ratios§**	**95% confidence intervals**	**Average all large trucks‡**
Fatalities									
Occupants of large trucks	19	45	0.8	23	55	2.0	2.82	(1.22–6.49)	38
Passenger vehicle occupants	60	34	4.0	116	66	10.9	2.92	(1.66–5.12)	183
Pedestrians and cyclists	9	53	59.3	8	47	152.8	2.76	(1.05–7.21)	19
Motorcyclists	5	45	57.9	6	55	119.5	2.02	(0.67–6.05)	12
MAIS 3+ injuries									
Occupants of large trucks	34	53	1.5	30	47	2.7	1.85	(0.90–3.77)	66
Passenger vehicle occupants	89	42	6.0	122	58	11.5	1.97	(1.16–3.33)	229
Pedestrians and cyclists	8	80	57.0	2	20	43.8	0.82	(0.24–2.75)	12
Motorcyclists	6	55	75.4	5	45	98.9	1.31	(0.44–3.85)	12
MAIS 2									
Occupants of large trucks	120	61	5.4	76	39	6.9	1.21	(0.69–2.10)	197
Passenger vehicle occupants	201	49	13.5	210	51	19.7	1.50	(0.97–2.32)	428
Pedestrians and cyclists	9	69	65.8	4	31	70.5	1.07	(0.36–3.17)	14
Motorcyclists	10	77	127.5	3	23	69.9	0.60	(0.20–1.79)	15
All involved persons (injured and uninjured)									
Occupants of large trucks	22,435	67		11,147	33				35,173
Passenger vehicle occupants	14,898	58		10,632	42				27,531
Pedestrians and cyclists	144	73		52	27				249
Motorcyclists	82	63		49	37				142

* MAIS is an injury severity scoring system in which 0 = no injury; 1 = minor injury; 2 = moderate injury; 3 = serious injury; 4 = severe injury; 5 = critical injury; and 6 = maximum injury (high likelihood of death).
† Calculated only for single-unit trucks and tractor-trailers.
‡ Includes large trucks where the category could not be determined.
§ Rates were calculated separately for each category of road user by truck type. For example, fatality rates per 1,000 passenger vehicle occupants were computed by dividing fatalities among passenger vehicle occupants by the numbers of passenger vehicle occupants involved in each type of large truck crash. Risk ratios and 95 percent confidence intervals were computed using the actual numbers, not the rates, so they may differ from rate patterns.

Table 6. Average annual numbers of large trucks involved in crashes by truck type and crash characteristics, combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

	Single-unit trucks		Tractor-trailers	
Crash characteristics	**Average**	**Row %**	**Average**	**Row %**
All crashes (fatal, non-fatal, no injury)				
Numbers of involved vehicles				
Single-vehicle	1,666	46	1,930	54
Two-vehicle	9,306	58	6,710	42
Three-vehicle	1,382	58	1,001	42
Run-off-road				
Single-vehicle run-off-road	353	40	526	60
Rollover	277	37	477	63
Pedestrian/cyclist collision	140	75	47	25
Single-vehicle pedestrian/cyclist involved	116	76	36	24
Multiple-vehicle pedestrian/cyclist involved	24	68	11	32
Location				
Urban*	9,113	61	5,733	39
Rural*	2,175	42	3,019	58
Interstate roadway	1,586	34	3,056	66
Intersection	3,315	59	2,283	41
Lighting conditions				
Daylight	10,388	58	7,576	42
Dawn or dusk	407	48	443	52
Dark, lit	939	59	642	41
Dark, unlit	486	39	757	61
Two-vehicle collisions				
Truck, front impact				
Head-on	1,197	57	889	43
Struck rear of other vehicle	180	68	84	32
Struck side of other vehicle	932	66	475	34
Truck, struck from the sides				
Passenger vehicles	810	57	607	43
Dark, lit	74	62	46	38
Dark, unlit	21	42	29	58
Truck, struck from the rear				
Passenger vehicles	225	63	135	38
Dark, lit	15	63	9	38
Dark, unlit	6	46	7	54

*Urban/rural data did not include Delaware because it lacked this variable.

3.2.4 Cargo Body Styles of Single-Unit Trucks

Categories of single-unit trucks were examined to determine the frequency with which they were involved in crashes resulting in fatalities or injuries (see table 7). Among single-unit trucks with specific assigned cargo body styles, the most common single-unit truck cargo body styles involved in police-reported accidents were flatbed trucks, large pickups, and cutaways,[66] followed by vans/box trucks, garbage trucks, cement mixers, and dump trucks. The rankings for hospital charges generally followed the frequency of persons involved in single-unit truck crashes by truck category.

Cement mixers, garbage trucks, van/box trucks, and dump trucks appeared to be the cargo body styles that were associated with the highest rates of fatalities, serious injuries, and hospitalizations per 1,000 road users involved in police-reported accidents. Dump trucks were associated with the highest rate of serious or worse (MAIS 3+) injuries (see figure 18). Dump trucks and cement mixers had the highest rate of people discharged to long-term care or rehabilitation facilities (see table 7).

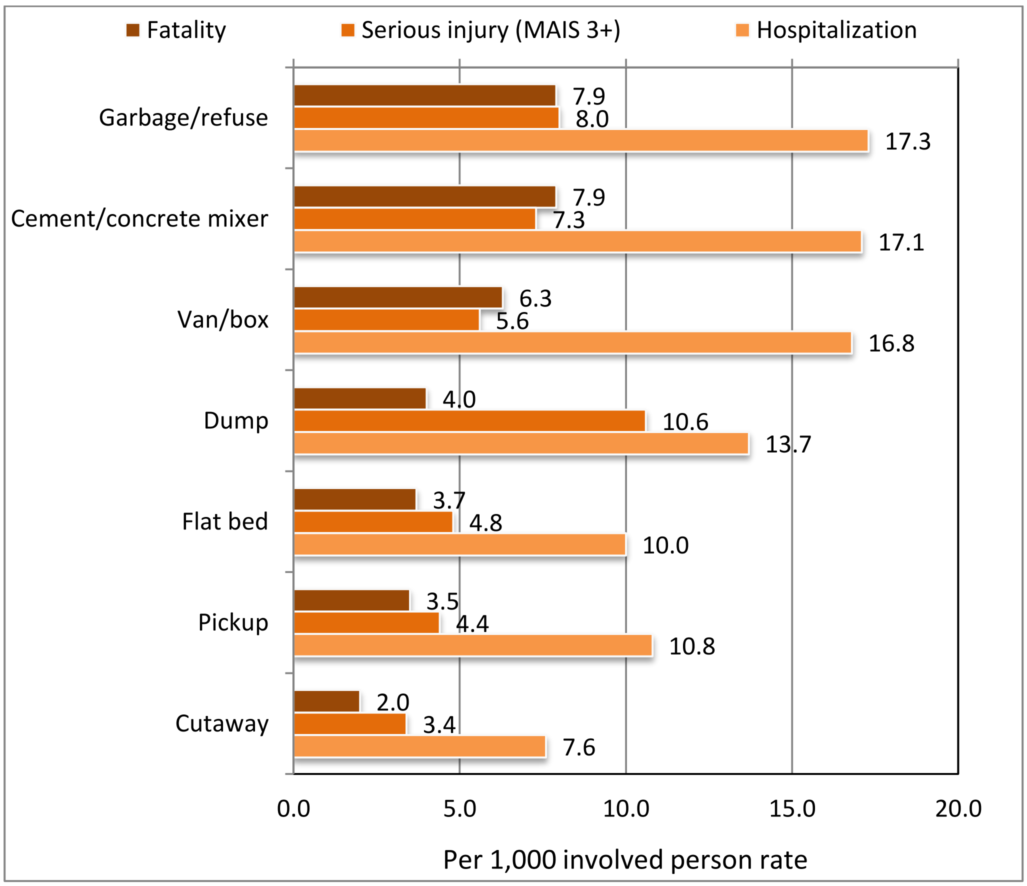


Figure 18. Average annual fatality, serious injury (MAIS 3+), and hospitalization rates per 1,000 involved persons by cargo body type, CODES, 2005–2009.

Of interest are medium/heavy pickups (hereafter referred to as large pickups), the category most likely to be classified as a passenger vehicle rather than a single-unit truck in police reports. The

[66] Cutaways are single-unit trucks sold as a cab and chassis. Secondary manufacturers then place a particular body on it, typically a large commercial van.

average annual number of road users involved in large pickup crashes was 3,352 in the participating states, which resulted in an average of 54 persons with MAIS 2+ injuries, 36 hospitalizations, and 309 emergency department visits each year. A yearly average of $1.77 million in hospital charges occurred as a result of crashes involving large pickups. Their injury and hospital use rates were similar to those of flatbed trucks but higher than those of cutaways.

3.2.5 Injury Outcomes by Crash Types

This study examined the injury outcomes by category of two-vehicle collisions involving single-unit trucks (see table 8). The category of two-vehicle collisions involving the most persons was a passenger vehicle colliding with the rear of a single-unit truck, followed by head-on collisions, trucks colliding with the sides of passenger vehicles, sideswipes, passenger vehicle collisions with the side of the truck, and trucks colliding with the rear-ends of other vehicles.

Two categories of collisions stood out as consistently having the highest rates of fatalities, seriously-injured persons (MAIS 3+), hospitalizations, emergency department visits, and discharge to long-term care/rehabilitation facilities:

(1) passenger vehicles colliding with the side of the single-unit truck, and
(2) sideswipes.[67]

The risks of fatalities and non-fatal injuries for the remaining types of two-vehicle collisions were ranked as follows:

(3) a single-unit truck colliding with the side of a passenger vehicle,
(4) a passenger vehicle colliding with the rear of a truck,
(5) head-on collisions, and
(6) a single-unit truck colliding with the rear of a passenger vehicle.

Impacts to the sides or rears of single-unit trucks on dark and unlit roads were of interest because current safety regulations mandate conspicuity treatments for the sides and rears of truck-tractors[68] and trailers but not for single-unit trucks. For collisions with the sides or rear of a single-unit truck, this study observed increased rates for serious injuries, inpatient hospitalizations, and emergency department visits per 1,000 involved passenger vehicle occupants on dark and unlit roads compared with the same types of collisions during daylight conditions (see table 9). Specifically, the rates for receiving a serious injury or for being hospitalized were twice as high on dark and unlit roads in crashes involving side or rear impacts to single-unit trucks compared with daylight conditions. These rates were based on small numbers of crashes and involve some uncertainty; however, they were consistent with other research indicating elevated risks of nighttime crashes (Varghese and Shankar 2007).

---

[67] Sideswipes are defined as collisions in which a vehicle strikes another vehicle along the side while traveling either in the same direction or opposite direction. This usually involves one vehicle encroaching upon the travel lane of the other vehicle. Neither the front end or rear end of either vehicle is contacted during sideswipes.

[68] Truck-tractors are the power units for tractor-trailers.

Table 7. Average annual injury outcomes by cargo body styles of single-unit trucks, combined state CODES, 2005–2009.

	Cement/ concrete mixer			Garbage/refuse			Dump truck			Van/box			Flat bed			Large Pickup			Cutaway			All single-unit trucks*		
Outcome	**Avg.**	**Row %**	**Rates***	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**
Fatalities	2	2	7.9	5	6	7.9	1	1	4.0	8	9	6.3	12	13	3.7	12	12	3.5	6	6	2.0	93	100	2.5
MAIS 3+	2	1	7.3	5	4	8.0	2	1	10.6	7	5	5.6	16	12	4.8	15	11	4.4	10	7	3.4	138	100	3.7
MAIS 2+	6	1	22.1	15	3	22.0	3	1	18.0	26	5	19.9	53	11	15.6	54	11	16.2	38	8	12.5	480	100	12.7
Hospitalization	4	1	17.1	12	4	17.3	2	1	13.7	22	7	16.8	34	11	10.0	36	11	10.8	23	7	7.6	321	100	8.5
Emergency department visits	32	1	122.4	74	2	108.9	21	1	114.2	142	4	108.0	312	10	92.1	309	10	92.2	268	8	88.4	3163	100	83.9
Long-term care/rehabilitation	1	2	3.9	2	3	2.6	1	1	4.1	3	5	2.0	4	8	1.3	7	12	2.0	6	11	2.1	56	100	1.5
Person-days	29	2		73	4		13	1		126	8		139	8		184	11		146	9		1658	100	
Charges (Millions)	0.28	2		0.60	4		0.15	1		1.13	8		1.32	9		1.77	12		1.37	10		14.30	100	
Persons involved	260	1		679	2		182	0		1,311	3		3,384	9		3,352	9		3,026	8		37,694	100	

* Rates are per 1,000 involved persons in crashes with these cargo body styles. Total includes single-unit trucks not defined as a distinct cargo body style.

Table 8. Single-unit trucks: Annual average injury outcomes by characteristics of two-vehicle collisions, combined states CODES, 2005–2009.

	Head-on collision			Truck hit side of vehicle			Other vehicle hit side of truck			Truck rear-ended vehicle			Other vehicle rear-ended truck			Sideswipe			All		
Outcome	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**	**Avg.**	**Row %**	**Rates**
Fatalities	2	3	0.5	6	11	2.0	13	24	5.0	0	0	0.0	6	11	1.1	12	22	4.6	55	100	1.9
MAIS 3+	6	7	1.6	10	12	3.3	17	20	6.5	0	0	0.4	10	12	1.7	17	20	6.4	85	100	3.0
MAIS 2+	24	8	6.6	46	15	14.9	50	16	19.0	1	0	1.8	47	15	8.2	49	16	18.8	305	100	10.6
Hospitalization	11	6	3.1	26	13	8.4	38	20	14.5	1	0	1.1	31	16	5.5	31	16	11.8	194	100	6.8
Emergency department visits	185	9	51.2	298	14	97.0	270	13	102.7	27	1	40.8	342	16	60.2	290	14	110.2	2131	100	74.2
Long-term care/rehabilitation	2	6	0.6	3	10	1.1	5	16	2.0	0	1	0.4	4	13	0.8	8	23	3.0	34	100	1.2
Person-days	61	6		119	12		152	15		7	1		156	16		201	20		992	100	
Charges (millions)	0.49	6		1.03	12		1.11	13		0.07	1		1.27	15		1.52	18		8.32	100	
Persons involved	3,611	13		3,076	11		2,627	9		666	2		5,683	20		2,632	9		28,701	100	

Table 9. Injury outcomes for passenger vehicle occupants in crashes involving vehicles colliding with the sides or rears of single-unit trucks in dark and unlit conditions versus daylight conditions, combined state CODES, 2005–2009.

	Dark and unlit		Daylight	
Outcome	**Annual Average**	**Rates***	**Annual Average**	**Rates***
Fatalities	1	6.9	12	4.3
Persons with serious Injuries (MAIS 3+)	2	18.0	16	6.1
Persons with moderate Injuries (MAIS 2+)	5	47.7	55	20.5
Hospitalizations (inpatient)	3	34.0	43	16.0
Emergency department visits	12	116.7	290	107.9
Persons involved	102		2,683	

* Rates per 1,000 vehicle occupants (passenger vehicle or truck).

3.2.6 Comparison of Police-Reported Vehicle Body Type Codes with VIN-based Truck Classifications

The participating states' government agencies used the vehicle body type variables for official reports to summarize motor vehicle accident statistics in their states, which resulted in undercounting single-unit truck crashes due to the misclassification of vehicle body types.[69] As described in the methods section, the NTSB relied heavily on information derived from the VINs to obtain more accurate counts of large trucks involved in crashes. This study identified 19,814 more vehicles as large trucks using VIN-based classifications than what the police-reported vehicle body type codes identified in the participating states. Of the 99,456 vehicles identified as large trucks by this study, 52 percent were single-unit trucks, 38 percent were tractor-trailers, and 9 percent were undefined large trucks (see table 10).[70]

Using VIN-based classifications, this study identified 52,051 single-unit trucks in crashes, but the vehicle body type codes identified only 40,428 single-unit trucks, which is a 23 percent undercount of single-unit trucks (similar to the 19 percent undercount identified in fatal crashes). Moreover, this study identified 38,247 tractor-trailers in crashes compared with 27,471 tractor-trailers identified by vehicle body type codes.

To better understand why certain single-unit trucks were not identified as such by police-reported vehicle body type codes, this study examined the VIN-derived GVWR and body styles of these particular vehicles. Almost half of the single-unit trucks that police considered as not being trucks (i.e., passenger vehicles) fell into the lower GVWR classes: 10,001–14,000 and 14,001–16,000 pounds (see table 11). Another 20 percent of such vehicles were heavy trucks with a GVWR over 26,000 pounds. Police coded pickup truck for 41 percent (N=10,152) of all

[69] Delaware: Veh_style; Maryland: bodytype_crash; Minnesota: vehtype; Nebraska: vehbdycd; Utah: UTvehtype

[70] The percentage distribution among vehicles coded as large trucks by police was very similar: 51 percent single-unit trucks, 34 percent tractor-trailers, and 15 percent undefined.

single-unit trucks recorded as passenger vehicles by police. Of the 1,844 single-unit trucks that police considered to be tractor-trailers, 75 percent fell into the two highest GVWR classes.

This study also examined vehicles coded as single-unit trucks by police but not identified as such by this study. Of these vehicles, about half (N=8,952) were tractor-trailers and they fell into the highest weight class of 33,001 pounds or higher. The rest were passenger vehicles, including cars (GVWR Class 0) and light-duty vehicles (GWVR Classes 1 or 2).

Table 10. Comparison of state truck classifications based on police-reported vehicle body types versus VIN-based methods, combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

Police-reported body type codes	VIN-based truck categories				
	Single-unit truck	**Tractor-trailer**	**Undefined truck**	**Not truck**	**Total**
Single-unit truck	22,674	8,952	1,238	7,384	40,248
Tractor-trailer	1,844	22,005	2,437	1,185	27,471
Undefined truck	2,811	6,354	1,657	1,101	11,923
Not truck	24,722	936	3,826	1,621,001	1,650,485
Total	**52,051**	**38,247**	**9,158**	**1,630,671**	**1,730,127**

Table 11. Distribution of single-unit trucks identified by this study where the police-reported vehicle body type codes indicated different categories of vehicles, combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

VIN-derived GVWR*	Study-identified single-unit trucks classified as either passenger vehicles† or as tractor-trailers by police reports			
	Passenger vehicle	**Percent**	**Tractor-trailer**	**Percent**
10,001–14,000 (Class 3)	8,095	33	32	2
14,001–16,000 (Class 4)	3,161	13	30	2
16,001–19,500 (Class 5)	944	4	33	2
19,501–26,000 (Class 6)	2,608	11	213	12
26,001–33,000 (Class 7)	4,815	19	1,030	56
33,001 and more (Class 8)	206	1	342	19
Weight unknown (GVWR of 0 or 9)	4,842	20	157	9
Faulty VIN	51	0	7	0
All NTSB-classified single-unit trucks	**24,722**	**100**	**1,844**	**100**

* VIN is the unique vehicle identification number assigned to each vehicle sold in the United States. GVWR is the gross vehicle weight rating (maximum allowable weight of vehicle and cargo).
† These were classified as not being trucks, so a few could have been buses rather than passenger vehicles.

3.3 National Estimates

CODES data from the participating states during 2005–2009 were used to generate national annual estimates for the numbers of persons receiving serious or worse injuries in single-unit truck and tractor-trailer crashes, in addition to numbers of emergency department visits and hospitalizations (see table 12). Federal databases do not provide detailed data on the severity of non-fatal injuries.

CODES data were also used to estimate the national number of fatalities in order to see how well this procedure predicted known fatalities according to TIFA. The estimated average annual number of fatalities in single-unit truck crashes was 1,657, whereas the actual national average in such crashes was 1,817 during 2005–2009, a 9 percent difference (see table 12). This suggests that extrapolation from the states to the nation as a whole was a reasonable procedure. As previously discussed, the state data on injury outcomes were underestimated; hence, the national estimates on injury outcomes are also likely underestimates.

As a result of single-unit truck crashes, an estimated 2,459 persons received MAIS 3+ injuries; 5,720 persons were hospitalized; and 56,359 persons went to the emergency department each year during 2005–2009 nationwide. An estimated 143 pedestrians/cyclists were injured each year during 2005–2009 nationwide. Estimated emergency department visits were considerably more common as a result of single-unit truck crashes than from tractor-trailer crashes, but estimated numbers of persons with MAIS 3+ injuries and hospitalizations were slightly lower for single-unit truck crashes.[71]

Table 12. National estimates of annual numbers of people receiving serious or worse (MAIS 3+) injuries, emergency department visits, and hospitalizations in crashes by truck type, US Census and combined state CODES for Delaware, Maryland, Minnesota, Nebraska, and Utah, 2005–2009.

	Single-unit trucks			Tractor-trailers		
Outcome	**Annual average**	**Rates***	**National annual estimates**	**Annual average**	**Rates***	**National annual estimates***
Fatalities	93	5.5	1,657	153	9.1	2,726
MAIS 3+ injured persons	138	8.2	2,459	159	9.4	2,833
Emergency department visits	3,163	187.1	56,359	2,059	121.8	36,687
Hospitalizations	321	19.0	5,720	336	19.9	5,987

* Per million persons.

The GES database, which is a national sample of police-reported accidents, was examined to provide additional national estimates of people injured in large truck crashes by truck type and truck involvements by crash categories. The GES estimates that 26,171 persons received injuries considered as incapacitating by police in single-unit truck crashes during 2005–

[71] See footnote 3.

2009; the estimate for lesser injuries was about 116,416 persons (see table 13). Tractor-trailer crashes resulted in higher estimated numbers of injuries, including about 46,025 incapacitating injuries.

Selected accident characteristics were examined within GES to generate national estimates of truck involvements by truck type during 2005–2009; these particular analyses included all police-reported accidents, whether or not an injury was recorded (see table 14). Single-unit trucks were involved in more backing-up crashes than tractor-trailers. Almost half of single-unit truck involvements occurred at intersections.[72] According to national data during 2005–2009, single-unit trucks were involved in fewer crashes involving passenger vehicles colliding with their rears than tractor-trailers: 11,544 versus 15,329. This also was true for passenger vehicle collisions with the sides of trucks: 20,618 versus 43,629. An estimated 5,914 single-unit involvements consisted of single-vehicle run-off-road crashes, and single-unit trucks were involved in 1,001 rollovers in which the rollover was the first harmful event.

About six percent of single-unit truck involvements occurred on roads that were dark and unlit, yielding a national estimate of 5,921 involvements, according to GES. To get more detail on lighting conditions in relation to crash type and cargo body style, this study examined state data. In the participating states, 21 percent of passenger vehicle collisions with the rears of dump trucks (single-unit trucks) and 8 percent of such collisions with the rears of flatbed trucks took place on dark and unlit roads. State data also showed that 8 percent of passenger vehicle collisions with the rears of vans/box trucks took place on dark and unlit roads.

[72] This was based upon a column percentage (referred to as "column %" in tables) to examine the distribution of crash characteristics within the large truck types.

Table 13. National estimates of people injured, excluding fatalities, in large truck crashes by truck type, type of road user, and injury level, GES, 2005–2009.

Type of injured road user	Single-unit trucks			Tractor-trailers		
	Estimates	Row %	Rates*	Estimates	Row %	Rates*
Occupants in large trucks						
Incapacitating injury	6,728	40	30	10,658	63	28
Other injury	32,384	43	144	44,615	59	119
All persons involved	224,117	37		374,892	62	
Occupants in passenger vehicles						
Incapacitating injury	17,703	34	79	33,542	64	89
Other injury	80,321	38	359	126,626	59	337
All persons involved	223,610	36		375,271	61	
All road users						
Incapacitating injury	26,171	36	57	46,025	63	61
Other injury	116,416	39	255	174,517	59	230
All persons involved	456,628	37		759,529	61	

* Rates per 1,000 involved road users in each category, including uninjured road users.

Table 14. National estimates for 2005–2009 of large truck involvements in police-reported crashes (fatal, injury, and property-damage-only) by truck type and selected crash characteristics, GES.

Crash characteristics*	Single-unit trucks		Tractor-trailers	
	Estimate	Column %	Estimate	Column %
Run-off-road	9,756	10	18,433	11
Single-vehicle run-off-road	8,914	9	16,359	10
Lighting conditions				
Dark, unlit	5,921	6	27,933	17
Dark, lighted	9,669	10	24,506	15
Daylight	85,827	85	112,207	68
Intersection	50,481	50	52,890	32
Non-intersection	45,772	45	95,931	58
Backing	1,685	2	1,365	1
Driver violations	31,613	31	50,016	30
Rollover	1,003	1	3,667	2
All involved trucks	101,417	100	164,650	100

*These rows are not mutually exclusive (large trucks can fall into more than one category).

3.4 Underride, Lighting Conditions, and Passenger Vehicle Driver Recognition Errors

The LTCCS included only large truck crashes resulting in fatal or non-fatal injuries. Because the LTCCS is a relatively small sample of large truck crash investigations, both crude counts and weighted estimates are presented to aid in interpretation (see table 15). All percentages are based on weighted data. Among single-unit trucks in two-vehicle collisions,[73] impacts involving the fronts of trucks were almost twice as common as truck side impacts: 59 percent and 30 percent, respectively. Impacts to the rear of single-unit trucks comprised nearly 10 percent of trucks involved in two-vehicle collisions.

In single-unit truck frontal impacts, truck front override[74] was recorded for an estimated 1,215 single-unit trucks, about 18 percent of impacts where truck fronts collided with passenger vehicles. Front override occurred most often when the fronts of single-unit trucks were impacted by the fronts of passenger vehicles: 37 percent of these collisions. When passenger vehicles collided with the sides of single-unit trucks, the weighted estimate for side underrides was 578, about 22 percent of all such side impacts. In comparison, side underride was coded for 39 percent of passenger vehicles striking the sides of tractor-trailers.[75] When passenger vehicles struck the rears of single-unit trucks, the weighted estimate for rear underrides was 793, about 79 percent of such impacts, compared with 73 percent for tractor-trailers (weighted estimate of 4,624).

Due to small numbers, it was not possible to analyze the relationships between the presence of retroreflective tape, dark roads, and passenger vehicle driver recognition errors[76] for either truck side impacts or truck rear impacts. Among single-unit trucks struck in the side by passenger vehicles, about 15 percent occurred on dark roads (lit or unlit) and 17 percent had retroreflective tape to enhance conspicuity on the side. An estimated 225 single-unit trucks were involved in truck side impacts on dark and unlit roads. Passenger vehicle drivers making errors in recognition were recorded for 23 percent of truck side involvements for single-unit trucks (weighted estimate was 597).

The percentage of single-unit trucks with retroreflective tape applied to the rear of the truck was 47 percent. Passenger vehicle driver recognition errors were recorded for 39 percent of truck rear impacts of single-unit trucks.

---

[73] LTCCS divided single-unit trucks by whether they were pulling trailers. This study only discusses results for single-unit trucks that were not pulling trailers. Table 15 presents data for both categories of single-unit trucks.

[74] Crashes in which the front of a truck goes over part or all of a passenger vehicle can be referred to either as front underrides or front overrides. Some databases code the large truck as having overridden the passenger vehicle, while others code the involved passenger vehicle as having underridden the large truck. Fault of the drivers of passenger vehicles or the drivers of large trucks is not a factor in either coding.

[75] Independent analyses of LTCCS by Brumbelow (2012) and Blower and Woodrooffe (2013) reported far higher percentages of front underride and side underride, as discussed in sections 4.3 and 4.5 of the Analysis and Discussion.

[76] Driver recognition errors in LTCCS were defined as follows: "The driver was inattentive, was distracted by something inside or outside the vehicle, or failed to observe the situation adequately for some other reason" (Craft 2007).

Table 15. National estimates of single-unit trucks and tractor-trailers involved in selected types of two-vehicle large truck crashes resulting in fatalities or injuries by crash characteristics, LTCCS, 2001–2003.

	Single-unit trucks, no trailers			Single-unit trucks with trailers			Tractor-trailers			Total	
Crash characteristics	**Crude**	**Weighted**	**Row %**	**Crude**	**Weighted**	**Row %**	**Crude**	**Weighted**	**Row %**	**Weighted**	**Row %**
All 2-vehicle crashes	155	14,397	22	23	1,276	2	353	49,128	76	64,801	100
2-vehicle truck-passenger vehicle collisions	114	10,419	21	18	958	2	286	37,584	77	48,962	100
Truck frontal impact	88	8,449	29	8	306	1	141	20,692	70	29,448	100
Truck struck passenger vehicle front	19	1,966	40	3	70	1	29	2,880	59	4,916	100
Truck struck passenger vehicle rear	15	1,989	35	1	14	0	26	3,667	65	5,670	100
Truck struck passenger vehicle side	34	2,709	25	3	110	1	59	8,138	74	10,957	100
Truck driver recognition cited (rear/side)	13	1,704	46	1	39	1	14	1,953	53	3,695	100
Override coded (any PV orientation)	20	1,215	23	2	64	1	36	4,074	76	5,353	100
Override coded (front)	9	733	29	2	64	3	19	1,700	68	2,497	100
Override coded (rear/side)	10	419	15	0	0	0	17	2,374	85	2,793	100
Truck side impact	40	4,361	21	7	392	2	112	16,189	77	20,942	100
Passenger vehicle struck side	30	2,643	14	6	385	2	103	15,258	83	18,286	100
Underride coded	8	578	9	0	0	0	38	5,883	91	6,461	100
Dark, unlit	2	225	16	0	0	0	10	1,203	84	1,428	100
Other dark	2	183	8	1	112	5	15	2,020	87	2,314	100
Daylight	26	2,235	15	5	274	2	78	12,036	83	14,544	100
Passenger vehicle driver recognition cited	7	597	16	2	197	5	22	2,866	78	3,660	100
Conspicuity treatment											
Yes	9	1,113	7	5	258	2	97	14,260	91	15,631	100
No	27	3,106	85	2	134	4	1	427	12	3,667	100
Unknown	4	142	9	0	0	0	14	1,502	91	1,644	100
Truck rear impact	20	1.243	11	6	541	5	83	9,962	85	11,745	100
Passenger vehicle struck rear	13	1,010	13	3	342	4	62	6,348	82	7,700	100
Underride coded	10	793	14	3	342	6	44	4,624	80	5,759	100

Dark, unlit	1	211	15	1	244	17	12	999	69	1,455	100
Other dark	5	119	6	1	73	4	14	1,777	90	1,970	100
Daylight	7	679	16	1	24	1	36	3,571	84	4,275	100
Passenger vehicle driver recognition cited	6	392	14	1	244	9	19	2,079	77	2,715	100
Conspicuity treatment											
Yes	8	570	7	4	356	5	62	6,949	88	7,875	100
No	11	605	30	2	185	9	9	1,232	61	2,022	100
Unknown	1	68	4	0	0	0	12	1,781	96	1,849	100
Truck backing up	0	0	0	0	0	0	2	135	100	135	100
Truck stopped	7	371	17	1	73	3	20	1,765	80	2,209	100
GVWR + CDL											
Classes 3-6 (10,001–26,000 lbs), no CDL violation	37	3,451	100	0	0	0	0	0	0	3.451	100
Classes 3-6 (10,001–26,000 lbs), had CDL violation	1	160	100	0	0	0	0	0	0	160	100
Classes 7-8 (> 26,000 lbs), no CDL violation	102	9,074	18	11	470	1	278	40,870	81	50,414	100
Classes 7-8 (> 26,000 lbs), had CDL violation	7	839	87	1	128	13	0	0	0	967	100
Unknown class, no CDL violation	8	873	9	11	679	7	74	8,223	84	9,775	100
Unknown class, had CDL violation	0	0	0	0	0	0	1	34	100	34	100

3.5 Commercial Driver's Licenses (CDL)

One issue of interest is whether drivers had invalid licenses at the time of crashes. In this study, "invalid license" could refer to one of the following violations: having no license; a license that was revoked, suspended or otherwise not in effect; not having a CDL required for the type of large truck being operated; or having a CDL without the required endorsements. CDLs are required for single-unit truck drivers if one of these conditions is met: (1) the vehicle is carrying hazardous materials, or (2) the vehicle has a GVWR or gross combination weight rating over 26,000 pounds. Neither the state data files nor GES appeared to report the presence of CDLs reliably; therefore, TIFA was used to explore the frequency of invalid licenses for fatal crashes and LTCCS was used to explore the issue of invalid licenses in its sample of investigated truck crashes. Of the single-unit trucks in fatal crashes during 2005–2009, 44 percent had GVWRs exceeding 26,000 pounds and thus their drivers were required to have a CDL.

About six percent of the single-unit truck drivers and two percent of the tractor-trailer drivers in fatal crashes had no driver's license or did not have a license valid for the type of truck that they were driving during 2005–2009. Of the 499 single-unit truck drivers who were operating a vehicle without the required license, 74 percent needed a CDL, but did not have one; 22 percent had a license that was suspended, revoked, expired, or otherwise not in effect; and 4 percent had a CDL but did not have required endorsements. Of the 307 tractor-trailer drivers who were not in compliance with license requirements, 23 percent needed a CDL but did not have one and the remaining drivers had suspended, revoked, expired, or invalid CDLs.

In LTCCS, 9 of 178 single-unit truck drivers in two-vehicle collisions were cited for not having a valid CDL, yielding an estimated 1,127 such drivers during the study period (2001–2003) (see table 16). Only one CDL violation was cited among the 353 tractor-trailer drivers in two-vehicle collisions.

3.6 Results from Case Reviews

To provide additional information about what happens in single-unit truck crashes and potential countermeasures, 11 single-unit truck cases were reviewed by an NTSB multidisciplinary case review team. These cases involved impacts to the front, side, and rear of the single-unit truck, along with collisions involving pedestrians struck by the single-unit truck. Table 16 summarizes the case review results, including whether underride occurred and whether there were countermeasures that could have mitigated the effects of the crashes. Figures 4, 19, and 20 show photos from several of the cases reviewed. See Appendix A for a link to a more detailed case summary.

One noteworthy observation was that some cases involved special purpose service trucks, such as snow plows or garbage trucks, being underridden by passenger vehicles while the trucks were traveling below the speed limit or had stopped during dark conditions. Countermeasures deemed as potentially effective included well-designed underride guards, collision warning systems, conspicuity improvements, vehicle-to-vehicle and vehicle-to-infrastructure communications, pedestrian detection technologies, and infrastructure changes. The case review team judged that these countermeasures may have reduced the severity of occupant injuries or prevented collisions with pedestrians for some of the crashes.

Table 16. Summary of findings of reviews of selected cases, LTCCS, 2001–2003.

Case number	Crash type	Truck type	Highest injury	Underride contributed to passenger vehicle injury	Countermeasures considered effective at mitigating injury	Comments
809004381	Two vehicle, impact into the back of truck	Three-axle, Class 8, garbage (refuse) truck	Incapacitating	Yes	Rear underride guard Truck conspicuity* improvements Collision warning systems†	Utility/service vehicles operate at a slower speed or frequently stop. Conspicuity is a large factor in crash avoidance.
821004749	Two vehicle, impact into the back of truck	Two-axle, Class 7, straight truck with dump bed	Fatal	Yes	Rear underride guard Vehicle-to-vehicle communication	Impact speed was an issue as it relates to forces and the degree of underride.
817004792	Two vehicle, impact into the back of truck	Three-axle, Class 8, dump/salt truck equipped with snowplow	Incapacitating	Yes	Rear underride guard Truck conspicuity improvements Collision warning systems	Utility/service vehicles operate at a slower speed or frequently stop. Conspicuity is a large factor in crash avoidance.
802003504	Two vehicle, impact into side of truck	Two-axle, Class 3, dump/salt truck	Incapacitating	Possible	Collision warning systems Side underride protection Vehicle to vehicle communication Vehicle to infrastructure communication	The damage to the passenger vehicle was not severe but the underride possibly increased the chances for injury. Underride was mitigated through the installation of a toolbox as accessory equipment on vehicle.

Case number	Crash type	Truck type	Highest injury	Underride contributed to passenger vehicle injury	Countermeasures considered effective at mitigating injury	Comments
811005482	Two vehicle, impact into side of truck	Two-axle, Class 3, straight box truck	Non-incapacitating	No	Collision warning systems Vehicle to vehicle communication Vehicle to infrastructure communication	The height of the side of the truck body above the ground, the size of the passenger vehicle, and the length of the hood allowed the passenger vehicle to pass under the side of the truck relatively undamaged and impact the frame. Injuries likely resulted from the speed of the passenger vehicle impact to the truck frame.
810003525	Pedestrian impact at front of truck, truck traveling straight	Two-axle, Class 7, straight truck pulling one tow-behind wood chipper	Incapacitating	Not applicable	Pedestrian detection technology‡	The pedestrian detection technology may have limited effectiveness if there was traffic on the two adjacent travel lanes.
810005767	Pedestrian impact at front of truck, truck turning left	Three-axle, Class 8, front-loading waste (refuse) collection truck	Fatal	Not applicable	Pedestrian detection technology Infrastructure design changes	The pedestrian detection technology should focus on this crash scenario, where the truck is turning left across traffic and the pedestrian is legally crossing the adjacent cross walk. Infrastructure changes could include a lighted intersection, pedestrian crossing lights but these changes may be difficult to justify at this intersection.

Case number	Crash type	Truck type	Highest injury	Underride contributed to passenger vehicle injury	Countermeasures considered effective at mitigating injury	Comments
810005042	Pedestrian impact at back of truck, truck backing up	Three-axle, Class 8, dump truck	Fatal	Not applicable	Improved mirrors Pedestrian detection technology (specifically backup cameras) Infrastructure design changes	Larger spot/convex mirrors with increased surface area and curvature may improve the visibility to the back of the truck. This crash is a classic example of the benefits of a backup camera system. Changes to the work zone including a spotter and other traffic control devices could have avoided this crash.
350006509	Two vehicle, head-on impact into front of truck	Two-axle, Class 7, straight truck with dump bed	Incapacitating	No	Collision warning systems Vehicle to vehicle communication Front underride guard	Due to the high speeds in head-on collisions, a front underride guard would need to both dissipate energy and possibly deflect the smaller vehicle.
821003690	Two vehicle, truck frontal impact into rear of passenger vehicle	Two-axle, Class 7, straight box truck	Fatal	Yes	Collision warning systems§ Vehicle to vehicle communication Front underride guard	The damage to the rear of the passenger vehicle was catastrophic. A front guard may have reduced the damage slightly but the high impact energy needed to be managed as well. Notable was the survival of the two rear seated children in child restraint systems.

Case number	Crash type	Truck type	Highest injury	Underride contributed to passenger vehicle injury	Countermeasures considered effective at mitigating injury	Comments
Police reported crash	Two vehicle, impact into the back of truck	Two-axle, Class 8, straight box truck	Fatal	Yes	Well-designed rear underride guard Collision warning systems Vehicle to vehicle communication Improved truck conspicuity	The impact speed was likely high due to the stopped truck on the 55 mph highway but the underride and subsequent intrusion into the passenger compartment of the minivan was catastrophic. Straight truck was equipped with some form of rear protection but of unknown design/standard

* Conspicuity included reflective tape, lighting, and signage.
† Including advanced active braking.
‡ A vehicle-based system designed to detect a pedestrian in the vehicle's path and alert the driver or actively brake the vehicle to mitigate the effects of the collision.
§ Although it was not clear that cruise control was used in this crash, reviewers noted that an adaptive cruise control system may aid the truck driver in maintaining a safe following distance even when the passenger vehicle began to slow due to the engine failure.

Figure 19. Photos of a front underride from case 350006509, LTCCS.

Figure 20. Photos of two single-unit trucks that struck pedestrians, cases 810003525 and 810005767, LTCCS.

4. Analysis and Discussion

4.1 Overview

Nationwide counts during 2005–2009 show that 9,084 people were fatally injured in crashes involving single-unit trucks. Many people also received non-fatal injuries in single-unit truck crashes—at least 142,000 during 2005–2009. As the results of this study have shown, the number of fatalities and injuries in single-unit truck crashes is underestimated in federal and state databases because single-unit trucks are misclassified and therefore not fully counted when relying on vehicle body type codes from police reports. These misclassifications translated into a 19 percent undercount of single-unit trucks involved in fatal crashes and a 20 percent undercount of the fatalities.

In the participating states' data, single-unit truck crashes resulted in substantial numbers of emergency department visits, inpatient hospitalizations, and non-fatal injuries of at least moderate severity, in addition to millions of dollars in hospital costs. Hospital costs are a fraction of societal costs from injuries in single-unit truck crashes (Wang et al. 1999). Data on large truck crashes from the participating states indicated that 61 percent of emergency department visits from large truck crashes involved single-unit trucks.

This study estimated the numbers of people injured in single-unit truck crashes nationwide using data from the participating states, which represented a mix of urban and rural states. Extrapolating from state injury and hospital treatment rates per population, single-unit truck crashes resulted in the following estimated nationwide outcomes[77] each year during 2005–2009 (see figure 21):

- 2,459 persons received MAIS 3+ injuries;
- 5,720 persons were hospitalized; and
- 56,359 persons went to the emergency department.

Hospitalizations and emergency department visits, as presented in this study, are mutually exclusive and do not overlap.

[77] The method used to derive national estimates of injuries and hospital treatments from state data appears to be reasonable because the estimated annual number of fatalities (1,657) was similar to the actual average annual number of fatalities from single-unit truck crashes (1,817) derived from TIFA.

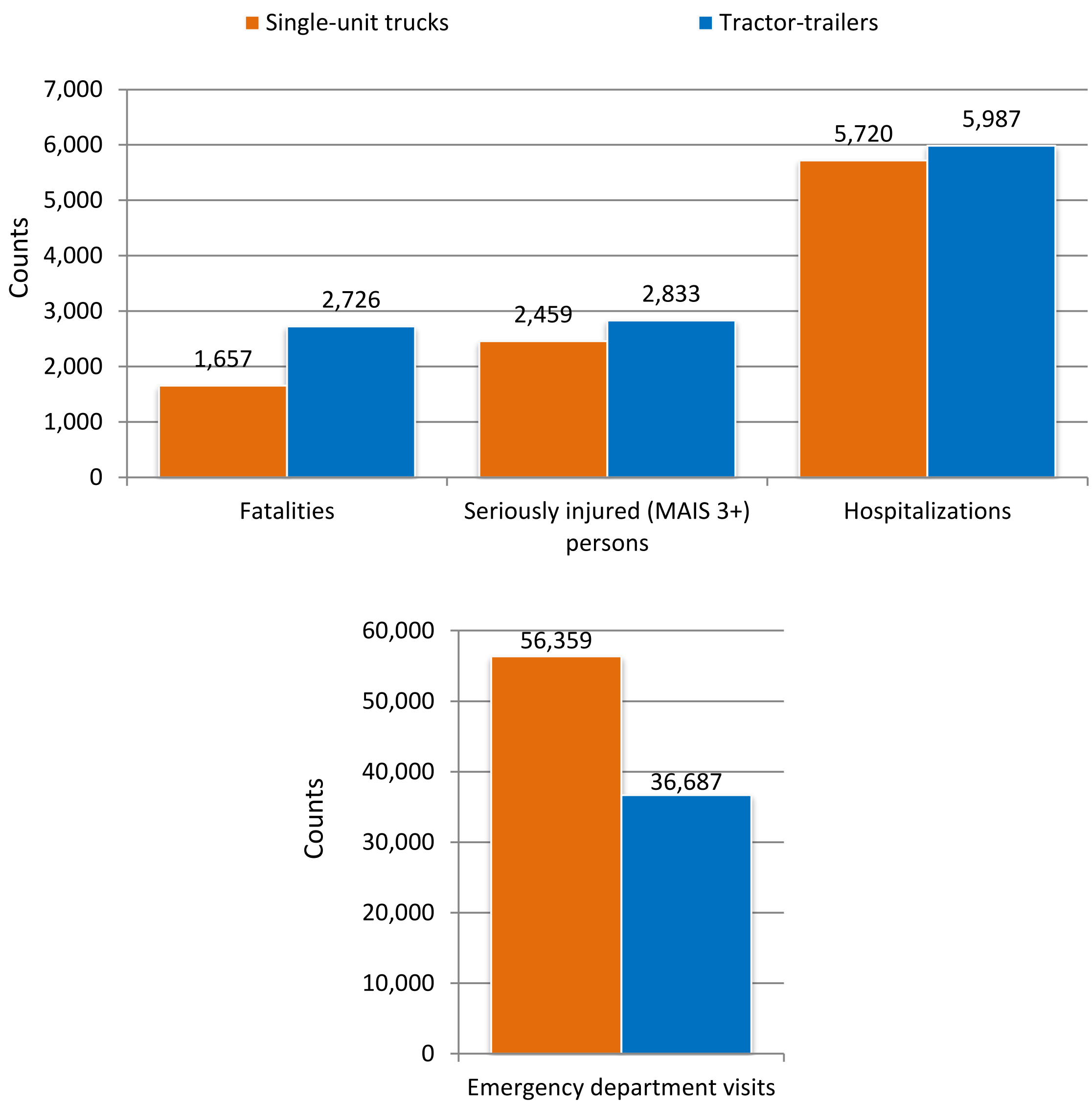


Figure 21. Estimated annual counts of fatalities, seriously injured (MAIS 3+) persons, hospitalizations, and emergency department visits attributed to single-unit truck and tractor-trailer crashes, 2005**–**2009.

As discussed in section 2, this study underestimated the numbers of people with serious or worse injuries and people receiving hospital treatment as a result of single-unit truck crashes and tractor-trailer crashes. Some of the reasons for this underestimation were that about 10 percent of large trucks were of an undefined type in state data and a range of 10–50 percent of hospitalized drivers could not be linked to a police accident record. Thus, the public health impact of single-unit truck crashes is higher than what this study's results indicate.

This study examined large truck crashes in two distinct ways: by examining the numbers and proportions of deaths, injuries, hospitalizations, and other adverse outcomes by truck type and by comparing the risk of adverse outcomes if involved in a crash by truck type. Among the participating states, rates for fatalities, serious injuries, hospitalizations, and discharges to long-term care/rehabilitation facilities per 1,000 involved persons were lower in single-unit truck crashes than in tractor-trailer crashes. Single-unit trucks travel on roads with lower speed limits and more congestion than tractor-trailers, which likely explains why their crashes result in lower rates of fatalities. Additionally, single-unit trucks may be involved in lower numbers of fatal crashes because they accumulate fewer VMT. The NTSB concludes that although single-unit truck crashes are neither as lethal nor as likely to cause the most severe injuries as compared with tractor-trailer crashes, available data show that they are involved in at least 37 percent of the fatalities, 49 percent of inpatient hospitalizations, and 61 percent of emergency department visits from large truck crashes.

Single-unit trucks are excluded from some of the federal safety regulations applicable to tractor-trailers, including requirements for enhanced conspicuity and for rear underride guards. This study examined crashes relevant to those exclusions. This study discusses and makes safety recommendations for the following safety issues:

- Vulnerable Road Users.
- Side Underride.
- Rear Underride.
- Front Underride.
- Conspicuity.
- Electronic Stability Control.
- Collision Warning Systems.
- Data Quality and Availability.
- Data on Crash Locations.
- Commercial Driver's License.

As noted earlier in this study, single-unit trucks have a variety of cargo body styles, including large heavy-duty pickup trucks, vans/box trucks, cement mixers, garbage trucks, dump trucks, flatbeds, cutaways, and highway maintenance vehicles. Therefore, the differences in the vehicle design and usage of these different cargo body styles will necessitate adapting any safety countermeasures, including the development of performance standards, to suit the type of single-unit truck.

4.2 Vulnerable Road Users

During 2005–2009, about three percent and six percent of all fatalities among pedestrians and cyclists, respectively, occurred in crashes involving single-unit trucks in the United States. The corresponding percentages for tractor-trailer crashes were four percent for pedestrians and five percent for cyclists. In the same period, 928 vulnerable road users died in single-unit truck crashes compared with 1,149 in tractor-trailer crashes. In the participating states, non-fatal injuries of at least moderate severity were more than twice as common as fatalities among vulnerable road users in single-unit truck crashes. Nationwide, an estimated 143 pedestrians/cyclists received serious or worse injuries each year during 2005–2009. More than 65 percent of vulnerable road users' moderate and serious injuries in large truck crashes were attributable to single-unit trucks in the participating states. The NTSB concludes that twice as many pedestrians and cyclists received non-fatal injuries in single-unit truck crashes as in tractor-trailer crashes, although the numbers of fatally injured pedestrians and cyclists were 19 percent lower in single-unit truck crashes than in tractor-trailer crashes.

The existence of large blind spots around large trucks has been well-documented and results in collisions where drivers of large trucks strike vulnerable road users as well as passenger vehicles because they cannot detect them (California 2013; Transport Canada 2009). These blind spots are larger than those of passenger vehicles and include the front, sides, and rear of the large truck (see figure 22 of a single-unit truck known as a roll-off truck). Both single-unit trucks and tractor-trailers have large blind spots that can obscure vulnerable road users, as well as other vehicles sharing the road. The blind spots for single-unit trucks vary according to vehicle design. When large trucks turn right or left, the blind spots can obscure very large areas near the truck (Missouri 2006) (see figure 23 of a tractor-trailer).

An unknown proportion of all crashes involving single-unit trucks and vulnerable road users is due to errors[78] on the part of pedestrians or cyclists; these errors may arise from alcohol, fatigue, distraction, or other factors. This is particularly true of fatal crashes, in which about one-third of fatally injured pedestrians and one-fifth of fatally injured cyclists had blood alcohol concentrations of 0.08 grams per deciliter or higher (NHTSA 2012b, 2012d). For non-fatal crashes, there were no reliable data on the exact reasons why collisions with vulnerable road users occurred. Technology that enables single-unit truck drivers to detect vulnerable road users in time to avoid striking them would reduce some, but not all, collisions with both vulnerable road users who are using roads appropriately and those who have made errors.

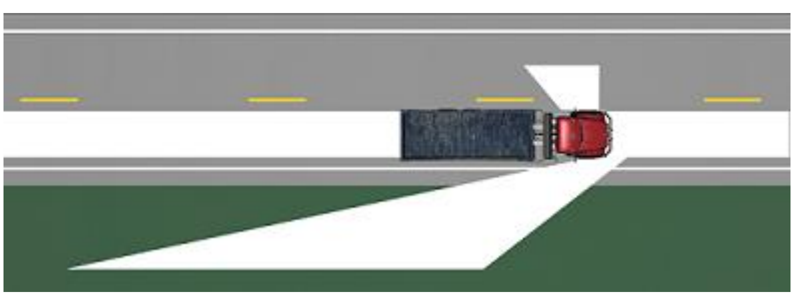


Figure 22. Diagram showing the locations of blind spots for a single-unit truck. (Dimensions are not necessarily to scale, and the ability to view an object also depends on its height.) Adapted from FHWA, 1999.

[78] Examples of errors made by vulnerable road users include crossing a road other than at a crosswalk or crossing against a light.

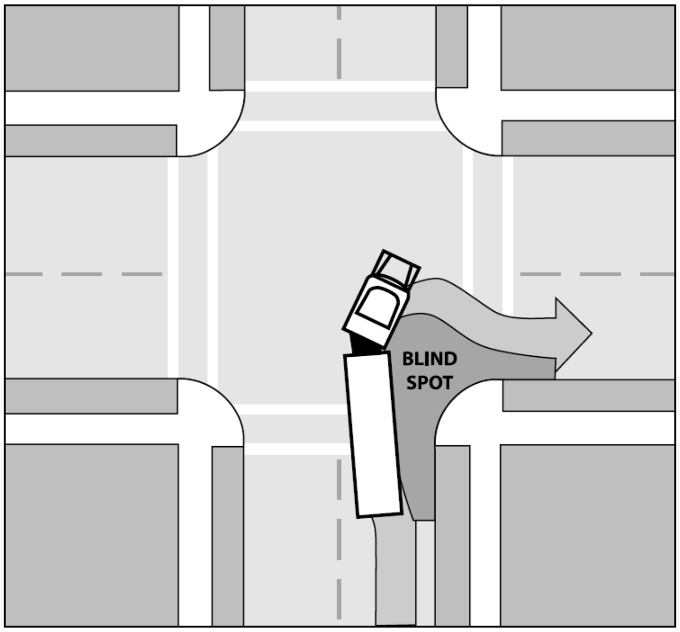
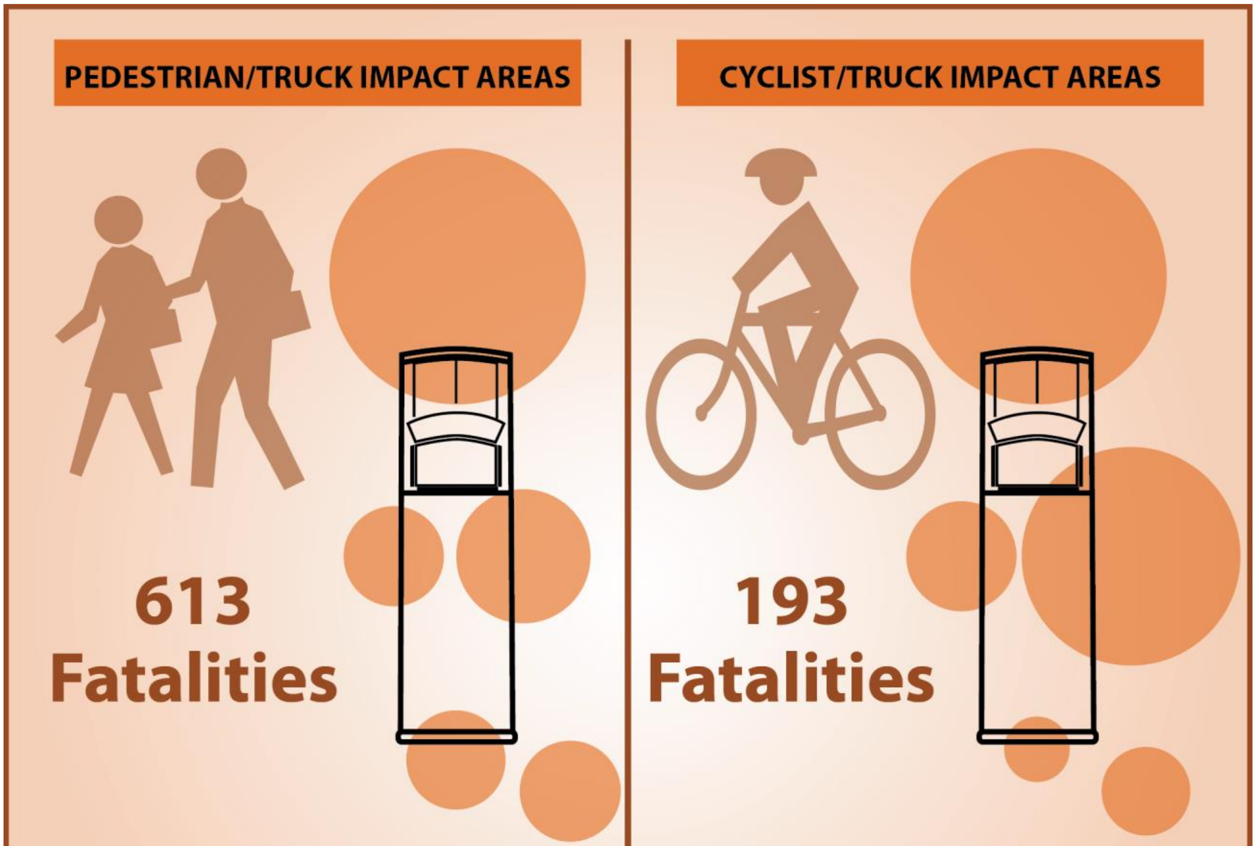


Figure 23. Diagram of blind spot while a tractor-trailer turns right, Missouri Bicycle and Pedestrian Federation, 2006.

Of the 613 pedestrians and 193 cyclists fatally injured in single-vehicle crashes involving single-unit trucks during 2005–2009, 58 percent of pedestrians and 48 percent of cyclists were contacted by the front of the single-unit truck.[79] Cyclists were more likely than pedestrians to have an impact with the right side of single-unit trucks (35 percent); this may be due to a combination of cyclists tending to travel in the right-hand lanes and the large blind spots on the right sides of single-unit trucks. Figure 24 shows the distribution by initial impact points of the single-unit trucks.

[79] See footnote 61.



Impact Area	Pedestrians	%
Front	354	58
Back	53	9
Right	97	16
Left	54	9
Other	55	9

Impact Area	Cyclists	%
Front	92	48
Back	6	3
Right	67	35
Left	17	9
Other	11	6

Figure 24. Distribution of single-unit truck crashes by initial contact points with pedestrians and cyclists, TIFA, 2005–2009.

As noted in section 1.3.2, New York has taken steps to enable truck drivers to see pedestrians in front of them by requiring a cross over mirror on the fronts of large trucks operating in cities with populations of at least one million and on highways other than limited access roads to reduce truck/pedestrian collisions (NYC DOT 2012). Europe also has requirements for mirrors on heavy-goods vehicles to enhance detection of pedestrians and cyclists (European 2003, 2005).[80] Advanced technologies to protect vulnerable road users also are in development and were available for several passenger vehicle makes in 2011 (IIHS 2011). These advanced technologies were also discussed in a request for comments by NHTSA published on April 5, 2013 (78 FR 20597) that described frontward and rearward pedestrian sensing systems combined with automatic braking. Some

[80] See footnote 31.

of these systems use radar combined with a camera while others rely on two cameras; some systems would be able to detect pedestrians at night, which is when most fatal pedestrian crashes occur.

This study reviewed cases of pedestrians struck by single-unit trucks in urban areas and determined that technology to detect the presence of pedestrians would have been beneficial in those cases. The size of the blind spots will depend on the vehicle design and size of the single-unit truck, so any countermeasures will need to take these and other characteristics of single-unit trucks into consideration. The NTSB concludes that onboard systems and equipment that compensate for blind spots and allow drivers of single-unit trucks to detect vulnerable road users could prevent fatalities and injuries that occur in crashes involving single-unit trucks. To reduce the numbers of non-occupants who are killed or injured by large trucks, the NTSB recommends that NHTSA develop performance standards for visibility enhancement systems to compensate for blind spots in order to improve the ability of drivers of single-unit trucks with gross vehicle weight ratings over 10,000 pounds to detect vulnerable road users, including pedestrians and cyclists, in their travel paths. Once the performance standards requested in H-13-11 have been developed, the NTSB recommends that NHTSA require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with visibility enhancement systems meeting the performance standards.

4.3 Side Underride

Large truck side impacts are a common safety problem affecting passenger vehicle occupants colliding with both single-unit trucks and tractor-trailers. Data from the participating states indicated that crashes in which passenger vehicles collided with the sides of large trucks were more common for single-unit trucks than tractor-trailers. This differed from national estimates, where tractor-trailers were involved in more of these types of crashes than single-unit trucks: 43,629 versus 20,618. The differences between the state data and national estimates might be due to misclassification and undercounting of single-unit trucks in GES, as well as the smaller numbers in the GES sample. Whether or not truck side impacts are more common among single-unit trucks or tractor-trailers, they pose high hazards for passenger vehicle occupants.

When considering different crash types, sideswipes[81] and passenger vehicle collisions with the sides of single-unit trucks stood out as having the highest average annual rates per 1,000 involved road users of serious injury and hospital treatment. Sideswipes include both those in which passenger vehicles were moving in the same direction as the single-unit trucks and those in which passenger vehicles were moving in the opposite direction. The average annual rates of seriously-injured persons per 1,000 involved road users were 6.5 when passenger vehicles collided with the sides of single-unit trucks compared with 3.0 for all types of crashes combined (see figure 25). Based on prior research, these crashes are at least as hazardous when they involve tractor-trailers (Blower et al. 2001).

[81] Sideswipes are defined as collisions that do not involve the fronts or rears of either vehicle and in which the impact swipes along the surfaces of the vehicles parallel to the direction of travel.

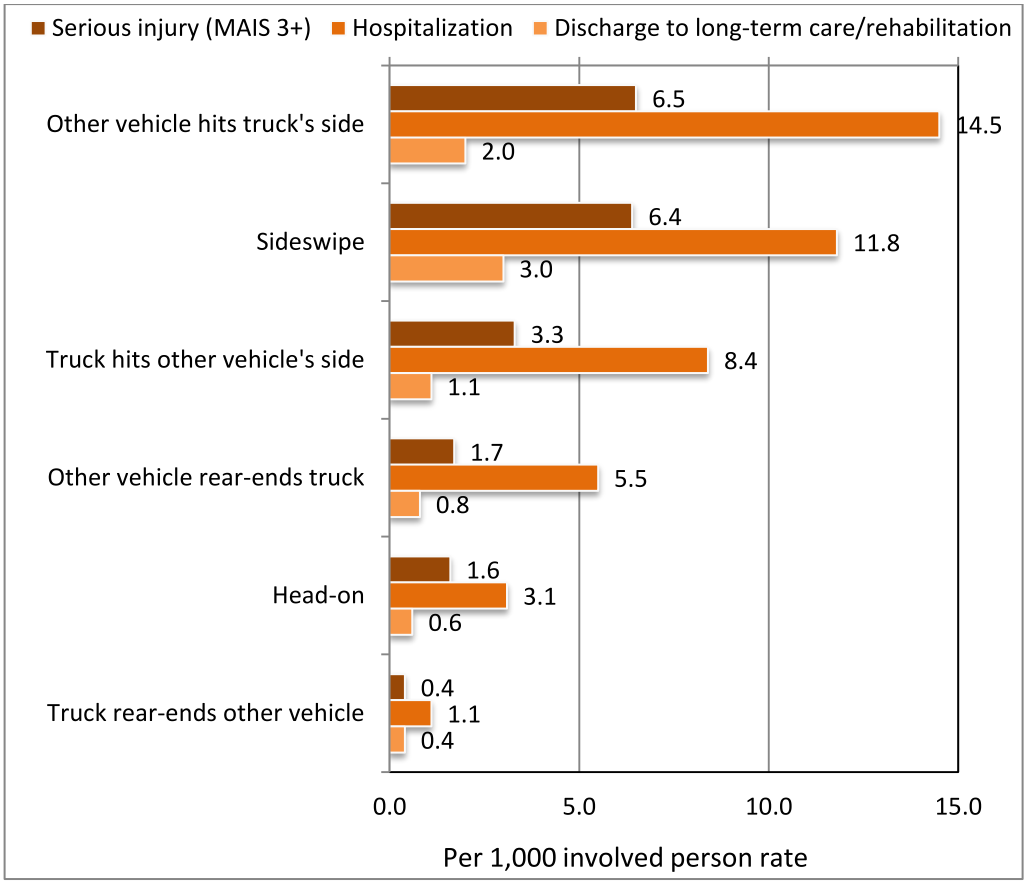


Figure 25. Average annual serious injury (MAIS 3+), hospitalization, and discharge to long-term care/rehabilitation rates per 1,000 involved persons by collision type, single-unit truck crashes, CODES, 2005–2009.

One reason why the risks of death and injury in side impact collisions are so high is that side underride is a common feature of these crashes. Side underride, like all underride crashes, occurs because passenger vehicle bumpers are not at the same height as the structure of the large truck. During a collision, this allows the passenger vehicle to impact the large truck with parts of the vehicle not designed to absorb crash forces, namely the windshield and those areas above the hood. This type of collision can cause deaths and severe injuries because it leads to the intrusion of truck components into the passenger compartment. Although LTCCS data were recorded as indicating that one-fifth of passenger vehicle collisions with the sides of single-unit trucks and two-fifths of the collisions with the sides of truck tractors resulted in side underride, an independent assessment of LTCCS cases determined that underride occurred more frequently than recorded by LTCCS (Blower and Woodrooffe 2013). Among single-unit trucks involved in collisions in which passenger vehicles struck their sides, side underride occurred in 53 percent of collisions with the sides of the cargo areas and 43.5 percent of collisions with the sides of cabs. Passenger compartment intrusion, which causes deaths and serious injuries, was common in truck side impacts. Another independent analysis using LTCCS data concluded that 78 of 206 crashes in which a passenger vehicle collided with the side of a large truck resulted in severe to catastrophic underride, and that side underride guards would have mitigated injury in 60 of the 78 severe/catastrophic side underrides (Brumbelow 2012).

Side underride guards are a countermeasure that is currently required by Europe and Japan to prevent pedestrians and cyclists from going underneath large trucks (Patten and Tabra 2010). There are technical challenges to installing side underride guards that are designed to prevent passenger vehicles from underriding the sides of single-unit trucks and trailers (Brumbelow 2012); however, at least one European manufacturer sells underride guards that reduce both side and rear underrides of trailers. Cargo bed heights of 50 inches or more increase the likelihood of side underride (Blower and Woodrooffe 2013), which suggests that guards that would reduce the side ground clearance could be effective. In 1991, NHTSA decided that side underride guard regulations would not be cost-effective, based on numbers obtained from FARS (NHTSA 1991). However, FARS has been shown to markedly undercount the occurrence of both side and rear underrides, which calls the previous cost-effectiveness analysis into question (Brumbelow 2012, Brumbelow and Blanar 2010, Braver et al. 1997). Any requirement for side underride guards could be tailored to the different cargo bed heights of single-unit trucks and trailers, including an assessment of the likelihood of the occurrence of side underride given a truck side impact.

The NTSB concludes that about half of all collisions resulting in injury between passenger vehicles and the side of single-unit trucks involve underride, pose a high risk of death and injury, and could be reduced by side underride guards. To protect passenger vehicle occupants from fatalities and serious injuries resulting from truck side impacts, the NTSB recommends that NHTSA develop performance standards for side underride protection systems for single-unit trucks with gross vehicle weight ratings over 10,000 pounds. Once the performance standards requested in H-13-13 have been developed, the NTSB recommends that NHTSA require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with side underride protection systems meeting the performance standards.

4.4 Rear Underride

Rear underride occurred in more than 70 percent of crashes leading to fatal and non-fatal injuries in which passenger vehicles collided with the rears of both single-unit trucks and tractor-trailers (see table 15). This is consistent with research conducted at IIHS and at the University of Michigan Transportation Research Institute (Brumbelow and Blanar 2010, Blower et al. 2012). The IIHS analysis reported that, among 22 passenger vehicles colliding with the rears of single-unit trucks in fatal and non-fatal crashes, 8 experienced severe to catastrophic underride, 11 experienced slight to moderate underride, and 3 experienced no underride.[82] Collisions by passenger vehicles with the rear of single-unit trucks were more common than tractor-trailers according to data from the participating states. However, fewer single-unit trucks were involved in crashes in which they were struck in the rear by passenger vehicles, according to national data. Whether rear impacts are more common among single-unit trucks or tractor-trailers, they pose a risk of death and serious injury for passenger vehicle occupants. Figure 26 shows the percentages (from LTCCS) of crashes involving single-unit trucks being struck in the rear by passenger vehicles that were coded as underride, compared with the same kind of crashes involving tractor-trailers.

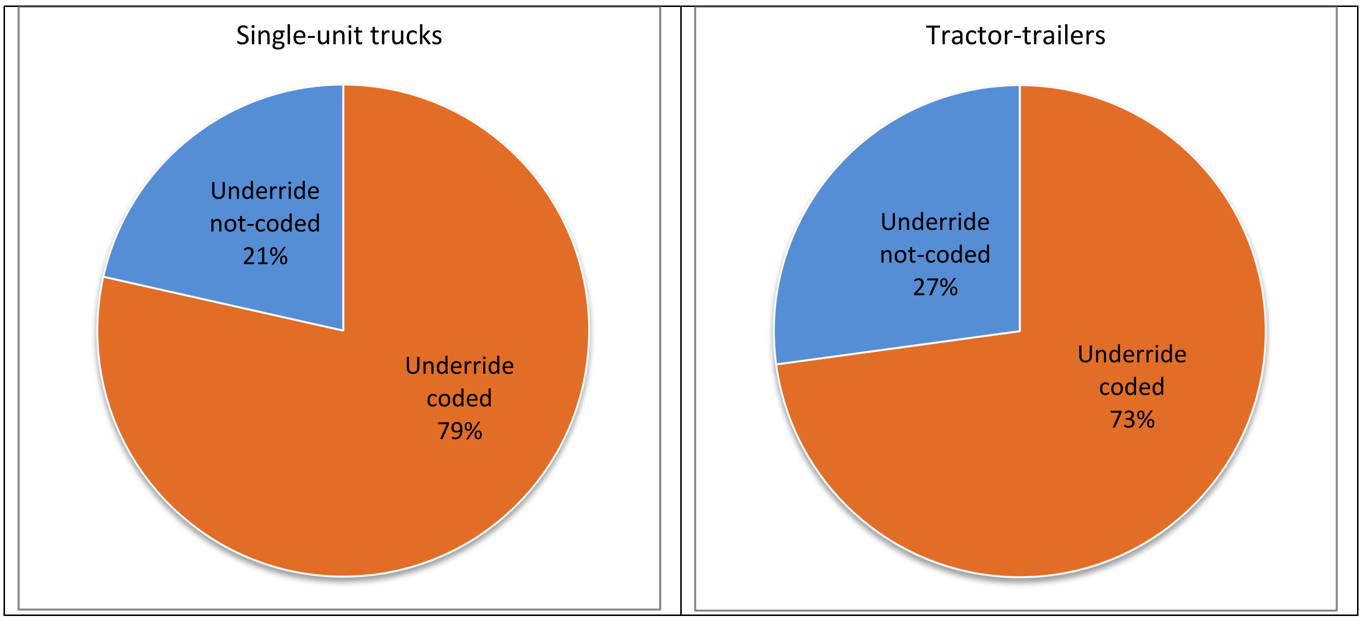


Figure 26. Percentages of crashes involving passenger vehicle striking the rears of large trucks with underride coding by truck types, LTCSS, 2001–2003.

The NTSB reviewed accident cases involving rear underrides of single-unit trucks and judged that well-designed rear underride guards would have mitigated the severity of these crashes. Research has indicated that the currently mandated rear underride guards for tractor-trailers in the United States are not as effective as intended and that the Canadian standards for rear underride guards provide better

[82] Slight underride is defined as the passenger vehicle going underneath up to one-half of the length of the hood; moderate underride is defined as the passenger vehicle receiving damage up to the base of the windshield; severe underride is defined as damage extending as far as the B-pillar (second pillar of the passenger vehicle). Catastrophic underride is defined as having the entire front-row space compromised by passenger compartment intrusion.

protection (Brumbelow and Blanar 2010, IIHS 2013). Crash tests have shown that underride guards on trailers that exceed the US regulations more effectively prevent injuries and fatalities than underride guards that only meet the current US standard (IIHS 2013).

In 1996, NHTSA decided not to include single-unit trucks in its requirement for improved rear impact guards for trailers and pointed out that regulating trailers was more cost-effective as there were fewer of them and tractor-trailers were involved in far more fatal large truck crashes (NHTSA 1996). However, the databases that NHTSA evaluated undercounted both single-unit truck fatalities and rear underrides. Thus, more occupants of passenger vehicles are at risk due to this type of crash than what NHTSA previously calculated.

The NTSB concludes that the fatalities and serious injuries that are caused by rear underrides, which occur in most collisions resulting in injury between passenger vehicles and the rears of single-unit trucks, could be mitigated by well-designed rear underride protection systems. To protect passenger vehicle occupants from fatalities and serious injuries resulting from rear impacts with single-unit trucks, the NTSB recommends that NHTSA develop performance standards for rear underride protection systems for single-unit trucks with gross vehicle weight ratings over 10,000 pounds. Once the performance standards requested in H-13-15 have been developed, the NTSB recommends that NHTSA require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with rear underride protection systems meeting the performance standards.

4.5 Front Underride

Truck frontal impacts pose a major hazard to passenger vehicle occupants and front underride contributes to the risk. The majority of fatal large truck crashes involve the fronts of large trucks (Jarossi et al. 2011). Data from the participating states indicated that collisions involving the fronts of trucks were the most common type of collision and occurred more frequently for single-unit trucks than for tractor-trailers (see figure 27).

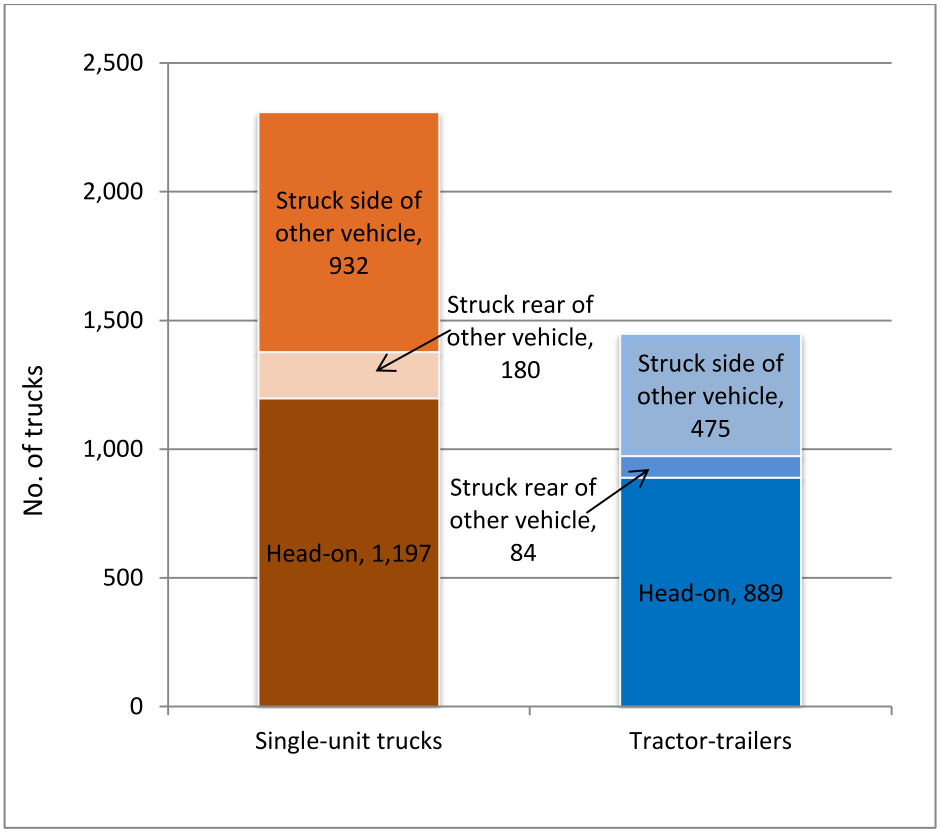


Figure 27. Average annual numbers of large trucks involved in front impact crashes by truck types, CODES, 2005–2009.

Passenger compartment intrusion in underride collisions results in deaths and serious injuries to passenger vehicle occupants and is common in truck frontal impacts. Blower and Woodrooffe (2013) indicated that front underride occurred in 72 percent and passenger compartment intrusion occurred in 64.5 percent of large truck front impacts resulting in injury or death. Their research also showed a strong relationship between the height of front truck bumpers and the occurrence of front underride, which suggests that a front underride protection system could prevent both front underride and passenger compartment intrusion.

This study found that about 18 percent of single-unit truck frontal impacts with passenger vehicles resulting in injury or death involved underride during 2001–2003. This resulted in a national estimate of 1,215 for front underrides involving single-unit trucks (see table 15). Front underride was most common in head-on collisions (37 percent).

Since 2003, European Union countries have required front underride protection systems on all newly manufactured heavy-goods vehicles, which indicates that such a standard is feasible. The NTSB concludes that collisions between passenger vehicles and the front of single-unit trucks or tractor-trailers are common types of crashes that result in fatalities, and front underride contributes to crash severity. The NTSB therefore reiterates its prior recommendations that (1) NHTSA develop performance standards for front underride protection systems for trucks with gross vehicle weight ratings over 10,000 pounds (Safety Recommendation H-10-12), and (2) that once the performance standards in Safety Recommendation H-10-12 have been developed, require all newly manufactured trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with front underride protection systems meeting the performance standards (Safety Recommendation H-10-13).

4.6 Conspicuity

An estimated 6 percent of single-unit trucks involved in crashes occurred on roads that were dark and unlit, yielding a national estimate of 5,921 involvements during 2005–2009. In the participating states, 4 percent of single-unit truck crashes occurred on dark and unlit roads compared with 8 percent of tractor-trailer crashes. Although crashes on dark and unlit roads constitute a small minority of single-unit truck crashes, state data indicated higher rates of serious injuries to vehicle occupants in crashes involving side or rear impacts to single-unit trucks compared with daylight conditions. These higher rates were based on small numbers of crashes, which limits their certainty, but they were consistent with other research on the risks of nighttime crashes (Varghese and Shankar 2007). Nighttime increases the likelihood of crash involvement and the likelihood of injury. Enhancing conspicuity of single-unit trucks could reduce collisions between passenger vehicles and single-unit trucks on dark and unlit roads and mitigate the severity of such collisions by allowing passenger vehicle drivers more time to react after detecting the presence of the single-unit truck.

The frequency with which a single-unit truck gets into a crash on dark and unlit roads varies by cargo body styles and by type of collision. For example, 21 percent of passenger vehicle collisions with the rears of dump trucks took place on dark and unlit roads. Highway maintenance vehicles are another example of how certain types of single-unit trucks are more prone to involvement in crashes on dark roads. These trucks often operate at slower speeds than the surrounding traffic or require frequent stops. As a result, increased conspicuity, such as flashing lights and illuminated arrows highlighting the slower moving or stopped vehicle, will reduce crashes between these maintenance trucks and other road vehicles (McCullouch and Stevens 2008). Most states require retroreflective tape on snow plows and other maintenance trucks operated by their departments of transportation, including Minnesota and Iowa (Kamyab 2002). The case reviews conducted as part of this study included instances when catastrophic rear impacts occurred when passenger vehicles traveling at highway speeds struck much slower-moving maintenance trucks on dark roads. Case reviews indicated that conspicuity-enhancing countermeasures may have mitigated the severity of the injuries.

Countermeasures addressing conspicuity for tractor-trailers and trailers have been required for about 20 years. Heavy trailers manufactured after December 1993 and tractor-trailers manufactured after July 1997 were required by NHTSA to have conspicuity treatments. Effective as of December 2001, the FMCSA extended the requirement for enhanced conspicuity treatments to include the entire on-road trailer fleet, including retrofitting those manufactured prior to 1993. In an evaluation of the retroreflective tape treatments applied to trailers to meet the conspicuity regulation, passenger vehicle impacts into the sides and rears of trailers were reduced by 41 percent in dark and unlit conditions (Morgan 2001). Retroreflective tape is simple to apply and inexpensive, and some owners of single-unit trucks have voluntarily applied this treatment.

Neither NHTSA nor the FMCSA included single-unit trucks in their requirements to enhance vehicle conspicuity. One rationale for this exclusion was that fewer single-unit trucks traveled on dark roads than tractor-trailers. Furthermore, regulating tractor-trailers and trailers was more cost-effective because there are fewer of them, yet they are involved in far more fatal large truck crashes. The NTSB notes that NHTSA made the decision to exclude enhanced conspicuity requirements using databases that undercounted single-unit truck fatalities by 20 percent (NHTSA 1992).

The NTSB concludes that available data regarding single-unit truck crashes indicate that the rates of serious injury and hospitalization are higher in collisions on dark and unlit roads than during daylight conditions, and the injury rates could be reduced by conspicuity treatments on these trucks. To reduce the occurrence of passenger vehicles colliding with single-unit trucks, the NTSB recommends that NHTSA require conspicuity treatments on the sides and rears of newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds consistent with the requirements for such treatments on truck-tractors and trailers specified in 49 CFR Part 571.108 (Federal Motor Vehicle Safety Standards: Lamps, Reflective Devices, and Associated Equipment). While NHTSA is developing the conspicuity standards for newly manufactured single-unit trucks in H-13-17, the NTSB recommends that the DOT direct either NHTSA or the FMCSA, as appropriate, to determine and implement the most efficient method to require the retrofit of treatments, according to the standards, on the sides and rears of single-unit trucks with gross vehicle weight ratings over 10,000 pounds.

4.7 Electronic Stability Control

Rollovers and single-vehicle run-off road crashes are two types of crashes that can be reduced by electronic stability control (ESC) systems. Prior research by Woodrooffe et al. (2012) reported that single-unit trucks were involved in more fatal loss-of-control crashes than tractor trailers, and that annual cost savings from preventing crashes by installing ESC on all single-unit trucks would be $1.2 billion to $1.5 billion. The fatal loss-of-control crashes usually resulted from single-unit truck drivers overcorrecting after encroaching upon roadway shoulders. The NTSB has previously recommended that all large commercial vehicles have electronic stability control systems (NTSB 2011b). ESC systems use automatic computer-controlled braking of individual wheels to assist the driver in maintaining control of the vehicle in critical driving situations. The NTSB's previous recommendation is further supported by this study, which found a large number of rollovers and single-vehicle run-off road crashes among both types of trucks.

During 2005–2009, an estimated 1,003 single-unit trucks and 3,667 tractor-trailers were involved in rollovers and an estimated 8,914 single-unit trucks and 16,359 tractor-trailers were involved in single-vehicle run-off road crashes nationwide. Data from the participating states indicated an average of 630 annual involvements of single-unit trucks in both rollovers and single-vehicle run-off road crashes. The NTSB concludes that single-unit trucks are involved in at least one-third of all large truck rollovers and single-vehicle run-off-road crashes, two types of crashes that can be mitigated by electronic stability control systems.

As noted in the introduction of this study, NHTSA proposed mandating electronic stability control for tractor-trailers and motorcoaches in 2012 but not for single-unit trucks. The NTSB is aware of NHTSA's concern about there being no electronic stability control systems currently on the market for hydraulically-braked, medium-weight trucks; however, as noted in the 2012 comments submitted to NHTSA in response to the proposed rule, the NTSB continues to advocate this safety technology for single-unit trucks (2012). Additionally, single-unit trucks with air brakes were not included in the proposal, although electronic stability control systems are available for them. The NTSB therefore reiterates its prior recommendations to the NHTSA to (1) develop stability control system performance standards for all commercial motor vehicles and buses with a gross vehicle weight rating greater than

10,000 pounds, regardless of whether the vehicles are equipped with a hydraulic or a pneumatic brake system (Safety Recommendation H-11-7); and (2) once the performance standards in Safety Recommendation H-11-7 have been developed, require the installation of stability control systems on all newly manufactured commercial vehicles with a gross vehicle weight rating greater than 10,000 pounds (Safety Recommendation H-11-8).

4.8 Collision Avoidance Technologies

Vehicle-based collision avoidance technologies and advanced vehicle-to-vehicle connectivity, as well as vehicle-to-infrastructure communications, could reduce a variety of different types of crashes involving single-unit trucks. The technologies include lane departure warnings, adaptive cruise control, collision warning systems, and variable message signs to notify drivers of distant traffic congestion. Previous research has demonstrated the value of collision avoidance systems for large trucks (Jermakian 2012). An FMCSA-sponsored evaluation of forward collision warning systems designed to prevent large truck collisions with the rears of other vehicles concluded that motor carriers investing in this technology would experience cost savings within five years of purchasing it for their fleets; these benefits were applicable to both single-unit trucks and tractor-trailers (Murray et al. 2009).

Field tests of forward crash, lateral drift, and lane-change/merge collision warning systems conducted by UMTRI "resulted in improvements in lane-keeping, fewer lane departures, and increased turn-signal use" for both tractor-trailers and passenger vehicles (Sayer et al. 2011). These results would also be applicable to single-unit trucks. Additionally, the case reviews conducted in this study pointed to some of these advanced technologies as being beneficial for specific crashes. This study also found that sideswipes posed a high risk of death and injury to passenger vehicle occupants, as did truck frontal impacts; these types of crashes can be mitigated by collision avoidance technologies, including lane departure warning and other warning systems.

The NTSB concludes that collisions with the sides and fronts of large trucks could be prevented or mitigated by lane departure systems, adaptive cruise control, and collision warning systems installed on large trucks. Accordingly, the NTSB reiterates its prior recommendations to NHTSA to (1) develop standards for adaptive cruise control and collision warning system performance standards for new commercial vehicles, addressing obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning (Safety Recommendation H-01-6); (2) after promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system (Safety Recommendation H-01-7); and (3) require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems (Safety Recommendation H-10-1).

4.9 Data Quality and Availability

This study used a variety of databases to fully characterize the risks resulting from single-unit truck crashes, and found that all the databases provide essential information. However, some misclassify large trucks. One database (TIFA) that classifies trucks accurately has been discontinued and another that contains specific injury and hospitalization data (CODES) is scheduled to be discontinued.

FARS is the most commonly used database for identifying fatal motor vehicle crashes in the United States. However, this study primarily used the TIFA database, which identified more single-unit trucks involved in fatal crashes (and the resulting fatalities) than FARS, adding anywhere from 196 to 393 single-unit trucks each year during 2005–2009. These misclassifications translated into a 19 percent undercount of single-unit trucks involved in fatal crashes and a 20 percent undercount of the fatalities. The TIFA database provides more accurate classifications of large truck vehicle body types by using information from the VIN and by collecting additional data for all fatal large truck crashes.

Figure 28 shows that the largest category of vehicles misclassified as passenger vehicles in FARS had a VIN-derived GVWR of 10,001–14,000 pounds (Class 3). This is not surprising because single-unit trucks with GVWRs above 10,000 pounds can resemble pickup trucks.

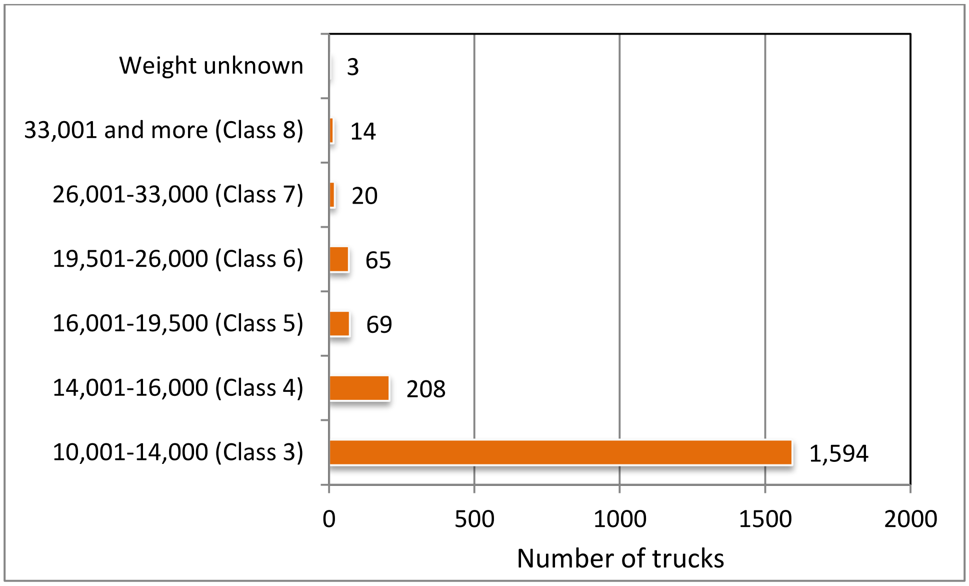


Figure 28. Distribution of single-unit trucks classified as passenger vehicles by VIN-derived GVWR, TIFA, 2005–2009.

The NTSB also used VINs and consequently observed similar misclassifications of single-unit trucks in state databases by vehicle body type variables. The frequency of single-unit truck misclassification and the types of misclassification errors were examined. Of the 52,051 single-unit trucks identified by VINs, 47 percent were incorrectly coded as passenger vehicles by the vehicle body type variable and 4 percent were incorrectly coded as tractor-trailers (see figure 29). The overall effect of misclassifications in the CODES state databases was a 23 percent undercount of single-unit trucks involved in police-reported accidents, which is similar to the 19 percent undercount observed for fatal crashes.

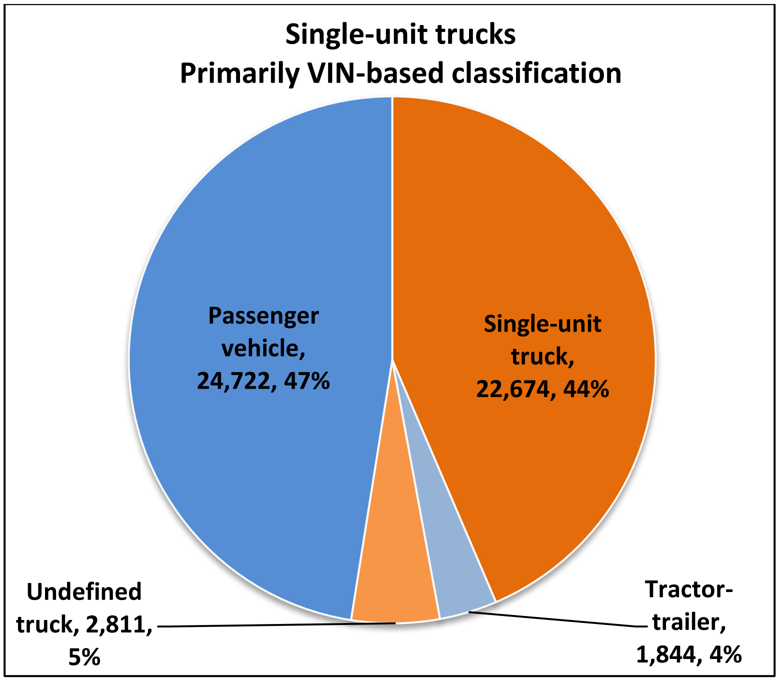


Figure 29. Distribution of single-unit trucks identified by VINs by how they were classified according to vehicle body type variables in state police accident report databases, CODES, 2005–2009

The NTSB concludes that 19 percent of single-unit trucks in fatal crashes have been misclassified in police reports and thus undercounted by FARS, and using information from VINs provides more accurate classification of single-unit truck and tractor-trailer crashes than relying solely on vehicle body type codes in federal and state databases.

Accurate accident data on large trucks is an important basis for appropriate decisions by policy makers. As noted earlier in this study, the single-unit trucks that are being misclassified as passenger vehicles are in crashes that result in fatalities and non-fatal injuries. Since 1980, TIFA has been adding new variables important for understanding fatal truck crashes, such as collision avoidance technologies on large trucks and information about motor carriers, as well as correcting existing variables in FARS, including vehicle body types, through a combination of using VINs, surveys, and in-depth scrutiny of existing data. However, TIFA data are not made available by NHTSA or the FMCSA, nor do agency websites refer users to TIFA data.

To improve the coding of large commercial vehicles in the Fatality Analysis Reporting System and the National Automotive Sampling System, the NTSB recommends that NHTSA develop and implement a plan for using VINs and other variables, such as cargo type or trailers, to improve the coding and classification of large commercial vehicles in FARS and NASS. The NTSB also recommends that NHTSA include data from each calendar year of the TIFA database on the FARS website.

Funding for TIFA data collection stopped after September 1, 2012, which means that the nation will not have improved fatal truck crash data after calendar year 2010.[83] Multiple scientific papers and reports on truck safety have been published that relied on TIFA data; these reports have increased knowledge of various factors contributing to large truck crashes. The NTSB concludes that the TIFA database increases the understanding of truck safety through the improved accuracy of data on fatal large truck crashes collected by FARS. The same is true for BIFA, which also improves the accuracy and completeness of fatality data relating to buses.

CODES, the project in which 13 states link people hospitalized due to motor vehicle crashes to police reports, is a unique data source that is scheduled to lose its funding after September 30, 2013. NHTSA bears a fraction of the full costs of CODES to each state and funds technical resource centers.[84] In addition to injury coding, the CODES technical resource center hosts technical trainings for CODES states, helps CODES states with their linkages, provides statistical software programs, does network-wide analyses, develops common variables to use across the states, and imputes missing values from CODES state data. Recently, CODES data were used to estimate the extent to which alcohol-impaired driving is underreported by police and by hospitals (Miller et al. 2012). Linking existing datasets together to improve understanding of the characteristics and consequences of motor vehicle crashes is an effective use of resources. The NTSB concludes that data from CODES provide detailed information on injury diagnoses and severity in relation to accident characteristics, cover a large proportion of the population of the participating states, are not available elsewhere, and provide useful insight into traffic safety problems. The NTSB recommends that the DOT develop and implement a plan to ensure the continued collection of data as performed for the TIFA database and the continuation of state linkage of hospital and police-reported data as performed by CODES.

This study made use of the LTCCS, which collected data during 2001–2003, as a source of accident cases to review, and to generate estimates for front underrides, side underrides, and rear underrides of single-unit trucks and tractor-trailers. The accident investigations, including scene diagrams, vehicle photographs, and other investigator-collected data, were critical for this purpose. The NTSB concludes that the crash investigation data from LTCCS can provide useful information on the details of crashes and identification of potential countermeasures. The FMCSA has announced plans to do an update to the LTCCS, but, as of the time of this study, has not yet determined the final data collection procedures and study design. The NTSB recommends that the FMCSA ensure that the data collection for the successor to the initial Large Truck Crash Causation Study includes full accident investigations that will enable scrutiny of crash, vehicle, environmental, roadway, and driver variables contributing to non-fatal injuries and deaths in large truck crashes.

4.10 Data on Crash Locations

This study showed that the distribution of fatal single-unit truck crashes varies across the United States. Locations of fatal single-unit truck crashes follow the distribution of the general population; however, some relatively less populated states had very high fatal single-unit truck involvement rates per million people, namely Montana, Wyoming, Colorado, and Arkansas. Fatal

[83] According to UMTRI, TIFA and its companion, Buses in Fatal Accidents (BIFA), cost about $700,000 annually (FMCSA contract DTMC75-08-H-00005).

[84] According to NHTSA, the federal share of annual costs is less than $1 million.

tractor-trailer crash locations tracked more closely with the network of the interstate highway system than single-unit truck locations. Location-based information, such as latitude and longitude, can be analyzed in geographic information systems (GIS) that works with spatially referenced information.

On December 4–5, 2012, the NTSB held a conference titled "GIS in Transportation Safety."[85] During the conference, many discussions focused upon the use of GIS data and technologies in highway safety. For example, with the passage of the MAP-21 reauthorization for the US Department of Transportation (DOT), the Federal Highway Administration (FHWA) is now using the Highway Performance Monitoring System (HPMS) to collect GIS roadway network data for all roads (not just federal aid roads) from state DOTs. Furthermore, the FHWA indicated that crash attributes will be added to the road network GIS data (Lewis 2012). The FHWA developed the GIS Safety Analysis Tool that merges crash data, roadway inventory data, and traffic operations data so that states and municipalities can identify problem locations and assess the effectiveness of implemented countermeasures. By integrating this traditional system with GIS spatial referencing capabilities and graphical displays, a more effective crash analysis can be performed (Thor 2012).

Some states are using advanced technology to apply GIS in traffic safety. For example, the California Highway Patrol and California Department of Transportation (Caltrans) collaborated with the University of California, Berkeley, to develop and maintain the Transportation Injury Mapping System (Bigham 2012). This online GIS database of all police-reported crashes in California and its free online map application helps identify hot spots of crashes, estimate risks, and evaluate the cost-effectiveness of potential countermeasures. A database of locations with the highest frequency of large truck rollovers was produced by the American Trucking Research Institute (ATRI) based on over 50,000 accident records from 31 states. Using GIS, the database provided valuable insight into the location of high frequency rollover locations to both public transportation officials and the trucking industry (ATRI 2012).

There is currently no repository of location-based information (such as latitude and longitude coordinates) for non-fatal crashes at the national level. However, the FHWA has been working with nine participating states[86] in compiling crash, roadway, and traffic variables into the Highway Safety Information System (HSIS) since 1987. This database can be used to analyze a large number of highway safety problems, from identification of problem locations to crash modeling. The NTSB concludes that a national repository of location-based information for crashes would be beneficial, and the FHWA is well-positioned to leverage its experience in the HSIS and its ability to collect expanded roadway GIS data through the HPMS to compile location-based information of all crashes. The NTSB recommends that the FHWA develop and implement a strategic plan for facilitating technology transfers between states that will lead to a complete and accurate database of spatially referenced highway crash locations for integration with roadway inventory and traffic operation data captured by the Highway Performance Monitoring System.

[85] See http://www.ntsb.gov/news/events/2012/GIS/index.html.

[86] California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, Utah, and Washington. See http://www.hsisinfo.org for more information.

4.11 Commercial Driver's Licenses (CDL)

This study examined how often drivers of single-unit trucks and tractor-trailers involved in fatal crashes had invalid[87] licenses for the type of truck they were operating. This study found that among fatal crashes during 2005–2009, six percent of single-unit truck drivers and two percent of tractor-trailer drivers had invalid licenses. This study did not have sufficient data to determine the relationship between invalid licenses and risk of involvement in a crash, nor was this study able to determine how often improper licensure existed among single-unit truck drivers in non-fatal crashes. The NTSB concludes that drivers of single-unit trucks in fatal crashes were three times more likely to have invalid licenses than the drivers of tractor-trailers involved in fatal crashes; however, neither the frequency of invalid licensure among single-unit truck drivers involved in non-fatal crashes nor the risks associated with invalid licensure among single-unit truck drivers are known. The NTSB recommends that the FMCSA conduct an assessment of the frequency with which single-unit truck drivers are operating with invalid licenses, together with the associated risks of invalid licensure, and publish the findings.

Since 1992, the US Department of Transportation has required interstate tractor-trailer drivers to obtain a CDL.[88] This requirement aimed to prevent such drivers from possessing more than one license and mandated that states administer tests of knowledge and road skills to ensure that affected drivers met minimum classifications. An assessment of the CDL program concluded that it has been successful in reducing the numbers of CDL holders with multiple driving licenses (Commercial Driver's License Advisory Committee 2008). Commercial driver licensure for single-unit truck drivers is required only if the single-unit trucks are carrying hazardous materials or have a GVWR over 26,000 pounds; a CDL is not required for drivers of single-unit trucks with GVWRs below 26,001 pounds. However, single-unit trucks with a GVWR below 26,001 pounds weigh more, have higher bumpers, and may have different driving characteristics than passenger vehicles, and therefore may require a higher degree of licensure. This study has documented a series of safety problems posed to road users by single-unit trucks; however, it is unclear whether commercial driver's licenses would increase safe driving practices among drivers of single-unit trucks not currently required to hold such licenses (Hagge and Romanowicz 1996). A previous NTSB accident investigation concluded that a contributing factor was that a driver of a single-unit dump truck had received insufficient training on how to inspect and operate air brakes (NTSB 2006a). To obtain a CDL, drivers must demonstrate their ability to operate large commercial vehicles by passing both a knowledge test and a road skills test. The NTSB concludes that requiring commercial driver's licenses for drivers to operate single-unit trucks with GVWRs less than 26,001 pounds may be an effective means of reducing the frequency and severity of single-unit truck crashes, but further data are needed to determine whether the requirements for commercial driver licensure should be expanded to some types of single-unit trucks. The NTSB recommends that the FMCSA evaluate the potential benefits of extending commercial driver licensure requirements to the operation of single-unit trucks with gross vehicle weight ratings below 26,001 pounds. If the evaluation in H-13-22 indicates a benefit from extending commercial driver's licensure,

---

[87] In this study, "invalid license" refers to the following: having no license, a license that was revoked, suspended or otherwise not in effect; not having a CDL required for the type of large truck being operated; or having a CDL without the required endorsements.

[88] This requirement also applies to bus drivers.

the NTSB recommends that FMCSA require CDLs for drivers of single-unit trucks in gross vehicle weight rating classes for which benefits have been shown.

5. Conclusions

Single-unit trucks comprise the majority of large trucks registered in the United States, 8.22 million during 2010 (76 percent of all large trucks), and they travel more than 110.7 billion miles each year. Single-unit trucks are excluded from some important safety rules applicable to tractor-trailers; therefore, one reason why the NTSB undertook this study was to determine whether these safety rules should be extended to single-unit trucks. A review of the accident record indicates that about 1,800 people died each year during 2005–2009 in crashes involving single-unit trucks and that single-unit trucks were overrepresented in multivehicle crashes resulting in fatal injuries to passenger vehicle occupants relative to their numbers of vehicle registrations and vehicle-miles of travel. Although single-unit trucks comprise three percent of registered motor vehicles and four percent of miles traveled, they are involved in nine percent of fatalities among passenger vehicle occupants in multivehicle crashes. Further, single-unit truck crashes resulted in thousands of serious injuries, hospitalizations, and emergency department visits each year during 2005–2009. By conducting a comprehensive review of single-truck truck safety, which included using multiple federal and state data sources, this study was able to quantify the impact of single-unit truck crashes in terms of fatalities, non-fatal injuries, hospital treatment, and hospital costs.

Characteristics of single-unit truck crashes were examined, which enabled identification of countermeasures to reduce the frequency or severity of such crashes among single-unit trucks. These included crashes occurring on dark and unlit roads; crashes that resulted in passenger vehicles underriding the sides, rears, and fronts of single-unit trucks; and rollovers and single-vehicle run-off-road crashes. An additional crash type consisted of collisions with vulnerable road users (pedestrians and cyclists).

This study found that the adverse effects of single-unit truck crashes have been underestimated in the past because these trucks are frequently misclassified and thus undercounted in federal and state databases (by 20 percent in the case of fatalities). Additionally, some databases used by this study to assess the safety of single-unit trucks have been or are scheduled to be discontinued, although they are essential for monitoring safety progress over time.

Single-unit trucks vary in vehicle design and usage, which will necessitate adapting any safety countermeasures, including the development of performance standards, to suit the type of single-unit truck. Areas identified for safety improvements include the need to (1) enhance the ability of drivers of single-unit trucks to detect vulnerable road users such as pedestrians and cyclists; (2) prevent passenger vehicles from underriding the sides and rears of single-unit trucks; (3) improve conspicuity of single-unit trucks; and (4) improve federal and state databases on large truck crashes. Other safety needs include (5) maintaining the functions performed by TIFA and CODES, (6) research on the frequency and consequences of single-unit truck drivers operating with an invalid license, and (7) research on the potential benefits of expanding the CDL requirement to lower weight classes. Safety recommendations relating to collision avoidance and collision mitigation technologies were reiterated based on study results.

Among federal agencies responsible for the safety of large trucks, NHTSA is responsible for designs of newly manufactured large trucks and the FMCSA regulates the safety of large trucks operating in interstate operations or transporting hazardous materials. The FHWA is responsible for safety efforts relating to the network of the nation's roadways. Accordingly, recommendations were addressed to all of these agencies, in addition to the US Department of Transportation.

5.1 Findings

1. Although single-unit truck crashes are neither as lethal nor as likely to cause the most severe injuries as compared with tractor-trailer crashes, available data show that they are involved in at least 37 percent of the fatalities, 49 percent of inpatient hospitalizations, and 61 percent of emergency department visits from large truck crashes.

2. Twice as many pedestrians and cyclists received non-fatal injuries in single-unit truck crashes as in tractor-trailer crashes, although the numbers of fatally injured pedestrians and cyclists were 19 percent lower in single-unit truck crashes than in tractor-trailer crashes.

3. Onboard systems and equipment that compensate for blind spots and allow drivers of single-unit trucks to detect vulnerable road users could prevent fatalities and injuries that occur in crashes involving single-unit trucks.

4. About half of all collisions resulting in injury between passenger vehicles and the side of single-unit trucks involve underride, pose a high risk of death and injury, and could be reduced by side underride guards.

5. The fatalities and serious injuries that are caused by rear underrides, which occur in most collisions resulting in injury between passenger vehicles and the rears of single-unit trucks, could be mitigated by well-designed rear underride protection systems.

6. Collisions between passenger vehicles and the front of single-unit trucks or tractor-trailers are common types of crashes that result in fatalities, and front underride contributes to crash severity.

7. Available data regarding single-unit truck crashes indicate that the rates of serious injury and hospitalization are higher in collisions on dark and unlit roads than during daylight conditions, and the injury rates could be reduced by conspicuity treatments on these trucks.

8. Single-unit trucks are involved in at least one-third of all large truck rollovers and single-vehicle run-off-road crashes, two types of crashes that can be mitigated by electronic stability control systems.

9. Collisions with the sides and fronts of large trucks could be prevented or mitigated by lane departure systems, adaptive cruise control, and collision warning systems installed on large trucks.

10. Nineteen percent of single-unit trucks in fatal crashes have been misclassified in police reports and thus undercounted by the Fatality Analysis Reporting System, and using information from vehicle identification numbers provides more accurate classification of single-unit truck and tractor-trailer crashes than relying solely on vehicle body type codes in federal and state databases.

11. The Trucks in Fatal Accidents database increases the understanding of truck safety through the improved accuracy of data on fatal large truck crashes collected by the Fatality Analysis Reporting System.

12. Data from the Crash Outcome Data Evaluation System provide detailed information on injury diagnoses and severity in relation to crash characteristics, cover a large proportion of the population of the participating states, are not available elsewhere, and provide useful insight into traffic safety problems.

13. The crash investigation data from the Large Truck Crash Causation Study can provide useful information on the details of crashes and identification of potential countermeasures.

14. A national repository of location-based information for crashes would be beneficial, and the Federal Highway Administration is well-positioned to leverage its experience in the Highway Safety Information System and its ability to collect expanded roadway geographic information systems data through the Highway Performance Monitoring System to compile location-based information of all crashes.

15. Drivers of single-unit trucks in fatal crashes were three times more likely to have invalid licenses than the drivers of tractor-trailers involved in fatal crashes; however, neither the frequency of invalid licensure among single-unit truck drivers involved in non-fatal crashes nor the risks associated with invalid licensure among single-unit truck drivers are known.

16. Requiring commercial driver's licenses for drivers to operate single-unit trucks with gross vehicle weight ratings less than 26,001 pounds may be an effective means of reducing the frequency and severity of single-unit truck crashes, but further data are needed to determine whether the requirements for commercial driver licensure should be expanded to some types of single-unit trucks.

6. Recommendations

6.1 New Recommendations

As a result of this safety report, the National Transportation Safety Board makes the following safety recommendations:

To the National Highway Traffic Safety Administration:

Develop performance standards for visibility enhancement systems to compensate for blind spots in order to improve the ability of drivers of single-unit trucks with gross vehicle weight ratings over 10,000 pounds to detect vulnerable road users, including pedestrians and cyclists, in their travel paths. (H-13-11)

Once the performance standards requested in H-13-11 have been developed, require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with visibility enhancement systems meeting the performance standards. (H-13-12)

Develop performance standards for side underride protection systems for single-unit trucks with gross vehicle weight ratings over 10,000 pounds. (H-13-13)

Once the performance standards requested in H-13-13 have been developed, require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with side underride protection systems meeting the performance standards. (H-13-14)

Develop performance standards for rear underride protection systems for single-unit trucks with gross vehicle weight ratings over 10,000 pounds. (H-13-15)

Once the performance standards requested in H-13-15 have been developed, require newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds to be equipped with rear underride protection systems meeting the performance standards. (H-13-16)

Require conspicuity treatments on the sides and rears of newly manufactured single-unit trucks with gross vehicle weight ratings over 10,000 pounds consistent with the requirements for such treatments on truck-tractors and trailers specified in 49 CFR Part 571.108 (Federal Motor Vehicle Safety Standards: Lamps, Reflective Devices, and Associated Equipment). (H-13-17)

Develop and implement a plan for using vehicle identification numbers and other variables, such as cargo type or trailers, to improve the coding and classification of large commercial vehicles in the Fatality Analysis Reporting System and the National Automotive Sampling System. (H-13-18)

Include data from each calendar year of the Trucks in Fatal Accidents database on the Fatality Analysis Reporting System website. (H-13-19)

To the Federal Motor Carrier Safety Administration:

Ensure that the data collection for the successor to the initial Large Truck Crash Causation Study includes full accident investigations that will enable scrutiny of crash, vehicle, environmental, roadway, and driver variables contributing to non-fatal injuries and deaths in large truck crashes. (H-13-20)

Conduct an assessment of the frequency with which single-unit truck drivers are operating with invalid licenses, together with the associated risks of invalid licensure, and publish the findings. (H-13-21)

Evaluate the potential benefits of extending commercial driver licensure requirements to the operation of single-unit trucks with gross vehicle weight ratings below 26,001 pounds. (H-13-22)

If the evaluation in H-13-22 indicates a benefit from extending commercial driver's licensure, require commercial driver's licenses for drivers of single-unit trucks in gross vehicle weight rating classes for which benefits have been shown. (H-13-23)

To the Federal Highway Administration:

Develop and implement a strategic plan for facilitating technology transfers between states that will lead to a complete and accurate database of spatially referenced highway crash locations for integration with roadway inventory and traffic operation data captured by the Highway Performance Monitoring System. (H-13-24)

To the US Department of Transportation:

While the National Highway Traffic Safety Administration is developing the conspicuity standards for newly manufactured single-unit trucks requested in H-13-17, direct either the National Highway Traffic Safety Administration or the Federal Motor Carrier Safety Administration, as appropriate, to determine and implement the most efficient method to require the retrofit of treatments, according to the standards, on the sides and rears of single-unit trucks with gross vehicle weight ratings over 10,000 pounds. (H-13-25)

Develop and implement a plan to ensure the continued collection of data as performed for the Trucks in Fatal Accidents database and the continuation of state linkage of hospital and police-reported data as performed by the Crash Outcome Data Evaluation System. (H-13-26)

6.2 Previously Issued Recommendations Reiterated in This Report

As a result of this safety report, the National Transportation Safety Board reiterates the following safety recommendations:

To the National Highway Traffic Safety Administration:

To improve highway vehicle crash compatibility, develop performance standards for front underride protection systems for trucks with gross vehicle weight ratings over 10,000 pounds (Safety Recommendation H-10-12).

Once the performance standards in Safety Recommendation H-10-12 have been developed, require that all such newly manufactured trucks be equipped with front underride protection systems meeting the performance standards (Safety Recommendation H-10-13).

Develop stability control system performance standards for all commercial motor vehicles and buses with a gross vehicle weight rating greater than 10,000 pounds, regardless of whether the vehicles are equipped with a hydraulic or a pneumatic brake system. (Safety Recommendation H-11-7)

Once the performance standards in Safety Recommendation H-11-7 have been developed, require the installation of stability control systems on all newly manufactured commercial vehicles with a gross vehicle weight rating greater than 10,000 pounds. (Safety Recommendation H-11-8).

Develop standards for adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning (Safety Recommendation H-01-6).

After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system (Safety Recommendation H-01-7).

Require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems (Safety Recommendation H-10-1).

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A.P. HERSMAN
Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Vice Chairman

MARK R. ROSEKIND
Member

EARL F. WEENER
Member

Adopted: June 17, 2013

Chairman Hersman filed the following concurring statement on June 11, 2013.

Board Member Statements

Chairman Deborah A.P. Hersman, concurring:

Member Rosekind joined in this statement.

High performing organizations exhibit traits such as being informed, just, flexible, open, and constantly learning. An organization can only stay on top of its game if it adapts and changes. An organization like the NTSB will enjoy greater success if others accept and implement our recommendations.

The original draft of this safety study provided to the Board Members by staff discussed fatality or injury events involving large trucks as “accidents” rather than “crashes.” During deliberations on the study, the Members engaged in a discussion regarding the nomenclature – specifically, the NTSB’s use of the word “accident.” With input from our professional staff, who hail from the public health and highway safety communities, we discussed the generally accepted, current terminology used by our peers in these fields. With unanimous Board agreement, we concluded the discussion by directing staff to evaluate the word "accident" each time it appears in the safety study and, at their discretion, either retain the word or replace it with another term, such as “crash,” “collision,” etc., as appropriate.

This specific discussion was an extension of a conversation begun over a year ago during events hosted by the NTSB on driver distraction and substance impairment and, more recently, at the Board meeting, two months ago, on the investigation of the US liftboat Trinity II abandonment, conducted by the Office of Marine Safety. At the Trinity II Board meeting, the General Counsel agreed to conduct a review of the language used by the Department of Transportation, Department of Defense and international transportation organizations, which was subsequently provided to the Board members.

In this week’s Board meeting on the “Safety Study – Characteristics of Single-Unit Truck Accidents Resulting in Injuries and Deaths,” we had a farther-reaching discussion among the Members and staff about whether the NTSB’s universal use of the term “accident” needs updating. Different positions were voiced by Members and staff, and different positions were respected. With regard to longer-term actions, the Board agreed that future reports would be evaluated on a case-by-case basis, the Managing Director will actively solicit feedback from the modal office directors, and our General Counsel, who is currently conducting a review of our underlying regulations, will identify opportunities to improve existing processes and protocols, including updating terminology to encourage greater consistency, as appropriate.

The Board is interested in being an informed, just, flexible, open, and constantly learning organization. We want to be in a position to influence others to make changes, and we recognize that the words in this ongoing safety conversation are important.

7. Acknowledgments

This study was made possible by the willingness of the National Highway Traffic Safety Administration to collaborate with the NTSB in obtaining state CODES data and to provide continuing technical advice and assistance. We also are grateful to the CODES organizations in the states that agreed to participate: Delaware, Minnesota, Nebraska, and especially Utah CODES at the University of Utah and Maryland CODES at the University of Maryland School of Medicine for their significant time invested in preparing the data.

8. References

ATRI (American Transportation Research Institute). 2012. "Mapping Large Truck Rollovers: Identification and Mitigation Through Spatial Data Analysis." http://atri-online.org/2012/05/09/safety-impacts-of-roadway-geometric-design-standards-mapping-rollovers-and-designing-a-driver-information-delivery-system-2/

Bigham, John. 2012. "Error Consideration in Geoconferencing Police-Reported Crash Data" (presentation at the NTSB's GIS in Transportation Safety Conference, Washington, DC, December 4-5, 2012).

Blower, Daniel and Anne Matteson. 2002. "Large Trucks in FARS and in TIFA, 1999." Ann Arbor: University of Michigan Transportation Research Institute.

Blower, Daniel and John Woodrooffe. 2013. "Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes." Washington, DC: National Highway Traffic Safety Administration. DOT HS 811 725. http://www.nhtsa.gov/DOT/NHTSA/NVS/Crashworthiness/Truck%20Underride/811725.pdf

Blower, Daniel, Vasanth Krishnaswami, Devi Putcha, and Alrik Svenson. 2001. "Analysis of Truck-Light Vehicle Crash Data for Truck Aggressivity Reduction." Paper presented at the International Truck & Bus Meeting & Exhibition, Chicago, November 12. doi: 10.4271/2001-01-2726.

Blower, Daniel, John Woodrooffe, and Oliver Page. 2012. "Analysis of Rear Underride in Fatal Truck Crashes, 2008." Ann Arbor: University of Michigan Transportation Research Institute.

Braver, Elisa R., Michael X. Cammisa, Adrian K. Lund, Nancy Early, Eric L. Mitter, and Michael R. Powell. 1997. "Incidence of Large Truck-Passenger Vehicle Underride Crashes in Fatal Accident Reporting System and National Accident Sampling System." *Transportation Research Record* 1595: 27-33. doi: 10.3141/1595-05.

Braver, Elisa R. and Sergey Y. Kyrychenko. 2004. "Efficacy of Side Airbags in Reducing Driver Deaths in Driver-Side Collisions." *American Journal of Epidemiology* 159 (6): 556–64. doi:10.1093/aje/kwh087.

Brumbelow, Matthew L. 2012. "Potential Benefits of Underride Guards in Large Truck Side Crashes." *Traffic Injury Prevention* 13 (6): 592–99. doi: 10.1080/15389588.2012.666595.

Brumbelow, Matthew L. and Laura Blanar. 2010. "Evaluation of US Rear Underride Guard Regulation for Large Trucks Using Real-World Crashes." *Stapp Car Crash Journal* 54: 119-31.

Bureau of Transportation Statistics (US Department of Transportation, Research and Innovative Technology Administration). 2012. "National Transportation Atlas Database." http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_database/index.html

California Department of Motor Vehicles. 2013. "California Driver Handbook – Sharing the Road." http://www.dmv.ca.gov/pubs/hdbk/shr_lgtruck_rv.htm

Commercial Driver's License Advisory Committee. 2008. "Commercial Driver's License Program Review: Recommended Measures For Achieving The Program's Full Safety Potential." Washington, DC: Federal Motor Carrier Safety Administration. http://www.fmcsa.dot.gov/facts-research/facts-figures/analysis-statistics/CDL-Task-Force-Report.pdf

Cook, L.J., M.J. Olson, and J.M. Dean. 2001. "Probabilistic Record Linkage: Relationships between File Sizes, Identifiers, and Match Weights." *Methods of Information in Medicine* 40 (3): 196-203.

Council of the European Communities. 1989. "Council Directive of 13 April 1989 on the Approximation of the Laws of the Member States Relating to the Lateral Protection (Side Guards) of Certain Motor Vehicles and Their Trailers." *Official Journal of the European Communities* L124. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1989:124:0001:0007:EN:PDF

Council of the European Union. 2000. "Directive 2000/40/EC of the European Parliament and of the Council of 26 June 2000 on the approximation of the laws of the Member States relating to the front underrun protection of motor vehicles" *Official Journal of the European Communities* L203/9. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:203:0009:0028:EN:PDF

Craft, Ralph. 2007. *LTCCS Summary*. Federal Motor Carrier Safety Administration, Office of Research and Analysis. Publication No. FMCSA-RRA-07-017. http://www.fmcsa.dot.gov/facts-research/research-technology/analysis/fmcsa-rra-07-017.htm

DOE (US Department of Energy). 2011. Vehicle Technologies Office: Fact #707: December 26, 2011 Illustration of Truck Classes. http://www1.eere.energy.gov/vehiclesandfuels/facts/2011_fotw707.html

European Parliament and Council of the European Union. 2003. "Directive 2003/97/EC of the European Parliament and of the Council of 10 November 2003 on the approximation of the laws of the Member States relating to the type-approval of devices for indirect vision and of vehicles equipped with these devices, amending Directive 70/156/EEC and repealing Directive 71/127/EEC (Text with EEA relevance.)" *EUR-Lex Access to European Union Law. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0097:EN:NOT*

———. 2005. "Commission Directive 2005/27/EC of 29 March 2005 amending, for the purposes of its adaptation to technical progress, Directive 2003/97/EC of the European Parliament and of the Council, concerning the approximation of the laws of the Member States relating to the type-approval of devices for indirect vision and of vehicles equipped with these devicesText with EEA relevance.)" *EUR-Lex Access to European Union Law. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005L0027:EN:NOT*

Farmer, Charles M. 2003. "Reliability of Police-Reported Information for Determining Crash and Injury Severity." *Traffic Injury Prevention* 4 (1): 38-44. doi: 10.1080/15389580309855.

FMCSA (US Department of Transportation, Federal Motor Carrier Safety Administration). 1999. “Share the Road Campaign Research Study Final Report.” Washington, DC: FMCSA.

———. 2005. “Report to Congress on the Large Truck Crash Causation Study.” Washington, DC: FMCSA. http://ai.fmcsa.dot.gov/ltccs/data/documents/reportcongress_11_05.pdf

FHWA (US Department of Transportation, Federal Highway Administration, Office of Highway Policy Information). 2012. *Annual Vehicle Distance Traveled in Miles and Related Data - 2010 1/ By Highway Category and Vehicle Type*. Table VM-1. Washington, DC: FHWA. http://www.fhwa.dot.gov/policyinformation/statistics/2010/pdf/vm1.pdf

Gerstman, B. Burt. 2003. *StatPrimer (Version 6.4): (16) Risk Ratios and Prevalence Ratios*. http://www.sjsu.edu/faculty/gerstman/StatPrimer/rr.pdf

Getis, Arthur. 2008. A history of the concept of spatial autocorrelation: A geographer’s perspective. *Geographical Analysis*, v40, n3, p 297-309.

Goodyear. 2003. “Truck Types and Weight Classes.” Radial Truck Tire and Retread Service Manual (Goodyear, 2003), 108.

Gugler J. 2009. *Heavy Vehicles (SP2)*. Integrated Project on Advanced Protection Systems. Aprosys, European Commission. http://www.transport-research.info/Upload/Documents/201203/20120313_143923_9154_Final%20SP2%20report%20AP-90-0002.pdf

Hagge, Robert A. and P.A. Romanowicz. 1996. “Evaluation of California's commercial driver license program.” *Accident Analysis and Prevention* 28(5):547-59.

IIHS (Insurance Institute for Highway Safety). 2010. “Fatality Facts: Large Trucks, 2010.” http://www.iihs.org/research/fatality.aspx?topicName=Large-trucks&year=2010

———. 2011. “Big Strides.” Status Report 46(3): 1-7, March 30, 2011.

———. 2012a. “IIHS Vehicle Ratings.” http://www.iihs.org/ratings/default.aspx

———. 2012b. “Petition for Rulemaking; 49 CFR Part 571 Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection.” http://www.iihs.org/laws/petitions/pdf/petition_2011-02-28.pdf

———. 2013. “Rear underride guards work well, but most could do better.” Status Report 48(2): 1-5, March 14, 2013.

Jarossi, Linda, Daniel Hershberger, Leslie Pettis, and John Woodrooffe. 2011. *2008 Trucks Involved in Fatal Accidents Codebook (Version January 21, 2011)*. Ann Arbor: University of Michigan Transportation Research Institute.

Jarossi, Linda, Anne Matteson, and John Woodrooffe. 2006. *Trucks Involved in Fatal Accidents Factbook, 2006*. UMTRI-2008-42. Ann Arbor: University of Michigan Transportation Research Institute.

———. 2007. *Trucks Involved in Fatal Accidents Factbook, 2007*. UMTRI-2010-4. Ann Arbor: University of Michigan Transportation Research Institute.

———. 2008. *Trucks Involved in Fatal Accidents Factbook, 2008*. UMTRI-2011-15. Ann Arbor: University of Michigan Transportation Research Institute.

Jermakian, JS. "Crash Avoidance Potential of Four Large Truck Technologies." Accident Analysis and Prevention 49 (Nov 2012): 336-46

Kamyab, Ali, Tom McDonald, and Brandon Storm. 2002. "Synthesis of Best Practice for Increasing Protection and Visibility of Highway Maintenance Vehicles." Ames: Iowa State University.

Knipling, Ronald R. and Joseph Bocanegra. 2008. "Comparison of Combination-Unit Truck and Single-Unit Truck Statistics from the Large Truck Crash Causation Study." Washington, DC: Federal Motor Carrier Safety Administration

Krusper, Aleksandra and Robert Thomson. 2008. "Crash Compatibility between Heavy Goods Vehicles and Passenger Cars: Structural Interaction Analysis and In-Depth Accident Analysis." *Proceedings of the International Conference on Heavy Vehicles, Paris, France*: 181–90. http://www.road-transport-technology.org/HVTT10/Proceeding/Papers/Papers_HVTT/paper_25.pdf

———. 2012. "Truck Frontal Underride Protection–Compatibility Factors Influencing Passenger Car Safety." *International Journal of Crashworthiness* 17 (2): 217–32. doi: 10.1080/13588265.2011.648514.

Lewis, Stephen. 2012. "Geospatial Coordination at USDOT and Transportation for the Nation (TFTN)" (presentation at the NTSB's GIS in Transportation Safety Conference, Washington, DC, December 4-5, 2012).

McCullouch, Bob and Brandon Stevens. 2008. "Investigation of the Effective Use of Warning Lights on Indiana Department of Transportation (INDOT) Vehicles and Equipment." West Lafayette: Joint Transportation Research Program, Indiana Department of Transportation and Purdue University. doi: 10.5703/1288284314302.

McGlincy, M.H. 2004. "A Bayesian Record Linkage Methodology for Multiple Imputation of Missing Links." *2004 Proceedings of the American Statistical Association,Survey Research Methods Section* [CD-ROM], American Statistical Association: 4001– 4008. http://www.amstat.org/sections/srms/Proceedings/y2004/files/Jsm2004-000683.pdf

Miller, Ted R., Rekaya Gibson, Eduard Zaloshnja, Lawrence J. Blincoe, John Kindelberger, Alexander Strashny, Andrea Thomas, Shiu Ho, Michael Bauer, Sarah Sperry, Justin Peng, Mike Singleton, Tracy J. Smith, and Ying Zhang. 2012. "Underreporting of Driver Alcohol Involvement in United

States Police and Hospital Records: Capture-Recapture Estimates." *Annals of Advances in Automotive Medicine* 56: 87-96.

Missouri Bicycle and Pedestrian Federation. 2006. "Bicyclists – Stay out of Trucks' Blind Spot." http://mobikefed.org/2006/08/bicyclists-stay-out-of-trucks-blind-spot.php

Moonesinghe, Ramal, Anders Longthorne, Umesh Shankar, Santohk Singh, Rajesh Subramanian, and Joseph Tessmer. 2003. "An Analysis of Fatal Large Truck Crashes." DOT HS 809 569. Washington, DC: National Center for Statistics and Analysis.

Morgan, Christina. 2001. "The Effectiveness of Retroreflective Tape on Heavy Trailers." DOT HS 809 222. Washington, DC: National Highway Traffic Safety Administration.

Murray, Dan, Sandra Shackelford, and Amy Houser. 2009. "Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry." Washington, DC: Federal Motor Carrier Safety Administration. http://www.fmcsa.dot.gov/facts-research/research-technology/report/09-021-RP-Forward-Collision.pdf

NHTSA (US Department of Transportation, National Highway Traffic Safety Administration). 1991. *Preliminary Regulatory Evaluation: Combination Truck Rear Underride Guards*. Docket Document No. 1-11-N09-002.Washington, DC: NHTSA

———. 1992. Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices, and Associated Equipment; Final rule. *Federal Register, Vol* 57, No. 238, p. 58406, December 10, 1992.

———. 1996. Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection; Final rule. *Federal Register, Vol.* 61, No. 16, p. 2004, January 24, 1996.

———. 2005. *Notice of proposed rulemaking: Federal Motor Vehicle Safety Standards, Rear View Mirrors*. Federal Register Vol. 70, No. 175, September 12, 2005, Pages 53753-53772. https://www.federalregister.gov/articles/2005/09/12/05-17987/federal-motor-vehicle-safety-standards-rearview-mirrors

———. 2008. *Withdrawal of rulemaking: Federal Motor Vehicle Safety Standards, Rear View Mirrors*. Federal Register Vol. 73, No. 140, July 21, 2008, Pages 42309-42312. https://www.federalregister.gov/articles/2008/07/21/E8-16530/federal-motor-vehicle-safety-standards-rearview-mirrors

———. 2012a. Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems for Heavy Vehicles; Notice of Proposed Rulemaking. *Federal Register, Vol.* 77, No.100, p. 2004, May 23, 2012.

———. 2012b. *Traffic Safety Fact Sheet, 2010 Bicyclists and Other Cyclists*. DOT HS 811 624. Washington, DC: NHTSA. http://www-nrd.nhtsa.dot.gov/Pubs/811624.pdf

———. 2012c. *Traffic Safety Fact Sheet, 2010 Large Trucks*. DOT HS 811 628. Washington, DC: NHTSA. http://www-nrd.nhtsa.dot.gov/Pubs/811628.pdf

———. 2012d. *Traffic Safety Fact Sheet, 2010 Pedestrians*. DOT HS 811 625. Washington, DC: NHTSA. http://www-nrd.nhtsa.dot.gov/Pubs/811625.pdf

NICB (National Insurance Crime Bureau). 1990. *1990 Commercial Vehicle Identification Manual*. Des Plaines, IL: NCIB.

———. 1995. *1995 Commercial Vehicle Identification Manual*. Des Plaines, IL: NCIB.

———. 2000. *2000 Commercial Vehicle Identification Manual*. Des Plaines, IL: NCIB.

———. 2005. *2005 Commercial Vehicle Identification Manual*. Des Plaines, IL: NCIB.

———. 2010. *2010 Commercial Vehicle Identification Manual*. Des Plaines, IL: NCIB.

NTSB (National Transportation Safety Board). 1971a. Recommendation H-71-042 (Side underride). Washington, DC. http://www.ntsb.gov/doclib/recletters/1971/H71_34_42.pdf

———. 1971b. Recommendations H-71-054–056 (Pedestrians). Washington, DC. http://www.ntsb.gov/doclib/recletters/1971/H71_54_56.pdf

———. 1997. *Truck Loss of Braking Control on Steep Downgrade and Collision with a Vehicle Near Plymouth Meeting, Pennsylvania, April 25, 1996*. HAR-97/02. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/1997/HAR9702S.pdf

———. 2001a. Recommendation letter resulting from the 1999 public hearing "Advanced Safety Technologies for Commercial Vehicle Applications." Washington, DC: NTSB. Accessed April 29, 2013. http://www.ntsb.gov/doclib/recletters/2001/H01_06_08.pdf

———. 2001b. *Vehicle- and Infrastructure-Based Technology for the Prevention of Rear-End Collisions*. SIR-01/01. Washington, DC: NTSB. http://www.ntsb.gov/doclib/safetystudies/SIR0101.pdf

———. 2002. *Analysis of Intrastate Trucking Operations*. SR-02/01. Washington, DC: NTSB. http://www.ntsb.gov/doclib/safetystudies/SR0201.pdf

———. 2006a. *Collision Between a Ford Dump Truck and Four Passenger Cars, Glen Rock, Pennsylvania, April 11, 2003*. HAR-06/01. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2006/HAR0601.pdf

———. 2006b. *Multivehicle Collision on Interstate 90 Hampshire-Marengo Toll Plaza Near Hampshire, Illinois, October 1, 2003*. HAR-06/03. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2006/HAR0603.pdf

———. 2006c. Recommendation letters resulting from the NTSB's investigation of the October 1, 2003, multivehicle collision on the approach to the Hampshire–Marengo toll plaza near Hampshire, Illinois. Washington, DC: NTSB. Accessed April 29, 2013. http://www.ntsb.gov/doclib/recletters/2006/H06_15.pdf http://www.ntsb.gov/doclib/recletters/2006/H06_16.pdf

———. 2009. Recommendation letter resulting from the NTSB's investigation of the October 16, 2005, accident comprising two events on Interstate Highway 94 (I-94) near Osseo, Wisconsin. Washington, DC: NTSB. Accessed April 29, 2013. http://www.ntsb.gov/doclib/recletters/2008/H08_15_H01_6_7.pdf

———. 2010a. *Bus Loss of Control and Rollover, Dolan Springs, Arizona, January 30, 2009*. HAR-10/01. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2010/HAR1001.pdf

———. 2010b. Recommendation letter resulting from the NTSB's investigation of the January 30, 2009, Dolan Springs, Arizona accident. Washington, DC: NTSB. Accessed April 29, 2013. http://www.ntsb.gov/doclib/recletters/2010/H-10-001-007.pdf

———. 2010c. *Tractor-trailer Semitrailer Rear-End Collision Into Passenger Vehicles on Interstate 44 Near Miami, Oklahoma, June 26, 2009*. HAR-10/02. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2010/HAR1002.pdf

———. 2011a. *Multivehicle Collision, Insterstate 44 Eastbound, Gray Summit, Missouri, August 5, 2010*. HAR-11/03. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2011/HAR1103.pdf

———. 2011b. *Rollover of a Tractor-trailer and Cargo Tank Semitrailer Carrying Liquefied Petroleum Gas and Subsequent Fire, Indianapolis, Indiana, October 22, 2009*. HAR-11/01. Washington, DC: NTSB. http://www.ntsb.gov/doclib/reports/2011/HAR1101.pdf

———. 2012. *Comments on Notice of Proposed Rulemaking to Establish a New Federal Motor Vehicle Safety Standard: Electronic Stability Control Systems for Heavy Vehicles.* DOT Docket No. NHTSA-2012-0065.

NYC DOT (New York City Department of Transportation). 2012. "Cross Over Mirrors for Trucks: New Legislation Goes into Effect January 13, 2012." http://www.nyc.gov/html/dot/downloads/pdf/crossover-mirrors-flyer.pdf

Patten, J.D. and C.V. Tabra. 2010. *Side Guards for Trucks and Trailers Phase 1: Background Investigation.* National Research Council Canada. Ottawa, Canada. http://www.safetrucks.ca/resources/National_Research_Council_Truck_Side_Guard_Study_2010-03-01.pdf

Raghunathan Trivellore E., James M. Lepkowski, John Van Hoewyk, and Peter Solenberger. 2001. A Multivariate Technique for Multiply Imputing Missing Values Using a Sequence of Regression Models. Survey Methodology, June 2001 85 Vol. 27, No. 1, pp. 8595. http://www.statcan.gc.ca/ads-annonces/12-001-x/5857-eng.pdf

Rothenberg, Heather. 2012. "Massachusetts Lane Departure Crash and CODES Data Analyses." http://www.ecs.umass.edu/masssafe/CODES%20WEBSITE/Lane_Departure_FactSheet.pdf

Rubin, Donald B. 1987. *Multiple Imputation for Nonresponse in Surveys*. New York: John Wiley & Sons.

SAS Institute Inc. 2004. *SAS Statistical Software, Version 9.2*, Cary, NC: SAS Institute Inc.

———. 2012. "Overview: MI Procedure." *SAS/STAT(R) 9.2 User's Guide, Second Edition.* http://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm#statug_mi_sect001.htm

Sayer, J., D. LeBlanc, S. Bogard, D. Funkhouser, S. Bao, M.L. Buonarosa, A. Blankespoor. 2011. "Integrated Vehicle-Based Safety Systems Field Operational Test Final Program Report." Washington, DC: US Department of Transportation, Research and Innovative Technology Administration. http://ntl.bts.gov/lib/45000/45600/45603/FHWA-JPO-11-150_IVBSS_Final_Program_Report_FINAL_508.PDF.pdf

Subramanian, Rajesh. 2002. "Transitioning to Multiple Imputation – A New Method to Impute Missing Blood Alcohol Concentration (BAC) Values in FARS." DOT HS 809 403. Washington, DC: National Center for Statistics and Analysis.

Thor, Craig. 2012. "Utilizing GIS to Improve Safety on the Nation's Highways" (presentation at the NTSB's GIS in Transportation Safety Conference, Washington, DC, December 4-5, 2012).

Transport Canada. 2009. "Car Drivers: Understanding Large Vehicles." http://www.tc.gc.ca/eng/roadsafety/safevehicles-busesvans-sharetheroad-page2-417.htm

US Census Bureau. 2010. National Intercensal Estimates (2000-2010). Washington, DC. http://www.census.gov/popest/data/intercensal/national/nat2010.html.

———. 2012. "2010 Geographic Terms and Concepts – Urban and Rural." http://www.census.gov/geo/reference/gtc/gtc_urbanrural.html

United Nations Economic Commission for Europe. 1988. "Uniform Regulation No. 73: Provisions Concerning the Approval of Goods, Vehicles, Trailers, and Semi-Trailers with Regard to Their Lateral Protection."

Vachal, Kimberly, Esther K. Tumuhairwe, and Mark Berwick. 2009. "Underride Safety Protection: Benefit-Cost Assessment of Rear-Impact Guards for the North Dakota Farm Truck Fleet." *Traffic Injury Prevention* 10 (2): 178-83. doi: 10.1080/15389580802593210

Varghese Cherian and Umesh Shankar. 2007. "Passenger Vehicle Occupant Fatalities by Day and Night – A Contrast." DOT HS 810 637. Washington DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/810637.pdf

Wang, Jing-Shiarn, Ronald R. Knipling, and Lawrence J. Blincoe. 1999. "The Dimensions of Motor Vehicle Crash Risk." *Journal of Transportation and Statistics* 2 (1): 19-44.

WHO (World Health Organization). 2009. *Global Status Report on Road Safety: Time for Action*. Geneva: WHO.

Williams, Allan F. 2013. "Protecting Pedestrians and Bicyclists: Some Observations and Research Opportunities." Arlington, VA: Insurance Institute for Highway Safety. http://www.iihs.org/research/topics/pdf/r1186.pdf

Woodrooffe John, Daniel F. Blower, and Paul E. Green. 2012. "Safety Benefits of Stability Control Systems for Single-Unit Trucks." *Proceedings of the 91st Annual Meeting of the Transportation Research Board*. Washington, DC. http://amonline.trb.org/1snsgm/2

Appendix A. Relevant Documents in Public Docket

1. Data File Instruction
   http://dms.ntsb.gov/pubdms/search/document.cfm?docID=393766&docketID=54546&mkey=79115

2. Single-Unit Truck Study – Case Review Report.
   http://dms.ntsb.gov/pubdms/search/document.cfm?docID=391907&docketID=54546&mkey=79115

3. SAS program for VIN-based initial classification by large truck type
   http://dms.ntsb.gov/pubdms/search/document.cfm?docID=392000&docketID=54546&mkey=79115

4. Truck identification using CODES data
   http://dms.ntsb.gov/pubdms/search/document.cfm?docID=393977&docketID=54546&mkey=79115