National Transportation Safety Board
Washington, DC 20594

Safety Recommendations

Date: April 3, 2014
In reply refer to: H-14-001 through -007

The Honorable David J. Friedman
Acting Administrator
National Highway Traffic Safety Administration
US Department of Transportation
Washington, DC 20590

The National Transportation Safety Board (NTSB) is providing the following information to urge the National Highway Traffic Safety Administration (NHTSA) to take action on the safety recommendations issued in this letter. These recommendations address four topics: (1) mitigation of blind spots to protect passenger vehicle occupants, pedestrians, cyclists, and motorcyclists from being struck when drivers of tractor-trailers fail to detect their presence; (2) protection of passenger vehicle occupants from being injured as a result of underriding the sides of tractor-trailers; (3) protection of passenger vehicle occupants from being injured as a result of underriding the rears of trailers; and (4) improving traffic safety data concerning trailers involved in crashes. The NTSB is issuing seven safety recommendations to NHTSA regarding the safety of tractor-trailers.[1] Information supporting these recommendations is discussed below.

Tractor-trailers

Large trucks are commercial vehicles with gross vehicle weight ratings (GVWR)[2] over 10,000 pounds that transport goods and can be tractor-trailers or single-unit trucks.[3] The recommendations in this letter pertain to components of tractor-trailers, including truck-tractors, semi-trailers, and full trailers. Truck-tractors are the towing vehicles and consist of an engine and a cab where the driver sits. Truck-tractors have a connection enabling them to pull semi-trailers, which are trailers without front axles. Full trailers are trailers with wheels on both front and rear axles and are used when truck-tractors pull multiple trailers or when single-unit trucks pull trailers.

[1] For information on other recent NTSB recommendations for large trucks, see National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[2] 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. Trailers have separate GVWRs from truck-tractors.

[3] Single-unit trucks typically have non-detachable cargo units and have all axles attached to a single frame.

Blind Spot Mitigation

Blind spots. Blind spots around tractor-trailers can result in collisions with passenger vehicles or vulnerable road users because the driver of the tractor-trailer cannot see them. These blind spots are larger than those of passenger vehicles and they exist on the front, sides, and rear of the tractor-trailer.[4] Driver ride height, locations and characteristics of mirrors and windows, and vehicle geometry can all affect the ability of drivers of tractor-trailers to detect passenger vehicles and vulnerable road users.[5] The blind spot on the right side of the tractor-trailer is of particular concern because it impinges on a large portion of the driver's field of view and is disproportionately involved in collisions involving pedestrians, cyclists, and passenger vehicles.[6]

Blind spots and vulnerable road users. Pedestrians, cyclists,[7] and motorcyclists are considered vulnerable road users because they have no external frame to protect them and thus are at higher risk of injury and death than vehicle occupants. The NTSB analyzed data from five states[8] (Delaware, Maryland, Minnesota, Nebraska, and Utah) that linked hospital records with police reports under the auspices of NHTSA's Crash Outcome Data Evaluation System (CODES). Data from these states showed that death rates of vulnerable road users involved in collisions with tractor-trailers were high: 152.8 per 1,000 involved pedestrians/cyclists and 119.5 per 1,000 involved motorcyclists. In comparison, death rates were 2.0 per 1,000 involved tractor-trailer occupants and 10.9 per 1,000 involved passenger vehicle occupants.

Pedestrians, cyclists, and motorcyclists are smaller than passenger vehicles and thus are harder to detect by drivers of tractor-trailers. A 1993 review of fatal large truck/pedestrian collisions in four cities found that the design of truck cabs obstructed the vision of drivers of large trucks and contributed to intersection collisions with pedestrians.[9,10] For example, in more than half of urban collisions where large trucks started from a stopped position and struck a pedestrian in the crosswalk while going straight, the truck drivers were unaware that they had struck a pedestrian until they were alerted by others in the vicinity.

---

[4] Reed, Matthew, Daniel F. Blower, and M.J. Flannagan. 2006. "Prioritizing Improvements to Truck Driver Vision." UMTRI-2005–31. Ann Arbor, Michigan: University of Michigan Transportation Research Institute. http://ntl.bts.gov/lib/38000/38400/38487/102737.pdf

[5] Krum, Andrew. 2009. Visibility Modeling from a Heavy-Vehicle OEM's Perspective. 19th Biennial TRB Visibility Symposium, Virginia Technical Transportation Institute, Blacksburg, VA. https://secure.hosting.vt.edu/www.apps.vtti.vt.edu/PDFs/TRBVS_presentations/Krum_Hvy_OEM_Visibility_Modeling_12may09.pdf

[6] Reed, Matthew, Daniel F. Blower, and M.J. Flannagan. 2006. "Prioritizing Improvements to Truck Driver Vision." UMTRI-2005–31. Ann Arbor, Michigan: University of Michigan Transportation Research Institute. http://ntl.bts.gov/lib/38000/38400/38487/102737.pdf

[7] A cyclist refers to bicyclists and other pedal cyclists.

[8] Data from these states were also examined in the following study: National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[9] Retting, R.A. 1993. "A review of fatal injuries to pedestrians induced by urban truck crashes." *Proceedings of the 37th Annual Conference of the Association for the Advancement of Automotive Medicine*, 117-28. Des Plaines, IL: Association for the Advancement of Automotive Medicine.

[10] Retting, R.A. 1993. "A study of fatal crashes involving pedestrians and trucks in four cities." *Journal of Safety Research* 24:195-203.

The NTSB examined the impact locations for collisions involving one tractor-trailer striking a pedestrian or cyclist in the absence of any other motorized vehicles. This type of collision resulted in 759 pedestrians and 181 cyclists dying during 2005–2009.[11] The distributions of the impact locations on the tractor-trailer body for pedestrian and cyclist fatalities are shown in table 1. Cyclists generally travel on the right side of the roadway, while pedestrians tend to cross in front of large trucks more often than cyclists. Consequently, the most common impact location among cyclist fatalities was the right side of the tractor-trailer (40 percent), whereas the front was the most common for pedestrians (60 percent). Pedestrian and cyclist fatalities were consistent with their travel patterns, with right-side impacts being far more common than left-side impacts, and impacts with the back of the tractor-trailer being the least frequent. Right side impacts are notable for both groups of fatalities because the right side of the tractor-trailer is the location where the blind spot is largest.

Impact area	Pedestrians		Cyclists		Motorcyclists	
	No.	%	No.	%	No.	%
Front	457	60	57	31	83	17
Back	15	2	1	1	79	16
Right Side	160	21	72	40	147	30
Left Side	61	8	28	15	132	27
Other*	66	9	23	13	49	10
Total	759	100	181	100	490	100

***** "Other" refers to initial impact point codes of top (roof), undercarriage, or unknown.

Table 1. Distribution of fatalities involving pedestrians, cyclists, and motorcyclists in single-vehicle collisions with tractor-trailers by location of impact, Trucks in Fatal Accidents, 2005–2009.

Like cyclists, motorcyclist fatalities occurred more often in collisions with the sides of tractor-trailers than with the fronts of them. Among the 490 motorcyclist fatalities in collisions involving one tractor-trailer and no other motorized vehicles during 2005–2009, more than half involved the sides of the tractor-trailers. Unlike cyclists, about the same percentage of motorcyclists collided with the right side (30 percent) as with the left side (27 percent). These distributions of collisions are consistent with travel patterns because motorcyclists are more likely to travel on both sides of tractor-trailers, whereas cyclists usually stay on the right side of the roadway. Motorcycle collisions with the fronts and backs of tractor-trailers also had similar percentages: 17 percent and 16 percent, respectively.

Blind spots and passenger vehicles. Research by Reed and colleagues found that crashes in which the drivers of large trucks needed to use their mirrors to complete their maneuvers (mirror-relevant crashes) comprised 20 percent of all large truck crash involvements (fatal and non-fatal combined).[12] Mirror-relevant crashes involving the right side of the truck (lane

[11] National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[12] Reed, Matthew, Daniel F. Blower, and M.J. Flannagan. 2006. "Prioritizing Improvements to Truck Driver Vision." UMTRI-2005–31. Ann Arbor, Michigan: University of Michigan Transportation Research Institute. http://ntl.bts.gov/lib/38000/38400/38487/102737.pdf. Mirror-relevant crashes included those in which (1) the large

change/merge and right turns) were more than four times as common as those involving the left side of the truck (lane change/merge and left turns). Reed and colleagues also identified four locations where the vision of drivers of large trucks needed to be improved and ranked them in the following order (see figure 1):

1. Area to the right of the large truck cab that covers an area equivalent to a right-side adjacent lane and five meters behind the front bumper of the large truck cab;
2. Area to the right of the truck that covers an area equivalent to a right-side adjacent lane and extends from the back of the large truck cab to five meters behind the trailer/cargo area;
3. Area immediately in back of the large truck (about five meters); and
4. Area that extends five meters in front of the large truck cab and one lane over to the right to cover the adjacent lane.

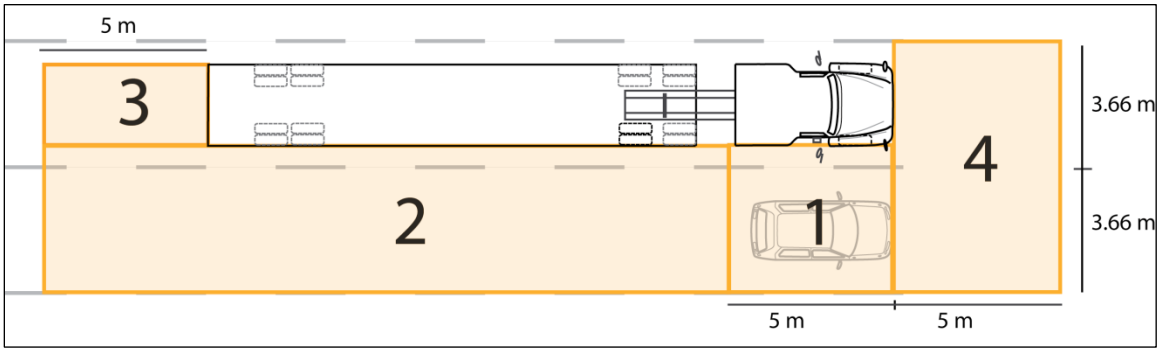

Figure 1. Priority zones for large truck cab vision improvement, Reed et al., 2006.

Countermeasures to mitigate blind spots. Countermeasures can address safety problems arising from the blind spots of tractor-trailers. Some simple and inexpensive technologies are already in use to enhance truck drivers' ability to identify vulnerable road users occupying space in blind spots. These include enhanced mirror systems. Based on a preliminary analysis of a sample of large trucks involved in crashes resulting in injuries or deaths, Blower reported in 2007 that large trucks lacking right fender mirrors were overinvolved in crashes resulting in deaths and injuries compared with large trucks that had right fender mirrors designed to mitigate the large blind spot on the right side.[13] Crossover convex mirrors are currently required by state law on large trucks operating in New York City,[14] and the European Union also has requirements for enhanced mirrors on large trucks to reduce the size of blind spots.[15,16]

---

truck changed to a right lane or merged right and then collided with another vehicle, (2) the large truck changed to a left lane or merged left and then collided with another vehicle, (3) the large truck turned right and collided with a vehicle or a pedestrian/cyclist in its blind spot, (4) the large truck turned left and collided with a vehicle in its blind spot, (5) the truck started up from a stopped position and then collided with a pedestrian or cyclist, or (6) the large truck backed into another vehicle or pedestrian/cyclist.

[13] Blower, Daniel F. 2007. "Truck Mirrors, Fields of View, and Serious Truck Crashes." UMTRI-2007-25. Ann Arbor, Michigan: University of Michigan Transportation Research Institute.

[14] NY Vehicle and Traffic Law, section 375, subdivision 10-e (2011).

[15] 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.

Advanced technologies to detect vehicles and vulnerable road users in blind spots are also in development and some versions have been installed on selected passenger vehicles for the past few model years. These technologies were discussed in a request for comments by NHTSA on its New Car Assessment Program published on April 5, 2013 (78 FR 20597, 20600) that described frontward and rearward pedestrian sensing systems combined with automatic braking.

Specific technologies to alert drivers of tractor-trailers about other vehicles traveling in their blind spots are already on the market. The side view assistance system has sensors that monitor the blind spot in the adjacent lane and provides an audio warning if there is a vehicle in the blind spot after the driver signals an intention to change lanes. This technology has been reported to be particularly promising as a means of reducing truck/vehicle collisions.[17] In addition, rear vision assistance systems, consisting of cameras and monitors, allow drivers to see pedestrians and passenger vehicles present in the rear blind spot while drivers are backing their vehicles.

The NTSB concludes that onboard systems and equipment that can allow tractor-trailer drivers to better detect passenger vehicles, motorcyclists, pedestrians, and cyclists are available and that the use of such systems could prevent fatalities and injuries that occur in collisions involving tractor-trailers. The NTSB recommends that NHTSA require that newly manufactured truck-tractors with GVWRs over 26,000 pounds be equipped with visibility enhancement systems to improve the ability of drivers of tractor-trailers to detect passenger vehicles and vulnerable road users, including pedestrians, cyclists, and motorcyclists.

Side Underride Protection Systems

Truck side impacts. NHTSA reported that large truck side impacts comprised 15 percent of fatal two-vehicle collisions between large trucks and passenger vehicles during 2011.[18] Furthermore, research indicated that passenger vehicle collisions with the sides of tractor-trailers resulted in more than 15,000 injured persons during 2001-2003,[19] which is consistent with other research on the effects of truck side impacts.[20,21] According to the General Estimates System

---

[16] European Parliament and Council of the European Union. 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 devices Text with EEA relevance.)" EUR-Lex Access to European Union Law.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005L0027:EN:NOT

[17] Jermakian, J.S. "Crash avoidance potential of four large truck technologies." Accid Anal Prev. 2012 Nov; 49:338-46. doi: 10.1016/j.aap.2010.10.033. Epub 2012 Jul 2.

[18] National Highway Traffic Safety Administration. 2013. "Traffic Safety Facts: Large Trucks, 2011." Washington, DC: US Department of Transportation. http://www-nrd.nhtsa.dot.gov/Pubs/811752.pdf

[19] National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[20] Blower, Daniel F., 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, 2001. doi: 10.4271/2001-01-2726.

(GES), tractor-trailers were involved in 43,629 police-reported collisions in which passenger vehicles collided with their sides during 2005–2009.[22]

Side underride. One reason why collisions with the sides of tractor-trailers are hazardous is that side underride may occur during these collisions.[23] Both belted and unbelted occupants are vulnerable to injuries as a result of side underride. Side underride occurs when passenger vehicle bumpers are not at the same height and do not engage the substantial side structure of tractor-trailers. Side underride collisions are an important safety problem because they defeat crumple zones and prevent air bag deployment, both vital safety advances in improving protection of passenger vehicle occupants during crashes.[24,25,26] Airbags will not deploy in some underride collisions when the sensors to trigger them are not contacted by vehicle structures.[27] Crumple zones do not work as intended in underride collisions when relevant passenger vehicle structures fail to engage tractor-trailer structures. Furthermore, the occupant's safety cage can be compromised when underride allows the passenger vehicle to sustain impacts at the level of the windshield and other areas above the hood. This effect can result in deaths and severe injuries due to intrusion of vehicle components.

The adverse effects of underride collisions in defeating safety advances have been demonstrated in a study of belted occupants injured in passenger vehicles with good frontal crash test ratings.[28] Head injuries were the most common type of serious injury in underride collisions, and underride collisions had higher rates of fatal and severe non-fatal injuries than other crash configurations. Intrusion into the passenger compartment was the most common contributing factor to injury in underride collisions.

In 2013, Blower and Woodrooffe reported results from an independent assessment of the frequency and consequences of side underride collisions using data from the Large Truck Crash

---

[21] Krishnaswami, Vasanth, Daniel F. Blower, Lawrence W. Schneider, Devi Putcha. 2002. "Heavy Truck Aggressivity Reduction: Statistics, Analysis, and Countermeasures." Ann Arbor, Michigan: University of Michigan Transportation Research Institute.
http://deepblue.lib.umich.edu/bitstream/handle/2027.42/84367/97643.pdf?sequence=1

[22] National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[23] Crashes in which a large truck goes over part or all of a passenger vehicle can be referred to either as underride or override collisions. The large truck may be coded as having overridden the passenger vehicle, while the involved passenger vehicle may be coded 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.

[24] Insurance Institute for Highway Safety. 2012. Small overlap crashes: new consumer test program aims for even safer vehicles. *Status Report* 47 (6): 1.

[25] Farmer, C.M. and A.K. Lund, A.K. 2006. Trends over time in the risk of driver death: What if vehicle designs had not improved? *Traffic Injury Prevention* 7:335-42;

[26] Kahane, C.J. 2004. *Lives saved by the Federal Motor Vehicle Safety Standards and other vehicle safety technologies, 1960-2002*. Report no. DOT HS 809 833. Washington, DC: National Highway Traffic Safety Administration.

[27] Braver, E.R., A.T. McCartt, C.P. Sherwood, David S. Zuby, Laura Blanar, M. Scerbo. Front air bag nondeployments in frontal crashes fatal to drivers or right-front passengers. Traffic Inj Prev. 2010 Apr;11(2):178-87.

[28] Brumbelow, Matthew L. and David S. Zuby. 2009. Impact and injury patterns in frontal crashes of vehicles with good ratings for frontal crash protection. *Proceedings of the 21st International Technical Conference on the Enhanced Safety of Vehicles* (Paper No. 11-0074). Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0257.pdf

Causation Study (LTCCS), a national sample of large truck crashes resulting in fatal and non-fatal injuries during 2001–2003.[29,30] Among collisions where passenger vehicles struck the sides of tractor-trailers (both angle collisions[31] and sideswipes), side underride occurred in 69 percent of collisions with the trailers' sides and 44 percent of collisions with the cabs' sides. Cargo bed height, which typically is 50 inches for trailers, was identified as an important determinant of the outcomes of truck side impacts. Passenger compartment intrusion, which compromises survival space, occurred in more than 60 percent of passenger vehicle impacts with cargo bed sides that were 50 inches or higher, suggesting that reducing the side ground clearance could be an effective countermeasure. Axles were contacted in 74 percent of the impacts to the sides of large trucks. Although axles may reduce underride, 59 percent of side collisions in which the axles were contacted were coded as resulting in underride. The authors suggested that side underride after contacting axles could be due to contact with only a portion of the tire or a narrow angle of impact.

In 2012, Brumbelow estimated that 530 passenger vehicle occupants died each year during 2006–2008 in two-vehicle collisions between passenger vehicles and the sides of large trucks.[32] Brumbelow also did an independent analysis using LTCCS data and concluded that the most severe injuries sustained by passenger vehicle occupants were usually due to the truck side impacts rather than other events that may have occurred during the crashes (many crashes included multiple events that could result in injury). This was the case for 69 percent of 206 crashes in which a passenger vehicle collided with the side of a large truck. About a third of collisions with the sides of large trucks involved truck-tractors and about half involved semi-trailers.

Side underride protection systems. There appear to be some promising technical solutions to protecting passenger vehicle occupants from being injured in side underride collisions with tractor-trailers. A 2009 project funded by the European Commission designed and tested a side underride guard for trailers that prevented passenger vehicle compartment intrusion from side underrides.[33] A side underride protection system on trailers was also developed and tested in the United States. It prevented passenger compartment intrusion and reduced the

---

[29] Blower, Daniel F. 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.

[30] Federal Motor Carrier Safety Administration. 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

[31] Angle collisions are those in which the front or rear of a passenger vehicle makes the initial contact with the side of a large truck. In contrast, sideswipes are collisions in which a vehicle strikes another vehicle along the side while traveling either in the same direction or opposite direction and in which neither the front nor the rear of either vehicle is contacted.

[32] 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.

[33] 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

likelihood of head, chest, neck, and femur injuries.[34] Some European researchers have proposed systems that would modify frames of trailers as an alternative to side underride guards and at least one manufacturer has sold trailers with a protective frame that is designed to prevent or mitigate both rear and side underride collisions. Optimal designs aimed at preventing side underride may differ between truck-tractors and their trailers.

Brumbelow's evaluation of the potential benefits of side underride guards strongly suggested that they would reduce injury severity. Of passenger vehicle occupants with serious to fatal injuries attributed to side impacts with semi-trailers[35], 89 percent were considered injuries that could have been mitigated by side underride guards. For passenger vehicle occupants with serious to fatal injuries attributed to side impacts with truck-tractor cabs, side underride guards were considered potentially beneficial for 83 percent.[36]

The NTSB concludes that passenger vehicle occupant deaths and injuries resulting from side underride collisions with tractor-trailers could be reduced by side underride protection systems. The NTSB recommends that NHTSA require that newly manufactured trailers with GVWRs over 10,000 pounds be equipped with side underride protection systems that will reduce underride and injuries to passenger vehicle occupants. The NTSB also recommends that NHTSA require that newly manufactured truck-tractors with GVWRs over 26,000 pounds be equipped with side underride protection systems that will reduce underride and injuries to passenger vehicle occupants.

Rear Underride Protection Systems

Truck rear impacts. Rear impacts to tractor-trailers are common: according to the GES, there were 15,329 police-reported collisions in which passenger vehicles collided with the rears of tractor-trailers during 2005–2009 (about 3,065 annually).[37] NHTSA reported that large truck rear impacts comprised 19 percent of fatal two-vehicle collisions between large trucks and passenger vehicles during 2011.[38] Of tractor-trailers involved in fatal crashes during 2008–2009, an estimated 633 tractor-trailers[39] were struck in the rear (about 315 annually).[40] Of the 633 tractor-trailers with a rear-end impact, about 75 percent had a collision with a passenger vehicle, 18 percent had a collision with a bus or another large truck, and 7 percent had a collision with a motorcycle.

---

[34] Kumar, Sri, Bruce Enz, Perry L. Ponder, Bob Anderson. 2009. Biomechanical Analysis of Protective Countermeasures in Underride Motor Vehicle Accidents. Rocky Mountain Bioengineering Symposium & International ISA Biomedical Sciences Instrumentation Symposium, Milwaukee, Wisconsin.

[35] A total of 28 collisions were in this category.

[36] A total of 12 collisions were in this category.

[37] National Transportation Safety Board. 2013. "Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths." NTSB/SS-13/01. Washington, DC. Available at: http://www.ntsb.gov/

[38] National Highway Traffic Safety Administration. 2013. "Traffic Safety Facts: Large Trucks, 2011." Washington, DC: US Department of Transportation. http://www-nrd.nhtsa.dot.gov/Pubs/811752.pdf

[39] This number does not include truck-tractors traveling in the absence of trailers.

[40] Blower, Daniel F. 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.

Rear underride guard effectiveness. Rear underride may occur during passenger vehicle collisions with the rears of trailers and increases the likelihood of fatal and severe non-fatal injury. As explained in this letter's section on side underride, underride can defeat safety advances in vehicle design and can injure both belted and unbelted occupants. As of 1953, trailers were subject to a rule requiring rear underride guards that were no more than 30 inches from the ground; however, this rule was found to be inadequate. To further reduce injuries and deaths from rear underride collisions with tractor-trailers, NHTSA promulgated a rule, effective in 1998, to strengthen and lower rear underride guards so that the guard ground clearance was no more than 22 inches on trailers with GVWRs over 10,000 pounds.[41] Some types of trailers were excluded from the 1998 rule, including those with a low chassis, because underride with passenger compartment intrusion was considered unlikely due to the trailer design.

Studies have examined the effectiveness of the 1998 rear underride guard requirement. One difficulty in evaluating the standard has been the absence of trailer model year information from federal databases and most state databases, which makes it impossible to distinguish trailers manufactured before 1998 from those manufactured after the requirement for improved rear underride guards went into effect in 1998. Consequently, a NHTSA evaluation in 2010 of the rear underride guard standard was limited to two states, Florida, which already had trailer data, and North Carolina, where a special effort was needed to collect trailer data.[42] A reduction in passenger vehicle occupant fatalities and injuries from rear impacts with trailers equipped with improved guards was observed, but NHTSA stated that the small numbers in the two states limited the conclusions that could be drawn about the rule's effectiveness.

A supplemental survey to the Trucks in Fatal Accident (TIFA) database for 2008–2009 was sponsored by NHTSA to determine the occurrence of rear underride by truck configuration and underride guard status.[43] By 2009, about 75 percent of all trailers pulled by truck-tractors that were involved in fatal crashes had been manufactured in 1998 or later and were subject to the requirement for improved rear underride guards.[44]

According to Blower and Woodrooffe (2013), when a collision occurs between a passenger vehicle and the rear of a tractor-trailer in which the trailer structure impacts the

---

[41] National Highway Traffic Safety Administration. Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection; Final rule. *Federal Register, Vol.* 61, No. 16, p. 2004, January 24, 1996. Federal Motor Vehicle Safety Standards 223 and 224: 49 C.F.R. § 571.223 Standard No. 223; Rear impact guards. 49 C.F.R. § 571.224 Standard No. 224; Rear impact protection.
http://www.gpo.gov/fdsys/pkg/CFR2008title49vol6/pdf/CFR-2008-title49-vol6-sec571-223.pdf

[42] Allen, Kirk. 2010. "The Effectiveness of Underride Guards for Heavy Trailers." DOT HS 811 375. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/811375.pdf

[43] Blower, Daniel F. 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.

[44] Blower, Daniel F. 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. Of the 2,164 trailers involved in fatal crashes (all types, not only rear-end collisions) during 2009, 20 percent were manufactured before 1998, 55 percent were manufactured in 1998 or later, and 25 percent had an unknown year of manufacture. Blower and Woodrooffe estimated that about 75 percent of trailers were manufactured in 1998 or later, assuming that most of the trailers with unknown model years fell into the 1998+ category.

windshield, "there is relatively little structure to resist intrusion on the horizontal plane,"[45] which means that passenger compartment intrusion is likely. Among the 229 trailers that had guards subject to the 1998 requirements and that incurred fatal rear impacts, 50 percent involved underride that extended to the passenger vehicle's windshield or further.

A 2010 study by Brumbelow and Blanar[46] reviewed data from the LTCCS[47] and examined the frequency and consequences of rear underride collisions through the use of photographs and other documentation. Rear underride collisions were examined that involved 30 semi-trailers produced in 1998 or later or that were determined to be in compliance with the 1998 NHTSA requirements for rear impact protection. Among these 30 semi-trailers, 20 passenger vehicles colliding with them had severe or catastrophic underride that resulted in passenger compartment intrusion.[48] The most common circumstances in which rear underride guards did not work as intended were those in which (1) a passenger vehicle had an impact with only one side of the guard, (2) the attachment between the guard and trailer failed, or (3) the trailer chassis buckled in such a way that the guard was out of position.

As a follow-up to the research done by Brumbelow and Blanar, the Insurance Institute for Highway Safety (IIHS) performed 35 mph crash tests involving passenger vehicles colliding with the rears of trailers and published the findings in 2011.[49,50] These included full-width tests, 50 percent overlap tests, and 30 percent overlap tests. Performance in tests with 50 percent or 30 percent overlap of the fronts of passenger vehicles is important because these types of real-world crashes result in severe injury. Overlaps of 50 percent or less were present in about half of the collisions with the rears of large trucks that were categorized as resulting in severe or catastrophic underride; the evaluation by NHTSA also identified corner impacts with trailers as particularly hazardous.[51,52]

The IIHS crash tests demonstrated that the rear underride guards mandated for trailers by NHTSA in 1998 performed poorly and that stronger underride guards currently available on the market provided somewhat better protection. A passenger vehicle with good front crash test

---

[45] See page 54 of Blower, Daniel F. 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.

[46] 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.

[47] Federal Motor Carrier Safety Administration. 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

[48] 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.

[49] Insurance Institute for Highway Safety. 2011. "Petition for Rulemaking; 49 CFR Part 571 Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection." Arlington, VA. http://www.iihs.org/laws/petitions/pdf/petition_2011-02-28.pdf.

[50] Brumbelow, Matthew L. 2011. Crash test performance of large truck rear underride guards. *Proceedings of the 22nd International Technical Conference on the Enhanced Safety of Vehicles* (CD-ROM). Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv22/22ESV-000074.pdf

[51] 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.

[52] Allen, Kirk. 2010. "The Effectiveness of Underride Guards for Heavy Trailers." DOT HS 811 375. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/811375.pdf.

ratings was used so that potential guard performance problems and injury predictions would not be attributed to suboptimal passenger vehicle design. One underride guard that met the 1998 US standards failed catastrophically during a full-width test. One underride guard that met the stronger requirements for Canadian Motor Vehicle Safety Standard 223[53] performed better than the guard meeting only the US requirements during the full-width tests and also did well during the demanding 50 percent overlap test. However, catastrophic underride occurred during its 30 percent overlap test when the ends of the guard bent forward. Yet another underride guard meeting the Canadian standard performed poorly during the 50 percent overlap test, resulting in severe underride.

IIHS repeated the rear impact crash tests for two trailer manufacturers after they redesigned their underride guards and also tested guards from five other companies.[54] All met the Canadian standards for underride guards and performed well in full-width tests and, with one exception, in 50 percent overlap tests. However, only one trailer passed the 30 percent overlap test.

As a result of the research that was published in 2010 and 2011, IIHS submitted a petition to NHTSA requesting that the 1998 rear underride guard standard be upgraded.[55] The following changes were requested: (1) Increase the strength of the guards by modifying testing requirements, (2) Require that the guards be designed to protect passenger vehicle occupants in collisions that occur with only a portion of the guard (off-set collisions), (3) Strengthen requirements for attachment hardware, (4) Require testing each type of guard "while attached to the trailers for which they are designed," (5) Determine whether it is feasible to lower the maximum guard ground clearance from 22 inches, and (6) Include additional types of trucks (i.e., single-unit trucks) and trailers in a revised rear underride guard rule.[56] As of December 2013, NHTSA has not formally responded to IIHS's petition, but the agency has sponsored additional research on rear underride.[57]

The NTSB concludes that passenger vehicle occupant injuries caused by rear underrides with tractor-trailers could be reduced by improving trailer rear underride protection systems. The NTSB recommends that NHTSA revise requirements for rear underride protection systems for newly manufactured trailers with GVWRs over 10,000 pounds to ensure that they provide adequate protection of passenger vehicle occupants from fatalities and serious injuries resulting

---

[53] Transport Canada. 2004. Motor Vehicle Safety Regulations (C.R.C., c. 1038) Rear Impact Guards (Standard 223). http://www.tc.gc.ca/eng/acts-regulations/regulations-crc-c1038-sch-iv-223.htm

[54] Insurance Institute for Highway Safety. March 14, 2013. "Not good enough." *Status Report* 48 (2):1-5. http://www.iihs.org/externaldata/srdata/docs/sr4802.pdf.

[55] Insurance Institute for Highway Safety. 2011. "Petition for Rulemaking; 49 CFR Part 571 Federal Motor Vehicle Safety Standards; Rear Impact Guards; Rear Impact Protection." Arlington, VA. http://www.iihs.org/laws/petitions/pdf/petition_2011-02-28.pdf

[56] As a result of its study of single-unit trucks, the NTSB recommended that NHTSA develop performance standards for rear underride protection systems for single-unit trucks and then, once the performance standards have been developed, require them for newly manufactured single-unit trucks with GVWRs over 10,000 pounds (H-13-15 and H-13-16).

[57] Blower, Daniel F. 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.

from full-width and offset trailer rear impacts.[58]

Improvements in Crash Data for Trailers

Deficiencies in trailer data. Although the majority of collisions involving the sides or rears of tractor-trailers consist of impacts to the trailers, police reports provide less information for trailers than for other types of motor vehicles. This is reflected in police accident report forms: few include spaces for the vehicle identification number (VIN) or license plate numbers of trailers. Also, the forms do not instruct police officers to fill in this information for trailers. The VIN can be decoded to indicate the trailer manufacturer, model year, and other trailer characteristics. The license plate number is a link to state vehicle registration records containing the trailer VIN.

Trailer data are essential. Having accurate trailer data is important for evaluating the effects of safety regulations and for determining the safety of trailer designs. About 80 percent of the collisions between passenger vehicles and the rears of tractor-trailers involve the trailer rather than the truck-tractor cab; the corresponding percentage for passenger vehicle collisions with the sides of tractor-trailers is more than 50 percent.[59] As noted earlier, NHTSA's evaluation of the effectiveness of rear underride guards was hampered by the lack of available data on trailer model year in state crash reports.[60] NHTSA also had to pay for supplemental data collection for its evaluation of retroreflective tape aimed at improving the conspicuity of tractor-trailers.[61]

Trailer designs directly affect the risk to passenger vehicle occupants involved in collisions. For example, IIHS showed that the different rear underride guard designs used by trailer manufacturers affected how well the guards performed in crash tests.[62] If trailer data were available in federal and state databases, analyses could be done to determine whether certain trailer designs and equipment should be altered to reduce injury risks to passenger vehicle occupants. Due to the lack of trailer data in federal and state databases, such studies cannot currently be done without extensive cost and time for data collection.

Collecting trailer data is feasible. Collecting trailer VINs is more challenging for trailers than for other motor vehicles because there is no standard location for VINs on the trailer. However, Florida consistently records trailer VINs as a result of a statewide effort to improve the completeness of the reporting of commercial motor vehicle crashes. According to Florida's Department of Highway Safety and Motor Vehicles, Florida required the trailer VINs and then

---

[58] As a result of its study of single-unit trucks, the NTSB recommended that NHTSA develop performance standards for rear underride protection systems for single-unit trucks and then, once the performance standards have been developed, require them for newly manufactured single-unit trucks with GVWRs over 10,000 pounds.

[59] Blower, Daniel F. 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.

[60] Allen, Kirk. 2010. "The Effectiveness of Underride Guards for Heavy Trailers." DOT HS 811 375. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/811375.pdf

[61] Morgan, Christina. 2001. "The Effectiveness of Retroreflective Tape on Heavy Trailers." DOT HS 809 222. Washington, DC: National Highway Traffic Safety Administration.
http://www.nhtsa.gov/cars/rules/regrev/evaluate/809222.html

[62] Brumbelow, Matthew L. 2011. Crash test performance of large truck rear underride guards. *Proceedings of the 22nd International Technical Conference on the Enhanced Safety of Vehicles* (CD-ROM). Washington, DC: National Highway Traffic Safety Administration. http://www-esv.nhtsa.dot.gov/Proceedings/22/isv7/main.htm

examined the completeness of the submitted forms. Feedback was then given to local police agencies about how well they were doing with form completion. Florida also transitioned to electronic submission of police reports, which aids the police in submitting accurate data efficiently. Vehicle registration records are available to police while they are investigating crashes and they can copy the trailer VIN from these electronic records into their electronic reports. Other states could capture trailer VINs in a similar manner. Electronic crash reports have been encouraged by NHTSA as part of the ongoing effort to improve the accuracy and timeliness of crash data.[63]

A critical component in the effort to standardize and improve the quality of traffic crash data is the Model Minimum Uniform Crash Criteria (MMUCC) Guideline.[64] As described on its website, the MMUCC Guideline sets forth a recommendation for the "minimum, standardized data set for describing motor vehicle crashes and the vehicles, persons and environment involved. The Guideline is designed to generate the information necessary to improve highway safety within each state and nationally."[65] When redesigning their police report forms, states compare what they are collecting with the MMUCC Guideline. Developing each edition of the MMUCC Guideline is a collaborative process by an expert panel that includes law enforcement professionals, state agencies for transportation and motor vehicles, traffic safety and medical professionals, federal agencies, state governments, and emergency responders. NHTSA is a highly influential stakeholder that coordinates the revisions. The most recent MMUCC Guideline was released in 2012; editions are revised about every five years. Including a requirement in the MMUCC Guideline for collecting trailer license plate and VIN numbers would likely improve the capture of this important data.

Other sources of data on trailer VINs are the investigations conducted by police officers affiliated with the Motor Carrier Safety Assistance Program (MCSAP), which is a comprehensive program conducted by states to improve the safety of large trucks and buses through performing inspections and collecting safety data. MCSAP receives funding from the Federal Motor Carrier Safety Administration (FMCSA). As part of an effort to improve the completeness of the crash data files maintained by FMCSA, there is an ongoing effort to match records in the Fatality Analysis Reporting System (FARS) [66] with FMCSA records.[67] Just as FMCSA makes use of records from FARS, FARS in turn can make use of FMCSA records to obtain VINs and model years for trailers involved in fatal crashes. Trailer VINs can also be obtained for non-fatal tractor-trailer crashes that are investigated by MCSAP-affiliated police officers and reported to FMCSA.

---

[63] National Highway Traffic Safety Administration. 2010. E-Crash: The Model Electronic Crash Data Collection System. DOT HS 811 326. Washington, DC.
http://tsass-tsis.com/trd/pdfs/6855_Model_Electronic_Crash_Data_07-20-10_v1c.pdf

[64] Model Minimum Uniform Crash Criteria Guideline, 4th edition, 2012. http://www.mmucc.us/

[65] Model Minimum Uniform Crash Criteria Guideline, 4th edition, 2012. http://www.mmucc.us/

[66] The Fatality Analysis Reporting System is a database that is a national census of fatal traffic crashes occurring on public roads in which at least one road user has died within 30 days of the crash. NHTSA is responsible for maintaining this database.

[67] Federal Motor Carrier Safety Administration. 2013. "FARS/MCMIS Fatal Crash Record Matching Tool." http://ai.fmcsa.dot.gov/DataQuality/DataQuality.asp?redirect=about_datatools_desc.asp

Collecting accurate trailer data for motor vehicles involved in police-reported crashes is feasible and would enhance the ability of government and industry to evaluate trailer designs and the impact of trailers on highway safety. The NTSB concludes that trailer VINs and trailer model year information are necessary data elements for national and state crash databases in order to detect risks associated with trailer designs and to evaluate the effectiveness of safety regulations for trailers. Accordingly, the NTSB recommends that NHTSA add trailer VIN and trailer model year to the FARS database for trailers with GVWRs over 10,000 pounds. The NTSB further recommends that NHTSA work with the MMUCC expert panel to modify the data element titled "Motor Vehicle License Number" to include the trailer license plate number in the next edition of the MMUCC Guideline. The NTSB also recommends that NHTSA work with the MMUCC expert panel to modify the data element titled "Vehicle Identification Number" to include the trailer VIN in the next edition of the MMUCC Guideline.

Therefore, the National Transportation Safety Board makes the following safety recommendations to the National Highway Traffic Safety Administration:

Require that newly manufactured truck-tractors with gross vehicle weight ratings over 26,000 pounds be equipped with visibility enhancement systems to improve the ability of drivers of tractor-trailers to detect passenger vehicles and vulnerable road users, including pedestrians, cyclists, and motorcyclists. (H-14-001)

Require that newly manufactured trailers with gross vehicle weight ratings over 10,000 pounds be equipped with side underride protection systems that will reduce underride and injuries to passenger vehicle occupants. (H-14-002)

Require that newly manufactured truck-tractors with gross vehicle weight ratings over 26,000 pounds be equipped with side underride protection systems that will reduce underride and injuries to passenger vehicle occupants. (H-14-003)

Revise requirements for rear underride protection systems for newly manufactured trailers with gross vehicle weight ratings over 10,000 pounds to ensure that they provide adequate protection of passenger vehicle occupants from fatalities and serious injuries resulting from full-width and offset trailer rear impacts. (H-14-004)

Add trailer vehicle identification number and trailer model year to the Fatality Analysis Reporting System database for trailers with gross vehicle weight ratings over 10,000 pounds. (H-14-005)

Work with the Model Minimum Uniform Crash Criteria expert panel to modify the data element titled "Motor Vehicle License Number" to include the trailer license plate number in the next edition of the Model Minimum Uniform Crash Criteria Guideline. (H-14-006)

Work with the Model Minimum Uniform Crash Criteria expert panel to modify the data element titled "Vehicle Identification Number" to include the trailer vehicle identification number in the next edition of the Model Minimum Uniform Crash Criteria Guideline. (H-14-007)

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

The NTSB is vitally interested in these recommendations because they are designed to prevent accidents and save lives. We would appreciate receiving a response from you within 90 days detailing the actions you have taken or intend to take to implement them. When replying, please refer to the safety recommendations by number. We encourage you to submit your response electronically to correspondence@ntsb.gov.

[Original Signed]

By: Deborah A.P. Hersman,
Chairman

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
H-14-001	1	SS-19-01	12/5/2019	Bicyclist Safety on US Roadways: Crash Risks and Countermeasures	N/A	N/A	N/A