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FINAL REGULATORY EVALUATION

FMVSS No. 223
Rear Impact Guards
and
FMVSS No. 224
Rear Impact Protection

Office of Regulatory Analysis and Evaluation
National Center for Statistics and Analysis

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This final regulatory evaluation (FRE) studies the impact of upgrades for Federal Motor Vehicle Safety Standard (FMVSS) Nos. 223 and 224 and accompanies the final rule as supporting material to upgrade the standards.

The National Highway Traffic Safety Administration (NHTSA) published FMVSS Nos. 223 and 224 in 1996 and these two standards became effective in 1998. These standards are intended to reduce injuries and fatalities resulting from the collision of light vehicles into the rear ends of heavy trailers and semitrailers. FMVSS No. 223 specifies performance requirements that rear impact guards must meet before they can be installed on new trailers and semitrailers. The second standard, FMVSS No. 224, establishes requirements that most new trailers and semitrailers with a gross vehicle weight rating (GVWR) of 4,536 kilograms (10,000 pounds) or more be equipped with a guard meeting the requirements of FMVSS No. 223, and includes requirements for the mounting location of the guard relative to the rear end of the vehicle.

In 2005, Transport Canada upgraded Canadian Motor Vehicle Safety Standard (CMVSS) No. 223, “Rear impact guards,” to include increased performance requirements for guard strength and energy dissipation over and above that of the US requirements. The upgraded CMVSS No. 223 became effective on September 1, 2007.

In 2009, the agency initiated an in-depth field analysis for assessing the extent of the underride and for characterizing the factors in rear end impacts that result in truck/trailer underride to help direct potential changes to our safety requirements that would reduce severe passenger vehicle underride in truck and trailer rear end impacts. Subsequently, the agency contracted University of Michigan Transportation Research Institute (UMTRI) in 2009 to conduct a study on heavy vehicle crash characterization for rear underride. The study collected a set of information related to underride guards and rear underride, including data on the extent of underride, damage to the underride guard, and whether the collision was offset. In addition, data were collected on estimated relative impact velocity, the mass of the striking vehicle, and the front geometry of the striking vehicle.[1]

On February 28, 2011, the Insurance Institute for Highway Safety (IIHS) submitted a petition for rulemaking to upgrade FMVSS Nos. 223 and 224 to mitigate rear underride crashes into trucks and trailers. IIHS provided a review of a sample of underride crashes in the Large Truck Crash Causation Study (LTCCS) database, and results of quasi-static tests of rear impact guards and crash tests of a passenger car into the rear of trailers as supporting material.

On November 15, 2021, President Biden signed the Infrastructure Investment and Jobs Act (IIJA), commonly referred to as the Bipartisan Infrastructure Law (BIL). Section 23011 of BIL specifies provisions for underride protection measures for trailers and semitrailers. The provisions direct the Secretary to upgrade current Federal safety standards for rear impact guards.

[1] Blower, D and Woodrooffe, J (2013), Contract No. DTNH22-11-D-00236/0004: Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes, University of Michigan Transportation Research Institute, Ann Arbor, Michigan.

Requirements

The agency analyzed real world crash data involving trucks and trailers and evaluated the feasibility of harmonization with other standards, specifically the Canadian standard, CMVSS No. 223. Based on the agency's analysis, the final rule amends FMVSS Nos. 223 and 224 as follows:

<u>Modifications to FMVSS No. 223</u>

1. Replace the current loading and performance requirements at the P3 location[2] with those specified in CMVSS No. 223. Specifically,
   a. Rear impact guards are required to resist a uniform distributed load of 350,000 Newtons (N) without deflecting more than 125 millimeters (mm).
   b. Rear impact guards that demonstrate resistance to uniform distributed load of 700,000 N or less are required to absorb at least 20,000 Joules (J) of energy within 125 mm of guard deflection when a uniform distributed load is applied and have a post-test ground clearance not exceeding 560 mm.
   c. Rear impact guards that demonstrate resistance to uniform distributed load greater than 700,000 N are required to maintain a post-test ground clearance not exceeding 560 mm.
2. Require that in the rear impact guard strength and energy absorption tests, the guard must withstand the specified loads without eliminating any load path that existed before the test was initiated.

[2] The P3 location as specified in FMVSS No. 223 is a point located 305 mm to 635 mm on the left or right side from the center of the horizontal member.

Modifications to FMVSS No. 224

1. Replace the current definition of "rear extremity" with that specified in CMVSS No. 223 that permits aerodynamic fairings to be located within a certain zone at the rear of the trailer.
2. Add "low chassis vehicles" into the list of vehicles excluded from FMVSS No. 224 in the applicability section which was inadvertently omitted in a 1996 final rule (61 FR 2035).

Benefits

Undiscounted, the agency estimates that approximately 0.56 lives and 3.5 serious injuries would be saved annually by requiring all applicable trailers to be equipped with CMVSS No. 223 compliant guards. By saving these lives and preventing these injuries, the final rule would produce annual monetized comprehensive benefits of $13.73 million and $10.90 million in 2020 dollars discounted at 3% and 7%, respectively, as shown in the following table. These annual monetized comprehensive benefits include both quality of life valuation based on the value of a statistical life (VSL) and societal economic savings. The lower bounds represent the savings for the 7 percent discount rate and the higher bounds represent savings for the 3 percent discount rate. Details are described in the main body of the analysis.

Discounted Benefits of the Final Rule (in Millions of 2020 dollars)

Discount rate	Undiscounted	3%	7%
Annual comprehensive benefits	$16.96	$13.73	$10.90

Costs

The annual average incremental fleet cost of equipping all applicable trailers with CMVSS No. 223 rear impact guards is estimated to be $2.10 million in 2020 dollars. In addition, the added weight of 48.9 pounds per vehicle would result in an estimated annual fleet fuel cost of approximately $4.43 million and $5.59 million discounted at 7% and 3%, respectively. As such the total incremental cost would range from $6.54 million to $7.69 million discounted at 7% and 3%, respectively.

Cost of the Final Rule with Average Increase in Weight (in Millions of 2020 dollars)

Discount rate	Undiscounted	3%	7%
Material*	$2.10	$2.10	$2.10
Fuel	$6.90	$5.59	$4.43
Total	$9.00	$7.69	$6.54

* Material costs are not discounted since they occur at the time of purchase

Cost Per Equivalent Life Saved

The estimated equivalent lives saved (ELS) ranges from 0.90 lives to 1.14 lives discounted at 7% and 3%, respectively. The cost of the final rule is the regulatory cost and ranges from $6.54 million to $7.69 million discounted at 7% and 3%, respectively. The cost per ELS ranges from $6.77 million to $7.25 million discounted at 3% and 7%, respectively as shown in the following table.

Cost per Equivalent Lives Saved (in Millions of 2020 dollars)

Discount rate	Undiscounted	3%	7%
Total cost	$9.00	$7.69	$6.54
Equivalent lives saved	1.40	1.14	0.90
Cost per ELS	$6.42	$6.77	$7.25

Net Benefits

A net benefit of the final rule is the difference between the comprehensive benefit and the total cost. The estimated net benefit ranges from $4.36 million to $6.04 million discounted at 7% and 3%, respectively.

Net Benefits (in Millions of 2020 dollars)

Discounted rate	Undiscounted	3%	7%
Comprehensive benefit	$16.96	$13.73	$10.90
Total cost	$9.00	$7.69	$6.54
Net benefit	$7.96	$6.04	$4.36

Leadtime

The agency sets forth a lead time of two years from the publication of the final rule for manufacturers to comply with the requirements.

Summary of Annual Costs and Benefits

The following table summarizes the total costs, comprehensive benefits, and net benefits for both 3 and 7 percent discount rates.

Costs and Benefits (in Millions of 2020 dollars)

Discount Rate	Material Cost	Fuel Cost	Total Costs	Comprehensive Benefits	Net Benefits
3%	$2.10	$5.59	$7.69	$13.73	$6.04
7%	$2.10	$4.43	$6.54	$10.90	$4.36

I. INTRODUCTION

A. Background

Rear underride crashes occur when a passenger vehicle crashes into the rear end of a generally larger vehicle, and the front end of the passenger vehicle slides under (i.e., underrides) the rear end of the larger vehicle. Underride may occur in collisions between a passenger vehicle and the rear of a large trailer or semi-trailer (referred to in this document collectively as “trailers”) because the bed and chassis of the trailer is often higher than the front of the passenger vehicle. In extreme underride crashes, “passenger compartment intrusion” (PCI) may occur when the passenger vehicle underrides the rear end of the trailer to such an extent that the rear end of the trailer strikes and enters the passenger compartment of the colliding passenger vehicle. PCI can result in severe injuries and fatalities to the occupants of the passenger vehicle. Rear impact guards are mounted on the rear of trailers to prevent underride and PCI. In a collision between a passenger vehicle and the rear of a trailer equipped with a rear impact guard, the rear impact guard engages the striking passenger vehicle and prevents it from sliding too far under the struck vehicle’s bed and chassis.

On January 8, 1981, NHTSA proposed a rear underride guard standard designed to mitigate the effects of a light duty vehicle (passenger car, light truck, and van) colliding with the rear of a straight body or combination truck. The proposed standard applied to full and semi-trailers with a GVWR greater than 10,000 pounds. One of the primary goals of the proposal was the prevention of PCI.

On January 3, 1992, NHTSA published a Supplemental Notice of Proposed Rulemaking (SNPRM) which was very similar to the 1981 proposal, except that the guard's strength would be specified in an equipment safety standard, rather than a vehicle-based safety standard. In the SNPRM, NHTSA adopted the term "rear impact guard" instead of the term "underride guard", to reflect the agency's belief that the guard would help protect the occupants of a colliding vehicle by absorbing crash forces as well as preventing extreme underride. The agency proposed the following rear impact guard requirements; a 22 in. maximum guard-to-ground clearance for the horizontal cross member, a 4 inch maximum between the ends of the horizontal cross member and the sides of the trailer, a 12 in. maximum offset allowance from the rear extremity, 3 quasi-static load application points along the horizontal member, maximum deflection or displacement allowed for each test point, and compliance labelling requirements. The proposed applicability was to trailers and semi-trailers with a GVWR greater than 10,000 pounds, and excluded single unit trucks, truck tractors, pole trailers, low chassis trailers, special purpose vehicles and "wheels back" vehicles. In addition, the guard would be compliance tested on a rigid test fixture. On January 3, 1992, a companion safety standard was also proposed which required trailers to be equipped with underride guards meeting the requirements of the equipment standard.

NHTSA promulgated FMVSS No. 223, “Rear impact guards,” and FMVSS No. 224, “Rear impact protection,” in 1996 which operate together to reduce the number of injuries and fatalities resulting from passenger vehicles underriding the rear of heavy trailers and semitrailers. FMVSS No. 223 specifies dimensional, strength, and energy absorption requirements that rear impact guards must meet before they can be installed on new trailers and semitrailers. FMVSS No. 224

requires that most new trailers and semitrailers with a GVWR of 4,536 kilograms (10,000 pounds) or more be equipped with a rear impact guard meeting FMVSS No. 223 specifications and specifies the location of the guard relative to the rear end of the trailer.[3] The standards became effective in January 1998.

B. Information and Actions Resulting in the Agency Re-Evaluating Requirements for Rear Impact Protection

1. 2005 Upgrade to Rear Impact Guard Requirements in Canada

In 2005, Transport Canada issued upgraded rear impact protection requirements for trailers and semitrailers in Canadian Motor Vehicle Safety Standard (CMVSS) No. 223, "Rear impact guards."[4] The upgraded requirements ensured rear impact guards have sufficient strength and energy absorption capability to prevent passenger compartment intrusion of compact and subcompact passenger cars in impacts to the rear of trailers at 56 kilometers per hour (km/h) (35 miles per hour (mph)).[5] In contrast, the requirements in FMVSS Nos. 223 and 224 were intended for preventing PCI in compact and subcompact passenger cars impacting the rear of trailers at 48 km/h (30 mph).[6] The new requirements in CMVSS No. 223 became effective in 2007. The agency estimates that approximately 94 percent of applicable new trailers sold in the U.S. are equipped with rear impact guards that also comply with the Canadian standard.

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[3] Pole trailers, pulpwood trailers, road construction controlled horizontal discharge trailers, special purpose vehicles, wheels back trailers, low chassis trailers, and temporary living quarters as defined in 49 CFR 529.2 are excluded from FMVSS No. 224 requirements.
[4] Canada Gazette Part II, Vol. 138, No. 20, 2004-10-06.
[5] Boucher D., Davis, D., "Trailer Underride Protection – A Canadian Perspective," SAE Paper No. 2000-01-3522, Truck and Bus Meeting and Exposition, December 2000, Society of Automotive Engineers.
[6] 61 FR 2004.

2. Petition for rulemaking from the Insurance Institute for Highway Safety

On February 28, 2011, IIHS submitted a petition for rulemaking to NHTSA to upgrade the FMVSSs on rear impact protection for trailers to provide greater protection to occupants in the impacting vehicle. Specifically, IIHS requested that NHTSA:

a. increase the strength requirements for rear impact guards (at least to the levels that are currently required in Canada);
b. evaluate whether ground clearance of rear impact guards can be further reduced;
c. reduce the number of heavy vehicles (trucks and trailers) exempted from requiring rear impact guards;
d. require attachment hardware to remain intact during the quasi-static tests;
e. require rear impact guards to be certified while attached to the trailer for which it is designed; and
f. move the P1 location[7] for the 50,000 Newton (N) point load quasi-static test more outboard to improve offset crash protection.

IIHS based its petition on a detailed review of rear impacts into trucks and trailers from the Large Truck Crash Causation Study (LTCCS)[8] and a series of trailer rear impact crash tests at 56 km/h (35 mph) impact speed with a 2010 Chevrolet Malibu. IIHS noted that among the 30 LTCCS cases of passenger vehicle crashes into the rear of trailers with rear impact guards, nearly all the guards failed to prevent PCI. IIHS stated that the most common failures of the rear impact guards were due to weakness in the attachment between the guard and the trailer, deformation of the trailer chassis, and bending of an outboard end of the guard in small overlap crashes. IIHS stated that more than half of the truck units in the LTCCS cases it reviewed were

[7] The P1 location as specified in FMVSS No. 223 is a point location 3/8th of the length of the horizontal member on the left or right side from the center of the horizontal member.
[8] LTCCS is based on a 3-year data collection project by NHTSA and FMCSA and is the first-ever national study to attempt to determine the critical events and associated factors that contribute to serious large truck crashes. https://www.fmcsa.dot.gov/research-and-analysis/research/large-truck-crash-causation-study, last accessed on August 12, 2021.

exempted from the Federal rear impact guard regulations, among which wheels back and single unit trucks accounted for most of the exemptions.

Results of the 56 km/h crash tests with the 2010 Chevrolet Malibu showed that the trailer guard compliant with FMVSS Nos. 223 and 224 was unable to prevent PCI into the Malibu. In contrast, trailers with rear impact guards compliant with CMVSS No. 223 were able to mitigate PCI into the Malibu in crashes where the Malibu fully engaged or had a 50 percent overlap (the overlap refers to the portion of the Malibu's width overlapping the underride guard). The results of IIHS tests are described in detail in Chapter IV.

3. 2014 Petition for rulemaking from Ms. Karth and the Truck Safety Coalition

On May 5, 2014, Ms. Marianne Karth and members of the Truck Safety Coalition (TSC) presented the Secretary of Transportation with more than 11,000 identical petitions from members of the public requesting that the agency improve the safety of rear impact guards on trailers and SUTs and that the Department of Transportation begin studies and rulemakings for side guards and front override guards. Ms. Karth and TSC stated that if the Federal standards for rear impact guards were amended to be equivalent to the Canadian standard, injuries and fatalities could be avoided. These two petitioners requested that the rear impact guards on trailers and semitrailers be mounted 16 inches from the ground, with vertical supports located 18 inches from the side edges of the trailer. On July 10, 2014, the agency granted the petition for rulemaking submitted by Ms. Karth and TSC with respect to rear impact guards.[9]

4. 2013 and 2014 Recommendations from the National Transportation Safety Board (NTSB) On Rear Impact Guards

[9] 79FR 39362.

In June 2013, the NTSB published a study of real world crashes involving single unit trucks (SUTs) that resulted in injuries and deaths.[10] The study used a variety of data sources: Crash Outcome Data Evaluation System (CODES)[11] from Delaware, Maryland, Minnesota, Nebraska, and Utah, Trucks in Fatal Accidents (TIFA), and the FARS, the National Automotive Sampling System (NASS)/General Estimates System (GES), and LTCCS. With respect to rear impacts and rear impact protection, the study found that SUTs were involved in 2,309 crashes annually in which passenger vehicles collided with the rear of SUTs; rear underride occurred in more than 70 percent of these crashes. Based on this study, the NTSB issued seven new recommendations to NHTSA for mitigating crashes and death and injury in crashes involving SUTs. Of these seven recommendations, two involve rear impacts guards:

> H-13-15: Develop performance standards for rear underride protection systems for single unit trucks with gross vehicle ratings over 10,000 pounds.
>
> H-13-16: 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.

On April 3, 2014, the NTSB issued seven new recommendations to NHTSA among which one involves rear impact protection for trailers. The NTSB recommendation on rear impact protection was based on its review of NHTSA's real world crash databases, the 2013 UMTRI

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[10] Crashes Involving Single-Unit Trucks that Resulted in Injuries and Deaths, Safety Study NTSB/SS-13/01 PB2013-106637, Adopted June 17, 2013. Also available at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj45fa_7qvyAhV4kmoFHSb4D4sQFnoECAIQAQ&url=https%3A%2F%2Fwww.aph.gov.au%2FDocumentStore.ashx%3Fid%3D5981b8a9-72af-404b-aa19-46d4664beeb5&usg=AOvVaw2g4MLSEn0b7OSg8gxaJmAm, last accessed on August 12, 2021.

[11] CODES links hospital discharge records with police accident report. Further information is available at http://www-nrd.nhtsa.dot.gov/Pubs/811181.pdf, last accessed on October 29, 2021.

study, IIHS's 2011 petition for rulemaking, and the IIHS study reviewing LTCCS cases and the crash tests with the 2010 Chevrolet Malibu into the rear of trailers. The NTSB's recommendation states:

> H-14-004: 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.

II. REQUIREMENTS

A. 2015 Notice of Proposed Rulemaking

The notice of proposed rulemaking (NPRM) published on December 16, 2015[12] proposed to align FMVSS No. 223 and FMVSS No. 224 with the rear impact guard standard in Canada (CMVSS No. 223) that requires rear impact guards to provide sufficient strength and energy absorption to protect occupants of compact and subcompact passenger cars impacting the rear of trailers at 56 km/h (35 mph).

The NPRM proposed the following changes to FMVSS No. 223:

- Require rear impact guards (except as noted below) to resist a uniform distributed load of 350,000 N without deflecting more than 125 mm, while absorbing at least 20,000 J of energy by plastic deformation within the first 125 mm of deflection;
  - Alternatively, guards may resist a minimum uniform distributed load of 700,000 N without deflecting 125 mm.
- Require rear impact guards to maintain a ground clearance after the energy absorption test not exceeding 560 mm. For rear impact guards with strength exceeding 700,000 N in the uniform distributed load test, the post-test ground clearance is measured after the uniform distributed load test. A definition of "ground clearance" was proposed for addition to FMVSS No. 223.
- Require that any portion of the rear impact guard and attachments not separate from their mounting structure after completion of FMVSS No. 223's uniform distributed loading test and the energy absorption test.

[12] 80 FR 78417

The NPRM proposed the following changes to FMVSS No. 224:

- Replace the current definition of "rear extremity" with that specified in CMVSS No. 223 to ensure that aerodynamic fairings are located within a certain safe zone at the rear of the trailer.

NHTSA received 50 comments on the NPRM. After carefully reviewing the comments, the final rule adopted most of the proposed rule, while clarifying the wording that attachment hardware remain intact during quasi-static load tests in FMVSS No. 223. NHTSA is also making a technical correction to the citation referenced in the definition of "temporary living quarters" in FMVSS No. 224.

B. Summary of the Final Rule

In order to reduce injuries and fatalities due to light vehicle impacts into the rear of trailers, the agency is issuing a final rule that:

1) Modifies FMVSS No. 223 by requiring that, during the rear impact guard strength and energy absorption tests, the guard must withstand the specified loads without eliminating any load path that existed before the test was initiated.
2) Modifies FMVSS No. 223 by replacing the current loading and performance requirements at the P3 location with those specified in CMVSS No. 223. Specifically,
    a. Rear impact guards are required to resist a uniform distributed load of 350,000 N without deflecting more than 125 mm.
    b. Rear impact guards that demonstrate resistance to a uniform distributed load of 700,000 N or less are required to absorb at least 20,000 J of energy within 125 mm of guard

deflection when a uniform distributed load is applied and have a post-test ground clearance not exceeding 560 mm.

c. Rear impact guards that demonstrate resistance to a uniform distributed load greater than 700,000 N need not meet the energy absorption requirements but are required to maintain a post-test ground clearance not exceeding 560 mm.

3) Modifies FMVSS No. 223 by adding specifications for the distributed load force application device and test procedures for conducting the distributed load test.

4) Modifies FMVSS No. 223 by including a definition for “ground clearance” and a method of assessing post-test ground clearance.

5) Modifies S3 of FMVSS No. 223 by replacing “Federal Motor Safety Standard,” with “Federal Motor Vehicle Safety Standard.”

6) Modifies FMVSS No. 224 by adding “low chassis vehicles” to the list of vehicles excluded from FMVSS No. 224 requirements.

7) Modifies FMVSS No. 224 by replacing the current definition of “rear extremity” with that specified in CMVSS No. 223 that permits aerodynamic fairings to be located within a certain zone at the rear of the trailer.

8) Technical Correction: Corrects the reference used to define temporary living quarters from 49 CFR 529.2 to 49 CFR 523.2.

III. REAR IMPACT GUARD AND PROTECTION RESEARCH

A. Rear Underride as a Cause of Fatality in Frontal Crashes to Belted Occupants of Newer Passenger Car Models

In 2009, NHTSA conducted a study to evaluate why fatalities were still occurring in frontal crashes despite high rate of seat belt use and presence of air bags and advanced safety features.[13] NHTSA reviewed cases of frontal crash fatalities to belted drivers or right-front passengers in model year (MY) 2000 or newer vehicles in the Crashworthiness Data System of the National Automotive Sampling System (NASS-CDS) through calendar year 2007. A breakdown of this data is shown in Figure 4. Among the 122 fatalities examined in this review, 49 (40%) were in exceedingly severe crashes that were not survivable, 29 (24%) were in oblique or corner impact crashes where there was low engagement of the vehicle's structural members to absorb the crash energy, 17 (14%) were underrides into trucks and trailers (14 were rear underride and 3 were side underride), 15 (12%) were fatalities to vulnerable occupants (occupants 75 years and older), 4 (3.3%) were narrow object impacts, and 8 (6.6%) were other types of impact conditions. In survivable frontal crashes of newer vehicle models resulting in fatalities to belted vehicle occupants, rear underride into large trucks and trailers were the second highest cause of fatality.

[13] Kahane, et al. "Fatalities in Frontal Crashes Despite Seat Belts and Air Bags – Review of All CDS Cases – Model and Calendar Years 2000-2007 – 122 Fatalities," DOT HS 811 102, September 2009.

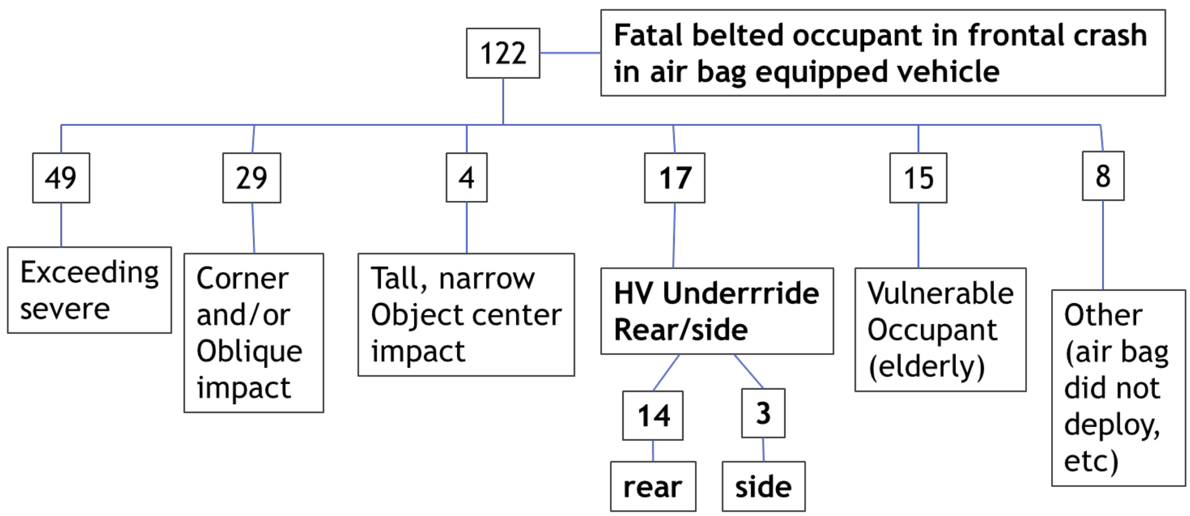

Figure 4: Breakout of belted occupant fatalities in frontal crashes of air bag equipped passenger vehicles

B. Evaluation of the Effectiveness of Rear Impact Guards

In 2010, NHTSA conducted a study of crash data involving trailers to determine the effectiveness of rear impact guards (those compliant with FMVSS Nos. 223 and 224) in preventing fatalities and serious injuries in crashes where a passenger vehicle impacts the rear of a trailer.[14] The study found that passenger compartment intrusion is more apt to occur when the corner of the trailer is impacted rather than the center of the trailer. The study concluded that it was not possible to use existing data to determine a nationwide reduction in fatalities when a passenger vehicle impacts the rear of a trailer – neither in terms of total number of fatalities, percentage of passenger vehicle fatalities in crashes into the rear of trailers relative to passenger vehicle fatalities in all crashes involving trailers, nor in terms of the number of fatal crashes into the rear of trailers per 1,000 light vehicle crashes involving trailers.

[14] Kirk Allen, "The Effectiveness of Underride Guards for Heavy Trailers", DOT HS 811 375, October 2010. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811375

C. Field Data on the Extent of Underride in Rear Impacts into Heavy Vehicles

NHTSA initiated research in late 2009 with the University of Michigan Transportation Research Institute (UMTRI) to gather supplemental data on the rear geometry of trucks and trailers, the configuration of rear impact guards on trucks and trailers, and the incidence and extent of underride, and fatalities in rear impacts with trucks and trailers. UMTRI collected the supplemental information as part of its Trucks in Fatal Accidents (TIFA) survey for the years 2008 and 2009.[15,16] This supplemental data provided information on underride and the rear geometry of the impacted heavy vehicle that was previously not available. The data enabled the agency to obtain national estimates of rear impact crashes into heavy vehicles that resulted in PCI. Details of the NHTSA/UMTRI study completed in 2013 are presented in Chapter V.

D. Canadian and European Standards for Rear Impact Guards

When FMVSS Nos. 223 and 224 were promulgated, all passenger cars were required to comply to a full frontal 48 km/h (30 mph) rigid barrier crash test by ensuring that the injury measures of crash test dummies positioned in the front seating positions were within allowable limits.[17] In 2000, NHTSA issued updates to FMVSS No. 208 to provide improved frontal crash protection for all occupants by means that include advanced air bag technology.[18] The upgraded standard required passenger cars to comply with a full frontal 56 km/h (35 mph) rigid barrier crash test by

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[15] Analysis of Rear Underride in Fatal Truck Crashes, 2008, DOT HS 811 652, August 2012.
[16] Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes, DOT HS 811 725, March 2013.
[17] Details of the crash test procedure, crash test dummies, and allowable limits of injury measures for the crash test dummies used in the tests is specified in FMVSS No. 208, "Occupant crash protection," 1996.
[18] 65FR 30680, Docket No. NHTSA-2000-7013, Final rule; Interim final rule, May 12, 2000.

ensuring that the injury measures of crash test dummies restrained in front seating positions were within allowable limits.

In 2005, Transport Canada issued upgraded rear impact protection requirements for trailers and semitrailers.[19] Given that passenger car models manufactured in 2005 and later in Canada are required to provide adequate occupant protection to restrained occupants in 56 km/h (35 mph) full frontal rigid barrier crashes, Transport Canada required rear impact guards to provide sufficient strength and energy absorption to prevent PCI of compact and subcompact passenger cars impacting the rear of trailers at 56 km/h (35 mph).[20]

CMVSS No. 223, "Rear impact guards," is applicable to trailers and semitrailers and has similar geometric specifications for rear impact guards as FMVSS No. 224. CMVSS No. 223 specifies quasi-static loading tests similar to those in FMVSS No. 223. However, CMVSS No. 223 replaced the 100,000 N quasi-static point load test at the P3 location with a 350,000 N uniform distributed load test on the horizontal member.[21] The guard is required to withstand this load and absorb at least 20,000 J of energy within 125 mm of deflection, and have a ground clearance after the test not exceeding 560 mm (22 inches). Through extensive testing,[22] Transport Canada demonstrated that these requirements would ensure that compact and subcompact passenger cars

[19] Canada Gazette Part II, Vol. 138, No. 20, 2004-10-06.
[20] Boucher, D. and Davis, D., "A Discussion on Rear Underride Protection in Canada," Informal Document, 127th WP.29, 25-28 June 2002, http://www.unece.org/fileadmin/DAM/trans/doc/2002/wp29/TRANS-WP29-127-inf05e.pdf.
[21] The load is applied uniformly across the horizontal member by a uniform load application structure with length that exceeds the distance between the outside edges of the vertical support of the horizontal member and which is centered on the horizontal member of the guard.
[22] Boucher, D, "Heavy Trailer rear underride crash tests performed with passenger vehicles," Technical Memorandum No. TMVS-0001, Transport Canada, Road Safety and Motor Vehicle Regulation Directorate, July 2000.

would not have passenger compartment intrusion when rear ending a CMVSS No. 223 compliant trailer at 56 km/h (35 mph).

The European standard, ECE R.58, "Rear underrun protective devices (RUPD); Vehicles with regard to the installation of an RUPD of an approved vehicle; Vehicles with regard to their rear underrun protection," specifies rear impact protection requirements for SUTs and trailers weighing more than 3,500 kg (7,716 lb). The dimensional and strength requirements for rear impact guards are similar to those specified in FMVSSs Nos. 223 and 224. ECE R.58 specifies that both during and after the quasi-static force application test, the horizontal distance between the rear of the rear impact guard and the rear extremity of the vehicle not be greater than 400 mm. However, ECE R.58 does not specify any energy absorption requirements. Table 1 presents a comparison of rear impact protection requirements in the U.S., Canada, and Europe.

Table 1: Comparison of rear impact protection requirements in U.S., Canada, and Europe

Requirement	U.S.	Canada	Europe
Applicable standards	FMVSS No. 223/224	CMVSS No. 223	ECE R.58
Applicable vehicles	Trailers	Trailers	Trailers and SUTs
Geometric requirements in unloaded condition			
Ground clearance	560 mm	560 mm	550 mm
Longitudinal distance from rear extremity	305 mm	305 mm	NA
Lateral distance from side of vehicle	100 mm	100 mm	100 mm
Quasi-static load tests			
Point load at P1 (outer edge of guard)	50 kN	50 kN	25 kN
Point load at P2 (center of guard)	50 kN	50 kN	25 kN
Point load at P3 (at the guard supports)	100 kN with no more than 125 mm displacement, 5,650 J energy absorption	NA	100 kN with distance of rear impact guard from vehicle rear extremity of 400 mm after test.

Distributed load	NA	350 kN with no more than 125mm displacement and 20,000 J energy absorption; guard ground clearance less than 560 mm after test.	NA

Table 1 suggests that rear impact protection for trailers in Canada is more stringent than that in the U.S and in Europe. However, rear impact protection requirements in Europe (ECE R.58) also apply to single unit trucks while FMVSS Nos. 223/224 and CMVSS No. 223 do not. Japan and Australia accept compliance of applicable trailers to ECE R.58.

IV. EVALUATION OF REAR IMPACT GUARDS BY IIHS

In 2010, IIHS completed a review of LTCCS data to evaluate fatal crashes into the rear of heavy vehicles.[23] IIHS conducted a review of 115 LTCCS cases of vehicle underride into the rear of heavy vehicles and documented the presence and type of underride guard and its performance in mitigating underride. Among the 115 cases reviewed, nearly half of the passenger vehicles had underride classified as severe or catastrophic. IIHS noted that for the cases involving trailers with rear impact guards, guard deformation or complete failure of the guard was frequent and commonly due to weak attachments, buckling of the trailer chassis, and bending of the lateral end of the guard under low overlap loading. IIHS stated that 57 percent of the heavy vehicles in the 115 LTCCS cases were excluded from FMVSS No. 224 requirements, among which a large proportion were wheels back vehicles and single unit trucks such as dump trucks. In its review of the LTCCS cases, IIHS was not able to estimate the crash speeds.

Following the review, in 2011, IIHS conducted an initial round of crash tests in which the front of a model year (MY) 2010 Chevrolet Malibu (a midsize sedan) impacted the rear of trailers equipped with an underride guard.[24] Three trailer/guard designs (2007 Hyundai, 2007 Vanguard, and 2011 Wabash trailers) were evaluated in various conditions. Each guard design was certified to FMVSS No. 223 requirements, and two (Vanguard and Wabash) were also certified to the more stringent CMVSS No. 223 requirements. A 2010 Chevrolet Malibu was first crashed into a trailer at 56 km/h (35 mph) with full overlap (the overlap refers to the portion of the Malibu's

[23] Brumbelow, M.L., Blanar, L., "Evaluation of US rear underride guard regulation for large trucks using real world crashes." Proceedings of the 54th Stapp Car Crash Conference, 119-31, 2010. Warrendale, PA, Society of Automotive Engineers.
[24] Brumbelow, M. L., "Crash Test Performance of Large Truck Rear Impact Guards," 22nd International Conference on the Enhanced Safety of Vehicles (ESV), 2011. https://www-esv.nhtsa.dot.gov/Proceedings/22/isv7/main.htm.

width overlapping the underride guard). If the rear impact guard of a trailer model was successful in preventing passenger compartment intrusion in the full overlap crash test, a new Malibu was crashed into a new trailer of the same model with 50 percent overlap of the Malibu. If the rear impact guard was successful in preventing PCI in this case as well, a third test was performed with only 30 percent overlap of the Malibu. The test results showed that the full overlap 56 km/h (35 mph) crash test of the Malibu with the guard of the Hyundai trailer (built to only FMVSS No. 223 requirements) resulted in catastrophic underride with PCI of the Chevrolet Malibu. The guard on the Vanguard trailer that was certified to the upgraded CMVSS No. 223 rear impact guard requirements did not prevent PCI in a 56 km/h (35 mph) crash test with 50 percent overlap of the Malibu because the attachments of the guard to the trailer failed. The rear impact guard on the Wabash trailer, also certified to meet CMVSS No. 223 requirements, prevented PCI in 35 mph crash tests with full and 50 percent overlap of the Malibu, but could not prevent PCI in the crash test with 30 percent overlap.

<u>Quasi-Static Load Testing of Rear Impact Guards</u>

IIHS conducted quasi-static load tests using a 203 mm square force application device (similar to that specified in FMVSS No. 223) at P1 and P3 locations of the horizontal member of the rear impact guards on the 2007 Hyundai, 2007 Vanguard and the 2011 Wabash trailers. The load was applied at a rate of 1.3 mm/sec until the force application device displaced 125 mm. Figure 5 shows the force-displacement curves for all three guards in the quasi-static test at the P3 location. Deformation patterns of the underride guards varied substantially in the quasi-static tests. In the test at P3 location on the Hyundai guard, a peak force of 163,000 N was achieved and then the vertical support member of the Hyundai guard was pulled slowly from some of the bolts attaching it to the fixture, whereas the vertical member itself deformed only minimally. In the test at P3 of the Vanguard guard, the vertical member flexed for the first 50 mm of loading achieving a peak load of 257,000 N and then the attachment bolts began to shear, causing the measured force to drop below that measured for the Hyundai later in the test. The Wabash guard reached its peak force of 287,000 N earliest, and then the vertical member began buckling near its attachment to the horizontal member. As the buckling continued, the rear surface of the guard eventually bottomed out against the diagonal gusset, causing the load to increase again late in the test. The Vanguard rear impact guard absorbed 14,000 J of energy, the Hyundai rear impact guard absorbed 13,900 J of energy and the Wabash guard absorbed 22,100 J of energy in the P3 point-load tests.

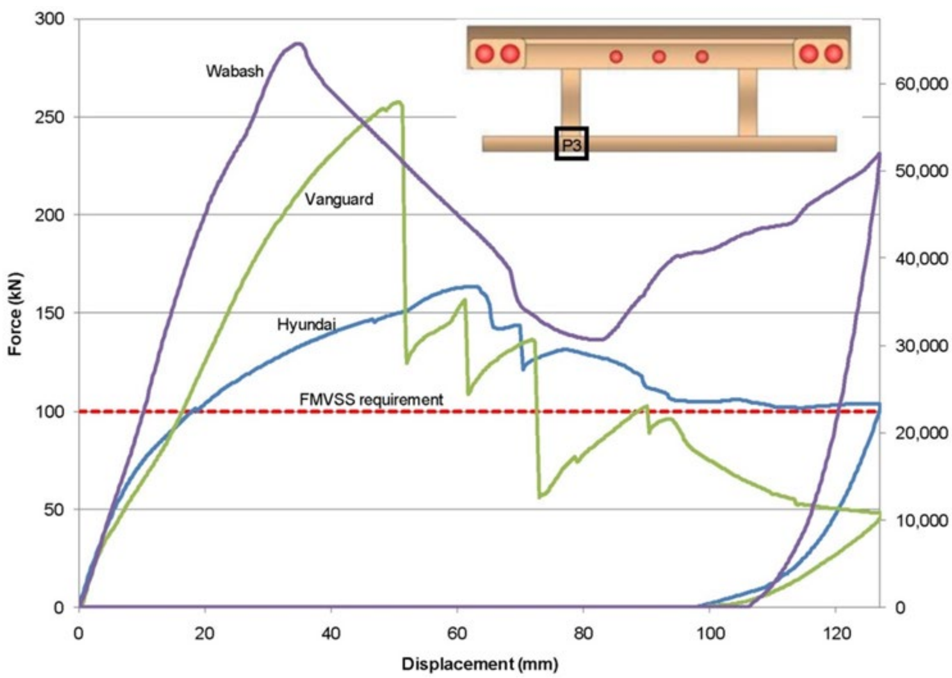

Figure 5: IIHS quasi-static test at P3 of the 2007 Hyundai, 2007 Vanguard, and 2011 Wabash trailer rear impact guards.

Table 2 summarizes the results of the initial five IIHS 56 km/h full-width crash tests. In the first test, the 2007 Hyundai guard was ripped from the trailer's rear cross member early in the crash, allowing the Malibu to underride the trailer almost to the B-pillar. The heads of both dummies were struck by the hood of the Malibu as it deformed against the rear surface of the trailer. Under the same test conditions, the main horizontal member of the 2011 Wabash guard bent forward in the center but remained attached to the vertical support members, which showed no signs of separating from the trailer chassis.

Table 2: Results of IIHS initial round of 56 km/h crash tests of the 2010 Chevrolet Malibu into the rear of trailers.

Conditions	Trailer	Guard performance	Underride	Max. longitudinal A-pillar deformation (cm)
100% overlap	2007 Hyundai	Attachments failed	Catastrophic	80
	2011 Wabash	Good	None	0
50% overlap	2007 Vanguard	Attachments failed	Severe	27
	2011 Wabash	End bent forward	None	6
30% overlap	2011 Wabash	End bent forward	Catastrophic	87

Table 3 summarizes the peak injury measures[25] of the 50th percentile male Hybrid III dummies (HIII 50M) in the front seating positions of the Malibu. For comparison purposes, Table 3 also presents the HIII 50M dummy injury measures in the full frontal 56 km/h rigid barrier crash test of the 2010 Chevrolet Malibu conducted as part of the New Car Assessment Program (NCAP). Head injury measures recorded by the dummies in the tests with severe underride were much higher than those reported for the Malibu's NCAP rigid wall test at the same speed. Chest acceleration and deflection measures were generally higher in tests without PCI than those with PCI. The frontal air bag deployed in the 100, 50, and 30 percent overlap crash tests of the Malibu into the rear of the Wabash trailer. The driver and passenger injury measures in the

[25] HII 50M dummy injury measures are those applicable to current model passenger vehicles as specified in FMVSS No. 208, see http://www.ecfr.gov/cgi-bin/text-idx?SID=77e2aab5d088f2e9b46d15606090f9b0&node=se49.6.571_1208&rgn=div8.

Malibu full width crash test with the Wabash trailer (where the guard prevented PCI) was similar to the injury measures in the Malibu NCAP frontal crash test.

Table 3: IIHS initial round of testing – Injury measures of dummies in front seating positions of the Malibu.

Test			Head Resultant acceleration (g)	Head Injury Criterion (15 ms)	Chest Resultant Acceleration (3 ms clip, g)	Chest Displacement (mm)	Left Femur Force (kN)	Right Femur Force (kN)
Full-width	Hyundai	*Driver*	128	754	21	19	0.3	0.3
		Passenger	107	557	14	20	0.1	0.1
	Wabash	*Driver*	54	328	36	38	2.2	1.2
		Passenger	50	319	36	37	2.3	1.8
	NCAP (rigid wall)	*Driver*	49	330	43	40	2.0	1.2
		Passenger	55	389	42	32	0.5	0.8
50% overlap	Vanguard	*Driver*	109	254	14	20	2.2	0
	Wabash	*Driver*	36	160	25	33	3.7	0.9
30% overlap	Wabash	*Driver*	130	880	37	16	0.6	0.1

Following the preliminary crash tests in 2011, IIHS conducted similar crash tests of a 2010 Chevrolet Malibu sedan with eight additional 2012 and 2013 model year trailers from various manufacturers, including newly redesigned Hyundai and Vanguard models. All guards in this round of testing were not only certified as complying with FMVSS No. 223 but were also certified to CMVSS No. 223. Table 4 presents certification data from trailer manufacturers showing compliance with CMVSS No. 223. Only one trailer manufacturer utilized the option in CMVSS No. 223 to test using half the guard with a point load force application of 175,000 N at P3, while the other rear impact guards were certified with the uniform distributed quasi-static load application of 350,000 N on the full guard. During each of the crash tests, all the rear impact guards tested met the requirement that the ground clearance of the guard after the test not exceed 560 mm.

Table 4: Trailer manufacturers' certification data (CMVSS No. 223) of rear impact guards

	P1	P2	Uniform Distributed Load	Uniform (1/2 of guard)
Requirement :	50 kN	50 kN	350 kN / 20 kJ	175 kN / 10 kJ
Strick	50.7	50.5		233.4 kN / 18.9 kJ
Vanguard	*50	*50	370.1 kN / 25.3 kJ	
Hyundai/ Translead	51.6	53.6	367.5 kN / 37.5 kJ	
Stoughton	53.7	56	404.6 kN @ 101.6mm/ 31.2 kJ	
Great Dane	*50	*50	386.7 kN @ 125mm / 28.8 kJ	
Manac	55.1	55.8	37.5 kN / 25.0 kJ	

* Loaded until 50 kN reached

The ground clearance of the bumper (vertical distance of the bottom of the bumper from the ground) of the 2010 Chevrolet Malibu is 403 mm and the vertical height of the bumper is 124 mm. Therefore, the Malibu bumper is located at a vertical height between 403 mm and 527 mm above the ground with its centerline located 465 mm above ground. The vertical height of the top of the engine block from the ground is 835 mm. The ground clearance of the horizontal member of each rear impact guard ranged between 400 mm and 498 mm (Table 5).

Table 5: Trailer guard ground clearance

Trailer	Guard Ground Clearance (mm)
2011 Wabash	445
2012 Manac	498
2012 Stoughton	477
2013 Great Dane	400
2012-2013 Hyundai	409
2013 Strick	413
2013 Utility	455
2013 Vanguard	452

Table 6, Table 7, and Table 8 present the extent of underride, deformation of the Malibu, performance of the guard, and whether there was passenger compartment intrusion in the 56 km/h frontal impact crash tests of the Malibu into the rear of trailers with full overlap, 50 percent overlap, and 30 percent overlap of the Malibu, respectively. All the rear impact guards on the trailers that were certified to CMVSS No. 223 were able to prevent passenger compartment intrusion in full overlap crashes. In the tests with 50 percent overlap of the Malibu, all the guards except the 2013 Vanguard was able to prevent PCI. The Vanguard rear impact guard failed at the attachments where the bolts sheared off during the crash resulting in PCI of the Malibu. All the rear impact guards tested except the 2012 Manac guard were not able to prevent PCI in the 30 percent offset crash tests of the Malibu.

Table 6: Rear impact guard performance in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with full overlap with the guard

2010 Chevrolet Malibu Into Trailer - Crash Test Results (100% Overlap @ 56 km/h)								
Trailer	**Guard Performance**			**PCI (due to underride)**	**Max. longitudinal deformation (cm)**		**Underride* (cm)**	**Peak Impulse (g at ms)**
	Overall	**Fastener Breakage**	**Material Failure**		**A-Pilar**	**Roof**		
2011 Wabash	Good	None	None	None	0	0	99	30g at 82ms
2012 Manac	Good	Some	None	None (windshield shattered)	0	0	135	18g at 101ms
2012 Stoughton	Good	None	None	None	0	0	117	25g at 85ms
2013 Great Dane	Good	None	None	None	0	0	96	21g at 109ms
2012 Hyundai	Good	None	None	None	0	0	92	23g at 49ms
2013 Strick	Good	None	None	None (windshield shattered)	0	0	121	26g at 93ms
2013 Utility	Good	None	None	None	0	0	99	30g at 47ms
2013 Vanguard	Good	Some	Some Tearing	None (windshield shattered)	0	0	94	34g at 80ms

**Calculated by relative center of mass positions collected at initial impact and maximum displacement.*

Table 7: Rear impact guard performance in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with 50 percent overlap with the guard

2010 Chevrolet Malibu Into Trailer - Crash Test Results (50% Overlap @ 56 km/h)								
Trailer	**Guard Performance**			**PCI (due to underride)**	**Max. longitudinal deformation (cm)**		**Underride* (cm)**	**Peak Impulse (g at ms)**
	Overall	**Fastener Breakage**	**Material Failure**		**A-Pilar**	**Roof**		
2011 Wabash	Good	None	None	None (windshield shattered)	6	None	135	19g at 95ms
2012 Manac	Good	None	None	None (windshield shattered)	0	None	129	19g at 50ms
2012 Stoughton	Good	None	None	None (windshield shattered)	11	None	147	14g at 66ms
2013 Great Dan	Good	Some	None	None (windshield shattered)	0	None	152	14g at 97ms
2013 Hyundai	Good	None	None	None (windshield shattered)	0	None	116	16g at 49ms
2013 Strick	Good	None	None	None (windshield shattered)	15	None	146	15g at 80ms
2013 Utility	Good	None	None	None (windshield shattered)	5	None	139	18g at 58ms
2013 Vanguard	Fail (full detachment)	Extensive	Extensive	Trailer rear sill directly contacted dummy head	146	Extensive	205	17g at 48ms

*Calculated by relative center of mass positions collected at initial impact and maximum displacement.

Table 8: Rear impact guard performance in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with 30 percent overlap with the guard

2010 Chevrolet Malibu Into Trailer - Crash Test Results (30% Overlap @ 56 km/h)								
Trailer	**Guard Performance**			**PCI (due to underride)**	**Max. longitudinal deformation (cm)**		**Underride* (cm)**	**Peak Impulse (g at ms)**
	Overall	**Fastener Breakage**	**Material Failure**		**A-Pilar**	**Roof**		
2011 Wabash	Fail	None	None	Trailer rear sill directly contacted dummy head	87	33	242	Not Reported
2012 Manac	Good	Some	None	None (windshield shattered)	5	None	160	17g at 66ms
2012 Stoughton	Fail	None	None	Trailer rear sill directly contacted dummy head	89	Extensive	218	12g at 144ms
2013 Great Dan	Fail	None	None	Trailer rear sill directly contacted dummy head	111	Extensive	244	18g at 151ms
2013 Hyundai	Fail	None	None	Trailer rear sill directly contacted dummy head	112	Extensive	242	18g at 200ms
2013 Strick	Fail	None	None	Trailer rear sill directly contacted dummy head	117	Extensive	245	16g at 202ms
2013 Utility	Fail	None	None	Trailer rear sill directly contacted dummy head	123	Extensive	237	10g at 225ms
2013 Vanguard	*Not tested due to failure of 50% overlap test at 56 km/h*							
**Calculated by relative center of mass positions collected at initial impact and maximum displacement.*								

Table 9, presents the injury measures of crash test dummies (HIII-50M) in the driver and front passenger seating positions in 56 km/h crash tests conducted by IIHS with 100 percent overlap of the 2010 Malibu with rear impact guard. Table 10, and Table 11 present the injury measures for the HIII-50M in the driver position in 56 km/h crash tests with 50 percent and 30 percent overlap of the 2010 Malibu with the rear impact guard, respectively.

The frontal air bags deployed in all the 100 percent and 50 percent overlap crash tests of the Malibu into the rear of 2011-2013 model year trailers. The air bag deployed in all the 30 percent overlap crash tests of the Malibu into the rear of 2011-2013 model year trailers except for the tests into the rear of the 2012 Hyundai, 2013 Great Dane, and 2013 Strick trailers. When the Malibu experienced PCI in a crash test, the dummy injury measures, specifically the head injury criteria (HIC) and the neck injury criteria (Nij), generally exceeded the allowable Injury

Assessment Reference Values (IARV) of 700 and 1.0, respectively, regardless of whether the air bag deployed.[26] When PCI was prevented by the rear impact guard, the accelerations on the vehicle are higher, resulting in higher chest deflection measures. Although the chest deflection measures were higher in these crash tests, indicating higher acceleration loads on the dummy, they were well within the allowable limits.

Table 9: Dummy injury measures in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with full overlap with the rear impact guard

2010 Chevrolet Malibu Into Trailer - Driver HIII 50M Injury Measures (100% overlap @ 56 km/h)								
	Driver				Passenger			
Trailer	HIC-15 (700)	Max N_{ij} (1.00)		Rib Compression (63mm)	HIC-15 (700)	Max N_{ij} (1.00)		Rib Compression (63mm)
2011 Wabash	328	0.33	Tension-Flexion	38	319	0.35	Compression-Extension	37
2012 Manac	206	0.28	Tension-Flexion	35	143	0.38	Tension-Flexion	37
2012 Stoughton	267	0.37	Tension-Flexion	40	265	0.37	Tension-Flexion	37
2013 Great Dane	49	0.22	Tension-Extension	32	65	0.16	Compression-Extension	35
2012 Hyundai	54	0.22	Tension-Flexion	39	110	0.20	Tension-Flexion	35
2013 Strick	107	0.26	Tension-Flexion	39	125	0.32	Tension-Flexion	37
2013 Utility	130	0.25	Tension-Flexion	37	173	0.33	Tension-Flexion	33
2013 Vanguard	212	0.31	Tension-Flexion	35	237	0.40	Tension-Flexion	31

Table 10: Dummy injury measures in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with 50 percent overlap with the rear impact guard

2010 Chevrolet Malibu Into Trailer- Driver HIII 50M Injury Measures (50% overlap @ 56 km/h)			
Trailer	HIC-15 (700)	Max N_{ij} (1.00)	Rib Compression (63mm)
2011 Wabash	101	0.23 Tension-Flexion	33
2012 Manac	38	0.13 Tension-Flexion	29
2012 Stoughton	65	0.17 Tension-Flexion	25
2013 Great Dane	78	0.24 Tension-Flexion	28
2013 Hyundai	155	0.35 Compression-Extension	32
2013 Strick	163	0.18 Tension-Flexion	27
2013 Utility	37	0.17 Tension-Flexion	30
2013 Vanguard	1954	0.65 Compression-Flexion	21

[26] Except for the neck injury measure in the 50 percent overlap crash with the Vanguard trailer, for which the Nij was 0.65.

Table 11: Dummy injury measures in frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers with 30 percent overlap with the rear impact guard

2010 Chevrolet Malibu Into Trailer - Driver HIII 50M Injury Measures (30% overlap @ 56 km/h)				
Trailer	**HIC-15 (700)**	**Max N_{ij} (1.00)**		**Rib Compression (63mm)**
2011 Wabash	880	1.16	Tension-Extension	16
2012 Manac	58	0.28	Tension-Flexion	31
2012 Stoughton	9069	1.23	Tension-Extension	14
2013 Great Dane	8708	2.45	Tension-Extension	16
2013 Hyundai	7346	1.94	Tension-Extension	19
2013 Strick	7742	2.38	Compression-Flexsion	19
2013 Utility	7415	2.55	Tension-Extension	17
2013 Vanguard	*Not tested due to failure of 50% overlap test at 56 km/h*			

Summary of the IIHS Test Data

The results, summarized in Table 12 and Table 13, show that the trailer guard designed only to be compliant with the current FMVSS No. 223 was unable to withstand an impact of the Malibu at 56 km/h (35 mph) and the crash test resulted in PCI in the Malibu. The tests also demonstrated that trailers that are designed to meet the Canadian standard, CMVSS No. 223, were able to mitigate passenger compartment intrusion in 35 mph impacts of the Malibu with full and 50 percent overlap with the rear impact guard. However, seven of the eight rear impact guards compliant with the Canadian standard could not prevent passenger compartment intrusion when only 30 percent of the Malibu front end engaged the rear impact guard.

In the quasi-static test at P3 location of the Vanguard rear impact guard, the attachments bolts sheared but still were able to meet the load and energy absorption requirements of CMVSS No. 223. However, in the 35 mph crash test with 50 percent overlap of the 2010 Malibu with the Vanguard trailer, the guard bolts sheared resulting in PCI of the Malibu. These results suggest that the integrity of the attachment hardware in the quasi-static test may provide valuable information on the dynamic performance of the guard in crashes.

In the tests where there was no PCI of the Malibu, the injury measures of the restrained test dummies in the Malibu were below injury threshold levels. When PCI was prevented by the rear impact guard, it resulted in generally higher chest injury measures, although well within the allowable limits.

When the Malibu sustained PCI, the head and neck injury measures were generally greater than the allowable threshold levels indicating high risk of serious head and neck injuries, regardless of whether the air bag deployed. The IIHS tests showed that when PCI occurs, air bag deployment does not improve injury outcome.

Table 12. Occurrence of PCI in 35 mph crash tests (conducted by IIHS) of the 2010 Chevrolet Malibu into the rear of trailers.

Trailer Model	Designed to	Full Width	50% overlap	30% overlap
2011 Wabash	CMVSS No. 223	None	None	Yes
2012 Manac	CMVSS No. 223	None	None	None
2012 Stoughton	CMVSS No. 223	None	None	Yes
2013 Great Dane	CMVSS No. 223	None	None	Yes
2012 - 2013 Hyundai	CMVSS No. 223	None	None	Yes
2013 Strick	CMVSS No. 223	None	None	Yes
2013 Utility	CMVSS No. 223	None	None	Yes
2013 Vanguard	CMVSS No. 223	None	Yes*	N/A
2007 Hyundai	FMVSS No. 224	Yes	N/A**	N/A

* The attachment of the guard to the trailer failed during impact.
** Since the guard was unable to withstand the loads in the first test, the second and third tests were not conducted.

Table 13: Summary of IIHS's frontal impact crash tests of a 2010 Chevrolet Malibu into the rear of trailers

Trailer	Compliance	Overlap/Underride		Injury			
	P_3 Peak Force (kN) Energy Absorbed (kJ)	Overlap	Underride* (cm)	HIC-15 (700)	Max N_{ij}** (1.00)		Rib Compression (63mm)
2011 Wabash	287 kN / 22.1 kJ (point load)	100%	99	328	0.35	Compression-Extension	37
		50%	135	101	0.23	Tension-Flexion	33
		30%	242	880	1.16	Tension-Extension	16
2012 Hyundai	367.5 kN / 37.5 kJ (distributed load)	100%	92	54	0.2	Tension-Flexion	35
		50%	116	155	0.35	Compression-Extension	32
		30%	242	7346	1.94	Tension-Extension	19
2012 Manac	361.8 kN / 25.0 kJ (distributed load)	100%	135	206	0.38	Tension-Flexion	37
		50%	129	38	0.13	Tension-Flexion	29
		30%	160	58	0.28	Tension-Flexion	31
2012 Stoughton	404.6 kN / 31.2 kJ (distributed load)	100%	117	267	0.37	Tension-Flexion	37
		50%	147	65	0.17	Tension-Flexion	25
		30%	218	9069	1.23	Tension-Extension	14
2013 Great Dane	386.7 kN / 28.8 kJ (distributed load)	100%	96	49	0.16	Compression-Extension	35
		50%	152	78	0.24	Tension-Flexion	28
		30%	244	8708	2.45	Tension-Extension	16
2013 Strick	233.4 kN / 18.9 kJ (½ guard)	100%	121	107	0.32	Tension-Flexion	37
		50%	146	163	0.18	Tension-Flexion	27
		30%	245	7742	2.38	Compression-Flexsion	19
2013 Utility	Not Available	100%	99	130	0.33	Tension-Flexion	33
		50%	139	37	0.17	Tension-Flexion	30
		30%	237	7415	2.55	Tension-Extension	17
2013 Vanguard	370.1 kN / 25.3 kJ (distributed load)	100%	94	212	0.4	Tension-Flexion	31
		50%	205	1954	0.65	Compression-Flexsion	21
		30%	*Not tested due to failure of 50% overlap test at 56 km/h*				
2007 Hyundai	163 kN / 13.9 kJ Point Load	100%	catastrophic	754		NA	19
		50%	*Not tested due to failure of 100% overlap test at 56 km/h*				
		30%	*Not tested due to failure of 100% overlap test at 56 km/h*				

*Calculated by relative center of mass positions collected at initial impact and maximum displacement.

**For 100% overlap only the driver dummy is presented for comparison to 50% and 30% overlap scenarios.

V. SAFETY PROBLEM

A. 2013 NHTSA/UMTRI Study

In 2009, the agency initiated an in-depth field analysis for assessing the extent of the underride and for characterizing the factors in rear end impacts that result in truck/trailer underride to help direct potential changes to our safety requirements that would reduce severe passenger vehicle underride in truck and trailer rear end impacts.

The first phase of the field analysis was published in 2012[27] and the final report of the analysis of 2008 and 2009 Trucks in Fatal Accidents (TIFA) along with supplemental information was published in March 2013.[28] The TIFA database contains records for all the medium and heavy trucks that were involved in fatal traffic crashes in the 50 U.S. states and the District of Columbia. TIFA data, collected by UMTRI, contains additional detail beyond what the FARS contains. The agency contracted UMTRI to collect supplemental data for the years 2008 and 2009 as part of the TIFA survey. The supplemental data included the rear geometry of the trucks and trailers, type of equipment at the rear of the trailer if any, whether a rear impact guard was present, and the type of rear impact guard and standards it complied with. For trucks and trailers involved in fatal rear impact crashes, additional information was collected on the extent of underride, damage to the rear impact guard, impact speeds, and whether the collision was offset or fully engaged the guard.

[27] Analysis of Rear Underride in Fatal Truck Crashes, DOT HS 811 652, August 2012. Also available at https://www.nhtsa.gov/sites/nhtsa.gov/files/811652.pdf, last accessed on August 13, 2021.
[28] Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes, DOT HS 811 725, March 2013. Also available at https://www.nhtsa.gov/sites/nhtsa.gov/files/811725.pdf, last accessed on August 13, 2021.

Average annual estimates were derived from the 2008 and 2009 TIFA data files along with supplemental information collected in the 2013 UMTRI study. The agency's review of these data files found that there are 3,762 trucks and trailers involved in fatal crashes annually among which, trailers accounted for 67 percent, SUTs for 29 percent, tractor alone for 1.8 percent, and the remaining 2.5 percent were unknown.[29] About 489 trucks and trailers are struck in the rear in fatal crashes, constituting about 13 percent of all trucks and trailers in fatal crashes (Figure 6). Among rear impacted trucks and trailers in fatal crashes, 68 percent are trailers, 31 percent are SUTs, and 1 percent are tractors alone.

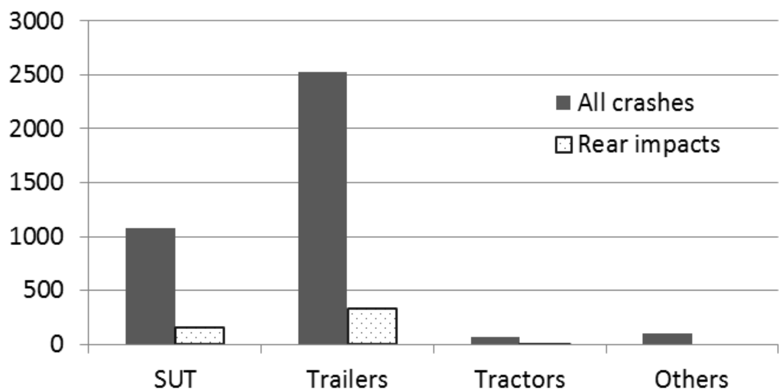

Figure 6: Annual number of trucks and trailers involved in fatal crashes (in all crash types and in rear impact crashes only).

B. Rear Impact Guard Presence on SUTs and Trailers

UMTRI evaluated the rear geometry of all the trailers and SUTs involved in fatal crashes in the 2008 and 2009 TIFA data and estimated whether the rear geometry met the specifications for requiring a rear impact guard per FMVSS No. 224 for trailers and FMCSR 393.86(b) for SUTs.[30]

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[29] Bobtail and tractor/other configurations were combined into "others" category) and tractor/trailer and straight trucks with trailer were combined into "trailers" category.

[30] UMTRI only evaluated the rear geometry to determine whether a single unit truck required a rear impact guard. It did not determine how the truck was operated and whether it was used in interstate commerce.

Based on this evaluation, UMTRI estimated that 65 percent of trailers required rear impact guards per FMVSS No. 224 (Table 14). Among the 35 percent of trailers that were excluded from FMVSS No. 224 requirements, 26 percent were wheels back trailers,[31] 2 percent were low chassis vehicles,[32] 1 percent had equipment in the rear, and 5 percent were exempt vehicles because of type of cargo or operation. UMTRI estimated that 38 percent of the SUTs involved in fatal crashes were required to have rear impact guards (based on the truck rear geometry according to FMCSA 393.86(b)), while only 18 percent were equipped with them (Table 14). It is likely that the remaining 20 percent of the SUTs that required a guard but did not have one were not used in interstate commerce. Among the 62 percent of SUTs that were exempt from installing rear impact guards, 27 percent were wheels back SUTs,[33] 12 percent were low chassis SUTs,[34] 2 percent were wheels back and low chassis SUTs, and 21 percent had equipment in the rear that interfered with rear impact guard installation (Table 14).

Table 14: Rear geometry of trailers and SUTs and whether a rear impact guard was required according to UMTRI's evaluation of trucks and trailers involved in fatal crashes in the 2008-2009 TIFA data files.

Type of Rear Geometry	Percentage of Trailers	Percentage of SUTs
Rear Impact Guard Required		
Guard present	65%	18%
Guard not present	0%	20%
Rear Impact Guard Not Required		
Excluded vehicle	6%	8%
Wheels back vehicle	26%	27%
Low chassis vehicle	2%	12%
Wheels back and low chassis vehicle	0%	2%
Equipment	1%	21%

[31] Wheels back trailers according to FMVSS No. 224 is where the rearmost axle is permanently fixed and is located such that the rearmost surface of tires is not more than 305 mm forward of the rear extremity of the vehicle.
[32] Low chassis trailers, are those where the chassis extends behind the rearmost point of the rearmost tires and the vertical distance between the rear bottom edge of the chassis assembly and ground is less than or equal to 560 mm.
[33] Wheels back SUTs according to FMCSR 393.86(b) is where the rearmost axle is permanently fixed and is located such that the rearmost surface of tires is not more than 610 mm forward of the rear extremity of the vehicle.
[34] Low chassis SUTs according FMCSR 393.86(b) is where the rearmost part of the vehicle includes the chassis and the vertical distance between the rear bottom edge of the chassis assembly and the ground is less than or equal to 762 mm (30 inches).

Since the data presented in Table 14 takes into consideration all trucks and trailers involved in all types of fatal crashes in 2008 and 2009 (total of 2,287 trucks and 5,236 trailers), it is reasonable to assume that the percentage of trucks and trailers with and without rear impact guards in Table 14 is representative of that in the truck and trailer fleet.

C. Light Vehicle Fatal Crashes into the Rear of Trailers and SUTs

Among the types of vehicles that impacted the rear of trucks and trailers, 73 percent were light vehicles, 18 percent were large trucks, 7.4 percent were motorcycles, and 1.7 percent were other/unknown vehicle types. UMTRI categorized passenger cars, compact and large sport utility vehicles, minivans, large vans (e.g., Econoline and E150-E350), compact pickups (e.g., S-10, Ranger), and large pickups (e.g., Ford F100-350, Ram, Silverado) as light vehicles. Since we do not expect trucks and buses to underride other trucks in rear impacts, the data presented henceforth only apply to light vehicles impacting the rear of trucks and trailers.

D. Underride Extent in Fatal Crashes of Light Vehicles into the Rear of Trailers and SUTs

In the UMTRI study of 2008 and 2009 TIFA data, survey respondents estimated the amount of underride in terms of the amount of the striking vehicle that went under the rear of the truck. The categories were “no underride,” “less than halfway up the hood,” “more than halfway but short of the base of the windshield,” and “at or beyond the base of the windshield.” When the extent of underride is “at or beyond the base of the windshield,” there is PCI that could result in serious injury to occupants in the vehicle. Rear impacts into trailers and trucks could result in some level of underride without PCI since the front end of the vehicle crushes and rear impact guards deform to some extent during impact. Rear impacts into the rear of heavy vehicles without PCI may not pose additional crash risk to light vehicle occupants than that in crashes with another light vehicle at similar crash speeds.

About 319 light vehicle fatal crashes into the rear of trucks and trailers occur annually. UMTRI determined that about 36 percent (121) of light vehicle impacts into the rear of trucks and trailers resulted in PCI. Among fatal light vehicle impacts, the frequency of PCI was greatest for passenger cars and sport utility vehicles (40 and 41.5 percent, respectively) and lowest for large vans and large pickups (25 and 26 percent respectively), as shown in Figure 7. It is likely that large vans and large pickups did not actually underride the truck or trailer but sustained PCI because of the high speed of the crash and/or because of very short front end of the vehicle.

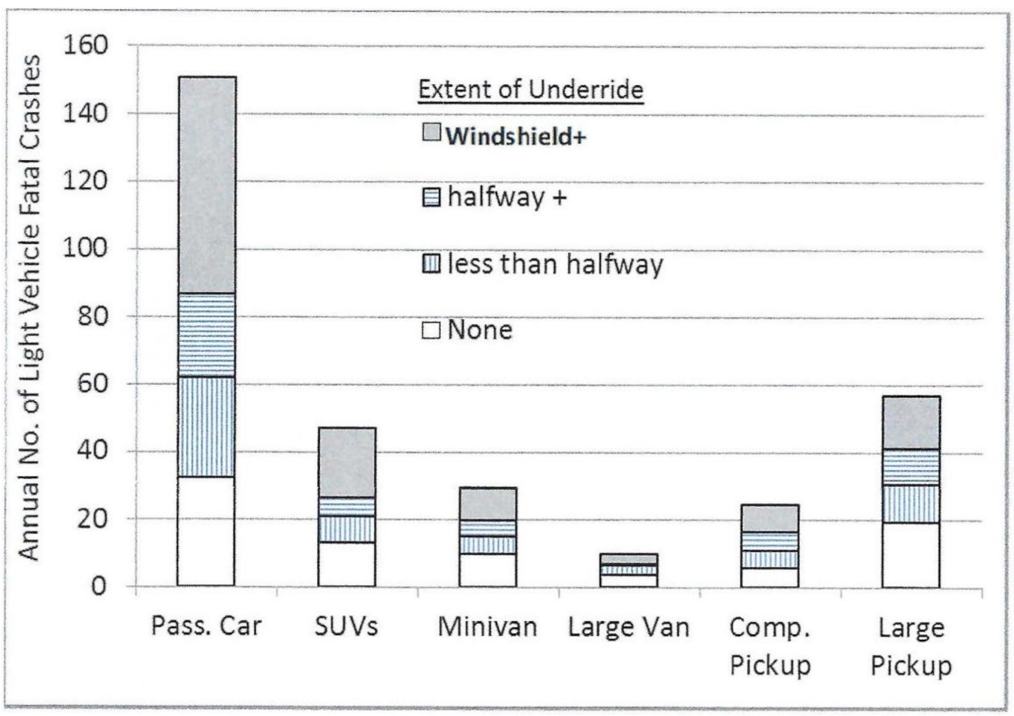


Figure 7: Annual light vehicle fatal crashes into the rear of trucks and trailers by type of light vehicle and extent of underride[35] (2008-2009 TIFA UMTRI study)

Fatal light vehicle crashes into the rear of trucks and trailers was further examined by the type of truck and trailer struck and whether a guard was required (according to FMVSS No. 224 for trailers and FMCSR 393.86(b) for SUTs) (Figure 8 and Figure 9).

Among fatal light vehicle crashes into trucks and trailers, 36 percent are into trailers with guards, 25 percent into SUTs without any guards, 7 percent into SUTs with guards, 14 percent into wheels back trailers, 5 percent into exempt trailers (due to equipment in rear, type of operation, low bed), and 14 percent were other types of trucks (Figure 8).

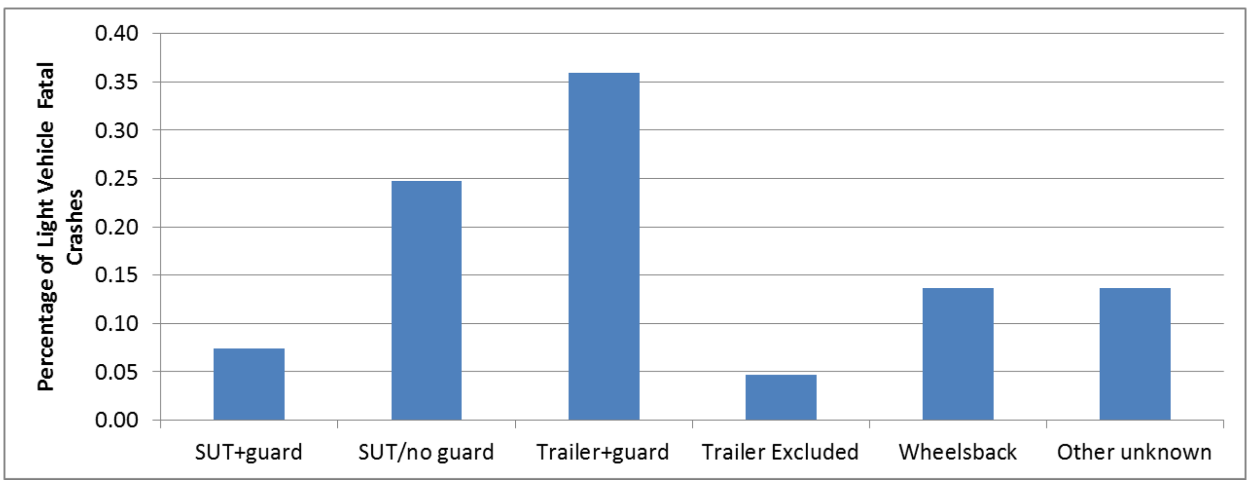
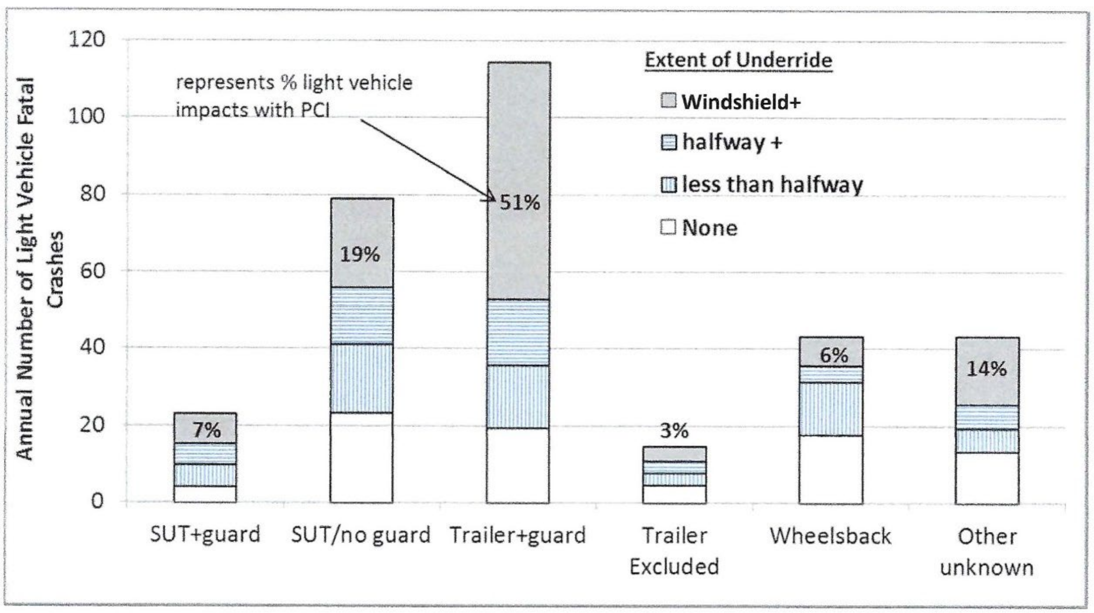


Figure 8: Percentage of light vehicle fatal crashes into the rear of trucks and trailers (2008-2009 TIFA UMTRI Study)

[35] The extent of underride in this and subsequent figures and tables means the following: None means "no underride"; less than halfway means "underride extent of less than halfway up the hood"; halfway+ means "underride extent at or more than halfway up the hood but short of the base of the windshield"; windshield+ means "extent of underride at or beyond the base of the windshield" or PCI.

Among these light vehicle fatal crashes, 121 result in PCI among which 51 percent occur in impacts with trailers with guards, 19 percent in impacts with SUTs without guards, 7 percent with SUTs with guards, 6 percent with wheels back trailers, and 3 percent with excluded trailers (Figure 5).[36] Annually, there are 62 light vehicle impacts with PCI into the rear of trailers with guards, 11 into the rear of trailers that are excluded from requiring rear impact guards (wheels back, low chassis, type of cargo or operation), 8 into the rear of SUTs with guards, 23 into the rear of SUTs without guards, and 18 into the rear of trailers and trucks of unknown configuration (Figure 9).



	Light vehicle fatal crashes into the rear of trailers & SUTs		Light vehicle fatal crashes into the rear of trailers & SUTs resulting in PCI	
	Annual #	Percentage	Annual #	Percentage
SUT+guard	24	7%	8	7%

[36] Underride extent was determined for 303 light vehicles, about 95 percent of the 319 light vehicle impacts into the rear of trucks and trailers. Unknown underride extent was distributed among known underride levels.

SUT/no guard	79	25%	23	19%
Trailer+guard	115	36%	62	51%
Trailer Exempt	15	5%	4	3%
Wheels back	44	14%	7	6%
Other unknown	44	14%	18	14%
Total	319		121	

Figure 9: Annual light vehicle fatal crashes into the rear of trailers and SUTs by type of truck/trailer and extent of underride

It is noteworthy that trailers with guards represent 36 percent of annual light vehicle fatal rear impacts but represent 51 percent of annual light vehicle fatal rear impacts with PCI. On the other hand, SUTs (with and without guards) represent 32 percent of annual light vehicle fatal rear impacts but represent 26 percent of annual light vehicle fatal rear impacts with PCI. The field data suggests that there are more light vehicle fatal impacts into the rear of trailers than SUTs and a higher percentage of fatal light vehicle impacts into the rear of trailers result in PCI than those into the rear of SUTs.

E. Relative Speed of Light Vehicle Fatal Crashes into the Rear of Trailers and SUTs

Using information derived by reviewing police crash reports,[37] UMTRI estimated the relative speed of fatal light vehicle crashes into the rear of trucks and trailers. Relative velocity was computed as the resultant of the difference in the truck (trailer) velocity and the striking vehicle velocity and could only be estimated for about 30 percent of light vehicle fatal crashes into the rear of trailers and SUTs. Most of the crashes (with known relative velocity) were at very high speeds and many were unsurvivable. The mean relative velocity at impact into the rear of trailers and SUTs was estimated at 44 mph. Among fatal light vehicle impacts into the rear of

[37] Information included police estimates of travel speed, crash narrative, crash diagram, and witness statements. The impact speed was estimated from the travel speed, skid distance, and an estimate of the coefficient of friction.

trailers that resulted in PCI, 74 percent were with relative velocity greater than 56 km/h (35 mph) (Figure 10). Among the remaining 26 percent fatal light vehicle impacts into the rear of trailers, 21 percent were trailers with guards and 5 percent were trailers excluded from FMVSS No. 224 requirements. Among fatal light vehicle crashes into the rear of SUTs that resulted in PCI, 70 percent were with relative velocity greater than 56 km/h (35 mph). Among the remaining 30 percent of fatal light vehicle crashes into the rear of SUTs, 3 percent of the SUTs had rear impact guards, 10 percent of the SUTs could be required to have a guard based on rear geometry but did not have a guard, 3 percent were excluded from requiring a guard (wheels back, low chassis vehicles), and 14 percent had equipment in the rear precluding rear impact guards.

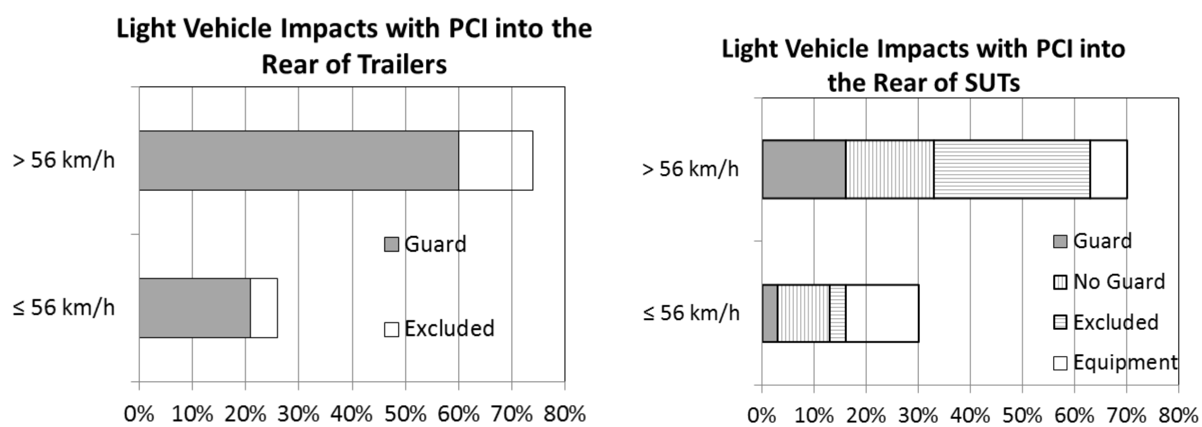


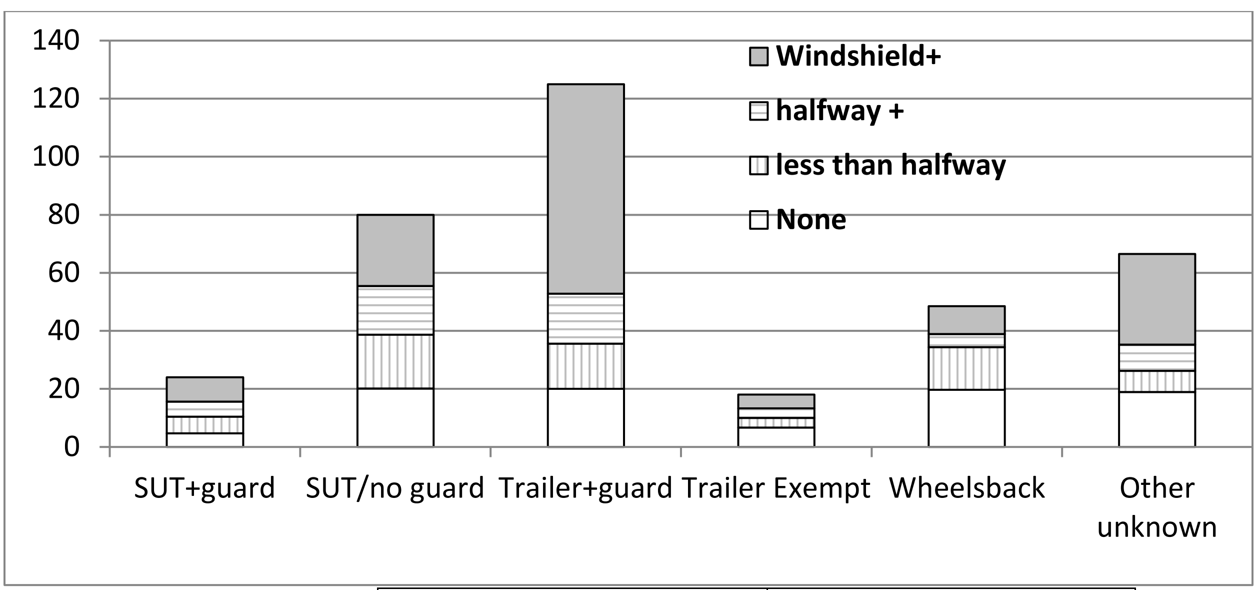
Figure 10: Percentage of fatal light vehicle crashes into the rear of trailers and SUTs that resulted in passenger compartment intrusion - categorized by the relative speed of the crash, presence of rear impact guard, exclusion, and equipment in rear of vehicle

F. Fatalities Associated with Light Vehicle Crashes into the Rear of Trailers and SUTs

There are about 362 light vehicle occupant fatalities annually due to impacts into the rear of trailers and SUTs. Of these fatalities, 192 (53 percent) are in crashes with trailers, 104 (29 percent) are in crashes with SUTs, and 66 (18 percent) are in crashes with an unknown truck type (Figure 11).

Among the 192 light vehicle occupant fatalities resulting from impacts with the rear of trailers, 125 occurred in crashes with trailers with rear impact guards while the remaining 67 were in crashes to trailers without guards (trailers excluded from requiring rear impact guards). PCI was associated with 86 annual light vehicle occupant fatalities resulting from impacts into the rear of trailers; 72 of these fatalities were in impacts with trailers with rear impact guards and 14 with trailers without guards (see Figure 11).

Among the 104 light vehicle occupant fatalities resulting from crashes with the rear of SUTs, 80 occurred in crashes with SUTs without rear impact guards while the remaining 24 were in crashes to SUTs with guards. PCI was associated with 33 annual light vehicle occupant fatalities resulting from crashes into the rear of SUTs; 25 of these fatalities were in impacts with SUTs without rear impact guards and 8 with SUTs with guards (see Figure 11).



	Light vehicle fatalities in crashes into the rear of trailers & SUTs		Light vehicle fatalities in PCI crashes into the rear of trailers & SUTs	
	Annual #	Percentage	Annual #	Percentage
SUT+guard	24	7%	8	7%
SUT/no guard	80	25%	25	21%
Trailer+guard	125	39%	72	59%
Trailer Exempt	18	6%	5	4%
Wheels back	48	15%	9	7%
Other unknown	67	21%	31	26%
Total	362		150	

Figure 11: Annual light vehicle occupant fatalities in impacts into the rear of SUTs and trailers categorized by the geometry of the rear of the impacted vehicle and the extent of underride

Among light vehicle occupant fatalities in impacts into the rear of trailers and SUTs, more than 60 percent were in vehicles with no underride, underride less than halfway or underride up to the hood without PCI. It is likely these fatalities are occurring due to occupants being unrestrained, other occupant characteristics (e.g., age), and other crash circumstances. Additionally, as shown in Figure 10, only 26 percent and 30 percent of light vehicle crashes with PCI into the rear of trailers and SUTs, respectively, had a relative velocity less than or equal to 56 km/h (35 mph). Since currently manufactured light vehicles are tested to ensure adequate occupant crash protection to restrained dummies in a 56 km/h (35 mph) rigid barrier frontal crash test, light vehicle occupant fatalities in impacts into the rear of trucks and trailers at speeds less than or equal to 35 mph that resulted in PCI may be preventable if intrusion into the passenger compartment was mitigated.[38]

[38] Some of the fatalities associated with PCI shown in Figure 6 may also be due to unrestrained status of the occupant.

VI. BENEFITS

For estimating the benefits of requiring applicable trailers to be equipped with CMVSS No. 223 certified guards, NHTSA estimated the annual number of fatalities and injuries in light vehicle crashes with PCI into the rear of trailers. In non-PCI crashes into the rear of trailers, the IIHS test data indicate that the passenger vehicle's restraint system, when used, would mitigate injury. Therefore, non-PCI crashes were not considered as part of the target population for estimating benefits.

Fatal injuries: Annually, there are 72 light vehicle occupant fatalities in crashes into the rear of trailers with rear impact guards with PCI. About 26 percent of fatal light vehicle crashes into the rear of trailers is at speeds 56 km/h (35 mph) or less. The agency estimates that 19 fatalities (=72 x0.26) are in crashes with relative velocity of 56 km/h (35 mph) or less. CMVSS No. 223 guards may not be able to mitigate all fatalities in crashes into the rear of trailers with relative velocity of 56 km/h (35 mph) or less because some crashes may be low overlap (30 percent or less) and some fatalities may be due to circumstances other than underride (i.e., unrestrained status of occupants, elderly and other vulnerable occupants). For the purpose of this analysis, NHTSA assumed that the incremental effectiveness of CMVSS No. 223 compliant guards over FMVSS No. 223 compliant guards in preventing fatalities in light vehicle impacts with PCI into the rear of trailers with crash speeds less than 56 km/h (35 mph) is 50 percent. Since only 26 percent of light vehicle crashes with PCI into the rear of trailers are at relative velocity less than or equal to 56 km/h, NHTSA estimated the overall effectiveness of upgrading to CMVSS No. 223 compliant guards to be 13 percent (=26% x 50%)

The target population of fatalities considered is representative of fatalities occurring in light vehicle crashes into the rear of trailers that result in PCI. As noted above, in estimating benefits, the agency assumed that the upgraded rear impact guards would mitigate fatalities and injuries in light vehicle impacts with PCI into the rear of trailers at impact speeds up to 56 km/h (35 mph) since the requirements of CMVSS No. 223 are intended to prevent PCI in impacts with speeds up to 56 km/h (35 mph). We recognize, however, that benefits may accrue from underride crashes at speeds higher than 56 km/h (35 mph), if, e.g., a vehicle's guard exceeded the minimum performance requirements of the FMVSS.

The agency estimates that 94 percent of new trailers are already equipped with CMVSS No. 223 compliant guards. Assuming 13 percent effectiveness of these guards in fatal crashes with PCI into the rear of trailers, the agency estimates that about 0.56 lives (= 72 x (1-0.94) x 0.13, rounded) would be saved annually by requiring all applicable trailers to be equipped with CMVSS No. 223 compliant guards.

Serious Injuries: According to the NASS CDS 1999-2006 data, there was a total of 22,251 front seat occupants with first row intrusion in front to rear end crashes in which passenger vehicles underrode the rear of a large truck with trailer. In addition, the data show that there was a total of 19,227 front seat occupants without first row intrusion. To estimate the benefits of Canadian standard compliant underride guards, we will first estimate the impact of shifting from a fleet with 100% FMVSS compliant guards to one with 100% Canadian standard compliant guards. This requires estimating a target population that reflects only FMVSS compliant underride guards. For this purpose, we have used data from the period 1999-2006. The Canadian standard became effective in 2007. Therefore, from 2007 forward a substantial portion of the on-road vehicle fleet would have underride guards that meet this standard. It is also likely that some portion of the on-road fleet had guards that met the Canadian standard prior to 2007 as manufacturers anticipated the standard and initiated production, but we do not have data to determine the actual transition experience of the on road fleet. To the extent that there were already Canadian standard compliant underride guards in the on-road fleet prior to 2007, their presence would have reduced the target population. Therefore, our assumption that the 1999-2006 fleet represents an injury profile for a fleet with FMVSS compliant underride guards provides a conservative estimate of the potential target population for such a fleet.[39]

Table 15: NASS CDS 1999-2006, front seat occupants with first row intrusion in front to rear end crashes where passenger vehicles underride the rear of a large truck with trailer

Intrusion "Yes"	No injury	MAIS[40] 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Total
No.	7,173	11,114	2,082	635	757	490	22,251
Row %	32.24%	49.95%	9.36%	2.85%	3.40%	2.20%	n/a
Est. %	41.79%	21.86%	11.43%	5.98%	3.13%	1.64%	85.83%
Adj. est%	**48.69%**	**25.47%**	**13.32%**	**6.97%**	**3.65%**	**1.91%**	100.00%
Adj. est. no.	10,834	5,667	2,964	1,551	811	424	22,251

Table 16: NASS CDS 1999-2006, front seat occupants without first row intrusion in front to rear end crashes where passenger vehicles underride the rear of a large truck with trailer

Intrusion "No"	No injury	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Total
No.	12,127	5,852	981	175	113	29	19,277
Row %	62.91%	30.36%	5.09%	0.91%	0.59%	0.15%	n/a
Est. %	69.00%	19.77%	5.66%	1.62%	0.46%	0.13%	96.65%
Adj. est%	**71.39%**	**20.45%**	**5.86%**	**1.68%**	**0.48%**	**0.14%**	100.00%

[39] We are assuming that truck trailers in the 1999-2006 fleet are all equipped with FMVSS compliant guards even though some portion in the 1999-2006 fleet could have truck trailers equipped with CMVSS compliant guards. Therefore, the target population for the analysis would include target populations for the fleet with FMVSS compliant guards and the fleet with CMVSS compliant guards. By doing so, we could be using a larger target population than the target population for the fleet with FMVSS compliant guards.

[40] MAIS = Maximum Abbreviated Injury Scale, MAIS 1 = Minor, MAIS 2 = Moderate, MAIS 3 = Serious, MAIS 4 = Severe, MAIS 5 = Critical

The potential injury benefits would be realized when the total injuries (22,251) in the "intrusion" crashes are redistributed with the injury distribution of the "non-intrusion" crashes. The difference in injury counts would be the potential injury benefits.

Table 17: Redistribute of First row intrusion and Potential benefits without additional adjustment

Parameter	No injury	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Total
W/ intrusion, est.	10,834	5,667	2,964	1,551	811	424	22,251
Adj. est. (%)	71.39%	20.45%	5.86%	1.68%	0.48%	0.14%	100.00%
W/o intrusion	15,885	4,551	1,304	374	107	31	22,251
Benefits	-5,051	1,116	1,660	1,177	704	394	0

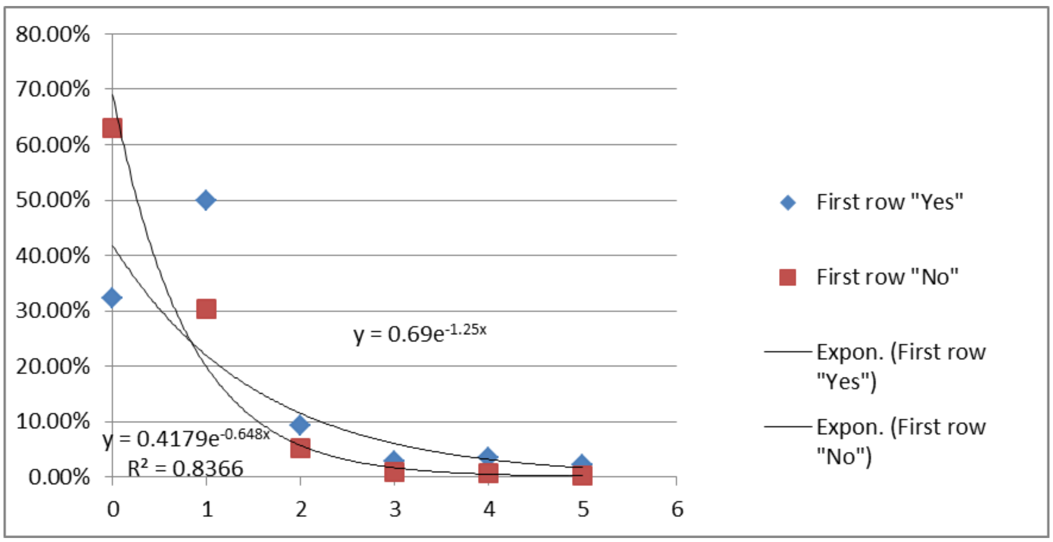


Figure 12: Injury distribution with and without intrusion, front row

Since Canadian standard underride guards would be effective in preventing intrusion at a delta-V of 35 mph or less whereas FMVSS compliant guards would be effective in preventing intrusion at a delta-V of 30 mph or less, we only considered crash at a delta-V range of 30 to 35 mph. According to the NASS CDS 2006-2008 data where front seat occupants of light vehicles that rear-end a vehicle, 32% of seriously injured occupants were in a delta-V range of 30 to 35 mph.[41] In addition, the injury benefits were further adjusted with number of years in the CDS data, exemption status of trailers and compliance rate.

Table 18: Number of Injuries Adjusted with Delta-V Range of 30 - 35 mph

Benefits	MAIS 3	MAIS 4	MAIS 5
Benefits, all Delta-V's	1,177	704	394
Benefits, 30 – 35 mph	373	223	125

Table 19: Additional Adjustments for Injury Benefit Estimate

No. of years in the CDS data[42]	8
Exemption rate	35%
Compliance rate	94%
Non-exempted trailers	65%
Adjustment factor*	0.49%

*Adjustment factor = (1-exemption rate) x (1-compliance rate) / number of data years

With the additional adjustments, we estimated that a total of 3.5 serious injuries would be prevented annually with the final underride guard rule.

Table 20: Adjusted injury benefits, no discount, considering only serious injuries

Benefits	MAIS 3	MAIS 4	MAIS 5	Total
Benefits, 30 – 35 mph	373	223	125	721
Adjusted injury benefits	1.8	1.1	0.6	3.5

In summary, the final rule would save 0.56 lives and 3.5 serious injuries annually.

[41] Due to limited data, the struck vehicle includes all vehicles including heavy trucks. In the crashes, the front of a passenger vehicle (the striking vehicle), which was going straight in a travel lane, strikes a motor vehicle (the struck vehicle) that was stopped or going straight in the same lane and direction as the striking vehicle and the struck vehicle driver did not steer to try to avoid the crash.

[42] NASS CDS 1999-2006

VII. COSTS AND LEADTIME

A. CMVSS Compliant Rear Guard Upgrade Impact

The agency conducted a study to develop cost and weight estimates for rear impact guards on heavy trailers.[43] In this study, the agency estimated the cost and weight of FMCSR 393.86(b) compliant rear impact guards, FMVSS No. 223 compliant rear impact guards, and CMVSS No. 223 compliant rear impact guards as shown in Table 21. All costs are converted to 2020 dollars using the consumer price index[44].

In estimating the cost and weight of guards, an engineering analysis of the guard system for each trailer was conducted, including material composition, manufacturing and construction methods and processes, component size, and attachment methods. However, the authors did not take into account the construction, costs, and weight changes in the trailer structure in order to withstand loads from the stronger guards. A limitation of this analysis is the fact that the authors did not evaluate the changes in design of the rear beam, frame rails, and floor of the trailer when replacing a rear impact guard compliant with FMCSR 393.86(b) with an FMVSS No. 224 compliant guard and then to a CMVSS No. 223 compliant guard.

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[43] Cost and weight analysis for rear impact guards on heavy trucks, Docket No. NHTSA-2011-0066-0086, June 2013.

[44] The consumer price index is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services. It is provided by the U.S. Department of Labor Bureau of Labor Statistics.
https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/

The average cost of four Canadian compliant rear impact guards is $546 which is $254 more than an FMVSS No. 224 compliant guard. In comparing the Great Dane rear impact guards, the 2012 Great Dane guard (CMVSS No. 223 compliant) is $90.46 more expensive than the 2001 Great Dane guard (FMVSS No. 223 compliant).

Table 21: Cost (2020 dollars) and weight of different types of rear impact guards

Type of Rear Impact Guard	Trailer Model Year/Make	Guard Assembly	Installation Cost	Total Cost	Weight (lb)
FMCSR 393.86(b)	1993 Great Dane	$72.54	$46.57	$119.11	78
FMVSS No. 224	2001 Great Dane	$170.18	$121.90	$292.08	172
CMVSS No. 223	2012 Great Dane	$212.33	$170.22	$382.55	193
	2012 Manac	$335.49	$276.28	$611.77	307
	2012 Stoughton	$275.48	$246.99	$522.47	191
	2012 Wabash	$496.54	$172.39	$668.94	243

The incremental cost of equipping CMVSS No. 223 compliant rear impact guards on applicable new trailers (those that are required to be equipped with FMVSS No. 223 compliant rear impact guards) is $254. There were 211,807 trailers produced in 2020[45] among which 65 percent (see Table 22) were required to be equipped with rear impact guards. Of those that were required to be equipped with rear impact guards, it is estimated that 94 percent were equipped with CMVSS No. 223 compliant guards. The annual incremental fleet cost of equipping all applicable trailers with CMVSS No. 223 rear impact guards is approximately $2.1 million.[46]

Table 22: Cost per Trailer and Total Cost (Cost in 2020 dollars)

CMVSS Guard	FMVSS Guard	Difference in Cost per Guard	% of Trailers That Requires Guard	Non Compliance	Total Number of Trailers Sold	Applicable Trailers	Total Incremental cost
$546.43	$292.08	$254.35	65%	6%	211,807	8,260	$2,101,060

[45] https://cdn.baseplatform.io/files/base/ebm/trailerbodybuilders/document/2021/04/TBB_Top_25_CY2020.6089da057e9d0.pdf

[46] 211,807*0.65*(1-0.94)*$254 = $2,101,060

B. Fuel Economy Impact

The average weight of four (4) Canadian compliant guards is estimated to be 233.5 pounds and the single FMVSS compliant guard (2001 Great Dane) is estimated to be 172 pounds as shown in Table 23. Upgrading from the FMVSS compliant guard to the CMVSS compliant guard would add an incremental weight of 48.9 pounds to the FMVSS compliant guard, thereby reducing the overall fuel economy during the lifetime of heavy trucks. Thus, for the fuel cost analysis, the increase in weight due to equipping a Canadian compliant guard is estimated 48.9 pounds per vehicle.

Table 23: Average Weight of Underride Guards

Make	standard	weight (lbs.)	Sales, 2013	Weighted sales	Weighted average weight (lbs.)
2001 Great Dane	FMVSS	172	--	n/a	n/a
2012 Great Dane	FMVSS/CMVSS	193	44,000	40.52%	78
2012 Manac	FMVSS/CMVSS	307	6,600	6.08%	19
2012 Stoughton	FMVSS/CMVSS	191	12,000	11.05%	21
2012 Wabash	FMVSS/CMVSS	243	46,000	42.36%	103
Total			108,600	100%	221

Table 24: Average Increase in Weight, CMVSS (Canadian) and FMVSS Guards

Average weight of CMVSS guard (lbs.)	233.5
Maximum weight increase (lbs.)	135
Sales weighted average weight increase (lbs.)	48.9
Minimum weight increase(lbs.)	19

A standard formula for estimating the impact of marginal weight increases on fuel economy is:

(Base vehicle weight/[vehicle weight + added weight])^0.8 * Baseline fuel economy

This formula is based on light vehicle data; however, it is the best available method for estimating changes in fuel economy due to weight increases at this time. Assuming that it does apply, we can estimate the impact that a weight increase would have on fuel economy. First, we assume that the average in-use weight of a loaded heavy truck is estimated to be 55,000 pounds.

Second, the average baseline miles per gallon (mpg) of a heavy truck is estimated to be 6.0 mpg.[47] Third, the projected price of diesel fuel was taken from reference case of the 2021 Annual Energy Outlook[48] in 2020 dollars starting in 2023, the assumed effectiveness year in this Final Regulatory Evaluation. The analysis uses a 3 percent and a 7 percent discount rate.

Adding 48.9 pounds changes the average fuel economy of that vehicle from 6.0 mpg to 5.9957 mpg. Over the lifetime of a heavy truck, the vehicle would use 404,594 gallons at 6.0 mpg and would use 404,881 gallons at 5.9957 mpg, so adding 48.9 pounds results in 288 additional gallons of diesel fuel used per vehicle for the lifetime of a vehicle. The estimated impact on a year to year basis is shown in Table 25.

[47] U.S. Department of Transportation Federal Highway Administration, Office of Highway Policy Information, Highway Statistics Series, https://www.fhwa.dot.gov/policyinformation/statistics/2019/vm1.cfm
[48] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2021&region=0-0&cases=ref2021~aeo2020ref&start=2019&end=2050&f=A&linechart=&sourcekey=0

Table 25: Undiscounted Value of Lifetime Fuel Economy Impact Per Vehicle in 2020 dollars

*The survival rate is based on heavy truck data

Year	Survival Probability	Exposer VMT	Aggregate Exposure	Fuel Price	Fuel Economy		Fuel Consumption		Value of Fuel Consumption	
					Base	New	Base	New	Base	New
1	1.0000	240,737	240,737	$2.83	6.0000	5.9957	40,123	40,151	$113,671	$113,751
2	0.9930	226,110	224,527	$2.93	6.0000	5.9957	37,421	37,448	$109,490	$109,568
3	0.9810	212,378	208,343	$2.99	6.0000	5.9957	34,724	34,748	$103,923	$103,997
4	0.9642	199,486	192,344	$3.05	6.0000	5.9957	32,057	32,080	$97,819	$97,888
5	0.9432	187,381	176,738	$3.10	6.0000	5.9957	29,456	29,477	$91,440	$91,505
6	0.9181	176,017	161,601	$3.16	6.0000	5.9957	26,934	26,953	$84,994	$85,055
7	0.8894	165,346	147,059	$3.19	6.0000	5.9957	24,510	24,527	$78,107	$78,163
8	0.8575	155,327	133,193	$3.29	6.0000	5.9957	22,199	22,215	$73,028	$73,080
9	0.8230	145,919	120,091	$3.32	6.0000	5.9957	20,015	20,029	$66,539	$66,587
10	0.7860	137,085	107,749	$3.36	6.0000	5.9957	17,958	17,971	$60,425	$60,467
11	0.7473	128,789	96,244	$3.38	6.0000	5.9957	16,041	16,052	$54,269	$54,307
12	0.7071	120,999	85,558	$3.40	6.0000	5.9957	14,260	14,270	$48,440	$48,475
13	0.6660	113,683	75,713	$3.41	6.0000	5.9957	12,619	12,628	$43,093	$43,123
14	0.6244	106,813	66,694	$3.42	6.0000	5.9957	11,116	11,124	$38,044	$38,071
15	0.5826	100,360	58,470	$3.46	6.0000	5.9957	9,745	9,752	$33,705	$33,729
16	0.5411	94,300	51,026	$3.49	6.0000	5.9957	8,504	8,510	$29,639	$29,660
17	0.5003	88,609	44,331	$3.48	6.0000	5.9957	7,389	7,394	$25,747	$25,766
18	0.4604	83,263	38,334	$3.54	6.0000	5.9957	6,389	6,394	$22,603	$22,619
19	0.4217	78,242	32,995	$3.57	6.0000	5.9957	5,499	5,503	$19,629	$19,642
20	0.3845	73,526	28,271	$3.59	6.0000	5.9957	4,712	4,715	$16,908	$16,920
21	0.3490	69,096	24,115	$3.62	6.0000	5.9957	4,019	4,022	$14,557	$14,567
22	0.3152	64,935	20,468	$3.63	6.0000	5.9957	3,411	3,414	$12,381	$12,390
23	0.2835	61,026	17,301	$3.62	6.0000	5.9957	2,883	2,886	$10,448	$10,455
24	0.2537	57,354	14,551	$3.67	6.0000	5.9957	2,425	2,427	$8,889	$8,895
25	0.2260	53,905	12,183	$3.68	6.0000	5.9957	2,030	2,032	$7,472	$7,477
26	0.2004	50,664	10,153	$3.68	6.0000	5.9957	1,692	1,693	$6,230	$6,234
27	0.1769	47,620	8,424	$3.70	6.0000	5.9957	1,404	1,405	$5,192	$5,196
28	0.1554	44,759	6,956	$3.69	6.0000	5.9957	1,159	1,160	$4,283	$4,286
29	0.1359	42,072	5,718	$3.74	6.0000	5.9957	953	954	$3,566	$3,569
30	0.1183	39,547	4,678	$3.79	6.0000	5.9957	780	780	$2,956	$2,958
31	0.1025	37,175	3,810	$3.84	6.0000	5.9957	635	636	$2,439	$2,441
32	0.0884	34,945	3,089	$3.89	6.0000	5.9957	515	515	$2,003	$2,004
33	0.0759	32,851	2,493	$3.94	6.0000	5.9957	416	416	$1,638	$1,639
34	0.0649	30,883	2,004	$3.99	6.0000	5.9957	334	334	$1,333	$1,334
35	0.0552	29,033	1,603	$4.04	6.0000	5.9957	267	267	$1,080	$1,081
Total			2,427,562				404,594	404,881	$1,295,977	$1,296,898

Table 26 shows the estimated incremental weight increase and the impact on fuel cost per vehicle at the 3 percent and 7 percent discount rate.

Table 26: Present Discounted Value of Increased Lifetime Fuel Costs per Vehicle (in 2020 dollars)

Impact Guard	Weight Increase (lb), avg.	Fuel Economy (mpg)		Incremental Increase in Lifetime Fuel Costs		
		Base	New	Undiscounted	3%	7%
Upgrade from FMVSS To CMVSS	48.9	6.0	5.9957	$921	$746	$592

The total fuel costs depend on the incremental weight increase and the discount rate applied. These are derived by taking the vehicle lifetime fuel cost in Table 26 and multiplying by the number of applicable vehicles.[49] In addition, we adjusted with the estimate fuel cost with the 94% compliance and 35% exemption rates as shown in Table 27.

Table 27: Unit Incremental Fuel Cost per Vehicle, in 2020 dollars

Adjustment	Not discounted	3%	7%
w/o adjustment	$921	$746	$592
w/ adjustment	$35.94	$29.09	$23.10

With 192,000 Class 8 truck annual sales, the total fuel cost was estimated to be $5.59 million and $4.43 million discounted at 3% and 7%, respectively, as shown in Table 28.

Table 28: Total Incremental Fuel Costs (2020 Dollars)

Impact Guard	Costs per Vehicle		Number of Applicable Vehicles	Total Incremental Increase Lifetime Fuel Costs in Millions		
	3%	7%		Undiscounted	3%	7%
Upgrade from FMVSS To CMVSS	$29.09	$23.10	192,000	$6.90	$5.59	$4.43

[49] Statista https://www.statista.com/statistics/261416/class-3-8-truck-sales-in-the-united-states/, last accessed on October 29, 2021.

VIII. COST EFFECTIVENESS AND BENEFIT-COST

This chapter provides cost-effectiveness and benefit-cost analysis of the CMVSS compliant trailer underride guard requirements. The Office of Management and Budget (OMB) requires all agencies to perform cost-effectiveness and benefit-cost analyses in support of rules, effective January 1, 2004.[50]

Cost-effectiveness measures the cost per equivalent life saved (i.e., per equivalent fatality), while benefit-cost measures the net benefit, which is the difference between benefits and costs in monetary values. Injury benefits are expressed as fatal equivalents in cost-effectiveness analysis and are further translated into monetary value in benefit-cost analysis. Fatal equivalents represent the savings throughout the vehicle's lifetime and are discounted to reflect their present values (2020 dollars).

A. Comprehensive and Economic Costs of Crashes

There are costs to society incurred as a result of an injury or fatality that are separate from the value of the life saved/injury prevented. Benefits occur from reducing these economic costs of crashes by reducing the number of people injured or killed. These items include reducing medical care costs, emergency services costs, insurance administrative costs, workplace costs, legal costs, and costs for reduced market productivity and household productivity. Table 29 shows NHTSA's current estimates of the economic costs as well as comprehensive costs for each injury level. As shown in Table 29, the cost components included medical, emergency services,

[50] See OMB Circular A-4.

market productivity, household productivity, insurance administration, workplace, legal, congestion, property damage, and the nontangible value of physical pain and loss of quality of life (i.e., quality adjusted life years, QALYs).

Table 29: Comprehensive and Economic Costs (2020 $)

Cost Components	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
Medical	$3,739	$15,299	$64,947	$182,093	$513,315	$15,117
Emergency Services	$129	$264	$496	$999	$1,020	$1,076
Market Productivity	$3,424	$24,318	$80,820	$176,891	$424,096	$1,172,349
Household Productivity	$1,083	$8,926	$28,500	$47,158	$119,849	$364,180
Insurance Administration	$3,933	$5,557	$18,332	$33,666	$86,497	$33,778
Workplace	$428	$3,321	$7,256	$7,991	$13,932	$14,802
Legal	$1,410	$3,997	$14,791	$31,806	$98,644	$127,003
Sub Total	$14,146	$61,682	$215,142	$480,604	$1,257,353	$1,728,305
Congestion	$1,791	$1,822	$1,872	$1,899	$1,921	$7,186
Property Damage	$9,492	$10,149	$19,114	$19,474	$18,000	$13,372
QALYs	$30,606	$479,493	$1,071,207	$2,713,724	$6,049,769	$10,201,971
Total	$44,752	$541,175	$1,286,349	$3,194,328	$7,307,122	$11,930,276
Relative QALYs	0.0030	0.0470	0.1050	0.2660	0.5930	1.0000

*Congestion and property damage are not included when crashworthiness FMVSSs are considered.

Combining the above information with the expected number of injuries and fatalities that would be reduced by the final rule the agency is able to project the potential monetizable benefits of the rule. Depending on the discount rate, the final rule is expected to save between $10.90 million and $13.73 million per year in lost quality of life and economic costs associated with motor vehicle injuries and fatalities. See Table 30 below.

Table 30: Benefits from Reduced Comprehensive Costs

Injury severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury reduced	0.0000	0.0000	1.8184	1.0877	0.6081	0.5616	
Economic value	$44,752	$541,175	$1,286,349	$3,194,328	$7,307,122	$11,930,276	
Undiscounted benefits	$0	$0	$2,339,066	$3,474,516	$4,443,405	$6,700,043	$16,957,030
Benefits at 3%	$0	$0	$1,893,410	$2,812,526	$3,596,816	$5,423,503	$13,726,255
Benefits at 7%	$0	$0	$1,503,318	$2,233,071	$2,855,776	$4,306,118	$10,898,283

B. Fatal Equivalents

To calculate a cost per equivalent fatality, nonfatal injuries must be expressed in terms of fatalities. This is done by comparing the values of preventing nonfatal injuries to the value of preventing a fatality. The Value of Statistical Life (VSL) is used to determine the relative ratio of nonfatal injuries to fatalities (i.e., relative injury factor). VSL measurements inherently include a value for lost quality of life plus a valuation of lost material consumption that is represented by measuring consumers' after-tax lost productivity. The societal economic costs including medical care, emergency services, insurance administrative costs, workplace costs, and legal costs were treated as part of savings that would reduce the regulatory costs. Therefore, societal economic costs were excluded from the determination of the relative injury factors. Table 31 shows the relative injury factors.

Table 31: Relative Injury Factor

Injury Severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatality
Relative Injury Factor[51]	0.0030	0.0470	0.1050	0.2660	0.5930	1.000

Fatal equivalents are derived by applying the relative injury factor shown in Table 31 to the estimated injury benefits. As discussed earlier, benefits are realized throughout a vehicle's life. Thus, fatal equivalents are required to be discounted at 3 and 7 percent. Table 32 shows the undiscounted and discounted fatal equivalents examined in the benefit chapter.

As shown, undiscounted, the final rule would save 1.4 fatal equivalents when all applicable trailers are equipped with the CMVSS compliant underride guards. At a 3 percent discount rate, the final rule would save 1.1 fatal equivalents. At a 7 percent discount rate, the final rule would save less than one fatal equivalent.

Table 32: Equivalent Lives Saved (ELS)

Injury severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury reduced	0.0000	0.0000	1.8184	1.0877	0.6081	0.5616	
Relative injury factors	0.0030	0.0470	0.1050	0.2660	0.5930	1.0000	
ELS undiscounted	0.0000	0.0000	0.1909	0.2893	0.3606	0.5616	1.4025
ELS at 3%	0.0000	0.0000	0.1546	0.2342	0.2919	0.4546	1.1353
ELS at 7%	0.0000	0.0000	0.1227	0.1860	0.2318	0.3609	0.9014

Value of a Statistical Life

Fatality and injury benefits are monetized based on the benefits from reduced comprehensive value of societal impacts which include societal benefits and benefits from value of a statistical life (VSL). The benefit of preventing a fatality is measured by what is conventionally called the

[51] See Table 29 Comprehensive and Economic Costs for relative injury factors.

value of a statistical life, defined as the additional cost that individuals would be willing to bear for improvements in safety (that is, reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one. Value-of-life measurements inherently include a value for lost quality of life plus a valuation of lost material consumption that is represented by measuring consumers' after-tax lost productivity.

In March 2021, the Department of Transportation issued revised guidance regarding the treatment of the economic value of a statistical life in U.S Department of Transportation regulatory analyses (2021 Update).[52] The VSL guidance is updated each year to take into account both the changes in price levels and changes in real incomes. Applying the procedure established by the agency for updating the overall VSL value yields an VSL of $11.6 million for analyses prepared in 2021 using a 2020 base year.

C. Cost-Effectiveness

The cost-effectiveness analysis derives the cost per equivalent life saved which is equal to the cost divided by the total fatal equivalents. The cost of the final rule would be the regulatory cost, and the cost effectiveness is shown in Table 33.

Table 33: Cost per Equivalent Life Saved (in Millions of 2020 dollars)

Discount Rate	Undiscounted	3%	7%
Total Cost	$9.00	$7.69	$6.54
Equivalent Lives Saved	1.4025	1.1353	0.9014
Cost per Equivalent Life Saved	$6.42	$6.77	$7.25

[52] For more information, please see a 2021 Office of the Secretary memorandum on the "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses – 2021 Update." http://www.dot.gov/policy/transportation-policy/economy

D. Net Benefits

Benefit-cost analysis derives the net benefits which is the difference between the injury benefits and the costs of the final rule in monetary values. Thus, benefit-cost analysis differs from cost-effectiveness analysis in that it requires that benefits be assigned a monetary value, and that this value be compared to the cost to derive a net benefit.

Table 34 summarizes the net benefits of the final rule. As shown, at a 3 percent discount rate, the net benefits of the final rule would be $6.04 million. At a 7 percent discount rate, the net benefits of the final rule would be $4.36 million in 2020 dollars.

Table 34: Net Benefits (in Millions of 2020 dollars)

Discount Rate	Undiscounted	3%	7%
Comprehensive Benefit	$16.96	$13.73	$10.90
Total Cost	$9.00	$7.69	$6.54
Net Benefit	$7.96	$6.04	$4.36

E. Summary

Table 35 summarizes the regulatory cost, net benefits, and cost-effectiveness of the final rule at the 3% and 7% discount rates. The final rule is cost beneficial with $6.04 million and $4.36 million net benefits at the 3% and 7% discount rate, respectively.

Table 35: Cost-Effectiveness and Net Benefits (in Millions of 2020 dollars)

Discount Rate	Regulatory Cost	Comprehensive Benefits	Net Benefits	Cost per ELS
3%	$7.69	$13.73	$6.04	$6.77
7%	$6.54	$10.90	$4.36	$7.25

* Costs are not discounted since they occur at the time of purchase, whereas benefits occur over the vehicle's lifetime and are discounted back to the time of purchase.
Net Benefit = Comprehensive Benefit – Regulatory Cost

IX. SENSITIVITY ANALYSIS

This chapter discusses the change in costs and benefits that result from different assumptions used in the analysis. When inputs that affect the analysis are uncertain, the agency makes its best judgment about the probable values or range of values that will occur. This analysis will examine alternatives to these selections to illustrate how sensitive the results are to the values initially selected. This process involves altering input values and interpreting and presenting the results. This is helpful not only because of the uncertainty inherent in estimations and predictions but also it provides insight into values chosen to represent abstract concepts.

In the fatal benefit analysis, we assumed that the proposed underride guard would be 50% effective in preventing fatalities at a delta-V of 35 mph or less. In this sensitivity chapter, in addition to the 50% assumed effectiveness, we examined 0% and 100% effectiveness as lower and upper ranges in fatal crashes. The cost per ELS ranges from $4.83 million to $11.29 million at the 3% discount rate and $5.18 million to $12.09 million at the 7% discount rate as shown in Table 36.

Table 36: Cost, Net Benefit and Cost per ELS with 0%, 50% and 100% Fatal Effectiveness (in Millions of 2020 dollars)

Parameter	3%			7%		
Fatal Effectiveness	0%	50%	100%	0%	50%	100%
Cost	$7.69	$7.69	$7.69	$6.54	$6.54	$6.54
Cost per ELS	$11.29	$6.77	$4.83	$12.09	$7.25	$5.18
Net Benefit[53]	$0.62	$6.04	$11.46	$0.06	$4.36	$8.67

[53] Note that the net benefits are positive numbers at both discount rates when fatal effectiveness is assumed to be 0%. We are calculating the net benefit with 0% fatal effectiveness (there are no lives saved with 0% fatal effectiveness) while MAIS 3-5 injuries prevented remain the same. This indicates that the benefits gained from injuries prevented are large enough to offset the costs associated with this final rule, which results in positive net benefits when fatal effectiveness is assumed to be 0%.

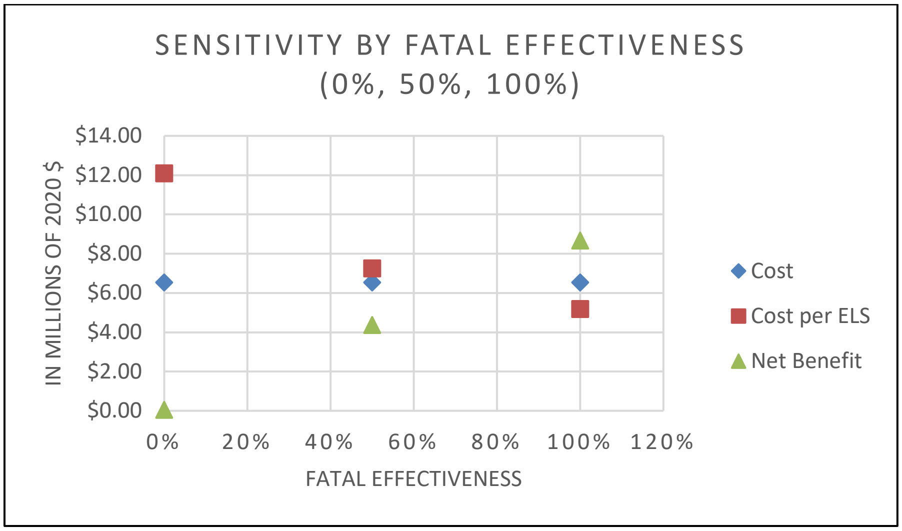

Figure 13: Cost, Cost per ELS and Net benefit with 0%, 50% and 100% Fatal Effectiveness

X. ALTERNATIVES

As an alternative to requiring only new underride guards, we analyzed the cost effectiveness and the practicability of retrofitting a CMVSS No. 223 compliant guard (CMVSS guard) for current trailers. For the analysis, these trailers were assumed to be equipped with a rear impact guard compliant with FMVSS No. 223 (FMVSS guard).

For the impacts of retrofitting trailers with CMVSS guards, we considered short-term impacts that would be expected due to a retrofit requirement, along with long-term impacts we expected to see as all the current FMVSS guards are gradually scrapped out and no longer used in operations.[54]

Costs

Regarding the monetized impacts of retrofitting applicable FMVSS trailers with CMVSS trailers, we examined the unit cost for retrofitting a FMVSS trailer with a CMVSS trailer and compared that with the baseline when these FMVSS trailers are gradually scrapped from their operation as each individual trailer reaches the end of its operational life.

For the short-term impacts, we analyzed labor hours needed to remove a current FMVSS guard from a trailer. For costs associated with the removal operation, we assume the same amount of labor hours is needed to remove FMVSS guards as that to install CMVSS guards. Accordingly, the removal cost for each trail was estimated to be $121.90 in 2020 dollars as shown in Table 38.

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[54] In the preliminary regulatory evaluation (PRE) that accompanied the NPRM, we only considered short-term impacts of retrofitting, and for this retrofit analysis for the FRE, we consider both short-term and long-term impacts.

As discussed in the costs section of this FRE, for the retrofit analysis, we assume that all applicable trailers manufactured since 2007 meet the Canadian standard. We also assume that all applicable trailers manufactured prior to 2007 comply with FMVSS but do not comply with the Canadian standard. The costs associated with removing the FMVSS guards are further discussed below.

Material and Labor Costs

We estimate that the number of trailers on the road that were manufactured prior to 2007 is approximately 2,161,593, of which 65% are required to be equipped with a rear impact guard. Thus, there are an estimated 1,405,035 (= 2,161,593 x 65%) trailers that are required to be equipped with a FMVSS guard in 2023.[55] Thus, the total cost of removing FMVSS guards on the 1,405,035 trailers is estimated to be approximately $171,273,821 (= 1,405,035 x $121.90) in 2020 dollars as shown in Table 37.

Table 37: Cost for Removing FMVSS Guards in 2020 dollars

1979 to 2006 sales on road in 2023	2,161,593
percent of trailers with a required guard	65%
FMVSS trailers that need to retrofit	1,405,035
cost for removing a FMVSS guard on a FMVSS trailer	$121.90
total cost for removing FMVSS guards	$171,273,821

One of the short-term impacts of retrofitting current FMVSS guards with CMVSS guards is that the $122 ($121.90) incremental cost that contributed to the removal of a FMVSS guard is substantial when compared to the cost of a CMVSS guard, which ranges from $383 to $669

[55] Trailer numbers are based on trailer output from trailer bodybuilders website.
https://www.trailer-bodybuilders.com/trailer-output/trailer-output-report-archive

(from $382.55 to $668.94), an average of $546 in 2020 dollars as shown in Table 38. In other words, if retrofitting is required, the total unit cost of a CMVSS guard including both hardware and removal costs would be on average $668 (= $546 + $122). Thus, for each trailer to be retrofitted with a Canadian guard, we expect on average $668 additional cost for the hardware and removal costs when compared with the baseline when these FMVSS trailers are gradually scrapped from their operation as each individual trailer reaches the end of its operational life.

Table 38: Cost (2020 dollars) and Weight of Different Types of Rear Impact Guards

Type of Rear Impact Guard	Trailer Model Year/Make	Guard Assembly	Installation Cost	Total Cost	Weight (lbs.)	Removal Cost
FMCSR 393.86(b)	1993 Great Dane	$72.54	$46.57	$119.11	78	N/A
FMVSS No. 224	2001 Great Dane	$170.18	$121.90	$292.08	172	
CMVSS No. 223	2012 Great Dane	$212.33	$170.22	$382.55	193	N/A
	2012 Manac	$335.49	$276.28	$611.77	307	N/A
	2012 Stoughton	$275.48	$246.99	$522.47	191	N/A
	2012 Wabash	$496.54	$172.39	$668.94	243	N/A

With the total material cost of $767,757,034 (= 1,405,035 x $546) for CMVSS guards, we estimate a total cost of $939,030,855 for retrofitting when the removal cost of $171,273,821 is considered (= $767,757,034 + $171,273,821) as shown in Table 39.

Table 39: Total Hardware and Removal Cost for Retrofitting FMVSS Trailers with CMVSS Trailers (in 2020 dollars)

Total cost for removing FMVSS guards from FMVSS trailers	$171,273,821
Total cost of CMVSS guards to install on FMVSS trailers	$767,757,034
Total hardware and removal cost for retrofitting FMVSS trailers with CMVSS trailers	$939,030,855

Time Delay Cost

The value of travel time is a critical factor in evaluating the benefits of transportation investment and rulemaking initiative. Thus, time saved from travel could be dedicated to production, yielding a monetary benefit to either travelers or their employers. Conversely, any transportation delay would result in negative impacts to fleet operators and their employees, such as when a FMVSS trailer is to be brought to a repair shop to be retrofitted with a CMVSS guard on the FMVSS trailer.

For the impacts of delay, the value of travel time savings (VTTS) is used in costs related to retrofitting.[56] According to VTTS, hourly values of travel time savings (2012 dollars per person-hour) for truck drivers range from $20.30 to $30.50 and are converted to 2020 dollars to range from $22.88 to $34.38 per person-hour. We assume that it takes one or two days to bring a FMVSS trailer to a repair shop and then remove a FMVSS guard and install a CMVSS guard on the FMVSS trailer. Therefore, the cost of time delay (time not worked while the trailer is being upgraded) ranges from $183 (= $22.88 / hour x 8 hours) to $550 (= $34.38 / hour x 16 hours) per trailer. With 1,405,035 FMVSS trailers to retrofit with CMVSS trailers, the total cost of time delay is estimated to range from $257 million to $773 million as shown Table 40.

Table 40: Total Cost of Time Delay in 2020 dollars

	Low	high
Hourly value of travel time savings for truck drivers	$22.88	$34.38
One or two days (8 - 16 hours)	8	16
Cost of time delay (time not worked) per trailer	$183.07	$550.10
Applicable FMVSS trailers	1,405,035	1,405,035
Total cost of time delay	$257,214,533	$772,910,666

[56] Office of the Secretary memorandum (U.S. Department of Transportation), Departmental Guidance for Conducting Economic Evaluations Revision 2 (2014 update): revised departmental guidance on valuation of travel time in economic analysis, July 2014.

Fuel Cost

Regarding the monetized fuel impacts of retrofitting FMVSS trailers with CMVSS trailers, we examined the unit fuel cost for retrofitting each trailer with a CMVSS trailer and compared that with the unit cost when these FMVSS trailers are gradually scrapped from their operation as each individual trailer reaches the end of its operational life. As discussed in the costs section of this FRE, there are approximately 8,260 applicable FMVSS trailers,[57] and the total incremental fuel cost of equipping the FMVSS trailers with CMVSS trailers is estimated to be $6.90 million ($6,899,772). With the 8,260 applicable FMVSS trailers, the unit incremental fuel cost is approximately $835 (= $6,899,772/8,260) per trailer as shown in Table 41.

Table 41: Unit Fuel Cost per FMVSS Trailer

Trailers Produced	Percent of Rear Guard Required	Non-Compliance Rate	Applicable FMVSS Trailers	Total Incremental Increase in Lifetime Fuel Cost	Unit Fuel Cost per Trailer
211,807	65%	6%	8,260	$6,899,772	$835

We assume that trailers are used at a constant rate until they are scrapped. From calculations using the trailer body-builder website output data (https://www.trailer-bodybuilders.com/trailer-output/trailer-output-report-archive), the weighted average age of applicable FMVSS trailers is approximately 28 years, and the operational life of an applicable FMVSS trailer is 45 years. Thus, the proportion of the retrofit benefits/costs to be claimed under retrofitting is 38% (= (45-28) years/45 years). There are 1,405,035 FMVSS trailers to retrofit with CMVSS certified

[57] 211,807 (trailers produced) x 65% (percent rear guard required) x 6% (non-compliance rate) = 8,260 applicable FMVSS trailers

guards, and thus the total fuel cost is estimated to be $446 million (= $835 x 1,405,035 x 38%) with an adjustment factor of 38%, as shown in Table 42.

Table 42: Total Fuel Cost of Retrofitting FMVSS Trailers with CMVSS Trailers in 2020 dollars

Unit Fuel Cost per Trailer	Applicable FMVSS Trailers to Retrofit	Total Incremental Fuel Cost	Adjustment Factor with Weighted Average Trailer Age	Total Fuel Cost for Retrofitting
$835	1,405,035	$1,173,591,924	38%	$445,964,931

Benefits and Net-Benefits

As discussed in the cost effectiveness and benefit-cost section of this FRE, we estimated the potential monetizable benefits with the expected number of injuries and fatalities that would be reduced by the final rule. These annual monetized benefits include both quality of life valuation based on the value of a statistical life (VSL) and societal economic savings. Undiscounted, the final rule is expected to save between $16.96 million per year in lost quality of life and economic costs associated with motor vehicle injuries and fatalities as shown in Table 43.

Table 43: Benefits from Reduced Comprehensive Costs in 2020 dollars

Injury severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury reduced	0.0000	0.0000	1.8184	1.0877	0.6081	0.5616	
Economic value	$44,752	$541,175	$1,286,349	$3,194,328	$7,307,122	$11,930,276	
Undiscounted benefits	$0	$0	$2,339,066	$3,474,516	$4,443,405	$6,700,043	$16,957,030

With the 8,260 applicable FMVSS trailers, the unit incremental benefits per trailer become $2,053 (= $16,957,030/8,260). The number of applicable FMVSS trailers to retrofit with

CMVSS trailers is approximately 1,405,035, and with the adjustment factor by the weighted average trailer age of 38%, the total benefits of retrofitting applicable FMVSS trailers with CMVSS trailers adjusted with the weighted average trailer age are estimated to be $1,096 million (= $2,053 x 1,405,035 x 38%) as shown in Table 44.

Table 44: Total Benefits of Retrofitting Applicable Trailers Adjusted with Weighted Average Trailer Age in 2020 dollars

Total incremental safety benefits	$16,957,030
Applicable FMVSS trailers	8,260
Unit incremental benefits per trailer	$2,052.91
FMVSS trailers to retrofit with CMVSS trailers	1,405,035
Total benefits of retrofitting applicable FMVSS trailers with CMVSS trailers	$2,884,410,203
Adjustment factor with weighted average trailer age	38%
Total benefits of retrofitting applicable FMVSS trailers with CMVSS trailers adjusted with weighted average trailer age	$1,096,075,877

The total cost (incremental material cost and removal cost) of retrofitting applicable FMVSS trailers with CMVSS trailers is approximately $939 million, the fuel cost for retrofitting adjusted with the weighted average trailer age is approximately $446 million, and the cost of time delay for retrofitting ranges from $257 million to $773 million. Thus, the net benefits range from -$1,062 million to -$546 million as shown in Table 45.

Table 45: Benefits, Costs and Net Benefits in 2020 dollars

Total benefits of retrofitting applicable FMVSS trailers with CMVSS trailers adjusted with weighted average trailer age	$1,096,075,877	
Total cost for retrofitting applicable FMVSS trailers with CMVSS trailers	$939,030,855	
Total fuel cost adjusted with weighted average trailer age	$445,964,931	
	Low	High
Cost of time delay (time not worked)	$257,214,533	$772,910,666
Net benefits	-$546,134,442	-$1,061,830,575

In addition to the quantified negative impacts of retrofitting, there are unquantified but significant other impacts, especially on small trucking companies. Our anecdotal data show there are about 1.2 million trucking companies in the U.S. Among these companies, a large portion of them are small and/or owner-operated, where 97% operate 20 or fewer trucks and 90% operate 6 or fewer trucks. Thus, if applicable FMVSS trailers are required to be retrofitted with CMVSS compliant guards, it could put owner-operators and small fleet owners at a significant disadvantage due to several factors working against them. For example, it is likely that owner-operators will need to bring in their current trailers to be fitted with CMVSS compliant guards, which may result in putting their entire operations, or major portions thereof, on hold while the trailers are being equipped with new guards. Conversely, when trailers are gradually scrapped as they reach the end of their operational lives, owner-operators will not lose operational time and will instead purchase new trailers already equipped with compliant guards. Operational disruption from retrofitting trailers would result in revenue loss since some fixed expenses would remain the same, such as rental payments for their operating facilities, insurance, and fringe benefits payments for their employees.

For the long-term impacts, the safety benefits in terms of the number of lives saved and injuries prevented and costs including both hardware and additional fuels consumed would be the same. However, the safety benefits and costs would be achieved sooner if current FMVSS trailers are replaced with CMVSS compliant trailers. For the short-term impacts as discussed above, the estimated incremental costs resulting from a regulatory action, i.e., retrofitting FMVSS trailers, demonstrate that the regulation action requiring retrofitting is not necessary.

In summary, although a retrofit requirement would promote earlier deployment of CMVSS compliant guards, it would result in substantial increased costs associated with installation, especially for small trucking companies.

XI. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

A. Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C. §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations and small governmental jurisdictions. In compliance with the Regulatory Flexibility Act, 5 U.S.C. 60l et seq., NHTSA has evaluated the effects of this final rule on small entities. The head of the agency has certified that this rule will not have a significant economic impact on a substantial number of small entities.

The factual basis for the certification (5 U.S.C. 605(b)) is set forth below. Although the agency is not required to issue an initial regulatory flexibility analysis, we discuss below many of the issues that an initial regulatory flexibility analysis would address.

5 U.S.C §603 requires agencies to prepare and make available for public comments initial and final regulatory flexibility analysis (RFA) describing the impact of proposed and final rules on small entities. Section 603(b) of the Act specifies the content of an RFA. Each RFA must contain:

1. A description of the reasons why action by the agency is being considered;
2. A succinct statement of the objectives of, and legal basis for the proposal;
3. A description of and, where feasible, an estimate of the number of small entities to which the proposal will apply;

4. A description of the projected reporting, recording keeping and other compliance requirements of the proposal including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the proposal;
6. Each initial regulatory flexibility analysis shall also contain a description of any significant alternatives to the proposal which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the proposal on small entities.

1. <u>Description of the reason why action by the agency is being considered</u>

NHTSA sets forth this action to improve the safety of light duty vehicle occupants by strengthening requirements of rear impact guards for trailers and semi-trailers. NHTSA sets forth this action in response to a petition for rulemaking from the Insurance Institute for Highway Safety and from Ms. Marianne Karth and the Truck Safety Coalition to improve underride protection in crashes into the rear of trailers. This final rule also responds to and fulfills the rulemaking mandate of Section 23011(b)(1)(A) of the November 2021 Infrastructure Investment and Jobs Act (IIJA), commonly referred to as the Bipartisan Infrastructure Law (BIL). This action requires all new applicable trailers and semitrailers in the United States to be equipped with rear impact guards with improved strength and energy absorption capability currently required in Canada. This action also adopts CMVSS No. 223 specifications regarding the location of aerodynamic fairings so they do not pose a safety hazard in crashes into the rear of trailers. Currently, 94 percent of new trailers and semitrailers in the United States comply with CMVSS No. 223 requirements.

2. Objectives of, and legal basis for, the proposal

Under 49 U.S.C. 322(a), the Secretary of Transportation (the "Secretary") has authority to prescribe regulations to carry out the duties and powers of the Secretary. One of the duties of the Secretary is to administer the National Traffic and Motor Vehicle Safety Act, as amended (49 U.S.C. 30101 et seq.). The Secretary is authorized to issue federal motor vehicle safety standards (FMVSS) that are practicable, meet the need for motor vehicle safety, and are stated in objective terms.[58] The Secretary has delegated the responsibility for carrying out the National Traffic and Motor Vehicle Safety Act to NHTSA.[59] NHTSA sets forth this rule under the Authority of 49 U.S.C. 322, 30111, 30115, 30117, and 30166; delegation of authority at 49 CFR 1.95. This final rule is needed to improve the safety of occupants in light duty vehicles. 3. Description and estimate of the number of small entities to which the proposal will apply

Business entities are defined as small businesses using the North American Industry Classification system (NAICS) code, for the purpose of receiving Small Business Administration assistance. One of the criteria for determining size, as stated in 13 CFR 121.201, is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, light and heavy duty trucks, buses, motor homes, new tires, or motor vehicle body manufacturing (NAICS code 336211), the firm must have less than 1,000 employees to be classified as a small business.

[58] 49 U.S.C. 30111(a).
[59] 49 U.S.C. 105 and 322; delegation of authority at 49 CFR 1.50.

The trailer manufacturing industry is fragmented, and NHTSA believes that there are hundreds of trailer manufacturers that can be classified as small businesses. The final rule will affect a substantial number of small trailer manufacturing businesses. While a substantial number of small trailer manufacturing businesses will be affected by the final rule, the agency believes that the final rule will not have a significant economic impact on a substantial number of small trailer manufacturers. This final rule sets forth changes to the strength requirements applying to underride guards but would not be amending the method by which small trailer manufacturers can certify compliance with FMVSS Nos. 223 and 224.

FMVSS No. 223, an equipment standard, specifies strength and energy absorption requirements in quasi-static force tests of rear impact guards sold for installation on new trailers and semitrailers. FMVSS No. 224, a vehicle standard, requires new trailers and semitrailers with a GVWR of 4,536 kg (10,000 lb) or more to be equipped with a rear impact guard meeting FMVSS No. 223. NHTSA established the two-standard approach to provide underride protection in a manner that imposes reasonable compliance burdens on small trailer manufacturers.

Under FMVSS No. 223, the guard may be tested for compliance while mounted to a test fixture or to a complete trailer. FMVSS No. 224 requires that the guard be mounted on the trailer or semitrailer in accordance with the instructions provided with the guard by the guard manufacturer. Under this approach, a small manufacturer that produces relatively few trailers can certify its trailers to FMVSS No. 224 without feeling compelled to undertake destructive testing of what could be a substantial portion of its production. The two-standard approach was devised to provide small manufacturers a practicable and reasonable means of meeting the safety need served by an underride guard requirement. This final rule does not set forth changing the method of certifying compliance to the underride guard requirements of FMVSS Nos. 223 and 224.

4. A description of the projected reporting, record keeping and other compliance requirements of the proposal including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record.

The final rule requires manufacturers to equip their trailers with a Canadian standard compliant guard and to certify that their products comply with the standard. The final rule includes no reporting requirements for trailer manufacturers.

5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the proposal

The final rule amends and upgrades FMVSS No. 223. There are no duplicate or overlapping Federal rules in this area.

6. A description of any significant alternatives to the proposal which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.

We believe this final rule will not have a significant economic impact on small entities. No alternatives were considered that could further limit the impacts on small entities. Alternatives have been discussed in Chapter X for retrofitting a Canadian compliant impact guard on applicable trailers.

B. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by States, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2020 results in $158 million (113.625/71.868 = 1.5810235). The assessment may be included in conjunction with other assessments, as it is here.

This final rule would not result in expenditures by State, local or tribal governments of more than $158 million annually. The final rule also would not result in an expenditure of more than that magnitude by trailer manufacturers. The estimated annual total expenditure for manufacturers is expected to be approximately $2.1 million. These effects have been discussed previously in this Final Regulatory Evaluation (see Costs, Benefits, and Cost Effectiveness Chapters).

APPENDIX A: DISCOUNT FACTOR

							Discount rate			
							3%		7%	
Year	Adjusted VSL millions	Survival Probability	Exposure (VMT)	Aggregate Exposure	Exposure Proportion	Pre-Discounting Aggregate VSL	Mid-Year Discount Factor (3%)	Discounted Aggregate VSL	Mid-Year Discount Factor (7%)	Discounted Aggregate VSL
2023	$11.60	1.0000	240,737	240,737	0.0992	1.1504	0.9853	1.1335	0.9667	1.1121
2024	$11.60	0.9930	226,110	224,527	0.0925	1.0729	0.9566	1.0264	0.9035	0.9693
2025	$11.60	0.9810	212,378	208,343	0.0858	0.9956	0.9288	0.9246	0.8444	0.8406
2026	$11.60	0.9642	199,486	192,344	0.0792	0.9191	0.9017	0.8288	0.7891	0.7253
2027	$11.60	0.9432	187,381	176,738	0.0728	0.8445	0.8755	0.7393	0.7375	0.6229
2028	$11.60	0.9181	176,017	161,601	0.0666	0.7722	0.8500	0.6563	0.6893	0.5323
2029	$11.60	0.8894	165,346	147,059	0.0606	0.7027	0.8252	0.5799	0.6442	0.4527
2030	$11.60	0.8575	155,327	133,193	0.0549	0.6365	0.8012	0.5099	0.6020	0.3832
2031	$11.60	0.8230	145,919	120,091	0.0495	0.5738	0.7778	0.4464	0.5626	0.3229
2032	$11.60	0.7860	137,085	107,749	0.0444	0.5149	0.7552	0.3888	0.5258	0.2707
2033	$11.60	0.7473	128,789	96,244	0.0396	0.4599	0.7332	0.3372	0.4914	0.2260
2034	$11.60	0.7071	120,999	85,558	0.0352	0.4088	0.7118	0.2910	0.4593	0.1878
2035	$11.60	0.6660	113,683	75,713	0.0312	0.3618	0.6911	0.2500	0.4292	0.1553
2036	$11.60	0.6244	106,813	66,694	0.0275	0.3187	0.6710	0.2138	0.4012	0.1278
2037	$11.60	0.5826	100,360	58,470	0.0241	0.2794	0.6514	0.1820	0.3749	0.1048
2038	$11.60	0.5411	94,300	51,026	0.0210	0.2438	0.6324	0.1542	0.3504	0.0854
2039	$11.60	0.5003	88,609	44,331	0.0183	0.2118	0.6140	0.1301	0.3275	0.0694
2040	$11.60	0.4604	83,263	38,334	0.0158	0.1832	0.5961	0.1092	0.3060	0.0561
2041	$11.60	0.4217	78,242	32,995	0.0136	0.1577	0.5788	0.0913	0.2860	0.0451
2042	$11.60	0.3845	73,526	28,271	0.0116	0.1351	0.5619	0.0759	0.2673	0.0361
2043	$11.60	0.3490	69,096	24,115	0.0099	0.1152	0.5456	0.0629	0.2498	0.0288

2044	$11.60	0.3152	64,935	20,468	0.0084	0.0978	0.5297	0.0518	0.2335	0.0228
2045	$11.60	0.2835	61,026	17,301	0.0071	0.0827	0.5142	0.0425	0.2182	0.0180
2046	$11.60	0.2537	57,354	14,551	0.0060	0.0695	0.4993	0.0347	0.2039	0.0142
2047	$11.60	0.2260	53,905	12,183	0.0050	0.0582	0.4847	0.0282	0.1906	0.0111
2048	$11.60	0.2004	50,664	10,153	0.0042	0.0485	0.4706	0.0228	0.1781	0.0086
2049	$11.60	0.1769	47,620	8,424	0.0035	0.0403	0.4569	0.0184	0.1665	0.0067
2050	$11.60	0.1554	44,759	6,956	0.0029	0.0332	0.4436	0.0147	0.1556	0.0052
2051	$11.60	0.1359	42,072	5,718	0.0024	0.0273	0.4307	0.0118	0.1454	0.0040
2052	$11.60	0.1183	39,547	4,678	0.0019	0.0224	0.4181	0.0093	0.1359	0.0030
2053	$11.60	0.1025	37,175	3,810	0.0016	0.0182	0.4059	0.0074	0.1270	0.0023
2054	$11.60	0.0884	34,945	3,089	0.0013	0.0148	0.3941	0.0058	0.1187	0.0018
2055	$11.60	0.0759	32,851	2,493	0.0010	0.0119	0.3826	0.0046	0.1109	0.0013
2056	$11.60	0.0649	30,883	2,004	0.0008	0.0096	0.3715	0.0036	0.1037	0.0010
2057	$11.60	0.0552	29,033	1,603	0.0007	0.0077	0.3607	0.0028	0.0969	0.0007
Total						11.6000		9.3899		7.4553
Discount factor								0.8095		0.6427

APPENDIX B: COST-BENEFIT ANALYSIS FOR 30 PERCENT OVERLAP REQUIREMENT

Rear impact guards are designed to absorb energy and prevent PCI by attaching to substantial structural elements of a trailer or semitrailer, such as the chassis frame rails, by way of vertical support members. The test results from the initial testing at IIHS reported in the NPRM show that many trailer rear impact guards designed to CMVSS No. 223 met the proposed performance requirements in the NPRM in full frontal and 50 percent offset crashes but were unable to prevent PCI in a 35 mph crash into the rear of the trailer, where only 30 percent of the width of the passenger vehicle front end overlapped with the rear of the trailer. In these 30 percent overlap crashes, only a small lateral portion of the rear impact guard (about 22 percent of the guard width) engaged with the front end of the passenger vehicle. This small lateral portion typically did not include a vertical support member of the guard, so when the passenger vehicle struck it, this small lateral portion deformed locally and did not prevent PCI.

NHTSA has estimated the potential benefits of adopting a 30 percent overlap crash in considering development of a FMVSS. The agency estimated the number of fatalities in 30 percent or lower overlap crashes in the field based on the available information, estimated the effectiveness of the rear impact guards that prevent PCI in 30 percent overlap crashes, and estimated the lives saved by a requirement for rear impact guards mitigating PCI in 30 percent overlap crashes.

Benefits

The 2013 UMTRI study found that there are annually 72 fatalities in light vehicle crashes into the rear of trailers that result in PCI. According to the 2013 UMTRI study, almost 40% of the impacts by light vehicles were "offset," meaning that they occurred on the outer left or right third of a trailer's rear. For trailers required to have rear impact guards, there was no difference in the extent of underride, including PCI, for offset and non-offset impacts of light vehicles into the rear of trailers.[60] Therefore, the number of annual fatalities in offset crashes with PCI into the rear of trailers was determined as the product of annual number of fatalities in light vehicle crashes with PCI into the rear of trailers (72) and the percentage of offset crashes (40%). Accordingly, the number of fatalities in offset crashes with PCI from the 2013 UMTRI study is 28.8 (=72 x 40%). NHTSA reviewed a sample of the offset crashes in the 2013 UMTRI study and found that in most of these offset crashes, there was more than 30 percent overlap of the impacting vehicle with the rear of the trailer such that the impacting vehicle engaged the rear impact guard at the location of a vertical member. NHTSA assumed 20 to 40 percent of these 28.8 annual fatalities were in crashes with 30 percent or less overlap of the front end of the impacting light vehicle with the trailer. Therefore, NHTSA estimated that 5.8 – 11.5 (= 28.8 x 20% to 28.8 x 40%) annual fatalities in low overlap crashes.

The 2013 UMTRI study also found that only 26 percent of light vehicle crashes into the rear of trailers were at relative impact speeds of 56 km/h (35 mph) or less. Though the 2013 UMTRI study found that the crash speeds in offset crashes were higher than those in non-offset crashes, NHTSA used 26 percent to estimate the number of crashes into the rear of trailers with 30

[60] Figure 5 in the 2013 UMTRI Study. Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes, DOT HS 811 725, March 2013, infra.

percent or lower overlap that were at crash speeds 56 km/h (35 mph) or lower. Rear impact guards may not be able to mitigate all fatalities in crashes into the rear of trailers with relative velocity of 56 km/h or less because some crashes may be due to circumstances other than underride (i.e., unrestrained status of occupants, elderly and other vulnerable occupants, post impact vehicle kinematics that could expose vehicle to subsequent impacts[61]). For the purpose of this analysis, NHTSA assumed that the incremental effectiveness of rear impact guards (CMVSS No. 223 compliant guards that also mitigate PCI in 30 percent overlap crashes) in preventing fatalities in light vehicle impacts with 30 percent overlap into the rear of trailers with crash speeds less than 56 km/h is 50 percent. Therefore, NHTSA estimated the overall effectiveness of upgrading from the final rule compliant guards to final rule compliant guards that also prevent PCI in 30 percent overlap crashes to be 13 percent (=26% x 50%). NHTSA estimates that the annual number of lives saved in low overlap crashes into the rear of trailers at relative velocities of 56 km/h (35 mph) or less to be 0.75 to 1.5 (= 5.8 x 0.13 to 11.6 x 0.13).

Costs

To prevent PCI in 30 percent overlap crashes, designs would have to either: (a) add additional vertical members at the lateral edge of the rear impact guard that connect to the trailer's transverse floor beam and strengthen the transverse floor beam of the trailer to withstand the loads transmitted from these vertical members at the edge of the guard; or (b) considerably strengthen the rear impact guard member so it would not deform locally in the 30 percent overlap crash. In these circumstances all the loads will still be taken up by the longitudinal chassis rails. This means that both these approaches would add significant weight to the vehicles because they

[61] The IIHS tests showed that in 30 percent overlap crashes where PCI is mitigated, the impacting light vehicle rotates during the crash and therefore could be exposed to impact by vehicles traveling in adjacent lanes.

involve adding more vertical members, strengthening the floor beams, or strengthening the guard itself.

Currently, there are 4 trailer manufacturers that offer rear impact guards that prevent PCI in all three IIHS crash test conditions (35 mph crash of a passenger vehicle with (1) full overlap, (2) 50 percent overlap and (3) 30 percent overlap with the rear of the trailer) as standard equipment. In 2020, the total trailer output of these 4 manufacturers is about 28 percent of the total number of trailers produced in 2020 (211,807).[62] Many other trailer manufacturers offer rear impact guards that prevent PCI in the three IIHS crash test conditions as optional equipment.

NHTSA reviewed the rear impact guard offerings in the trailer industry. The incremental cost and weight increase of a trailer with a rear impact guard that prevents PCI of passenger vehicles in all three overlap conditions (full, 50 percent, and 30 percent overlap) compared to an equivalent trailer by the same manufacturer with a rear impact guard that meets the performance requirements of this final rule[63] ranges from $100 to $1,000 and from 25 kg (55 lb) to 118 kg (260 lb), respectively. The weighted average (weights based on trailers produced in 2020)[64] of this incremental cost and weight increase of trailers with rear impact guards which prevent PCI in 30 percent overlap crashes is $306 and 35 kg (77 lb), respectively.

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62 https://cdn.baseplatform.io/files/base/ebm/trailerbodybuilders/document/2021/04/TBB_Top_25_CY2020.6089da057e9d0.pdf

63 As noted previously, the final rule requirements ensure preventing PCI in a 35 mph passenger vehicle crash with full and 50 percent overlap with the rear of a trailer.

64 https://cdn.baseplatform.io/files/base/ebm/trailerbodybuilders/document/2021/04/TBB_Top_25_CY2020.6089da057e9d0.pdf

Stoughton Trailer, a trailer manufacturer, produces trailers with rear impact guards that prevent PCI in all three overlap conditions at 56 km/h (35 mph) as standard equipment and notes on its website that its rear impact guards do not add additional weight, cost, or negative impacts of aerodynamics (presumably compared to rear impact guards that would meet this final rule requirements).[65] The Stoughton rear impact guard, made of steel, includes two vertical supports on the outer ends of the horizontal member that fasten to a robust undercarriage of the trailer. It is not clear how the additional material (two steel vertical members on the outer edge of the horizontal member that is bolted to a reinforced undercarriage) would not add weight or cost to the trailer and so this guard design was not considered in this analysis. There are some unique rear impact guard designs that meet the performance requirements in this final rule and are also able to mitigate PCI in 30 percent overlap crashes. However, these unique designs may have restrictions in intermodal operations at loading docks[66] and may not be practicable for all types of trailers covered by FMVSS No. 224. The benefit-cost analysis assumes intermodal operability is maintained and so these unique rear impact guard designs were not considered for this analysis.

Material Cost

There were 211,807 trailers produced in 2020[67] among which 65 percent (137,675 = 211,806 x 65%) were required to be equipped with rear impact guards, of which 28 percent were equipped with rear impact guards that meet the performance requirements of this final rule and also

[65] https://www.stoughtontrailers.com/Portals/0/documents/Rear%20Underride%20Guard%20Sales%20Sheet.pdf
[66] In order to comply with OSHA requirements (OSHA 29 CFR 1910.26(d)), loading docks have vehicle restraints that are designed to connect to rear impact guards to prevent the vehicle from moving during loading and unloading operations. Unique rear impact guard designs that are wider than 7.5 inches, with unique profiles (such as pentagonal shapes) have provided challenges to connect the vehicle restraints to the rear impact guard.
[67] https://cdn.baseplatform.io/files/base/ebm/trailerbodybuilders/document/2021/04/TBB_Top_25_CY2020.6089da057e9d0.pdf

mitigate PCI in 30 percent overlap crashes. The annual average and minimal incremental fleet cost of equipping all new applicable trailers[68] (99,126 = 137,675 x 72%) with rear impact guards that mitigate PCI in 30 percent overlap crashes is $30.3 million (= 99,126 x $306) and $9.9 million (=99,126 x $100), respectively as shown in Table B-1.

Table B-1: Cost per Trailer and Total Material Cost (Cost in 2020 dollars)

	Incremental Cost Increase per Guard	% of Trailers that Requires Guards	Non-compliance	Total Number of Trailers Produced	Applicable Trailers	Total Incremental Cost
Average	$306	65%	72%	211,807	99,126	$30,332,457
Minimum	$100	65%	72%	211,807	99,126	$9,912,568

Fuel Cost

The average weight increase of 35 kg (77 lb) from installing a guard that could mitigate PCI in a 30 percent overlap crash would increase fuel consumption. Adding 77 lb changes the average fuel economy of that vehicle from 6.0 mpg to 5.9933 mpg. Over the lifetime of a heavy truck, the vehicle would use 404,594 gallons at 6.0 mpg and would use 405,047 gallons at 5.9933 mpg. Therefore, adding 77 lb results in 453 additional gallons of fuel used per vehicle for the lifetime of a vehicle. Adding 55 lb changes the fuel economy from 6.0 mpg to 5.9952 mpg and results in 324 additional gallons of fuel for the lifetime of a vehicle. The estimated fuel economy impact on a year to year basis is shown in Tables B-2 and B-3.

[68] There were 211,807 new trailers produced in 2020, among which 65 percent (137,675 = 211,807 x 0.65) are required to be equipped with rear impact guards. Among applicable trailers, 28 percent are already equipped with guards that mitigate PCI in 30 percent overlap crashes.

Table B-2: Undiscounted Value of Lifetime Fuel Economy Impact Per Vehicle in 2020 dollars (Weight Increase of 77 lb)

Year	Survival Probability	Exposure VMT	Aggregate Exposure	Fuel Price	Fuel Economy		Fuel Consumption		Value of Fuel Consumption	
					Base	New	Base	New	Base	New
1	1.0000	240,737	240,737	$2.83	6.0000	5.9933	40,123	40,168	$113,671	$113,798
2	0.9930	226,110	224,527	$2.93	6.0000	5.9933	37,421	37,463	$109,490	$109,612
3	0.9810	212,378	208,343	$2.99	6.0000	5.9933	34,724	34,763	$103,923	$104,039
4	0.9642	199,486	192,344	$3.05	6.0000	5.9933	32,057	32,093	$97,819	$97,928
5	0.9432	187,381	176,738	$3.10	6.0000	5.9933	29,456	29,489	$91,440	$91,542
6	0.9181	176,017	161,601	$3.16	6.0000	5.9933	26,934	26,964	$84,994	$85,090
7	0.8894	165,346	147,059	$3.19	6.0000	5.9933	24,510	24,537	$78,107	$78,194
8	0.8575	155,327	133,193	$3.29	6.0000	5.9933	22,199	22,224	$73,028	$73,110
9	0.8230	145,919	120,091	$3.32	6.0000	5.9933	20,015	20,038	$66,539	$66,614
10	0.7860	137,085	107,749	$3.36	6.0000	5.9933	17,958	17,978	$60,425	$60,492
11	0.7473	128,789	96,244	$3.38	6.0000	5.9933	16,041	16,059	$54,269	$54,329
12	0.7071	120,999	85,558	$3.40	6.0000	5.9933	14,260	14,276	$48,440	$48,495
13	0.6660	113,683	75,713	$3.41	6.0000	5.9933	12,619	12,633	$43,093	$43,141
14	0.6244	106,813	66,694	$3.42	6.0000	5.9933	11,116	11,128	$38,044	$38,087
15	0.5826	100,360	58,470	$3.46	6.0000	5.9933	9,745	9,756	$33,705	$33,743
16	0.5411	94,300	51,026	$3.49	6.0000	5.9933	8,504	8,514	$29,639	$29,672
17	0.5003	88,609	44,331	$3.48	6.0000	5.9933	7,389	7,397	$25,747	$25,776
18	0.4604	83,263	38,334	$3.54	6.0000	5.9933	6,389	6,396	$22,603	$22,629
19	0.4217	78,242	32,995	$3.57	6.0000	5.9933	5,499	5,505	$19,629	$19,650
20	0.3845	73,526	28,271	$3.59	6.0000	5.9933	4,712	4,717	$16,908	$16,927
21	0.3490	69,096	24,115	$3.62	6.0000	5.9933	4,019	4,024	$14,557	$14,573
22	0.3152	64,935	20,468	$3.63	6.0000	5.9933	3,411	3,415	$12,381	$12,395
23	0.2835	61,026	17,301	$3.62	6.0000	5.9933	2,883	2,887	$10,448	$10,459
24	0.2537	57,354	14,551	$3.67	6.0000	5.9933	2,425	2,428	$8,889	$8,899
25	0.2260	53,905	12,183	$3.68	6.0000	5.9933	2,030	2,033	$7,472	$7,480
26	0.2004	50,664	10,153	$3.68	6.0000	5.9933	1,692	1,694	$6,230	$6,237
27	0.1769	47,620	8,424	$3.70	6.0000	5.9933	1,404	1,406	$5,192	$5,198
28	0.1554	44,759	6,956	$3.69	6.0000	5.9933	1,159	1,161	$4,283	$4,287
29	0.1359	42,072	5,718	$3.74	6.0000	5.9933	953	954	$3,566	$3,570
30	0.1183	39,547	4,678	$3.79	6.0000	5.9933	780	781	$2,956	$2,959
31	0.1025	37,175	3,810	$3.84	6.0000	5.9933	635	636	$2,439	$2,442
32	0.0884	34,945	3,089	$3.89	6.0000	5.9933	515	515	$2,003	$2,005
33	0.0759	32,851	2,493	$3.94	6.0000	5.9933	416	416	$1,638	$1,639
34	0.0649	30,883	2,004	$3.99	6.0000	5.9933	334	334	$1,333	$1,335
35	0.0552	29,033	1,603	$4.04	6.0000	5.9933	267	267	$1,080	$1,081
Total							404,594	405,047	$1,295,977	$1,297,428

Table B-3: Undiscounted Value of Lifetime Fuel Economy Impact Per Vehicle in 2020 dollars (Weight Increase of 55 lb)

Year	Survival Probability	Exposure VMT	Aggregate Exposure	Fuel Price	Fuel Economy		Fuel Consumption		Value of Fuel Consumption	
					Base	New	Base	New	Base	New
1	1.0000	240,737	240,737	$2.83	6.0000	5.9952	40,123	40,155	$113,671	$113,762
2	0.9930	226,110	224,527	$2.93	6.0000	5.9952	37,421	37,451	$109,490	$109,577
3	0.9810	212,378	208,343	$2.99	6.0000	5.9952	34,724	34,752	$103,923	$104,006
4	0.9642	199,486	192,344	$3.05	6.0000	5.9952	32,057	32,083	$97,819	$97,897
5	0.9432	187,381	176,738	$3.10	6.0000	5.9952	29,456	29,480	$91,440	$91,513
6	0.9181	176,017	161,601	$3.16	6.0000	5.9952	26,934	26,955	$84,994	$85,062
7	0.8894	165,346	147,059	$3.19	6.0000	5.9952	24,510	24,529	$78,107	$78,169
8	0.8575	155,327	133,193	$3.29	6.0000	5.9952	22,199	22,217	$73,028	$73,086
9	0.8230	145,919	120,091	$3.32	6.0000	5.9952	20,015	20,031	$66,539	$66,592
10	0.7860	137,085	107,749	$3.36	6.0000	5.9952	17,958	17,973	$60,425	$60,473
11	0.7473	128,789	96,244	$3.38	6.0000	5.9952	16,041	16,054	$54,269	$54,312
12	0.7071	120,999	85,558	$3.40	6.0000	5.9952	14,260	14,271	$48,440	$48,479
13	0.6660	113,683	75,713	$3.41	6.0000	5.9952	12,619	12,629	$43,093	$43,127
14	0.6244	106,813	66,694	$3.42	6.0000	5.9952	11,116	11,125	$38,044	$38,075
15	0.5826	100,360	58,470	$3.46	6.0000	5.9952	9,745	9,753	$33,705	$33,732
16	0.5411	94,300	51,026	$3.49	6.0000	5.9952	8,504	8,511	$29,639	$29,663
17	0.5003	88,609	44,331	$3.48	6.0000	5.9952	7,389	7,394	$25,747	$25,768
18	0.4604	83,263	38,334	$3.54	6.0000	5.9952	6,389	6,394	$22,603	$22,621
19	0.4217	78,242	32,995	$3.57	6.0000	5.9952	5,499	5,504	$19,629	$19,644
20	0.3845	73,526	28,271	$3.59	6.0000	5.9952	4,712	4,716	$16,908	$16,922
21	0.3490	69,096	24,115	$3.62	6.0000	5.9952	4,019	4,022	$14,557	$14,568
22	0.3152	64,935	20,468	$3.63	6.0000	5.9952	3,411	3,414	$12,381	$12,391
23	0.2835	61,026	17,301	$3.62	6.0000	5.9952	2,883	2,886	$10,448	$10,456
24	0.2537	57,354	14,551	$3.67	6.0000	5.9952	2,425	2,427	$8,889	$8,896
25	0.2260	53,905	12,183	$3.68	6.0000	5.9952	2,030	2,032	$7,472	$7,478
26	0.2004	50,664	10,153	$3.68	6.0000	5.9952	1,692	1,694	$6,230	$6,235
27	0.1769	47,620	8,424	$3.70	6.0000	5.9952	1,404	1,405	$5,192	$5,197
28	0.1554	44,759	6,956	$3.69	6.0000	5.9952	1,159	1,160	$4,283	$4,286
29	0.1359	42,072	5,718	$3.74	6.0000	5.9952	953	954	$3,566	$3,569
30	0.1183	39,547	4,678	$3.79	6.0000	5.9952	780	780	$2,956	$2,958
31	0.1025	37,175	3,810	$3.84	6.0000	5.9952	635	636	$2,439	$2,441
32	0.0884	34,945	3,089	$3.89	6.0000	5.9952	515	515	$2,003	$2,004
33	0.0759	32,851	2,493	$3.94	6.0000	5.9952	416	416	$1,638	$1,639
34	0.0649	30,883	2,004	$3.99	6.0000	5.9952	334	334	$1,333	$1,335
35	0.0552	29,033	1,603	$4.04	6.0000	5.9952	267	267	$1,080	$1,081
Total							404,594	404,917	$1,295,977	$1,297,014

Table B-4 shows the estimated incremental weight increase and the impact on fuel cost per vehicle at the 3 percent and 7 percent discount rate.

Table B-4: Present Discounted Value of Increased Lifetime Fuel Costs per Vehicle (in 2020 dollars)

	Fuel Economy (mpg)		Incremental Increase in Lifetime Fuel Costs		
Weight Increase (lb)	Base	New	Undiscounted	3%	7%
Average (77 lb)	6.0	5.9933	$1,451	$1,175	$933
Minimum (55 lb)	6.0	5.9952	$1,037	$839	$666

The total fuel costs depend on the incremental weight increase and the discount rate applied. These are derived by taking the vehicle lifetime fuel cost in Table B-4 and multiplying by the number of applicable vehicles. We adjusted the incremental fuel cost per vehicle with the 28% compliance and 35% exemption rates as shown in Table B-5.

Table B-5: Incremental Fuel Cost per Vehicle in 2020 dollars

	Adjustment	Not discounted	3%	7%
Average	w/o adjustment	$1,451	$1,175	$933
	w/ adjustment	$679	$550	$437
Minimum	w/o adjustment	$1,037	$839	$666
	w/ adjustment	$485	$393	$312

With 192,000 class 8 truck annual sales,[69] the total average incremental lifetime fuel cost (for weight increase of 77 lb) is estimated to be $130 million undiscounted, $106 million with 3 percent discounting and $84 million with 7 percent discounting. If the minimum weight increase of 25 kg (55 lb) is used instead, the total minimum incremental lifetime fuel cost is estimated to

[69] See statista for class 8 truck annual sales. https://www.statista.com/statistics/261416/class-3-8-truck-sales-in-the-united-states/

be $93 million undiscounted, $75 million with 3 percent discounting, and $60 million with 7 percent discounting as shown in Table B-6.

Table B-6: Total Incremental Fuel Costs (2020 Dollars)

	Costs per Vehicle			Number of Applicable Vehicles	Total Incremental Increase Lifetime Fuel Costs		
	Un-discounted	3%	7%		Un-discounted	3%	7%
Average	$679	$550	$437	192,000	$130,407,220	$105,561,101	$83,812,720
Minimum	$485	$393	$312	192,000	$93,151,737	$75,403,800	$59,868,621

The total undiscounted cost increase (material cost and lifetime fuel cost) on average is $161 million and a minimum of $103 million.

Cost-Effectiveness

The cost-effectiveness analysis derives the cost per life saved which is equal to the cost divided by lives saved. The cost of the 30 percent overlap requirement would be the regulatory cost (material and fuel costs), and the cost effectiveness is shown in Table B-7. The cost per life saved (undiscounted) using average cost estimate ranges from $107 million to $215 million while that using minimum cost estimate ranges from $69 million to $138 million, which is significantly greater than the value of a statistical life ($11.6 million).[70]

[70] For more information on the value of a statistical life, see a 2021 Office of the Secretary memorandum on the "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses – 2021 Update." https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

Table B-7: Cost per Equivalent Life Saved in 2020 dollars

	Average		Minimum	
Total cost	$160,739,677	$160,739,677	$103,064,305	$103,064,305
Lives saved	0.7488	1.4976	0.7488	1.4976
Cost per life saved	$214,663,030	$107,331,515	$137,639,296	$68,819,648