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Final Regulatory Evaluation

Bus Rollover Structural Integrity
FMVSS No. 227

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

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EXECUTIVE SUMMARY

This analysis presents the costs and benefits of requiring new large buses (over-the-road buses (OTRBs)[1] regardless of their gross vehicle weight rating (GVWR) and other buses with a GVWR greater than 11,793 kilograms (kg) (26,000 pounds (lb)) to meet rollover structural integrity requirements in the new Federal motor vehicle safety standard (FMVSS) No. 227, "Bus rollover structural integrity."[2] The term "large bus" in this document refers to the various bus designs covered by FMVSS No. 227. FMVSS No. 227 is based on the United Nations Economic Commission for Europe Regulation Number 66 (ECE R.66). According to the test procedure, the subject vehicle is overturned onto its side from a height of 800 mm (31.5 inches). The large bus would be required to meet the following:

- Intrusion into the survival space, demarcated in the vehicle interior, by any part of the bus outside the survival space (except for debris such as small glazing fragments, nuts, and bolts weighing not more than 15 grams) must not occur; and
- Emergency exits must remain closed during and after the test.

[1] An over-the-road bus (OTRB) is a bus characterized by an elevated passenger deck located over a baggage compartment, except a school bus. It is also often referred to as a motorcoach.

[2] FMVSS No. 227 applies to: (a) new OTRBs, regardless of GVWR; and (b) all new non-OTRBs with a GVWR greater than 11,793 kg (26,000 lb), including double-decker buses. Transit buses, prison buses, school buses, and perimeter-seating buses are excluded from the standard.

We expect that approximately 2,200 new large buses will be affected annually by the final rule promulgating FMVSS No. 227.[3]

Previously, NHTSA published a final rule[4] (NHTSA-2013-0121-0001) on the first area detailed in NHTSA's Approach to Motorcoach Safety, requiring seat belts for each passenger seating position in: (a) all new over-the-road buses; and (b) new buses other than over-the-road buses, with a GVWR greater than 11,793 kg (26,000 lb).[5] The final rule accompanying this analysis builds on the seat belt final rule by requiring those buses to meet increased structural integrity and other requirements to protect both restrained and unrestrained occupants in rollover crashes. As a result, the requirements in the final rule apply to generally the same buses that are covered in the final rule on seat belts.[6]

a) Annual Target Population

Fatality data from Fatality Analysis Reporting System (FARS) averaged from 2004 to 2018 shows there are annually 13 fatally injured occupants in rollover crashes of buses covered

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[3] Evaluation of the Market for Small-to-Medium-Sized Cutaway Buses, Federal Transit Administration Project Number: Ml-26-7208.07.1, December 2007, available at https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/AnEvaluationofMarketforSmalltoMediumSizedCutawayBuses.pdf, last accessed November 4, 2016.

[4] 78 FR 70416, published in the Federal Register on November 25, 2013. Available online at https://www.govinfo.gov/content/pkg/FR-2013-11-25/pdf/2013-28211.pdf#page=2, last accessed September 8, 2021.

[5] Some buses are excluded from this latter category such as transit and school buses.

[6] As discussed further in the final rule preamble, the requirements also fulfill various provisions of the "Moving Ahead for Progress in the 21st Century Act" (MAP-21). Pub. L. No. 112-141. Among other matters, MAP-21 requires DOT to "establish improved roof and roof support standards for motorcoaches that substantially improve the resistance of motorcoach roofs to deformation and intrusion to prevent serious occupant injury in rollover crashes involving motorcoaches." In addition, MAP-21 directs DOT to consider "portal improvements to prevent partial and complete ejection of motorcoach passengers, including children." These improvements must be made if the agency determines the rulemakings meet the requirements and considerations of the Safety Act. Under MAP-21, "motorcoach" means an over-the-road bus but does not include a bus used in public transportation provided by, or on behalf of, a public transportation agency, or a school bus.

by FMVSS No. 227. In addition, using the National Automotive Sampling System-General Estimate System (NASS-GES), we estimated on average a total of 85 seriously injured occupants, annually, in rollover crashes involving the above-referenced bus types. NHTSA completed a rulemaking requiring seat belts on those buses in November 2013 and published a final rule requiring electronic stability control (ESC) on those buses in June 2015.[7] Assuming that seat belt usage rates vary from 15 to 90 percent, the projected target population (after the benefits to those rules are accounted for) is:

4 - 10 fatally injured occupants
23 - 67 seriously to critically injured occupants

b) Benefits

The benefits assume that all large buses covered under the FMVSS No. 227 final rule are equipped with ESC and lap/shoulder belts. The seat belt use rate is estimated to vary from 15 percent to 90 percent. We expect that the FMVSS No. 227 final rule would save 3 lives and 4 seriously injured occupants annually for a 15% belt use rate and 2 lives and 4 seriously injured occupants for a 90% belt use rate.

Fatalities and Serious to Critical Injuries Saved Annually

Annual fatal and non-fatal injuries	Benefits with 90% and 15% belt use rates
Fatalities	2 (1.79) to 3 (2.52)
MAIS 1-2 injured occupants (Minor injuries)*	0
MAIS 3-5 injured occupants (Serious injuries)	4 (3.76) to 4 (4.07)

* We are not assuming benefits at these lower level injuries since these minor injuries such as arm bumping the arm rest, superficial scratches, etc. are difficult to prevent regardless of improved structural integrity.

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[7] Seat belt final rule published on November 25, 2013: 78 FR 70416; ESC final rule published on June 23, 2015: 80 FR 36050.

c) Costs

The countermeasures may include a stronger roof and side walls, shock-resistant latches for the emergency exits, stronger seat and overhead storage compartment anchorages, and improved window mounting. These countermeasures would result in a weight increase of 14 pounds for large buses, covered under the FMVSS No. 227 final rule, which do not need stronger roof and side walls and 564 to 1,114 pounds for the remaining large buses, covered by the FMVSS No. 227 final rule, which require strengthening the side walls and roof. The average weight increase is estimated to range from 399 to 784 pounds per vehicle. The sales adjusted average incremental material cost per large bus ranges from $325 to $591. The average incremental fuel cost due to weight increases is estimated to range from $2,441 to $4,790 per vehicle at a 3 percent discount rate and from $1,862 to $3,654 per vehicle at a 7 percent discount rate over the lifetime of the vehicle.

Estimated Incremental Material and Fuel Costs per Large Bus, in 2020 dollars

	Cost per Large bus
Material Costs	$325 – $591
Fuel Costs Increase, 3% Discount Rate	$2,441 – $4,790
Fuel Costs Increase, 7% Discount Rate	$1,862 – $3,654

Assuming 2,200 new large buses sold annually, the annual total costs are estimated to be $4.81 million to $11.84 million.

Estimated Total Costs, in 2020 dollars

	Total Fleet Cost
Total Material Costs	$0.71 M – $1.30 M
Total Fuel Costs, 3% Discount Rate	$5.37 M – $10.54 M
Total Fuel Costs, 7% Discount Rate	$4.10 M – $8.04 M
Total Cost Range	$4.81 M – $11.84 M

Note: M = millions; the numbers are rounded to two decimal places.

d) Net Economic Impact

The FMVSS No. 227 final rule is expected to be cost-beneficial based on the costs and monetized benefits.

We expect that the FMVSS No. 227 final rule would result in 2 to 3 equivalent lives saved (ELS).[8] With the total comprehensive saving of $17.59 to $29.40 million and the total cost of $4.81 to $11.84 million, the FMVSS No. 227 final rule is expected to produce a net economic benefit of between $8.25 million and $23.31 million in 2020 dollars. The total cost per equivalent life saved would range from $2.48 million to $4.99 million at 15 percent belt use and from $3.17 million to $6.38 million at 90 percent belt use.

Annual Cost and Benefits (in Millions, in 2020 dollars) at 15% Seat Belt Use Rate

Discount Rate	Annual Costs	Annual Benefits	Net Benefits
3%	$6.08 to $11.84	$29.40	$17.56 to $23.31
7%	$4.81 to $9.34	$22.43	$13.09 to $17.61

Annual Cost and Benefits (in Millions, in 2020 dollars) at 90% Seat Belt Use Rate

Discount Rate	Annual Costs	Annual Benefits	Net Benefits
3%	$6.08 to $11.84	$23.05	$11.21 to $16.97
7%	$4.81 to $9.34	$17.59	$8.25 to $12.78

Total Cost per Equivalent Life Saved (in Millions of 2020 dollars)

Discount Rate	15% Seat Belt Use Rate	90% Seat Belt Use Rate
3%	$2.48 to $4.83	$3.17 to $6.17
7%	$2.57 to $4.99	$3.28 to $6.38

The lower cost estimate reflects a lower estimated amount of materials necessary to improve the structure of the large buses covered under the FMVSS No. 227 final rule. The higher cost estimate reflects an increased amount of materials for some vehicles to comply

[8] Refer to Chapter V, Cost-Effectiveness Analysis and Benefit-Cost Analysis for estimating equivalent lives saved.

with the final rule. The increase in structural materials will decrease the vehicle's fuel economy, which has also been factored into costs. In summary, the lower bound of net benefits represents a higher belt use rate and higher estimate of materials and fuel costs due to more weight needed to meet the requirements. The higher net benefits represent a lower belt use rate and the lower estimate of materials and fuel costs.

I. INTRODUCTION

FMVSS No. 227 applies generally to buses with a gross vehicle weight rating (GVWR) greater than 11,793 kilograms (26,000 pounds) manufactured on or after the date that is three years after the publication of the final rule. Specifically, FMVSS No. 227 applies to OTRBs (regardless of GVWR) and other buses with a GVWR above 11,793 kilograms (26,000 pounds). However, this standard does not apply to prison buses, school buses, transit buses, and perimeter-seating buses.

The agency believes that it makes sense to apply the structural integrity requirements to the same group of vehicles that are covered by the final rule requiring seat belts since both rulemakings originated from NHTSA's 2007 Approach to Motorcoach Safety[9] and are intended to help reduce fatalities and injuries occurring in large buses during rollovers.

The following section provides a brief background, describes the need for regulatory action, and a summary of the technical requirements in the FMVSS No. 227 final rule.

A. Background

Each year the motorcoach industry transports millions of people between cities for short and long distance tours, school field trips, commuter and entertainment-related trips. According to the American Bus Association, there are 2,963 motorcoach carriers in the United

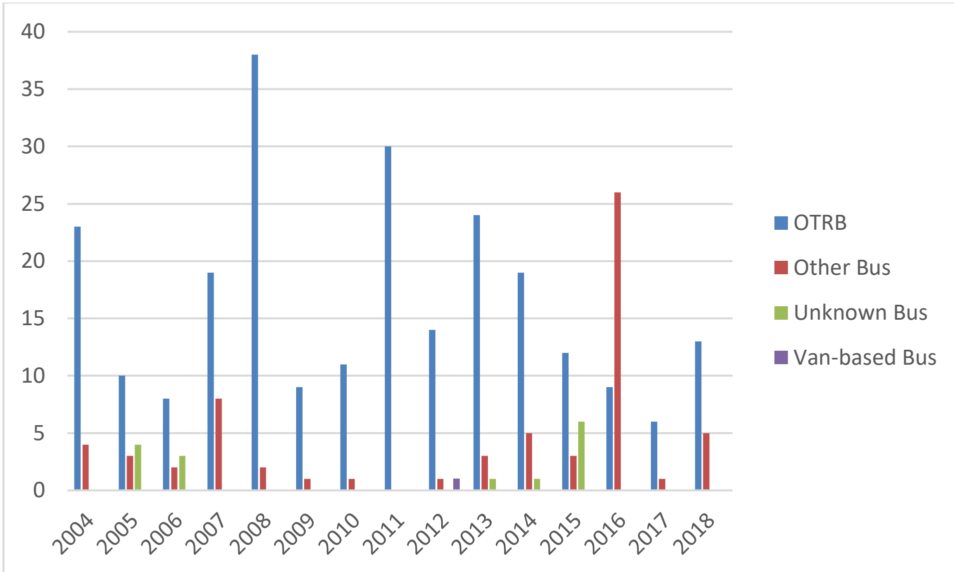
[9] NHTSA's 2007 Approach to Motorcoach Safety is a NHTSA planning document that presents comprehensive motorcoach safety issues and the course of action NHTSA will pursue to address them (https://www.nhtsa.gov/DOT/NHTSA/Vehicle%20Safety/Articles/Associated%20Files/481217.pdf*).*

States. These carriers operate over 32,920 motorcoaches, logging 1.5 billion miles annually.[10] The agency believes that other large buses, such as body-on-frame buses offering similar seating capacity, have also been operating on longer routes with similar trip patterns.

Although motorcoach crashes and crashes involving other large buses are rare, fatalities resulting from such a crash can be high since those vehicle types may carry up to 60 occupants. The Fatality Analysis Reporting System (FARS) is a census of fatal traffic crashes in the United States. Data from FARS was examined over the years of 2004 to 2018. During the 15-year period, among buses covered by FMVSS No. 227, there were 245 occupant fatalities in cross-country/intercity buses, 65 in other buses, 15 in unknown buses, and one in van-based buses in crash/rollover events as shown in Figure 1. Since the four bus body types represent the group of large buses covered by our large bus rulemakings, our analysis of the safety problem examines the data for all four of those bus body types from FARS. According to the FARS data, there were a total of 326 large bus occupant fatalities in the 15-year period. [11]

[10] Motorcoach Census, "A Study of the Size and Activity of the Motorcoach Industry in the United States and Canada in 2017," Prepared for the American Bus Association Foundation by John Dunham & Associates, June 5, 2019. https://www.buses.org/assets/images/uploads/pdf/FINAL_2017_Census.pdf

[11] Fatalities due to incidents where the impact point and other crash events could not be identified are not included in the fatality counts resulting from motorcoach crash events.



Data source: FARS, 2004-2018

Figure 1

Fatally Injured Occupants in Large Bus Crashes

As shown in Figure 1, fatalities in certain years are significantly higher than average. There were more than 25 large bus occupant fatalities in 2004, 2007, 2008, 2011, 2013, and 2016.

The 40 large bus passenger fatalities in 2008 were mainly a result of 3 separate events. The first event was a large bus rollover crash that occurred in Mexican Hat, Utah, where the bus overturned as it departed the roadway and rolled one full turn, striking several rocks in a drainage ditch bed at the bottom of the embankment, and came to rest on its wheels. The roof separated from the body, and 51 of the 53 occupants were ejected. Nine passengers were fatally injured, and 43 passengers and the driver received various injuries.

The second 2008 event was a large bus crash in Sherman, Texas, where the bus went through a bridge railing and fell off the bridge, and 17 bus passengers were fatally injured. The NTSB report concluded that the overhead luggage rack had detached from its mounting, fell diagonally across the aisle onto the passengers, and impeded passenger egress and rescue efforts[12].

The third 2008 event was a rollover crash near Williams, California, where the bus flipped and rolled into a ditch, killing 9 people and injuring more than 30 others. According to a media report,[13] at least 35 people suffered critical injuries, while the rest of the passengers received moderate to minor injuries. There were 10 passengers either partially or completely ejected from the bus in the crash.[14]

Figure 2 shows the 326 large bus fatalities categorized by rollover/first impact point for the 15-year period (2004-2018). If a large bus was involved in a rollover, it is generally categorized as a rollover event since it is most likely the most harmful event in a crash and results in most of the large bus fatalities. Large buses not involved in a rollover are categorized by first impact point (front, side, or rear) of the bus. Among the 326 large bus occupant fatalities, rollovers accounted for 189 fatalities (58 percent) and 56 crashes.

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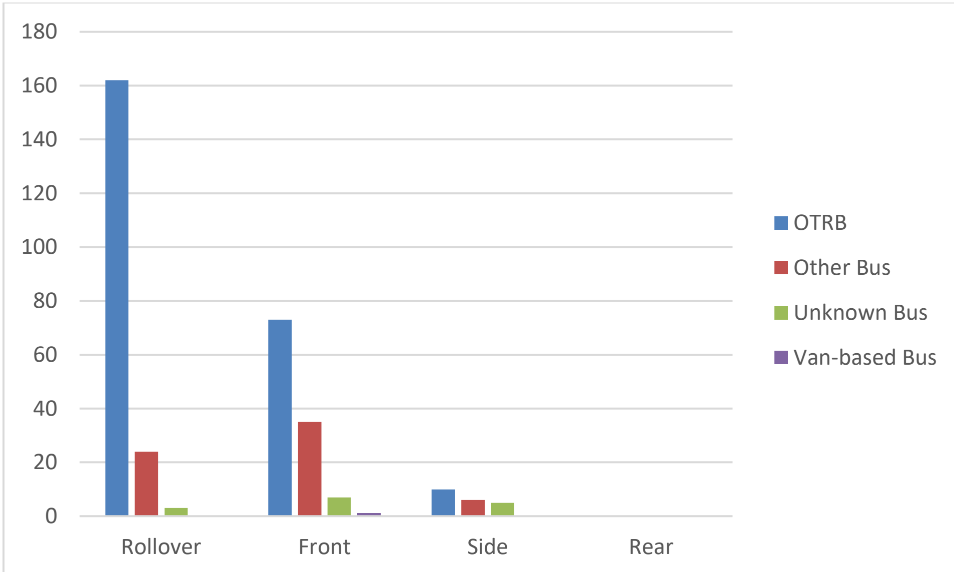
[12] NTSB/HAR-09/02 PB2009-916202; Motorcoach Run-Off-the-Bridge and Rollover Sherman, Texas August 8, 2008; October 2009; http://www.ntsb.gov/doclib/reports/2009/HAR0902.pdf, last accessed Septem 8, 2021.

[13] Colusa County Bus Accident, Accident and Injury News, October 6, 2008, http://www.californiainjuryblog.com/2008/10/colusa-county-bus-accident-kil.html

[14] FARS 2008 data, State case 2129



Data source: FARS 2004 - 2018

Figure 2

Occupant Fatalities in Large Buses by Rollover/First Point of Impact

In fatal large bus crashes, ejection is highly correlated to a fatal outcome for an occupant. Windows which fall into the occupant compartment or detach from the frame, and roof exits which unlatch are potential portals of ejection. Of the 189 fatalities from 2004-2018 in FARS large bus rollover crashes, there were 98 fatal passenger ejections and 8 fatal driver ejections.

B. Need for Regulatory Action

Section 32703(b) of MAP-21[15] directs the Secretary to prescribe certain regulations if they meet the requirements and considerations set forth in the Motor Vehicle Safety Act. Specifically, in subsection (b)(1), MAP-21 directs the Secretary to establish improved roof and roof support standards that "substantially improve the resistance of motorcoach roofs to

[15] *See* Moving Ahead for Progress in the 21st Century Act, Pub. L. No. 112-141 (Jul. 6, 2012).

deformation and intrusion to prevent serious occupant injury in rollover crashes involving motorcoaches." In addition, subsection (b)(2) directs the Secretary to "consider advanced glazing standards for each motorcoach portal and [to] consider other portal improvements to prevent partial and complete ejection of motorcoach passengers."[16] In order to fulfill the agency's statutory obligations under MAP-21, the FMVSS No. 227 final rule supported by this Final Regulatory Evaluation (FRE) addresses the aforementioned concerns.

In addition to our statutory obligations, the agency believes that there are important safety benefits for this rule. The rule would help prevent large bus occupant ejections and protect occupants within a survival space in a bus rollover event. As discussed further in this document, the available information indicates that there are cost-beneficial countermeasures available to address the safety problem. While large bus crashes are not as common as other vehicle crashes, a single large bus crash can contribute to a significant number of fatal and serious injuries due to the high occupancy of these vehicles. Further, a significant portion of large bus riders are students and seniors (age 55 +), which comprise 22 percent and 26.6 percent of riders, respectively.[17]

The requirements of the FMVSS No. 227 final rule accompanying this FRE are intended to work in conjunction with the agency's recent final rule on seat belts on large buses. As the agency's latest large bus rule requires seat belts on these buses, the agency believes that there

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[16] *See id*.

[17] Motorcoach Census, "A Study of the Size and Activity of the Motorcoach Industry in the United States and Canada in 2014," Prepared for the American Bus Association Foundation by John Dunhan & Associates, February 11, 2016. https://buses.org/assets/images/uploads/pdf/Motorcoach_Census_2014.pdf
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is a greater need to make surethat occupants using seat belts will not receive substantial injuries from a compromised survival space or from partial ejections. In addition, the requirements to help prevent ejection are important for protecting unbelted bus occupants. As we discuss further in this document, we do not anticipatethat bus occupant belt use (at least initially) will be high. Therefore, there continues to be a need to reduce ejection portals as occupant ejection continues to be highly correlated with occupant fatalities in such crashes.

C. NHTSA Research

In support of the second action item of NHTSA's 2007 Approach to Motorcoach Safety, the agency evaluated two existing roof crush/rollover standards: FMVSS No. 220, "School bus rollover protection" and ECE R.66, "Uniform Technical Prescriptions Concerning the Approval of Large Passenger Vehicles with regard to the Strength of their Superstructure."[18] We sought to evaluate the extent to which these preexisting standards would provide a standard which addresses the safety need present in these types of buses, particularly as to providing a minimum level of protection for vehicle occupants who are retained in the vehicle during a rollover event.

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[18] ECE R.66 defines "superstructure" as "the load-bearing components of the bodywork as defined by the manufacturer, containing those coherent parts and elements which contribute to the strength and energy absorbing capability of the bodywork, and preserve the residual space in the rollover test." "Bodywork" means "the complete structure of the vehicle in running order, including all the structural elements which form the passenger compartment, driver's compartment, baggage compartment and spaces for the mechanical units and components."

The agency purchased three different models of OTRBs to examine the performance in two existing roof crush/rollover standards (FMVSS No. 220 and ECE R.66). Two older models[19] were selected because they were representative of the range of roof characteristics (such as design, material, pillars, shape, etc.) of OTRB roofs in the U.S. fleet. The older model buses selected were two 12.2 meters (40 feet) long Model Year (MY) 1992 Motor Coach Industries (MCI) model MC-12, and two 12.2 meters (40 feet) long MY 1991 Prevost model (Prevost) LeMirage buses. The MCI and Prevost models were selected because they were similar in size and weight but exhibited visible differences in construction. The most discernable difference between these two models was that the Prevost LeMirage had smaller side windows and more roof support pillars. One of each model was subjected to a FMVSS No. 220 crush test and the other vehicle from each model was tested according to the ECE R.66 full vehicle rollover test. This test plan permitted an assessment of their performance under the two test conditions.

Many OTRBs, newer than the tested MCI and Prevost models, are 13.7 meters (45 feet) instead of 12.2 meters (40 feet) in length. As such, the agency believes that manufacturers could have significantly redesigned their OTRB models when introducing the longer OTRB designs. Thus, the agency also procured a MY 2000 MCI OTRB, Model 102-EL3, which was 13.7 meter (45 feet) in length. The MY 2000 MCI bus was only subjected to the ECE R.66 test. We

[19] We first conducted tests with older buses to be able to evaluate more buses and examine different candidate test procedures (we tested 4 older buses using two different test procedures). However, as explained further in this document, we conducted additional testing (using the ECE R.66 test) with a newer bus model (a 45-foot model similar to current bus models) to determine whether the results of the tests would be different based on the newer bus design. We found that the performance of the older buses was comparable to the newer buses as they also failed to meet the criteria of the ECE R.66 test.

conducted this test to evaluate the feasibility of performing the test on the longer buses and to compare the performance of this bus to previous buses in the ECE R.66 test.

All five of the large buses purchased were tested to requirements in either FMVSS No. 220 or ECE R.66. For further information on the four older OTRBs tested, a detailed discussion of the bus tests and results are available in the docket entry NHTSA-2007-28793-0019. For further information on the newer vehicle tested, see the test report, "ECE Regulation 66 Based Research Test of Motorcoach Roof Strength, 2000 MCI 102-EL3 Series Motorcoach," NHTSA No. MY0800, October 1, 2009, and Report No. ECE 66-MGA-2009-001, which can be found on NHTSA's website.[20]

1. Findings of the FMVSS No. 220-Based Tests

In evaluating FMVSS No. 220, the agency used one of the MY 1992 OTRBs and one of the MY 1991 Prevost OTRBs.

The FMVSS No. 220 test applies a uniformly distributed compressive load (equivalent to 1.5 times the unloaded vehicle weight (UVW) of the bus) on the roof of the bus along the vehicle's longitudinal centerline using a 915 mm (3 feet) wide plate that is 305 mm (1 foot) shorter than the bus length. The requirements specify that the bus roof must not compress more than 130 mm (5.118 inches) and the emergency exits remain operable.

Since there were some uncertainties regarding the strength of the OTRB roofs and whether they could withstand a force of 1.5 times UVW, we slightly changed the test

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[20] See http://www-nrd.nhtsa.dot.gov/database/VSR/SearchMedia.aspx?database=v&tstno=6797&mediatype=r&r_tstno=6797, Report 8. Step-by-step instructions on accessing the research report can be found in a memorandum in Docket No. NHTSA-2007-28793-0025 at http://www.regulations.gov.

procedures specified in FMVSS No. 220. In particular when the applied force reached the magnitude of 0.5 times UVW and 1.0 times UVW, the force was held constant at that level for a period of time in order to examine the operability of the emergency exits. In addition, survival space templates[21] (similar to those used in the ECE R.66 test) were installed for comparison with the results of the ECE R.66 tests.

Neither the MY 1992 MCI nor the MY 1991 Prevost bus was able to meet the force requirement (i.e., 1.5 times of the UVW) for school buses. For the MCI bus, a peak load of 0.91 times UVW was achieved when the force application device reached its maximum displacement range. Approximately 13 seconds after the peak load was recorded, contact was made between the front survival space template and the left and right overhead luggage racks. The emergency exit windows were operable after the load reached 0.5 times UVW and after the test with the load removed. For the MY 1991 Prevost bus, a peak load of 1.17 times UVW was achieved during the test. This peak load was reached when the force application device reached its maximum displacement range. Approximately 12 seconds after the peak load was reached, contact was made between the front survival space template and the left and right overhead luggage racks. The emergency exit windows were operable after the load reached 0.5 times UVW and after the test with the load removed. However, no measurements were made at 1.0 UVW for safety reasons.

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[21] The templates are used to delineate the occupant survival space. The templates are 1,250 mm (50.2 inches) tall and are tapered from the sidewall a distance of 150 mm (5.9 inches) at the bottom and 400 mm (15.8 inches) at the top. Several templates are placed in the bus passenger compartment. Encroachment of any bus structure into the survival space, as delineated by the templates, would be prohibited by ECE R.66.

The following was observed in the tests: (1) even though the OTRBs tested were heavier, larger, and structurally different than school buses,[22] the testing demonstrated that the FMVSS No. 220's test protocol could be adapted to test these large buses with only minor changes to the test device and procedure for mounting and stabilizing the bus on the test device; (2) front sections of these two bus models are weaker than the rear sections. (this is because the windshield and service door are in the front of the bus and offer little resistance to the compressive load); and (3) the front of the MY 1992 MCI bus yielded to the compressive load at 0.91 times UVW, while the front of the MY 1991 Prevost bus yielded at 1.17 times UVW.

2. Findings of the ECE R.66-Based Tests

Testing of Older Large Bus Models

The agency also used one of the MY 1992 MCI OTRBs and one of the MY 1991 Prevost OTRBs to evaluate the ECE R.66 test procedure.

In the ECE R.66 full vehicle test, the vehicle is placed on a tilting platform that is 800 mm above a smooth and level concrete surface. One side of the tilting platform along the length of the vehicle is raised at a steady rate of not more than 5 degrees/second until the vehicle becomes unstable, rolls off the platform, and impacts the concrete surface below. The vehicle typically strikes the hard surface near the intersection between the sidewall and the roof. The encroachment of the survival space during and after the rollover structural integrity test may be

[22] Generally, motorcoach designs are integral constructions whereas school buses are the traditional body-on-chassis designs. The loads specified in FMVSS No. 220 are applied to the frame structure of the school bus chassis which is easy to identify. In contrast, identifying load bearing points on a motorcoach can be challenging and requires some understanding of its construction. The location of load bearing points can vary for different motorcoach designs. In the two motorcoaches tested, the loads were applied at load bearing points near the wheel supports.

assessed using high speed photography, video, deformable templates, electric contact sensors, or any other suitable means.

In agency research for the ECE R.66 test, high speed video cameras and transfer media were applied to each survival space template in order to determine if any portion of the vehicle interior had entered the occupant survival space during the rollover event. In addition, two Hybrid III 50th percentile restrained and unrestrained adult male Anthropomorphic Test Devices (ATDs) (test dummies) were installed in the vehicle to measure injury potential and seat anchorage performance.

The following was observed in testing of the older OTRBs:

- The testing demonstrated that it is practicable to apply the ECE R.66 complete vehicle test to large buses. However, neither of the two buses tested was able to meet the requirement to maintain the integrity of the survival space during and after the test. Contact between the front survival space template and left side window was made on both bus models. As in the FMVSS No. 220-based tests, the testing indicated that the front sections of these two large bus models were weaker than the rear. This is because the windshield and service door are in the front of the bus and offer little resistance upon impact with the ground.
- On both buses, the windows on the impact side remained intact. The highspeed video footage from both tests indicatedthat the side windows located on the far-side of the impact underwent a substantial amount of flexion during the impact with the ground but remained intact. The windshield broke from its mounting and fell to the ground.

- For both buses, the roof emergency exits opened when the bus impacted the ground. The video footage also indicated that the side emergency exit windows on the Prevost bus unlatched and opened but closed when the bus came to its final resting position.
- For the MY 1992 MCI bus, all of the left side overhead luggage rack inboard hangers (hangers connect the overhead luggage rack to the ceiling of the large bus, and are spaced along the length of the rack to hold it up) rearward of the front two hangers, broke during the impact, leaving exposed sharp metal edges.
- For the MY 1991 Prevost bus, all the seats on the right side (opposite the impact side) of the bus detached from their wall mounts and the seat with the restrained dummy broke completely from its anchorages.

3. Anthropomorphic Test Device (ATD) Response in Older OTRBs

The Injury Assessment Reference Values (IARVs)[23] were relatively low for the ATDs restrained by the lap/shoulder belts (even for the seat in the Prevost bus that broke away from its side and floor anchorages). The IARVs were well below the threshold limits in FMVSS 208, "Occupant crash protection" although the left leg struck the aisle seat directly across from it. However, for the ATDs that were unrestrained, the type and severity of the injury indicated by

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[23] Injury assessment reference values (IARVs) were developed by Mertz in 1978 to assess the efficacy of General Motors (GM) restraint system designs under a variety of simulated frontal accident conditions using the Hybrid III midsize adult male dummy as the vehicle occupant. It refers to a human response level below which a specified significant injury is considered unlikely to occur for the given size of individual. If an IARV response measurement is below its corresponding tolerance limit, then the occurrence of the associated injury for that size occupant is considered unlikely for the accident environment simulated. See Mertz H J. Injury assessment values used to evaluate Hybrid III response measurements, NHTSA Docket 74-14, notice 32, Enclosure 2, attachment 2, part III, General Motors submission USG 2284, March 22, 1984.

the dummy IARVs depended on how they fell from their initial seated position during the rollover sequence. In the case of the MCI large bus, the unrestrained ATD received only one IARV (neck injury criterion Nij = 1.10) that was over the performance limit used in FMVSS No. 208. However, in the case of the MY 1991 Prevost large bus, the unrestrained ATD fell across the bus head-first onto the side window which was in contact with the ground, resulting in multiple IARVs exceeding the performance limits specified in FMVSS No. 208.

4. Testing of a Newer OTRB Model

NHTSA also conducted the ECE R.66 test on a MY 2000 MCI OTRB Model 102-EL3 that was 13.7 meters (45 feet) in length. This test was conducted to determine whether the ECE R.66 test protocol could be applied to the large buses sold in the United States and to examine different ballasting methods. Survival space templates were installed, and the bus was placed on a tilting platform that was 800 mm above a smooth and level concrete surface. One side of the tilting platform was raised at a steady rate of not more than 5 degrees/second until the bus became unstable, rolled off the platform, and impacted the concrete surface below.[24]

Occupant ballast was used in the test, as specified in ECE R.66. ECE R.66 specifies the option of two different methods of securing occupant ballast to the passenger seats. NHTSA tested both types of ballast to determine the feasibility of each and the differences (if any) that exist between the two methods. The agency believed that ballasting was important because it increases the weight and raises the center of gravity of the large bus, making the rollover structural integrity test more stringent and representative of a rollover event of a fully loaded

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[24] See "ECE Regulation 66 Based Research Test of Motorcoach Roof Strength, 2000 MCI 102-EL3 Series Motorcoach, NHTSA No.: MY0800," October 1, 2009, *supra*.

large bus. In addition, ballasting simulates an average restrained occupant in a rollover as the seat anchorages experience the forces when the seat is occupied by a restrained occupant. NHTSA evaluated the two ballasting methods to assess the feasibility and merits of the ballast methods. Four anthropomorphic ballasts, commercially available "water dummies," [25] were installed in one full row of seats (four seating positions) and were secured with ratchet straps that were configured to simulate Type 2 seat belts. The water dummies were each filled with 68 kg (150 lb) of sand. Steel ballasts, 68 kg (150 lb) per seating position, were installed in a second full row of seats (four seats). In this row, steel plates were placed on top of each seat cushion and were secured with bolts that passed through the cushion and attached to a bar which clamped onto the seat frame. (In the ECE R.66 test, each designated seating position with occupant restraints would be ballasted.)

The bus (MCI Model 102-EL3) was also seated with two 50th percentile adult male ATDs on the opposite side of the impact. This arrangement was similar to the earlier tests with the older large buses (See Section 3. Anthropomorphic Test Device (ATD) Response in Older OTRBs).

The following was observed in the testing of the MY 2000 large MCI bus (Model 102-EL3):

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[25] These water dummies are plastic containers constructed to simulate the torso shape of a passenger and can be secured in place using belts. Such water dummies have the capacity to be loaded to a weight of 176 pounds (80 kg). However, since the GVWR of a vehicle is typically estimated using an occupant weight of 150 pounds per seating position and since ECE R.66 specifies ballasts of 150 pounds, the agency only loaded the water dummies to 150 pounds. The water dummies were filled with sand instead of water because filling the ballast partially with water would cause the water's mass to slosh during the rollover test, possibly introducing some variability.

- Based on an analysis of image data from the high-speed camera located outside the vehicle, it appears that a side pillar in the front of the vehicle along the impact side may have intruded into the survival space. However, this was not assessed using the survival space templates since they were not located at the position of the side pillar during the test, and there was no contact between the survival space templates and the bus structure.
- All side emergency exit windows remained latched during the test. However, both roof emergency exits opened when the roof of the bus impacted the ground.
- During impact, the glazing on five of the seven windows on the right side of the bus (opposite the impacted side) dislodged from their window mounting and fell into the occupant compartment during the test (Figure 3). The glazing in one of the windows was retained by an overhead TV monitor and prevented the windowpane from separating from its mounting gasket and falling into the bus. The glazing in the last window near the rear shattered but was retained and did not fall into the passenger compartment, because the window was shorter in length than the other windows. After the bus impacted the ground, both sides of the windshield lost retention and fell from its supporting structure.

Figure 3
Bus window intrusion from ECE R.66 procedure testing

5. ATD Response in Newer Model (MY 2000) Tested

One ATD was positioned in an original equipment seat (without a restraint system) and one ATD was positioned in a Freedman seat (with an integrated 3-point seat belt). The Freedman seat was adapted to mount on the same attachment points as the original equipment seats.

The ATD restrained by the lap/shoulder belt measured forces that were below the FMVSS No. 208 IARVs (Table 1).

Table 1
Restrained ATD Test Results for 2000 MCI 102-EL3
Aisle seat in opposite side of impact

	IARV Results (ATD response measurements)	Tolerance Limits*
HIC15	2	700
Chest 3ms Clip (g)	7	60
Nij Maximum (Nte)	0.1	1
Neck Tension (N)	329	4170
Neck Comp. (N)	79	4000

* FMVSS 208 limits

However, the unrestrained ATD had multiple IARVs that exceeded the limits specified in FMVSS 208 (Table 2, in bold).

Table 2
Unrestrained ATD Test Results For 2000 MCI 102-EL3
Aisle seat in opposite side of impact

	IARV Results (ATD response measurements)	Tolerance Limits*
HIC15	**1458**	700
Chest 3ms Clip (g)	37	60
Nij Maximum (Nce)	**1.6**	1
Neck Tension (N)	367	4170
Neck Comp. (N)	**9238**	4000

* FMVSS 208 limits

The following was observed for the unrestrained ATD:

- Head contacted overhead luggage rack;
- Left and right knees hit the seat back;
- The head hit the glazing at the lower rear corner of window;
- The left and right knees hit the glazing at the center of the same window; and
- The direct distance from the initial position to the dummy's initial point of contact (luggage rack) was 1,060 mm (3.5 ft). The direct distance from the first point of contact

to the second point of contact (window L3, 3rd left side of window from the front of the bus) was 906 mm (3 ft).

The following was observed for the restrained ATD:

- The back of the head hit the head rest of its own seat.

In terms of the feasibility of the test procedure, the test results showed that it was possible to ballast the seats with either the anthropomorphic ballast or steel weights. All seats with both types of ballast remained attached to their original anchorages.

D. Literature Review of Injury Mechanism on Large buses

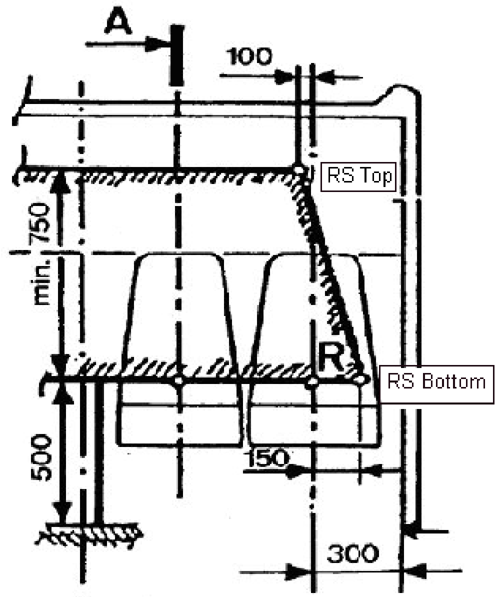
Rollover test simulations conducted by Martella et al[26, 27] show that an increase in the mass in the vehicle causes greater deformations in case of rollover. The first simulated test was a standard ECE R.66 rollover test of an occupant bay section[28] with 2 seats on either side of an aisle (a total of 4 designated seating positions). The second simulation simulated an ECE R.66 rollover test but with a 50th-percentile Eurosid-1 dummy restrained with three-point belts, while the other three seating positions in that row were ballasted with 72 kg (159 lb). The residual space was defined in ECE R. 66 (Figure 4). The dummy was simulated in each of the

[26] Belingardi, G., Martella, P., and Peroni, L. (2005). Coach Passenger Injury Risk during Rollover: Influence of the Seat and the Restraint System. Paper Number 05-0439. Department of Meccanica, Torino Polytechnic. Available at: https://www-esv.nhtsa.dot.gov/Proceedings/19/05-0439-W.pdf

[27] Belingardi, G., Gastaldin, D., Martella, P., and Peroni, L. (2003). Multibody Analysis of M3 Bus Rollover: Structural Behaviour and Passenger Injury Risk. ESV. Paper Number 288. Available at: https://www-esv.nhtsa.dot.gov/Proceedings/18/18ESV-000288.pdf

[28] A section containing at least two identical vertical pillars on each side representative of a part or parts of the structure of the vehicle.

four seating positions, two from the first simulation and the other two from the second simulation.



Note: RS = Residual Space. The measurements are in millimetres.

Figure 4
Occupant Residual Space from ECE R.66 Test Procedure

The simulation showed that wall intrusions with the dummy restrained with 3-point belts were up to 0.5 meter (20 inches) intruding into the survivable space by about 0.16 m (6 inches). Three-point belts coupled more of the occupant mass to the structure causing greater deformation, emphasizing the need for increased structural integrity to maintain the benefit of safety belts, particularly for those seated closest to the side of impact. The HIC values for the dummy when seated in the seating position closest to the window on the side of impact exceeded 1,000 HIC. Their research noted that the dummy seated in the position closest to the side wall does not benefit from the use of any kind of belts (two or three point belts) as they cannot prevent the impact of the head with the side window. This poses head and torso injury risk to the belted occupants seating nearest the side of impact that exceed allowed HIC and chest G values. The load on the pubic symphysis is over the limit for all seating positions due to the impact of the lower torso with the armrest, except that of the dummy seated in the aisle seat on the side of impact. The simulated testing by Martella et al did not take into account the full structure of the large bus or occupant interaction, so injuries due to other occupants, detached window glazing or falling overhead storage compartments were not analyzed.

NHTSA and Transport Canada entered into a joint program to investigate glazing and bonding techniques since glazing which separates from a frame frequently results in an ejection portal.[29] The numerical analysis of a large bus rollover determined that the occupant impacted the side window at a speed of 20 ft/s. An estimate of the roof crush load magnitude required to produce window glazing failure could not be reached from this study alone. However, for the events where the deformation is in the range of 1,000 mm, it is expected that the glazing will not remain in place. Some events have an impact area over a small region of the bus roof and may therefore produce a more localized failure. It was determined that significant improvements in roof strength and structural integrity of windows are required before realizing the benefits of advanced glazing materials.[30]

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[29] National Motor Coach Glazing Test Development for Occupant Impact during a Rollover. (2007). NHTSA-2002-11876. Available at: http://www.regulations.gov/#!documentDetail;D=NHTSA-2002-11876-0015

[30] Motorcoach Safety Action Plan, U.S. Department of Transportation. DOT HS 811 177. November 2009. Available at: https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/MotorcoachSafetyActionPlan_final2009report-508.pdf

Albertsson et al[31] investigated real world rollover crashes and was able to note some instances and causes of injury due to occupant interaction. All the occupants in the analysis were unrestrained. Occupant interaction occurred in many cases, including occupants falling toward the impacted side of the large bus and thrown laterally around in the vehicle if seated on the non-impacted side. When reaching the other side, they either hit other passengers or the interior side of the overturned vehicle. When the occupant was sitting next to the impacted side, other occupants fell on top of them causing injuries. In rollovers, striking the luggage rack also resulted in serious injuries, usually increased by interaction with other occupants and the side of the vehicle. In one case, four fatalities were associated with this type of injury mechanism. Only one of these fatalities was in an area where there had been a roof deformation. Occupants also struck other seats and armrests than their own, causing injuries.

A study in Spain was performed with analyses of injury data from rollovers for the period of 1995–1999.[32] Three rollover cases with unrestrained occupants were selected from the Enhanced Coach and Bus Use Occupant Safety (ECBOS) database for further research, and simulation with a mathematical model. The model showed that a 2-point lap belt could prevent ejection and reduce the injury severity for occupants with MAIS 3 and MAIS 2 level injuries located in the external side of the rollover (side opposite of impact). For occupants sitting on

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[31] Albertsson, P., Falkmer, T., Kirk, A., Mayerhofr, E., Bjornstig, U. (2006). Case Study: 128 Injured in Rollover Coach Crashes in Sweden – Injury Outcomes, Mechanisms, and Possible Effects of Seat Belts. Journal of Safety Science. (44) 2, 87 – 109. Available at: http://www.sciencedirect.com/science/article/pii/S0925753505000858

[32] Martinez, L., Aparicio, F., Garcia, A., Paez, J., Ferichola, G. (2003). Improving Occupant Safety in Coach Rollover. *International Journal of Crashworthiness (8) 2, 121-132*. Available at: http://www.tandfonline.com/doi/abs/10.1533/ijcr.2003.0214#preview

the impact side, a lap belt would not protect them from being partially ejected. Other solutions like glazing, pillars or rail would additionally be necessary to prevent head and torso from being partially ejected.

From a statistical study performed within the ECBOS project, the main interior components which are cause of injury for passengers include the window pillar, the side window, the overhead luggage rack and the seat.[33] An in-depth case study of 128 occupants[34] showed that cases of partial ejection in rollovers may not have been addressed with a restraint system for the occupant seated on the impact side closest to the window. Among the 66 occupants who could recall their cause of injury 32 percent cited broken glass, while hitting the seat back and arm rest were the most common cause of MAIS 3-4 injuries. The most dangerous risk in large bus rollovers however is that of being ejected.

E. Seat Belt Use

As further discussed in this document, seat belt use is an important factor in estimating the potential benefits of the FMVSS No. 227 final rule. Although seat belts will be required to be installed on the types of large buses covered by this rulemaking, belt usage rates by the occupants of these vehicles remains uncertain. In a pilot study of Alabama students on school buses specially equipped with seat belts, belt use rates were as low as 5%,[35] making the

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[33] ECBOS Work Package 2. Task 2.5. "Cause of Injury Summary" Final Report. European Union.

[34] Albertsson, P., Falkmer, T., Kirk, A., Mayrhofer, E. & Bjornstig, U. (2005). Case Study 128 injured in rollover coach crashes in Sweden – injury outcome, mechanisms and possible effects. *Safety Science, 44, 87-109*. Available at: http://www.sciencedirect.com/science/article/pii/S0925753505000858.

[35] Turner, D., Lindly, J. and Tedla, E. Preliminary Report on School Bus Seat Belt Use Rates. University Transportation Center for Alabama, University of Alabama, Report 07407-4, 2009.

crashworthiness of the large bus another avenue of injury mitigation in which people would be protected aside from seat belts. In 2003, a study was conducted on seat belt use on 12 school buses in Queensland, Australia. Half the school buses were fitted with a seat belt sensor. Even when encouraged by parents and teachers, seat belt wearing rates were low. Students frequently removed the belts to talk over the high-backed seats to peers. The usage rates varied highly from 14% to 89%.[36]

Observations of an in-depth analysis from ECBOS of 31 severe large bus crashes in Europe, show belt use rates are often low, around 3 percent.[37] In one case, 2 full large buses, both equipped with 2-point lap belts, impacted each other with no one wearing their restraint. Similar studies in Australia, where three-point lap belts on large buses have been mandatory since 1994, show use rates may be less than 20 percent.[38] Increased structural integrity is a means of passive safety which could mitigate injuries and fatalities in the cases where riders neglect to wear seat belts.

Seat belt use is predicated on assessment of safety risk and comfort and is correlated with some demographic and social factors. The general perception of large bus travel is that it

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[36] "Three Point Seat Belts on Coaches – the First Decade in Australia", Griffiths, Paine, and Moore, Queensland Transport Australia. Available at: https://www.academia.edu/26500332/Three_Point_Seat_Belts_on_Coaches_the_First_Decade_in_Australia?auto=download, last accessed December 2, 2021.

[37] Albertsson, P., Falkmer, T., Kirk, A., Mayrhofer, E. and Björnstig, U. (2006.) Case study: 128 injured in rollover coach crashes in Sweden—Injury outcome, mechanisms and possible effects of seat belts. Safety Science. 44, 87 - 109. Available at: http://www.sciencedirect.com/science/article/pii/S0925753505000858.

[38] "Three Point Seat Belts on Coaches – the First Decade in Australia", Griffiths, Paine, and Moore, Queensland Transport Australia. Available at: https://www.academia.edu/26500332/Three_Point_Seat_Belts_on_Coaches_the_First_Decade_in_Australia?auto=download, last accessed December 2, 2021.

is a safe mode of transport; transit riders perceive it as safer than both auto and bicycle. [39] Given that transit riders are generally aware that buses are a relatively safe mode of travel,[40,41] they may be less apt to use belts when riding in a large bus than in a passenger vehicle, which may lead to a lower average belt use rate. Children and young people have been shown in several studies to use seat belts less often than older persons in passenger vehicles. This is significant since one-third of large bus riders are students.[42] On the other hand, seat belt use rates have been shown to increase with age, education, and income.[43]

While the agency is optimistic about belt use rates and encourages safety belt usage as an effective means of preventing injuries and fatalities on large buses, this must be balanced with the likelihood that large bus riders will choose to wear safety belts. Australia has generally higher reported belt usage rates than the United States, which can be attributed to cultural norms and varying stringency of the law (i.e. primary versus secondary compliance). [44] Some countries in the European Union (e.g. Germany, France, and Sweden) also have higher belt

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[39] Noland, R. "Perceived risk and modal choice: Risk compensation in transportation systems", Accident Analysis & Prevention. (1995). Vol. 27 (4). Available at: http://www.sciencedirect.com/science/article/pii/0001457594000873

[40] Ibid

[41] Beck, L., Dellinger, A., and O'Neil. M. Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences. American Journal of Epidemiology. (2007). 166 (2): 212-218. Available at: http://aje.oxfordjournals.org/content/166/2/212.full

[42] Bourquin, P. Motorcoach Census 2008. Nathan Associates Inc. December 2008. Available at: http://www.buses.org/files/Motorcoach%20Census%202008%2012-18-2008.pdf

[43] National Highway Traffic Safety Administration. 1998 Motor Vehicle Occupant Safety Survey. Volume2: Seat Belt Report. Technical Report, DOT HS 808 061, March 2000. Available at: http://www.nhtsa.gov/people/injury/research/safetysurvey/index.html

[44] Belt usage rates in Australia recently have varied from 90% to 95%. Centre for Accident Research and Road Safety, http://www.carrsq.qut.edu.au/publications/corporate/seat_belts_fs.pdf, last accessed February 3, 2012.

usage rates than the United States.[45] Counter to that however large bus belt usage rates appear to be quite low in Australia and the European Union, although belt use on large buses has been required since 1994 and 2006 respectively.[46] Based on the research presently available the agency believes that belt use rates will tend to be lower, at least initially, and closer to the belt use rates seen in the studies from Australia, Europe, and the United States (see the Alabama study). The demographics of large bus riders in the United States, with the exception of seniors, are also less likely to wear seat belts in passenger vehicles but we are still uncertain how this would translate to belt use in large buses.

F. Requirements and Applicability

The agency examined two protocols commonly used to address rollover structural integrity and protection in large buses. Specifically, the agency examined FMVSS No. 220 (school buses),[47] and United Nations Economic Commission for Europe Regulation No.66 (ECE R.66) complete vehicle test.[48] The ECE R.66 complete vehicle test is used for large buses (that are similar to the bus types we are examining in the FMVSS No. 227 final rule) in countries that

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[45] See The European Transport Safety Council, http://www.etsc.eu/enforcement-seatbeltuse-whyincrease.php, last accessed February 3, 2012. See also The United Kingdom Department of Transport, http://www.dft.gov.uk/rmd/project.asp?intProjectID=12795, last accessed December 3, 2012.

[46] In the European Union Directive 2003/20/EC came into effect in 2006. In Australia. Motorcoach seat belt use was required starting in 1994 with Australian Design Rule 68.

[47] Laboratory Test Procedure for FMVSS 220 School Bus Rollover Protection. National Highway Traffic Safety Administration. Department of Transportation.

[48] The results of the complete vehicle tests are available from NHTSA's Vehicle Crash Test database http://www-nrd.nhtsa.dot.gov/database/aspx/vehdb/queryvehicle.aspx. Enter MCI or Prevost into the vehicle make field. Summary report is available at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Public%20Paper/SAE/2009/Hott%202009%20SAE.pdf.

are contracting parties to the 1958 Agreement.[49] Based on the agency's testing, the ECE R.66 complete vehicle test was determined to be a better protocol for ensuring rollover structural integrity of the buses covered under the FMVSS No. 227 final rule. The agency believes that a protocol similarto the ECE R.66 is better suited for addressing major rollover safety concerns such as the ejection of unbelted occupants for the group of buses covered under the FMVSS No. 227 final rule.

The FMVSS No. 227 final rule adopted the ECE R.66 complete vehicle test procedure as the method for large bus roof strength and structural integrity evaluation. The complete vehicle test involves tipping of a large bus off a raised platform 800 mm (31.5 in) above a horizontal concrete surface. The vehicle can be placed on either side (right or left) but typically will be placed on the side with the least amount of side reinforcement. To represent the effect of occupant mass, the large bus may be ballasted up to, and including its gross vehicle weight rating (GVWR).[50]

According to the ECE R.66 test procedure, a laden large bus is tilted on to its side from an 800 mm high platform. When compared to tests involving more "rotations" (greater than 2 full rotations), this test imposed greater dynamic impact loads to the superstructure. (The parts of a large bus structure which contribute to the strength of the large bus in the event of a

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[49] Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions (United Nations Economic Commission for Europe).

[50] The mass used ballast is 150 lb. This 150 lb ballast weight in each designated seating position is also specified in Part 567.4 (3) to determine Gross Vehicle Weight Rating (GVWR) of a vehicle and was also used in NHTSA's 2000 MCI model rollover test.

rollover crash are referred to as the superstructure).[51] Large buses are required to complete the ECE R.66 test procedure with the following performance criteria:

(1) Intrusions into the survival space (delineated in the bus interior) by any part of the bus outside the survival space (except for debris such as small glazing pebbles, nuts, and bolts weighing not more than 15 grams) must not occur; and

(4) Emergency exits must remain closed during the test.

Note that *Survival space* means a three-dimensional space to be preserved in the occupant compartment during the rollover structural integrity test. The FMVSS No. 227 final rule defines the survival space as a three-dimensional volume which runs the length of the area that can be occupied by the driver and by passengers. The rear boundary of the survival space would be the inside surface of the rear wall of the occupant compartment of the vehicle.

The vertical boundaries on both the left and right sides of vehicle centerline are defined by three line segments. See Figure 5, below. Segment 1 extends vertically from the floor to an end point 500 mm above the floor and 150 mm inboard of the side wall. Segment 2 starts at the end point of Segment 1 and extends to a point 750 mm above and 250 mm horizontally inboard of the end point of Segment 1. These values are used in ECE R.66. Segment 3 is a horizontal line beginning at the end point of Segment 2 and extending to the vertical longitudinal center plane of the vehicle.

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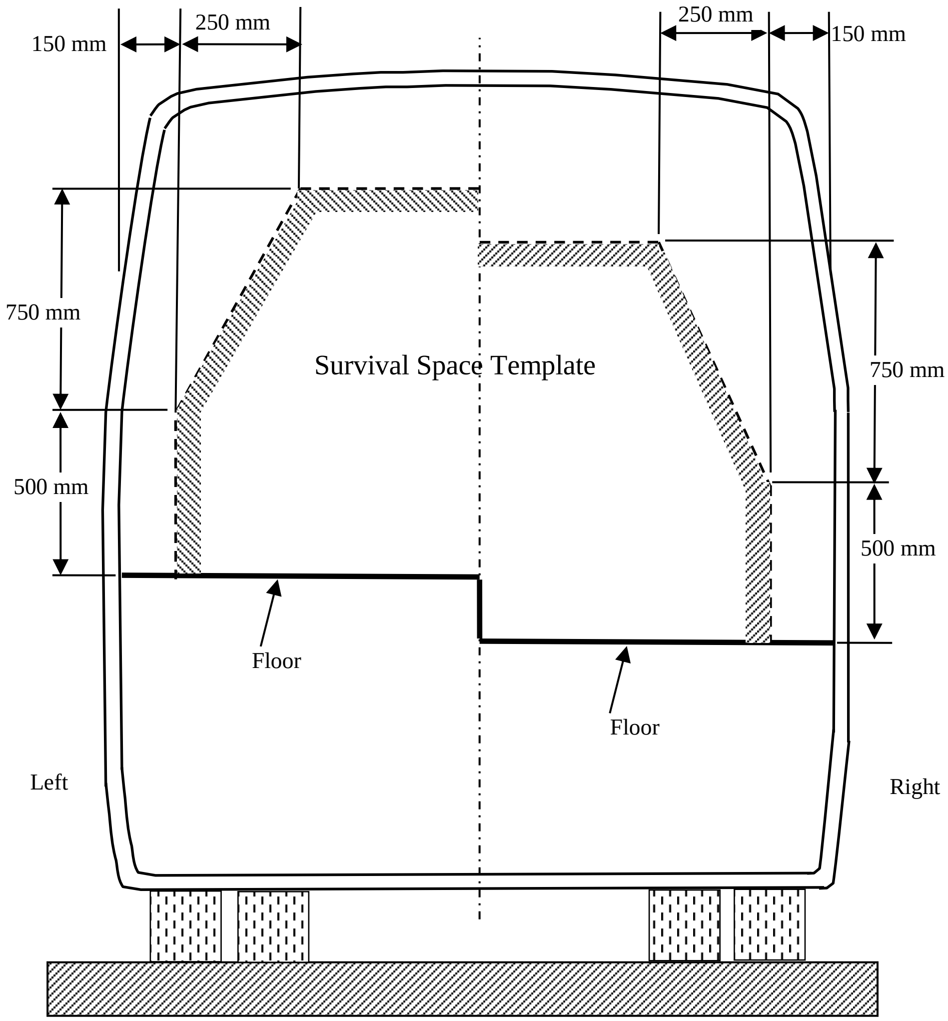
[51] Matolcsy, M. (2007). "The Severity of Bus Rollover Accidents", Enhanced Safety of Vehicles (ESV) Paper 989, 20th ESV Conference, Lyon, France. Available at: https://www.researchgate.net/publication/237279051_THE_SEVERITY_OF_BUS_ROLLOVER_ACCIDENTS, last accessed December 2, 2021.



Note: mm = millimeters

Figure 5
Survival Space Template

1. Determining Intrusions into the Survival Space

The FMVSS No. 227 final rule prohibits any object outside the survival space from entering the survival space. One possible means to monitor for potential survival space intrusion during and after bus testing involves the usage of survival space templates. Use of templates is consistent with ECE R.66. The templates are 1,250 mm (50.2 inches) tall and are tapered from the sidewall a distance of 150 mm (5.9 inches) at the bottom and 400 mm (15.8 inches) at the top.

Several survival space templates can be placed within the survival space to assist in determining whether there was intrusion into the survival space. The templates could contain a transfer medium (such as chalk or another substance capable of demonstrating contact between two objects) along the upper edge of each template. Transfer marks from contact with the survival space templates would demonstrate that an object intruded into the survival space during movement of the tilting platform or resulting from impact of the vehicle on the impact surface.

The agency emphasizes that the templates are simply tools to assist in determining whether there was intrusion into the survival space. If an object intruded into the survival space without contacting the templates - such as if a television monitor fell into the survival space - that intrusion could be a noncompliance, even if contact with the templates did not occur. Other tools could also be used to help determine whether there was intrusion into the survival space, such as highspeed video, photography, or a combination of means. NHTSA could use templates and/or other means of determining whether intrusion occurred. However, the final rule does not require survival space templates as the means of evaluating intrusion into the survival space during and after the bus tip over.

The agency believes the requirements would provide reasonable and needed improvements to large bus safety. The requirements of the test build on the agency's MAP-21 final rule on seat belts. Since passengers are more likely to be retained in the bus interior as a result of the agency's seat belt rulemaking, the FMVSS No. 227 final rule improves the protective attributes of the occupant compartment in which they are retained. This additional passive safety measure would improve outcomes for those who use belts and to some degree, those passengers who do not use belts.

The requirements for maintaining the survival space would set a minimum level of structural integrity for large buses, to help prevent dangerous structural intrusions into the occupant survival space. The requirement that emergency exits remain closed during the rollover test ensures that emergency exits do not become ejection portals during rollover events.

II. ANALYSIS OF ALTERNATIVES

In deciding on the approach that could lead to the final rule, NHTSA examined existing regulations as alternatives to the FMVSS No. 227 final rule. The agency concludes that FMVSS No. 216, "Roof crush resistance," and FMVSS No. 220, "School bus rollover protection," were not designed to address the safety problem in the large bus types covered under this final rule and are not as representative of the dynamics of a rollover of these vehicle types as a test based on ECE R.66. As the agency is concerned that an FMVSS No. 216 or FMVSS No. 220-based test would not be able to address the safety concerns that the agency has identified with large OTRB rollovers, the FMVSS No. 227 final rule does not include provisions for an FMVSS No. 216 or FMVSS No. 220-based test.

A. FMVSS No. 216

NHTSA considered the requirements of FMVSS No. 216, "Roof crush resistance." FMVSS No. 216 applies to vehicles with a gross vehicle weight rating (GVWR) of 4,536 kg (10,000 lb) or less and specifies a test that applies a localized load to the front of the vehicle. The FMVSS No. 216 test applies localized static loads to the front of the vehicle. Unlike passenger vehicles, large buses are larger/heavier and are more likely to roll than yaw. As a result, in a large bus rollover, the entire length of the vehicle is loaded as in the ECE R.66 test. Therefore, the ECE R.66 test is more representative of this type of rollover than the FMVSS No. 216 test since it imparts loads along the full length of the vehicle. In addition, the ECE R.66 is a dynamic test where additional safety issues specific to large buses (intrusion of survival space by parts outside the survival space, and opening of emergency exits) can be evaluated. This is not possible in the FMVSS No. 216 test since it is a quasi-static test. Since two-thirds of rollover fatalities in the applicable group of buses are due to ejections, addressing these additional safety issues is critical to addressing the safety problem in rollovers involving these vehicles. Therefore, the ECE R.66 test is a better representation of a rollover crash involving the bus types covered by this rule than the FMVSS No. 216 test, and the agency has not included a test based on FMVSS No. 216 in the FMVSS No. 227 final rule.

B. FMVSS No. 220

FMVSS No. 220 is a school bus roof crush standard which places a uniformly distributed vertical force pushing directly downward on the top of the bus with a platen 914 mm (36 inches) wide and 305 mm (12 inches) shorter than the length of the bus roof. The standard specifies that when a uniformly distributed load equal to 1.5 times the unloaded vehicle weight is applied to the roof of the vehicle's body structure through a force application plate, the downward vertical movement at any point on the application plate shall not exceed 130 mm (5.125 inches) and the emergency exits must be operable during and after the test.

The agency included FMVSS No. 220 in its research into large over-the-road bus rollover structural integrity. However, we have decided on a test based on ECE R.66 rather than a test based on FMVSS No. 220 for several reasons. First, the agency believes that an ECE R.66 based test is more suitable for the large buses covered under the FMVSS No. 227 final rule than an FMVSS No. 220 based test because a significant portion of fatalities in rollovers involving these buses result from occupant ejections, and many of these buses are designed with higher center of gravity than school buses and utilize larger windows which are correlated to occupant ejection. Unlike school buses, large over-the-road buses operating intercity routes typically travel at higher speeds than school buses transporting children to a local educational facility. These characteristics (higher speeds, higher center of gravity, and larger windows) of these large buses can lead to a higher incidence of occupant ejections during rollovers. Thus, the dynamic rollover test in ECE R.66 affords the agency the opportunity to better evaluate ejection mitigating factors such as the emergency exits and window retention during a rollover crash involving the buses covered by the FMVSS No. 227 final rule.

Second, the agency believes that the proven record of ECE R.66 in the European Union's large bus safety regulations is a significant advantage over selecting a test for over-the-road buses based on FMVSS No. 220. By modeling our test on an existing test, designed specifically to evaluate the performance of this vehicle type in rollover crashes, NHTSA has greater assurance (than with an FMVSS No. 220 based test) that this standard will be practicable and appropriate for large buses. Further, by basing our test on ECE R.66, we believe that manufacturer familiarity with the standard would help in designing to achieve compliance. In addition, the ECE R.66 based test allows the agency to further its harmonization efforts with the European Union. With requirements similar to the European Union, the agency anticipates that manufacturers of buses covered by the FMVSS No. 227 final rule would be able to avoid the additional cost of meeting two fundamentally different rollover structural integrity compliance standards.

After assessing the results of the test, the agency believes that ECE R.66 is more suited than FMVSS No. 220 for evaluating rollover structural integrity in the buses covered under the FMVSS No. 227 final rule. While FMVSS No. 220 has a proven record of ensuring rollover safety in school buses, it was not designed for the purpose of evaluating performance of OTRBs in rollover crashes. Therefore, the FMVSS No. 227 final rule requires a test based on ECE R.66.

C. ECE R.66 Alternative Compliance Methods

The test in the FMVSS No. 227 final rule is based on the complete vehicle test from ECE R.66. In addition to the complete vehicle test, ECE R.66 provides four alternative options for complying with ECE R.66 requirements.[52]

The following options are considered by ECE R.66 to be equivalent approval tests: (1) rollover test of body sections representative of the vehicle, (2) quasi-static loading tests of body sections, (3) quasi-static calculations based on testing of components, and (4) computer simulation (finite element analysis) of complete vehicle.[53] The agency has considered these alternative compliance methods but has determined they would not be practical for use by the agency.

We have determined that Alternatives 1 and 2 would not be practical for use by the agency as they would not achieve the goals of this rulemaking. These alternative methods test body sections of the vehicle and poses compliance difficulties. Alternatives 1 and 2 require that the body-sections be representative of the entire vehicle. Determining the representativeness of a body-section would require input and analysis from the manufacturer, and even with that, determining what is "representative" could be subjective and difficult for NHTSA to verify (e.g.,

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[52] There are significant differences in the manner in which a manufacturer demonstrates compliance with safety regulations in European Union and in the United States. In Europe, European governments use "type approval," which means that they approve particular designs as complying with their safety standards. In the U.S., NHTSA issues performance standards, the compliance with which manufacturers self-certify their vehicles or equipment. NHTSA does not pre-approve vehicles or equipment before sale. Under the National Traffic and Motor Vehicle Safety Act, the FMVSSs must be objective, repeatable, and meet certain other statutory criteria. NHTSA enforces the FMVSSs by obtaining new vehicles and equipment for sale and testing them to the procedures specified in the FMVSSs.

[53] Further information regarding the alternative certification methods of ECE R.66 is available at: Motorcoach Roof Crush/Rollover Testing Discussion Paper, March 2009, Docket No. NHTSA-2007-28793-0019

is the center of gravity of the body section representative of the whole vehicle?). Also, testing an entire vehicle rather than body sections is preferable because it would better ensure the assessment of all body sections, including representative as well as worse-case (weakest) sections of the bus. Finally, if manufacturers were to provide the test specimens, a more conscientious effort might be taken to manufacture the specimen, and so the specimen might not be representative of the typical, mass produced large bus. Thus, the agency does not prefer to involve manufacturer-supplied body sections in NHTSA's compliance test program.

Alternatives 3 and 4 would not be suitable for incorporation into the FMVSS because they may not be sufficiently objective. NHTSA is directed to issue performance standards,[54] the compliance with which must be measured objectively.[55] Assessing compliance using calculations and extrapolations or computer simulations introduces an element of subjectivity into the compliance process. A manufacturer might believe that its vehicle met the structural integrity requirements based on its calculations and computer simulations, while someone else might not agree that the assumptions made in the calculations or on which the simulations were based were appropriate or correct for demonstrating compliance in the particular instance. While a manufacturer may have the knowledge of the materials and joint structure for their vehicles to be able to make a more accurate model, an external entity may not be able to easily reproduce these results. The variability of assumptions in such models makes this

[54] In 49 U.S.C. § 30102, the National Traffic and Motor Vehicle Safety Act defines "motor vehicle safety" as the "performance" of motor vehicles or motor vehicle equipment in a way such as to avoid creating an unreasonable risk of accident to the general public. The same Act defines "motor vehicle safety standards" as minimum standards for motor vehicle or motor vehicle equipment "performance."

[55] In 49 U.S.C. § 30111 (a), the National Traffic and Motor Vehicle Safety Act requires that Federal motor vehicle safety standards be stated in objective terms.

method unsuitable for use by NHTSA in evaluating compliance with an FMVSS. For example, for Alternative 3, the agency would need to identify the location of the plastic zones and plastic hinges as well as estimate their load-deformation curves. For Alternative 4, mathematical models that simulate accurately the actual rollover event of the specific vehicle model are required.

Moreover, basing compliance on calculations and computer simulations does not take into account any differences that may occur between the analytical model and the vehicle as manufactured. Because they do not utilize actual vehicles, these approaches do not account for variation or flaws in material properties, or defects or errors in the manufacturing build processes. In contrast, NHTSA prefers to test actually-manufactured vehicles, to assess not only the design of the vehicle but the real-world manufacturing processes as well.

The options based on analysis and simulations will require detailed information about the vehicle design and if NHTSA were to use models for its own compliance testing it would introduce additional subjectivity into the compliance process. NHTSA does not believe that these alternative compliance methods are suitable for incorporation into an FMVSS, and therefore does not consider them to be acceptable alternatives for testing by the agency. Thus, the FMVSS No. 227 final rule is based on the complete vehicle test of ECE R.66 and does not provide for NHTSA’s use of Alternatives 1 through 4 to determine compliance.

D. Retrofitting

The Secretary of Transportation has authority to promulgate safety standards for "commercial motor vehicles and equipment subsequent to initial manufacture."[56] The Office of the Secretary has delegated authority to NHTSA to "promulgate safety standards for commercial motor vehicles and equipment subsequent to initial manufacture when the standards are based upon and similar to a [FMVSS] promulgated, either simultaneously or previously, under chapter 301 of title 49, U.S.C."[57] Further, §32703(e)(2) of MAP-21 states that the "Secretary may assess the feasibility, benefits, and costs with respect to the application of any requirement established under subsection . . . (b)(2) to motorcoaches manufactured before the date on which the requirement applies to new motorcoaches."[58] Subsection (b)(2) directs the agency to consider portal improvements to prevent partial and complete ejection of motorcoach passengers.

As further described in the FMVSS No. 227 final rule accompanying this document, the agency's testing of the MY 1991 Prevost and the MY 1992 MCI buses indicates that major structural changes to the vehicle's entire sidewall and roof structure would be needed for many existing large buses to meet the rollover structural integrity requirements in this final rule. Specifically, in regard to the proposed requirements for side window glazing retention and

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[56] Under Sec. 101(f) of Motor Carrier Safety Improvement Act of 1999 (Public Law 106-159; Dec. 9, 1999).

[57] See 49 CFR Section 1.50(n). Additionally, the Federal Motor Carrier Safety Administration (FMCSA) is authorized to enforce the safety standards applicable to commercial vehicles operating in the U.S.

[58] See Moving Ahead for Progress in the 21st Century Act, Pub. L. No. 112-141, § 32703(e)(2). Section 32703(e)(2)(B) states that the Secretary shall submit a report on the assessment to Congress not later than 2 years after date of enactment of the Act.

emergency exits that address §32703(b)(2) of MAP-21, the agency also believes that major structural changes would be necessary to ensure a comparable level of performance (when compared to a new large bus manufactured to meet the requirements in the FMVSS No. 227 final rule). The agency is concerned that such extensive modifications may not be possible on many of the existing buses that would be covered if the provisions of the FMVSS No. 227 final rule were extended to require retrofitting old buses. NHTSA expects that these major structural changes may carry significant additional costs beyond those estimated here[59] and possibly having a substantial impact on a significant number of small entities. Thus, the agency has concluded that requiring retrofitting of existing vehicles would be impracticable and NHTSA has not included any retrofit requirements in the FMVSS No. 227 final rule accompanying this document. A further discussion of the agency's consideration of retrofit requirements is available in the preamble of the FMVSS No. 227 final rule.

[59] The agency did not specifically estimate the cost of retrofitting the bus since the level of reinforcement needed would depend not only on the existing bus designs but also on the wear and tear of each bus during its service life. We currently do not have sufficient information to make this estimate. However, we believe it would be impractical to reinforce the existing superstructure in many buses and instead would require a complete rebuild of the superstructure (essentially rebuilding the bus from the ground-up).

III. BENEFITS

This chapter estimates the benefits of the FMVSS No. 227 final rule. Structural integrity is a crashworthiness countermeasure aimed at improving the outcome of a crash, i.e., to save lives and reduce injuries. The injury benefits discussed in this chapter are the estimated reduction in the number of fatally injured and non-fatally injured persons attributable to the FMVSS No. 227 final rule.

The benefit analysis is categorized into two groups: (1) benefits from fatality reduction, and (2) benefits from non-fatal MAIS 3-5 injury mitigation. The general procedure is to first identify the baseline target population and then to estimate the fatality or injury reduction rate. Real world crash data, laboratory test results, and other relevant test data are used to calculate fatal and serious non-fatal injury reduction rates. The injury reduction rates are applied to the corresponding target population, which results in fatality or injury reduction benefits.

A. Target Population

The fatally injured occupants in large bus crashes are drawn from the Fatality Analysis Reporting System (FARS), a census of traffic fatalities maintained by the agency's National Center for Statistics and Analysis (NCSA). The number of injured people is estimated using the National Automotive Sampling System-General Estimate System (NASS-GES)[60] also maintained by NCSA.

[60] NASS-GES was discontinued in 2016 and so NASS-GES (2006-2015) was used for this study.

1. Fatalities

We analyzed fatalities over a 15-year period between 2004 and 2018 in FARS and determined that there were 13 fatalities per year attributable to the types of buses to be covered under the FMVSS No. 227 final rule as a result of rollover crashes. FARS categorizes buses as “school,” “cross-country/intercity,” “transit,” “van-based,” “other,” and “unknown” bus types. These may have overlapping definitions in some cases. For example, cross-country buses may be used to transport students for a field trip, or a school bus may have been modified for another purpose other than transporting students to and from school.

For the purposes of this analysis of the target population, the agency examined FARS data for buses categorized as “cross-country/intercity,” “van-based,” “other,” and “unknown” bus types. As transit and school buses are easily recognized and identified for coding in FARS, the agency believes that the remaining bus types (the “cross-country/intercity,“ “van-based,” “other,” and “unknown” buses) with the relevant GVWR would be the population of vehicles covered by the FMVSS No. 227 final rule.[61] There were 56 rollovers from 2004 to 2018 in which there were passenger and/or driver fatalities. Fatalities attributable to these rollover crashes

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[61] The agency believes that it is appropriate to examine the FARS data for large buses with a GVWR greater than 26,000 lb as well as less than 26,000 lb in the case of OTRBs when analyzing the target population for FMVSS No. 227. As further discussed in the final rule accompanying this document, the final rule applies to all OTRBs (even with a GVWR less than 26,000 lb) and other buses that are not transit buses, not school buses, and not buses with a GVWR of 26,000 lb or less. As such we examined the FARS data for van-based, other, and unknown buses with a GVWR greater than 26,000 lb and cross country/intercity buses with a GVWR greater than 10,000 lb for this analysis. The final rule accompanying this analysis contains further discussion on the agency’s rationale for its decision to apply the requirements to the aforementioned buses. Separately, we also note that buses in the other bus and unknown bus categories in the FARS database with an unknown GVWR were distributed by the known GVWR for that bus category.

accounted for 189 of the total 326 fatalities[62] in crashes involving the bus types from 2004 to 2018 (i.e., 58 percent of large bus fatalities).

In arriving at the above figures, the agency analyzed large bus fatalities by point of impact. The distribution of fatalities by rollover occurrence/initial point of impact is shown in Table 3, below. If a rollover occurred as a primary or subsequent event, then it has been included in the category "rollover" in Table 3.

Table 3
Total and Annual Large Bus Fatalities from 2004-2018
by Rollover Occurrence/Initial Point of Impact

Point of Impact	Total Fatalities	Annual Average	Distribution of fatalities
Rollover	189	12.60	58.0%
Frontal	116	7.73	35.6%
Side	21	1.40	6.4%
Rear	0	0	0.0%
Total	326	21.73	100.0%

Data source: FARS, 2004 – 2018

2. Injured Occupants

The number of people injured is estimated using the National Automotive Sampling System-General Estimate System (NASS-GES). However, the relevant vehicle types for this discussion are coded under the general category of "buses" in NASS-GES, making it difficult to separate the number of people injured in crashes involving vehicles covered by this rulemaking from other bus types including transit, recreational vehicles, and school buses. For the purpose of estimating the incidence of injured occupants for this analysis, we assumed that the distribution of large bus fatalities is representative of those injured. In other words, the

[62] Fatalities due to crashes where the initial point of impact could not be identified are not included in the fatality counts resulting from motorcoach crash and rollover events.

distribution of fatalities on buses in FARS, as shown in Table 3, is used to estimate the number of injured occupants in large buses in the overall bus population.

The non-fatal injury data is presented according to the KABCO[63] injury severity scale which is recorded by police at the time of the crash.

Table 4
Injured Occupants of Transit, Cross-Country/Intercity, Van-based and Other Buses, except School Buses (GVWR of 10,000 lb or more)

KABCO Injury Severity Level	Transit, Cross-Country, and Other Buses
No Injury (O)	48,317
Possible Injury (C)	6,167
Non-incapacitating Injury (B)	1,518
Incapacitating Injury (A)	255
Injured, Severity Unknown (U)	711
Total	56,969

Data source: NASS-GES, 2006 – 2015, annual average.

The KABCO designations in the table above are the injury severity scale used in police crash reports. The KABCO coding scheme allows non-medically trained persons to make on-scene injury assessments without a hands-on examination. However, KABCO ratings are imprecise and inconsistently coded between States and over time. To estimate injuries based on the Abbreviated Injury Scale (AIS) coding structure, a conversion table was established using two data systems: 2000 – 2008 Crashworthiness Data Systems (CDS) and 1982 – 1986 National Accident Sampling System (Old NASS). The CDS is a sample system of passenger vehicle crashes in which at least one passenger vehicle was towed away from the crash site. The CDS collects injury information only for passenger vehicle occupants in a more severe crash environment

[63] K= Killed, A = Incapacitating Injury, B = Non-incapacitating Injury, C = Possible Injury, O = No injury

(i.e., at least one passenger vehicle was towed). Therefore, a KABCO-to-MAIS[64] conversion table derived solely from the CDS might not be representative of the overall injury outcomes especially for those involving heavy vehicles. Although the conversion table is not specific to heavy vehicles such as large buses, for the purposes here, it is assumed to be reflective of the patterns of coding in police crash data.

The translated MAIS injuries represent the maximum severity injuries (i.e., MAIS) for occupants. Table 5 shows the KABCO-to-MAIS conversion table. Note that the police-reported fatal injuries (K) were all translated to fatalities in the MAIS system.

Table 5
KABCO-to-MAIS Conversion Table

	Police-Reported Injury Severity System						
MAIS	O	C	B	A	K	U	
	No Injury	Possible Injury	Non Incapacita-ting	Incapacita-ting	Fatality	Injured, Severity Unknown	Unknown
0	0.92535	0.23431	0.08336	0.03421	0.00000	0.21528	0.42930
1	0.07257	0.68929	0.76745	0.55195	0.00000	0.62699	0.41027
2	0.00198	0.06389	0.10884	0.20812	0.00000	0.10395	0.08721
3	0.00008	0.01071	0.03187	0.14371	0.00000	0.03856	0.04735
4	0.00000	0.00142	0.00619	0.03968	0.00000	0.00442	0.00606
5	0.00003	0.00013	0.00101	0.01775	0.00000	0.01034	0.00274
Killed	0.00000	0.00025	0.00128	0.00458	1.00000	0.00046	0.01707
Total	1.00001	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

Source: 1982-1986 Old NASS; 2000-2008 CDS

Applying the KABCO-to-MAIS conversion factors to corresponding initial KABCO non-fatal injuries reported in Table 4 derives the MAIS injuries in Table 6.

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[64] MAIS = Maximum AIS, AIS = Abbreviated Injury Scale, MAIS 0 = No Injury, MAIS 1 = Minor, MAIS 2 = Moderate, MAIS 3 = Serious, MAIS 4 = Severe, MAIS 5 = Critical, MAIS 6 = Fatal

Table 6
Conversion of KABCO Score to MAIS Level
Estimated Annual Number of Injured Occupants in Transit, Cross-Country/Intercity, Van-based and Other Buses, except School Buses from 2006 to 2015
(GVWR of 10,000 lb or more)

MAIS Injury Level	No Injury	Possible Injury	Non-Incapacitating	Incapacitating	Injured, Severity Unknown	Total
	O	C	B	A	U	
0	44,711	1,445	127	9	153	46,444
1	3,506	4,251	1,165	141	446	9,509
2	96	394	165	53	74	782
3	4	66	48	37	27	182
4	0	9	9	10	3	31
5	1	1	2	5	7	16
Fatal	0	2	2	1	0	5
Total	48,318	6,167	1,518	255	711	56,969
MAIS 1-5	3,607	4,721	1,390	245	557	10,520

Data source: 1982-1986 NASS; 2000-2008 CDS

We assumed that the injured occupants in large buses followed the same trend as those injured in fatal large bus crashes categorized by rollover occurrence and initial point of impact (as shown in Table 3). The rollover event is usually the most harmful event in a crash, and frequently the most significant factor in fatal injuries is ejection in both large bus and passenger vehicle crashes. Despite the initial trajectory of a crash, belts are more effective in rollovers compared to side impact or frontal impact crashes due to preventing ejection.

The subset of injured people involved in rollovers (attributable to buses covered by the FMVSS No. 227 final rule) is shown in Table 7, where the distribution in Table 3 is applied to the target population in Table 6. These estimates are later used to calculate the reductions in people injured if the countermeasures are installed.

Large buses covered under the FMVSS No. 227 final rule comprise 64% (63.8%, 326 fatalities of the 511 fatalities) [65] of the fatalities on all buses which include transit, cross-country and all other buses with a GVWR greater than 10,000 pounds. Of the 326 fatalities on large buses, rollovers account for 189 fatalities (58.0% = 189/326). These proportions are used to estimate the number of injured occupants in large bus crashes and large bus rollovers as shown in Table 7, resulting in a total of 3,891 occupants involved in large bus rollover crashes annually; the number of injured occupants which may benefit from the rule is 85 (MAIS 3 to 5). Lesser injury levels of MAIS 1 or MAIS 2, such as bruises from an arm hitting an armrest, cannot be significantly reduced by improved structural integrity.

Table 7
Distribution of Injury Target Population
for Large Buses (Covered in the FMVSS No. 227 Final Rule)

MAIS Level	Injured Occupants in Transit, OTRBs and all Other Buses with GVWR > 10,000 lb	Injured Occupants in Covered Large Buses including OTRBs with GVWR > 10,000 lb (64%)*	Injured Occupants in Covered Large Bus Rollovers (58%)
MAIS 1	9,509	6,066.41	3,517.03
MAIS 2	782	498.89	289.23
MAIS 3	182	116.11	67.32
MAIS 4	31	19.78	11.47
MAIS 5	16	10.21	5.92
Total	10,520	6,711.39	3,890.96

Data source: NASS-GES 2006 - 2015, annual average; * The numbers were rounded.

[65] The number of fatalities 326 does not include fatalities in crashes where the initial point of impact could not be identified to reflect an incident rate in all covered large buses relative to the 511 fatalities in all large buses with a GVWR greater than 10,000 lb except school buses. This number is used to closely match the broad population that is represented in GES including cross country/intercity, transit, van-based, other, and unknown buses.

We assumed that all first-event and subsequent-event rollovers are included in rollovers in Table 7. While this may overestimate the number of low level injuries (i.e., MAIS 1 and MAIS 2), the agency is not assuming benefits at these lower injury levels. The agency believes this methodology provides a good estimate of the more severe injuries in rollovers. For perspective, the agency estimates that there are about 7 MAIS 3 to 5 injured persons per fatality (= (67.32 + 11.47 + 5.92) / 12.6) in both fatal and non-fatal large bus rollover crashes.

B. Projected Target Population

The base target population estimates the number of injured and fatally injured occupants of large buses (that are covered under the FMVSS No. 227 final rule) involved in rollover crashes. However, to adequately reflect the potential future effect of the 2013 seat belt final rule on large buses and the 2015 final rule on ESC that would include these vehicles, we have adjusted the target population based on the projected benefits of those rules. The target population must be reduced by the estimated number of injuries and fatalities that will be prevented due to ESC and seat belts. The sections below show our calculations.

1. Benefits due to Electronic Stability Control (ESC)

The total number of fatal large bus rollover crashes from 2004-2018 was 56. The average number of fatalities per crash is then 3.38 with the 189 fatalities for the period (189/56). The 2015 final rule requiring ESC on heavy vehicles applies to about the same population of large buses as that applicable to the rollover structural integrity requirements. We assumed that none of the buses in the target population are equipped with ESC. The target population must therefore be reduced by the reduction in the number of fatally and non-fatally injured occupants attributed to ESC prior to estimating the benefits of improved large bus structural integrity.

According to the NHTSA publication (DOT-HS-811-437), ESC installed on truck tractors is estimated to range from 40% to 56% effective in reducing crashes involving non-tripped rollover as a first event, and to be 14% effective in preventing loss-of-control crashes. Two types of heavy vehicle stability control systems are available - roll stability control (RSC) and ESC. RSC detects when the rollover threshold of the vehicle is being approached during a turning maneuver, and automatically reduces engine power and applies the vehicle's service brakes to slow the vehicle down to mitigate a rollover event. ESC employs automatic braking at individual wheels to regain directional control of the vehicle during steering maneuvers that may lead to vehicle loss-of-control, and also includes the RSC functionality described above for heavy vehicles. A light vehicle with a lower center of gravity (CG) is more prone to rollover due to an off-road, tripped rollover precipitated by directional loss-of-control, while a heavy vehicle with a higher CG is more prone to experience rollover when its rollover threshold is exceeded during a hard cornering event. Large buses, which are generally lighter than loaded tractor trailers and have a lower CG height, may experience off-road, tripped rollovers due to directional loss of control, or non-tripped, on-road rollovers during severe cornering maneuvers. Due to insufficient sample size, it is not possible to conduct a statistical analysis of the crash data to establish ESC effectiveness for large buses. Since ESC effectiveness for heavy vehicles was only established for tractor trailers that mainly need roll stability control to prevent rollovers, the effectiveness of ESC for large buses was estimated to be at the lower effectiveness range of 40-56 percent established for tractor trailers. For the purpose of this analysis, the estimated effectiveness of ESC in large buses is 40 percent.

Applying the estimated effectiveness of ESC to the target population of 3.38 fatalities per year, the estimated benefits of ESC for the given target population is 1.35 fatalities annually. The injured occupants in fatal crashes were estimated using the same methodology, reducing the target population by 9.1 seriously injured persons per year. The remaining fatal target population, assuming ESC systems are engaged, is 11.25 fatalities (= 12.6 – 1.35) and 75.62 seriously injured occupants (84.7 from Table 7 less 9.1) as shown in Table 8a.

Table 8a
Target Population for Passengers and Drivers Combined after ESC Benefits Adjustment

Injury Severity Level	Target Population	ESC Adjustment	Injured Occupants in Large Bus Rollovers
MAIS 3	67.32	7.21	60.10
MAIS 4	11.47	1.23	10.24
MAIS 5	5.92	0.63	5.28
Total (MAIS 3 to 5)	84.70	9.07	75.62
Fatal	12.60	1.35	11.25

Data source: FARS 2004-2018 and NASS-GES 2006-2015, averaged annually

2. Benefits due to Lap-Shoulder Belts

The following estimates take into account the agency's 2013 final rule[66] requiring safety belts in the same type of vehicles covered by the FMVSS No. 227 final rule accompanying this document. We assumed that none of the buses in the target population are currently equipped with any kind of belt system for passengers. The target population must be reduced by the reduction in the number of fatally and non-fatally injured occupants attributed to safety belts

[66] 78 FR 70416, November 25, 2013; denial of petitions for reconsideration, 81 FR 19902, April 6, 2016.

prior to estimating the benefits of improved large bus structural integrity. However, large buses are required to be equipped with seat belts at the driver's seating position, and therefore drivers should not be included in the fatally injured and injured target population of occupants who would benefit from seat belts. There were 11 driver fatalities in large buses crashes in the period which must be excluded from the fatalities, leaving 10.52 (= 11.25 annual fatalities – 11 drivers/15 years) fatally injured passengers in the target population. The ratio of driver fatalities to the total number of fatalities in rollovers (11 fatalities/189 fatalities) is applied to the total number of injured occupants to estimate injured drivers in rollovers, leaving 56.18 MAIS 3 injured passengers, 9.57 MAIS 4 injured passengers and 4.94 MAIS 5 injured passengers in the target population as shown in Table 8b.

Table 8b
Target Population for Passengers after ESC Benefits Adjustment
(Injured and Fatally Injured Drivers Excluded)

Injury Severity Level	Injured Occupants
MAIS 3	56.18
MAIS 4	9.57
MAIS 5	4.94
Fatal	10.52

Data source: FARS 2004-2018 and NASS-GES 2006 - 2015, averaged annually

Since data on the effectiveness of safety belts in large buses is not presently available, the effectiveness has been assumed to be equivalent to the effectiveness found for occupants in outboard rear seating positions in passenger vehicles in rollover crashes.[67] The effectiveness rates for lap-shoulder seat belts in rollover crashes by injury severity are presented in Table 9.

[67] Morgan, C. *Effectiveness of Lap/Shoulder Belts in the Back Outboard Seating Positions*, Washington, DC, National Highway Traffic Safety Administration, June 1999. (http://www-nrd.nhtsa.dot.gov/Pubs/808945.PDF) Data from this report were divided into crash mode in the report Kahane, C. *Lives Saved by the Federal Motor Vehicle Safety*

Table 9
Estimated Large Bus Lap-Shoulder Belt Effectiveness

Injury Severity	Lap-Shoulder Belt Effectiveness Rate (Rollover)
AIS 1	10%
AIS 2 – 5	82%
Fatal	77%

Source: Final Regulatory Impact Analysis, FMVSS No. 208 Large Bus Seat Belts[68]

Regarding bus occupant belt use rates, at the high end of the range, it is assumed that belt use on large buses would be no higher than the belt use rate in passenger vehicles, which was 90 percent for 2020 (taken from the 2020 National Occupant Protection Use Survey).[69] We note limited studies have been conducted on belt use in large buses. A pilot study of belt use on school buses in Alabama found the lower bound of usage rates by students to be 5 percent.[70] A study of large buses equipped with lap/shoulder belts in Australia found use rates reported at about, or less than, 20 percent.[71] For this analysis, the agency assumes a belt use

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Standards and Other Vehicle Safety Technologies, 1960-2002, October 2004, DOT HS 809-833. (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809833)

[68] See Final Regulatory Impact Analysis for FMVSS No. 208, Lap/Shoulder Belts for All Over-The-Road Buses and Other Buses with GVWRs Greater Than 11,793 kg (26,000 lb) (https://www.regulations.gov/document?D=NHTSA-2013-0121-0002)

[69] National Highway Traffic Safety Administration. *Seat Belt Use in 2020 – Overall Results.* (DOT HS 813 072). Available at: https://crashstats.nhtsa.dot.gov/Api/Public/Publication/813072

[70] "Improving Student Safety: School Bus Seat Belt Pilot Program." UTC Spotlight Newsletter. Research and Innovative Technology Administration. March 2010. Available from: http://utc.dot.gov/publications/spotlight/2010_03/html/spotlight_1003.html

[71] Griffiths, M., Paine, M., and Moore, R. (2009). Three Point Seat Belts on Coaches – the First Decade in Australia. Queensland Transport Australia. Available from:

rate of 15 percent for the low end of the range, [72] and at the high end of the range, 90 percent belt use, the belt use rate in passenger vehicles. The agency believes that seat belt usage rates (at least initially) will be closer to 15% rather than 90% (in part because many passengers are not accustomed to using seat belts on large buses due to the current lack of availability of belts in these vehicles and the fact that passengers have not yet been educated regarding the benefits of buckling up in these vehicles). The following estimates assume that all new large buses are equipped with safety belts and safety belt utilization rates fall between 15 to 90 percent leaving 10 to 85 percent of the occupants still unrestrained in large buses.

The benefits of the safety belt rule are calculated as follows:[73]

Safety belt benefits = Passenger fatalities in large bus rollover crashes x Belt use rate x Belt effectiveness

For example, if we assume belt use is 15 percent, using values from Table 9, the safety belt benefits for fatally injured occupants are:

Safety belt benefits = 10.52 x 0.15 x 0.77 = 1.21

For injured occupants*:*

Safety belt benefits = Injured in large bus rollover crashes x Belt use rate x Belt effectiveness

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https://www.academia.edu/26500332/Three_Point_Seat_Belts_on_Coaches_the_First_Decade_in_Australia?auto=download, last accessed December 2, 2021.

[72] Preliminary Regulatory Impact Analysis – FMVSS No. 208, Motorcoach Seat Belts. National Highway Traffic Safety Administration. (2010). Available at: http://www.regulations.gov/#!documentDetail;D=NHTSA-2010-0112-0006

[73] It is assumed that zero or at least a very low percent of the large bus fleet was equipped with seat belts from 2004 to 2018.

For example, using MAIS 3 injured occupants and assuming a 15% belt use rate:

Safety belt benefits = 56.18 x 0.15 x 0.82 = 6.90

The target population less ESC benefits (Table 8a above) is therefore reduced by the expected benefits from the lap-shoulder safety belt rule shown in Table 10a. The benefits shown in Table 10a will reduce the target population of restrained occupants in the following portion of the analysis.

Table 10a
Estimated Benefits of Lap-Shoulder Belts in Large Bus Rollovers for Passengers

Injury Severity Level	Restrained Occupants (15% belt use)	Restrained Occupants (90% belt use)
MAIS 3	6.90	41.46
MAIS 4	1.18	7.06
MAIS 5	0.61	3.65
Total MAIS 3 - 5	8.69	52.2
Fatal	1.21	7.29

Data source: NASS-GES 2006 – 2015 and FARS 2004-2018, averaged annually

The rollover structural integrity performance requirements offer some protection to the unrestrained occupant from being ejected through the emergency exits and windows as well as intrusion.[74] In addition, it offers protection to the restrained occupant by maintaining residual survival space. Therefore, the benefits of this rulemaking action are computed separately for unbelted and belted occupants. While driver fatalities and injuries were excluded from the benefits of the seat belt rule,[75] they were included in the target population (i.e., fatal and serious injuries in large bus rollovers) in Table 11 as they may benefit from improved structural

[74] Intrusion: the occupant being injured inside the vehicle due to structural deformation

[75] Drivers are assumed to be all belted in the seat belt rule and hence there are no benefits for drivers in the seat belt rule.

integrity. The target population after ESC adjustment (Table 8b) less the seat belt benefits (Table 10a) with injured and fatally injured drivers excluded is shown in Table 10b.

Table 10b
Target Population for Passengers after ESC and Seat Belt Benefits Adjustments
(Injured and Fatally Injured Drivers Excluded)

Injury Severity Level	15% belt use	90% belt use
MAIS 3	49.28	14.72
MAIS 4	8.39	2.51
MAIS 5	4.33	1.29
Fatal	9.31	3.23

The target population after ESC adjustment (Table 8b) less the seat belt benefits (Table 10a) with injured and fatally injured drivers included for the final rule is shown in Table 10c.

Table 10c
Target Population for Passengers and Drivers Combined after ESC and Seat Belt Benefits Adjustments
(Injured and Fatally Injured Drivers Included for the Final Rule)

Injury severity Level	15% belt use	90% belt use
MAIS 3	53.20	18.64
MAIS 4	9.06	3.18
MAIS 5	4.67	1.63
Fatal	10.04	3.96

Since three of the eleven driver fatalities in the FARS data were belted, they have been distributed accordingly. The fatal and non-fatal occupant injuries in the target population based on a belt use rate of 15 percent (i.e., as the lower bound) are shown in Table 11. The fatally injured and injured target population based on the seat belt use rate in passenger vehicles (90%, as the upper bound) is shown in Table 12. The target population for injured occupants (i.e., MAIS 3 to 5) ranges from 23.45 to 66.90 and the target population for fatally injured ranges from 3.96 to 10.04 persons.

Table 11
Projected Target Population in Large Bus Rollovers
Low Belt Use Rate (15%)

Injury Severity Level	Restrained Occupants	Unrestrained Occupants	Total Occupants
MAIS 3	1.64	51.56	53.20
MAIS 4	0.28	8.78	9.06
MAIS 5	0.14	4.53	4.67
Total MAIS 3-5	2.06	64.87	66.90
Fatal	0.56[76]	9.48	10.04

Data source: NASS-GES 2006-2015 and FARS 2004-2018 averaged annually

Table 12
Projected Target Population in Large Bus Rollovers
High Belt Use Rate (90%)

Injury Severity Level	Restrained Occupants	Unrestrained Occupants	Total Occupants
MAIS 3	11.53	7.12	18.64
MAIS 4	1.96	1.21	3.18
MAIS 5	1.01	0.62	1.63
Total MAIS 3-5	14.50	8.95	23.45
Fatal	2.38	1.59	3.96

Data source: NASS-GES 2006-2015 and FARS 2004-2018 averaged annually

If the seat belt usage rate is low at 15 percent, the target population is:

10 fatally injured occupants

67 seriously to critically injured occupants

If the seat belt usage rate is high at 90 percent, the target population is:

4 fatally injured occupants

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[76] The following data are used to calculate the number of fatally injured restrained occupants at 15% belt use for projected target population; fatally injured occupants after ESC benefits adjustment less fatally injured drivers are 10.52 occupants (Table 8b), belt use rate is 15%, effectiveness is 77% (Table 9), fatally injured drivers are 0.73 (11 driver fatalities/15 years), and percent driver belt use rate assuming drivers not ejected are belted is 27% (3 not ejected driver fatalities/11 driver fatalities). The equation used for calculation is as follows: 10.52*15%-10.52*15%*77%+0.73*27%=0.5628 (fatally injured restrained occupants). The ratio of fatally injured restrained occupants to total fatally injured occupants is estimated to be 0.5606 (=0.5628/10.04). (See Table 11 for the 10.04.) This ratio is applied to total fatally injured occupants in projected target population resulting in 0.56 (=0.5606*10.04).

23 seriously to critically injured occupants

C. Effectiveness

Occupant injuries and fatalities can be prevented by a countermeasure to the following injury mechanisms:

1. Projection: occupant interaction with other occupants and the interior of the large bus;
2. Total ejection: the occupant being ejected or thrown out of the vehicle;
3. Partial ejection: part of the occupant's body was thrown out of the vehicle; or
4. Intrusion: the occupant being injured inside the vehicle due to structural deformation or intrusion of an object.

In fatal large bus crashes, ejection is highly correlated to a fatal outcome for the occupant. Windows which fall into the occupant compartment or detach from the frame, and roof exits which unlatch are potential portals of ejection. Of the 189 unbelted fatalities in rollovers from 2004-2018 in FARS large bus rollover crashes, there were 106 fatalities who were completely or partially ejected. There were 83 fatalities in which the occupant was not ejected but died during rollover crashes from 2004 to 2018 as shown in Table 13. About 43 percent (106/249) of ejected occupants died versus 6 percent (83/1,432) of contained occupants, according to the data available in FARS. Note that FARS is a census of fatal crashes but does not necessarily produce accurate counts of injured occupants. Thus, Table 13 undercounts surviving occupants since FARS focuses and covers every fatal crash while only limited injuries are covered.

Table 13
Unbelted Occupants in Fatal Large Bus Rollover Crashes

Ejection Status	Fatal	Survived	Total
Ejected	106	143	249
Not Ejected	83	1,349	1,432
Total	189	1,492	1,681

Data source: FARS, 2004 – 2018.

As shown in Table 13, ejection is highly correlated to a fatal outcome with 106 ejected fatalities (completely or partially ejected) out of the 189 unbelted occupant fatalities in rollovers, or about 56 percent of occupant fatalities in rollover crashes. This proportion is used to distribute fatalities by ejection status of occupants by restraint use in Table 14 and Table 15 (for example, 9.48 x (0.56) = 5.32 rounded). Restrained occupants are assumed not to be ejected.

Table 14
Estimated Fatally Injured by Ejection Status
Low belt use (15%)

Ejection Status	Restrained Occupants	Unrestrained Occupants	Total Occupants
Ejected	0.00	5.32	5.32
Not ejected	0.56	4.16	4.72
Total	0.56	9.48	10.04

Data source: FARS 2004-2018 averaged annually.

Table 15
Estimated Fatally Injured by Ejection Status
High belt use (90%)

Ejection Status	Restrained Occupants	Unrestrained Occupants	Total Occupants
Ejected	0.00	0.89	0.89
Not ejected	2.38	0.70	3.07
Total	2.38	1.59	3.96

Data source: FARS 2004-2018 averaged annually.

As shown in Tables 18a and 18b, ejected occupants have a much higher risk of fatal injury (more than eleven times higher) when compared to non-ejected occupants. In addition, a study by the agency on light truck rollover crashes shows that the number of fatalities is about three times higher than the number of all non-fatal injuries.[77] Based on the fatal risk of ejected occupants and the comparison of fatal and non-fatal occupants in light vehicle rollovers, non-fatal injuries have not been allocated to either ejection category (i.e., ejected or not ejected). The effectiveness of the FMVSS No. 227 final rule in preventing injuries less than MAIS 3 is assumed to be zero, since these minor injuries such as an arm bumping the arm rest, or superficial scratches, are difficult to prevent regardless of structural integrity.

The effectiveness of the countermeasures for reducing fatalities in first and subsequent event rollovers are assumed to be the same. First event rollovers are rollovers in which a large bus overturns for any reason without antecedent collision. The antecedent collision is typically with a curb, or other object which trips the bus. The agency does not expect the effectiveness of the countermeasures for fatalities to be impacted whether the bus was tripped and then rolled, or if it was loss of control and tripped due to yaw, loss of road friction, or other non-collision related factors. The large bus rollover is typically the most harmful event, and more highly correlated to fatal outcomes than the collision.

The effectiveness rates of the FMVSS No. 227 final rule, to be discussed in this portion of the FRE, are summarized for fatally injured occupants and seriously injured occupants in Tables 16 and 17 below. The basis for these estimates is discussed in the following pages.

Table 16
Estimated Effectiveness of the FMVSS No. 227 Final Rule for Fatally Injured Occupants

	Restrained	Unrestrained
Ejected	0.00	0.37
Not ejected	0.60	0.05

[77] "Characteristics of Fatal Rollover Crashes," DOT HS 809 438, April 2002.

Table 17
Estimated Effectiveness of the FMVSS No. 227 Final Rule for Injured Occupants

Restrained	Unrestrained
0.25	0.05

One shortcoming of this analysis is the understanding of occupant interaction in injury causation. It has been noted that occupant loading due to unbelted occupants falling onto belted occupants is a source of injury and even fatal injury.

1. Unbelted Occupant

a) Fatally Injured

Unbelted fatal outcomes are highly correlated to ejection. The ejection and survival status of large bus occupants in rollovers (FARS 2004-2018) are shown in Table 18:

Table 18a
Ejection, Survival Status and Resulting Odds Ratio, Large Bus Occupants in Rollovers

Ejection Status	Survived	Fatally Injured	Odds
Ejected	143	106	0.7413
Not Ejected	1,349	83	0.0615
Odds ratio			0.0830

Table 18b
Ejection, Survival Status and Resulting Odds Ratio, Large Bus Occupants in Rollovers with 300 Ejected Survived Occupants Added

Ejection Status	Survived	Fatally Injured	Odds
Ejected	443	106	0.2393
Not Ejected	1,349	83	0.0615
Odds Ratio			0.2571

The odds ratio is 0.0830 (=0.0615/0.7413), or stated another way, preventing ejection is 92 percent (= 1-0.0830) effective in reducing fatalities as shown in Table 18a. Table 18a, however, likely undercounts the number of surviving occupants, as FARS is a census of only fatalities, and thus, if there are uncounted surviving ejected fatalities, the effectiveness of containment (i.e., not being ejected) may be overstated in the data. According to the 2014 Motorcoach Census, the average number of passengers per service mile was 35.3 in 2014.[78] However, the FARS total number of occupants, 1,681 results in 30.0 (1,681 occupants/56 large bus fatal crashes) occupants per large bus. So we add an additional 300 surviving ejected occupants to increase the total number of occupants from 1,681 to 1,981, or 35.4 (1,981 occupants/56 large bus fatal crashes) occupants per large bus. As a result, adding an additional 300 passengers would bring the number of occupants per large bus close to the average. However, even if there were 300 ejected survivors, which were not included in Table 18a above, the effectiveness of containment (i.e., not being ejected) in reducing fatalities is still highly effective, at 74 percent (=1-0.2571) as shown in Table 18b.

The primary ejection portals are side windows, due to either window retention failure or latch release, and emergency exit roof hatches. The rule would require improved latches for windows and emergency exits, thus the remaining significant portals of ejection are the side windows. NHTSA, in conjunction with Transport Canada, studied the retentive capabilities of window glazing.[79] Based on a numerical analysis of a large bus rollover, NHTSA determined that the impact velocity of an occupant striking the glazing was 20 feet per second. A dynamic impact test device that replicates the Side Impact Crash Test Dummy, 50th percentile adult

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[78] Motorcoach Census, "A Study of the Size and Activity of the Motorcoach industry in the United States and Canada in 2014," American Bus Association, Prepared for the American Bus Association by John Dunham and Associates, February 11, 2016. https://buses.org/assets/images/uploads/pdf/Motorcoach_Census_2014.pdf

[79] Motorcoach Glazing Retention Test Development for Occupant during Rollover, August 2006. Docket Number NHTSA-2002-11876-15.

male[80] was tested against large bus glazing at 20 feet per second. The failure during testing was due to the racking of the bus structure and inadequate structural connectivity of the glazing to the window frame during the testing, but the windows themselves did not break as a result of the impact. The rule requires that windows do not separate from the frame, and since the windows during impact testing did not break as a result of the force applied, the occupants should be better contained in the occupant compartment as a result of the FMVSS No. 227 final rule.

The rule will address the primary ejection portals, and ejection is highly correlated to fatalities. Estimated from FARS data, containment may be 74 percent or more effective at preventing fatalities. However, as the test procedure does not include a condition to simulate occupant loading on the window glazing, the window retention capabilities in the case of occupant loading are uncertain despite the countermeasures which would improve retention. If occupant loading exceeds the window retention capabilities required by the rule, the effectiveness of containment is zero. Given that the effectiveness estimated from the FARS data is 74 percent, the agency has incorporated the uncertainty surrounding window retention capabilities under occupant loading by assuming a midpoint for effectiveness between 0 and 74. Therefore, the agency has estimated that the rule would be 37 percent effective (the midpoint between 0 and 74) at reducing unbelted ejected fatalities.

NHTSA testing, as well as media coverage and NTSB reports, has shown intrusion into the occupant space from detached luggage racks and heavy glazing falling on passengers. The

[80] 49 CFR part 572 subpart U, available at https://www.govinfo.gov/app/details/CFR-2011-title49-vol7/CFR-2011-title49-vol7-part572-subpartU/context, last accessed September 20, 2021.

FMVSS No. 227 final rule contains performance requirements intended to reduce intrusion into the survival space by overhead storage compartments (including luggage racks) and glazing. The agency is unaware of studies which have reviewed the specific consequences of intrusion by large bus interior equipment to passengers within the occupant compartment. The effectiveness of the FMVSS No. 227 final rule for non-ejected unbelted occupants in rollover crashes is estimated to be small, 5 percent, due to the fact that the occupants will still essentially be moving objects within the vehicle. The effectiveness is based on the improved survival space and reduced intrusion from glass, overhead storage compartments and other fixtures.

b) Injured

Estimating the reduction in injuries for unbelted injured occupants is problematic since without restraint they essentially become moving objects within the vehicle. One mechanism of injury that the unbelted occupants may benefit from is decreased intrusion into the survivable space by structural collapse, large glass panes and overhead luggage compartments.

While the agency is unaware of any data available that would indicate the effectiveness of reduced intrusions of storage compartments and windows in preventing seriously (MAIS 3+) injured persons, the agency expects there to be a small level of benefit. Thus, the agency has estimated that decreased intrusions of storage compartments and windows into the survival space would prevent approximately 5 percent of unbelted MAIS 3+ injured persons.

2. Belted Occupant

a) Fatally Injured

While belted occupants will not realize benefits from the FMVSS No. 227 final rule in terms of ejection mitigation, the agency expects that belted occupants will benefit significantly from the structural integrity improvements required in this final rule. The agency realizes that occupants that are no longer fatally injured through ejection may still be fatally injured through collapsing large bus structure. As the FMVSS No. 227 final rule specifically prohibits intrusions into the survival space (where the belted occupant of a large buse is located), the agency expects the effectiveness of preventing a fatality of a belted large bus occupant due to structural intrusions to be very high since a belted occupant within the survival space should be protectable.

If occupants are belted and the survival space is well-protected, the agency believes the risk of fatal injuries in a large bus rollover would be significantly reduced. The row of occupants seated closest to the side of impact, which is approximately 25 percent of a large bus capacity given the typical seat configuration of an aisle with 2 seats on either side, would be most susceptible to side wall intrusion. Although the rule requires this space to be maintained in the test procedure, the occupant torso may still shift enough that their head contacts the window or side pillar. For this analysis, we assume that riders adjacent to the point of impact would not experience measurable safety benefits even if the structure of the bus is strengthened as a result of the final rule. With approximately 25 percent of a large bus capacity seated closest to the side of impact, the number of injured occupants who could potentially benefit from the rule are reduced to 75 percent (= 1 - 0.25, where 25% of the occupants are closest to the side of impact).

As discussed earlier in this FRE, there is a lack of data about the source of injury for belted occupants. The agency also notes a lack of data available on the number of rotations that may occur in some rollovers.[81] While the agency is unaware of available data on the effectiveness of maintaining the survival space of belted occupants, the agency estimates that approximately 20 percent of fatalities would still occur due to unpreventable contact with the side wall even if the structure of a large bus is strengthened. Thus, with the strengthened structure, we assumed that 80 percent (i.e., 100% - 20% = 80%) of bus occupants who are not seated closest to the side of impact (i.e., seated in the well-protected area) would be saved. Taking that portion into account, the estimated effectiveness in belted fatal events is 60 percent (= 0.75 x (1 – 0.20)).

b) Injured

Agency testing included Anthropomorphic Test Devices (ATD) in the testing procedures. The resulting IARV values (1991 Prevost, 1992 MCI and 2000 MCI) for the restrained test dummies are well below the tolerance limits (Threshold Value) (Table 19). The test results indicate that occupants seated on the side opposite of the impact have a low risk of injury when restrained.

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[81] However, testing in the European Union showed the ECE R.66 test procedure exerts greater loads on the structure than some rollovers with more rotations.

Table 19
Restrained ATD Test Results
Non-Impact side, aisle seat

	Threshold	IARV Value		
Criteria Description	Value	1991 Prevost	1992 MCI	2000 MCI
Head Injury Measurements:				
HIC36	1,000	10	2.2	5.3
HIC15	700	10	1.0	2.4
Neck Injury Measurements:				
Axial tensile force (N)	4,170	305	250.6	328.5
Axial compressive force	-4,000	-1,474	-51.4	-79.0
Nij (tension-flexion)	1.00	0.02	0.0	0.05
Nij (tension-extension)	1.00	0.08	0.1	0.12
Nij (compression-flexion)	1.00	0.40	0.0	0.05
Nij (compression-extension)	1.00	0.12	0.0	0.02
Thoracic Injury Measurements:				
Chest acceleration (g)	60	6.0	6.3	6.8
Chest compresson (mm)	63	-1.0	0.9	-0.2

Source: NHTSA; threshold values are from FMVSS 208.

The large bus rollover simulations by Martella et al. showed that three-point belts protect occupants in most seating positions well; however, contact by the side wall or side pillar for the occupant seated closest to the side of impact cannot be prevented. The HIC values in those simulations for the occupant seated closest to impact exceeded 1,000.

The numbers of occupants in the seating position closest to impact averages 25 percent of occupants as there are typically two seats on either side of the center aisle. It is estimated that occupants in other seating positions (e.g. those not seated in the seat immediately next to the side of impact) would benefit from decreased intrusion by overhead storage compartments and detached glass in maintaining the survival space.

The agency does not anticipate the countermeasures required by the FMVSS No. 227 final rule to be as effective in protecting belted occupants from injuries as they are from fatalities. While the agency notes that there is a lack of data regarding how exactly belted occupants can be injured during a large bus rollover, the agency anticipates that there will be more scenarios (in addition to contact with the large bus sidewall on the side of the rollover impact) that can cause serious (MAIS 3-5) injuries. Possible scenarios for injury include occupant interaction with the adjacent belted passenger or with unbelted passengers, intrusion from window glazing which may have fallen due to occupant loading, or non-fatal injuries from side wall intrusion. Injuries, particularly due to occupant interaction, are difficult to estimate or effectively create countermeasures against. The agency anticipates that there are a significant number of possible scenarios that can cause an injury to belted large bus occupants although the agency does not have data regarding how exactly belted occupants can be injured during a large bus rollover. Due to lack of data, the agency assumes that 25 percent of seriously injured (MAIS 3-5) occupants in rollover crashes would be prevented through decreased side wall intrusion and decreased intrusion into the occupant space from overhead luggage compartments and glass that NHTSA testing and real world crashes have shown.

D. Benefits

Based on the above information, the agency has calculated benefits separately by restraint use,[82] if 15 percent of occupants wear seat belts, the agency estimates that the

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[82] We note that, while we have estimated benefits separately based on belt-use, we were unable to estimate the benefits of individual requirements of the rule (e.g., show the benefits attributable to the survival space requirements versus the window retention requirements, etc.). The available data does not contain sufficient detail to enable the agency to accurately determine the specific circumstances under which persons can be injured and distribute the benefits accordingly to each of the requirements. For example, the current crash data does not include any injuries or fatalities from belted occupants because seat belts are not available on the vast majority of buses. Therefore, the data does not show whether the belted occupant is injured from (for example) the lack of survival space, the window glazing dropping into the occupant compartment, or the overhead storage compartment detaching from their mountings. Absent this data, it is unlikely the agency can reliably assign benefits to each requirement.

reductions to the number of fatally injured occupants would be 2.52 per year (Table 20). The reduction in injured persons due to the rule would be low, about 4 seriously injured (3.76) persons annually (Table 21).

To estimate the reduction of fatally injured persons, the agency is using the target population from Table 14 and the effectiveness rates discussed in section C of this chapter (Tables 16 and 17). (For example, 5.32 unbelted, ejected fatalities x 37% effectiveness for unbelted ejected occupants = 1.97 fatally injured persons.)

Table 20
Estimated Benefits of the FMVSS No. 227 final rule
Number of Fatally Injured Occupants Reduced by Restraint use
Low belt use rate (15%)

Ejection Status	Restrained Occupants	Unrestrained Occupants	Total Occupants
Ejected	0.00	1.97	1.97
Not ejected	0.34	0.21	0.55
Total	0.34	2.18	2.52

Data source: FARS 2004-2018, averaged annually

Table 21
Estimated Benefits of the FMVSS No. 227 final rule
Number of Seriously Injured Occupants Reduced by Restraint use
Low belt use rate (15%)

Injury Severity Level	Restrained Occupants	Unrestrained Occupants	Total Occupants
MAIS 3	0.41	2.58	2.99
MAIS 4	0.07	0.44	0.51
MAIS 5	0.04	0.23	0.26
Total MAIS 3 – 5	0.52	3.24	3.76

Data source: NASS-GES 2006-2015, averaged annually

Separately, the reductions in injured persons and fatally injured persons are estimated assuming the belt use rate is 90 percent, equivalent to that of light motor vehicles is presented below (Table 22 and Table 23). The number of injured occupants (MAIS 3 – 5) and fatally injured persons prevented, assuming a 90 percent belt use rate, are 4.07 and 1.79, respectively.

Table 22
Estimated Benefits of the FMVSS No. 227 final rule
Number of Fatally Injured Occupants Reduced by Restraint use
High belt use rate (90%)

Ejection Status	Restrained Occupants	Unrestrained Occupants	Total Occupants
Ejected	0.00	0.33	0.33
Not ejected	1.43	0.03	1.46
Total	1.43	0.36	1.79

Data source: FARS 2004-2018, averaged annually

Table 23
Estimated Benefits of the FMVSS No. 227 final rule
Number of Seriously Injured Occupants Reduced by Restraint use
High belt use rate (90%)

Injury Severity Level	Restrained Occupants	Unrestrained Occupants	Total Occupants
MAIS 3	2.88	0.36	3.24
MAIS 4	0.49	0.06	0.55
MAIS 5	0.25	0.03	0.28
Total MAIS 3 – 5	3.63	0.45	4.07

Data source: NASS-GES 2006-2015, averaged annually

Seat belts, assuming a 15% belt use rate, are estimated to protect 11 percent (= 1.21/11.25, See Tables 8 and 10) of the fatally injured portion of the target population, while the FMVSS No. 227 final rule saves an additional 22 percent (= 2.52/11.25), as a large portion of the fatalities are unbelted (Table 20). Seat belts protect 11 percent (= 8.69/75.62) of the injured target population, and structural integrity is estimated to save an additional 5 percent (= 3.76/75.62) of the injured target population (Table 21).

Assuming a 90% belt use rate, seat belts are estimated to protect 65 percent (= 7.29/11.25) of the fatally injured portion of the target population, while the FMVSS No. 227 final rule is estimated to save an additional 16 percent (= 1.79/11.25). Seat belts are estimated to protect 69 percent (= 52.2/75.62) of the injured target population, and structural integrity is estimated to protect an additional 5 percent (= 4.07/75.62) of the injured target population (Table 23).

The benefits estimated here can be considered conservative in that seat belts have been assumed to be as effective as they are in passenger vehicles. The effectiveness of safety belts in passenger vehicles predominantly rests on the prevention of ejection and ejection is commonly correlated with a fatal outcome in large buses. However, in the future when occupants are belted into the occupant space, fatalities may still occur due to crush injuries, and this has not been taken into account quantitatively here as data on belted occupants on large buses is not available. For example, while a belted passenger may not be ejected, he or she can still be struck by the collapsing side wall of a large bus.

Some crashes are examples of fatalities that may not have been prevented despite the use of safety belts. On May 31, 2011, a 2000 Setra bus carrying 58 passengers traveling from Greensboro, North Carolina to New York City on Interstate 95 departed the roadway near Doswell, Virginia, rolled 180 degrees, and landed on its roof. NTSB, who investigated this accident, noted that there was considerable deformation of the roof into the occupant survival space as evidenced by the seat back deformation resulting from contact with the roof structure. Four passengers were killed as a result of encroachment of the occupant survival space by the roof and fourteen passengers sustained serious injuries. In March 2011, a large bus headed for New York ran off an elevated highway, turned on its side, and hit a utility pole at the level of the windows shearing off its roof. Fifteen passengers were killed. NTSB noted that in this case improved structural integrity may have lessened the degree to which the roof separated from the passenger compartment.

IV. COSTS AND LEADTIME

Estimates of material costs and weight increases were developed from data voluntarily submitted by four large bus manufacturers to NHTSA.[83] According to market data obtained from manufacturers, there is little dissimilarity across models of over-the-road buses. Therefore, it is assumed that costs associated with the rule will be approximately the same across models. The manufacturers however did not provide any detail as to whether double-decker large buses were included in the cost estimates, or if the costs would vary significantly. The cost of the FMVSS No. 227 final rule is comprised of material costs and fuel costs due to weight increases from reinforcing the overall superstructure of the large bus.

The cost of the FMVSS No. 227 final rule is the incremental cost of going from the 2020 planned compliance rate to 100 percent of all new large buses meeting the structural requirements. There are approximately 2,200 large buses sold annually that would be covered by the FMVSS No. 227 final rule;[84] the agency estimates that there are 2,100 OTRBs and 100 cutaway-type buses. Based on NHTSA testing and comments received from four manufacturers, we believe that at least some modifications are needed in order for large buses to meet the test procedure when weighted to occupancy.

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[83] In order to abide with our confidentiality agreements with the manufacturers, the particular make/models will not be disclosed.

[84] Evaluation of the Market for Small-to-Medium-Sized Cutaway Buses, Federal Transit Administration Project#: MI-26-7208.07.1, December 2007, available at https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/AnEvaluationofMarketforSmalltoMediumSizedCutawayBuses.pdf, last accessed November 04, 2016.

A. Installation Costs

1. Costs of strengthening side walls/pillars

During NHTSA testing of all three large buses (MY1991 Prevost LeMirage, MY1992 MCI MC-12, and MY2000 MCI 102-EL3), either the residual template was contacted by the side walls or the side wall pillars appeared to enter the residual space. Improving the strength of the side walls or side pillars with additional materials is one method of avoiding intrusion into the residual space.

The material costs of reinforcing the large bus structure are based on the estimates of manufacturers who responded that they are in compliance with ECE R.66, and who provided an estimate of overall increases in curb weight required to comply with ECE R.66. Manufacturers responded that the initial weight increase (due to increased materials to support the pillars and side walls) to meet ECE R.66 is estimated to be between 550 and 1,100 pounds. While NHTSA sets forth an additional measure which would allow NHTSA to weight the large bus to the maximum gross vehicle weight rating (GVWR) to simulate the impact from the additional weight due to passengers, manufacturers who stated that they currently meet the requirements of ECE R.66 stated that the additional requirement would not cause an increase in weight nor materials. Reinforcing the A-pillar, reinforcing the cant rail joints, welding additional tubes to the B-pillars, or redesigning the existing structure to distribute impacts better over the whole of the superstructure are some methods that may be employed to meet the FMVSS No. 227 final rule.

Manufacturers whose superstructure is compliant with ECE R.66 as judged by their responses to the voluntary information collection, consist of about 30% of the market, are not assumed to be fully compliant in the other areas of window retention, seat anchors, and emergency exit latch retention.

Manufacturers with experience in designing their coaches to meet the ECE R.66 standard similar to the one in the FMVSS No. 227 final rule indicated that the weight increases would range from 550 pounds to 1,100 pounds. Manufacturer specification sheets identified the large bus body as being composed of a stainless-steel lower frame and high-tensile low-alloy steel in upper-body framing and high-stress areas with galvanized steel side walls. However, while the agency assumes in these estimates that steel is applied to reinforce the large bus structure, the agency is aware that other methods of reinforcing the structure (such as the use of high strength steel sections, rigid polyurethane foam filling to reinforce and stabilize thin walled hollow sections, and optimized designs that redistribute the impact loads and enhance the energy absorption capability) may enable a large bus to withstand greater crash forces without increasing as much weight.[85]

The agency estimated the average price for steel mill products using value of shipment data and output quantities reported in the U.S. Census Bureau's Current Industrial Report (CIR) for Steel Mill products.[86] In 2009, the CIR reports approximately 130,500 metric tons of steel

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[85] *See* Lilley, K. and Mani, A., "Roof-Crush Strength Improvement Using Rigid Polyurethane Foam," SAE Technical Paper 960435, 1996. Available at: https://www.sae.org/publications/technical-papers/content/960435/, *see also* Liang, C. and Le, G. Optimization of bus rollover strength by consideration of the energy absorption ability. International Journal of Automotive Technology. Vol. 11.(2) 173 – 185. Available at: https://link.springer.com/article/10.1007/s12239-010-0023-3.

[86] Available from the United States Census Bureau at: http://www.census.gov/manufacturing/cir/historical_data/ma331b/index.html.
The U.S. Census Bureau terminated the collection of data for the Current Industrial Report (CIR) program after the publication of the 2010 data tables for MA331B – Steel Mill Products.

mill products were shipped at a value of $110 billion. This implies an average price of $0.38 per pound in 2009 dollars and a cost of $0.46 per pound (=0.38x1.206369997) in 2020 dollars.[87] The material cost must be adjusted to the price consumers will pay for the final product, reflecting costs to design, fabricate, and assemble the reinforced body structure, as well as indirect costs such as research, depreciation, capital equipment, etc.

NHTSA has commonly used retail price equivalent (RPE) multipliers to approximate the indirect costs associated with manufacturing. The RPE is a ratio of total revenues to direct manufacturing costs. Because, by definition, total revenues = direct costs + indirect costs + profit, the RPE is the factor that, when multiplied by direct manufacturing costs, recovers total revenue. Indirect costs include production-related costs (research, development, and other engineering), business-related costs (corporate salaries, pensions and manufacturer profits), and retail-sales-related costs (dealer support, marketing and dealer profits). While a multiplier specific to heavy duty vehicles has yet to be developed, the light-vehicle RPE will be used as a proxy. Applying the RPE multiplier to the cost of steel estimates the incremental cost per pound of steel at $0.69 (= $0.46 x 1.51). Labor and fabrication costs are assumed to be unchanged since the increased amount of steel or other materials to support the existing side walls or side pillars are not expected to change construction processes.

The specification sheets for Van Hool and Setra (available from manufacturer websites) indicate that they currently meet ECE R.66. According to National Bus Trader, Van Hool and

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[87] Consumer Price Index (CPI) data is provided by the U.S. Department of Labor Bureau of Labor Statistics. The consumer price index for all urban consumers for 2009 and 2020 are 214.537 and 258.811, respectively and 258.811/214.537=1.206369997.
https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/

Setra comprise 30 percent of the U.S. large bus market. Thus, the increase in costs applies to the other 70 percent of the market (1,540 large buses annually, 2,200 x 70% = 1,540). The agency estimates the incremental increase in retail price, due to increasing the strength of side walls/pillars, would range from $381 to $761 per large bus. The lower bound is estimated based on an additional 550 pounds of steel[88] and the upper bound is estimated based on an additional 1,100 pounds of steel. The lower cost estimate for all large buses covered by the final rule to increase the strength of the side walls and pillars is thus $0.59 million (= $381 x 1,540). The upper bound is based on the 1,100 pounds additional weight to increase the strength of side walls and pillars, at an estimated cost of $1.17 million (= $761 x 1,540) in 2020 dollars.[89]

2. Costs of improved window mounting

Manufacturers responded that there would be no significant cost to retain windows. However, in 2008 and 2009, NHTSA conducted testing on 3 large bus models to investigate the impacts of the proposed ECE R.66 test. The newest model tested had windows which separated from the frames and fell into the passenger compartment. In the two older model large buses, the windows did not separate from the frames on the side opposite the impact; however, the emergency exit windows unlatched and opened on one model.

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[88] The business cycle and inventories are only two factors in metal price determination. Other factors that affect prices include changes in metals production, speculation, strategic stockpiling, foreign exchange rates, geopolitical instability, and production costs (USGS).

[89] Exact cost is $761.44, not $761.

The stylistic trend over the past 20 years has increased large bus window pane size by about 60 percent[90] given the areas of the windows tested (Row 3, Table 24). NHTSA believes that the larger window size is more indicative of current and future large buses. We therefore assume all new buses will require reinforcement to meet these standards. Increasing the lip of the window frame may improve window retention. The materials necessary to make such modification are estimated at approximately one pound of steel per window, where the typical large bus has 12 windows (6 per side). The mark-up retail cost of steel is $0.69 per pounds and the addition of a small amount of steel to the frame is not expected to change the fabrication costs. Thus, the cost is approximately $8.31 per large bus (12 pounds x $0.69 cost per pound). The total cost for the fleet to improve window retention is approximately $0.018 million (2,200 x $8.31).

[90] Large buses manufactured in 2009 have windows similar in size to the 2000 model NHTSA tested according to manufacturer specification sheets.

Table 24
Window Specifications and ECE R.66 Test Results

	1991 Prevost LeMirage	1992 MCI MC-12	2000 MCI 102-EL3
Window height (in.)	32	52	62
Window length (in.)	41	27	35
Window area (sq. in.)	1,312	1,404	2,170
Window area % increase (over 1991 model)	-	15%	55%
Window retention test results	Far side remained in frame	Far side remained in frame	Far side fell into passenger compartment

3. Costs of shock-resistant emergency exit latches

The roof emergency exits in all 3 large buses tested by NHTSA in 2008 and 2009 became unlatched. The loss of side window retention on one older model large bus was caused by emergency exits that became unlatched and opened during the test. The agency estimates that replacing the current emergency exit roof latches with "shock-resistant" latches will require the addition of a spring to remain closed and operable during and after the test. The typical large bus has 1 or 2 emergency roof exits.[91] NHTSA has observed 6 emergency window exits per large bus (3 per side) and 2 emergency roof exits. Thus, the retail cost of shock resistant emergency exit latches is $40 per large bus (8 emergency exits x $5),[92] and $0.088 million in total industry costs (= $40 x 2,200 large buses).

4. Costs of improved luggage compartment suspension

Manufacturer responses indicated that there would be no additional costs to ensure luggage compartments do not intrude into the survival space. However, real world crash data

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[91] S5.2.2.1 FMVSS 217 requires buses to have a rear emergency exit that can be used when the bus rolls over. If a rear exit is not feasible then a roof exit is required. Large buses typically have roof exits instead of a rear exit.

[92] Based on approximate price differences between shock-resistant latches and regular latches from part supply websites.

and NHTSA testing indicate overhead luggage rack and overhead luggage compartment retention failure. One of the three models tested had overhead rack damage resulting in intrusion into the occupant space. Additionally, a rollover crash which occurred in California in 2008 (involving a large bus which was manufactured in 2008) showed interior intrusion from overhead fixtures.[93] The additional cost of improving the supporting structure of overhead luggage compartments or racks is estimated to be $10 per large bus for additional brackets, screws, and bolts including the retail mark-up.[94] The industry cost to improve overhead luggage rack suspension is therefore $0.022 million ($10 x 2,200).

5. Material Cost Summary

The countermeasures to meet the FMVSS No. 227 final rule include a stronger roof and side walls, shock-resistance latches for the emergency exits, overhead storage compartment anchorages, and improved window mounting. These countermeasures would result in a weight increase of 14 pounds for large buses (660 large buses, 30 percent of the 2,200 large bus sales) which do not need stronger roof and side walls and 564 to 1,114 pounds for the remaining large

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[93] Colusa County Bus Accident, Accident and Injury News, October 6, 2008, http://www.californiainjuryblog.com/2008/10/colusa-county-bus-accident-kil.html

[94] Investigation by NTSB of the Sherman, Texas crash showed there are 9 supports for the overhead luggage racks on either side of the motorcoach. Assuming this is typical for a large bus, there are a total of 18 supports for the overhead luggage compartments/racks per vehicle. A support here is assumed to fundamentally be an L-bracket with a mid-point pillar to the roof plus additional anchors and bolts related to supporting the L-bracket and mid-point pillar. The agency estimates that the incremental cost is $0.36 per support for increased bracket strength, increased anchor support, and additional bolts ($0.08 + 5*$0.04 + 8*$0.01). The incremental cost of increasing the strength of 18 brackets is estimated at $0.08 per bracket for an incremental cost per vehicle of $1.44 (= 18 x $0.08). Assuming there is a total of 5 joint or anchorage points per bracket, where the incremental cost of improving a joint or anchor is $0.04, the incremental cost per vehicle is $3.60 (= 18 x 5 x $0.04). If there are an additional 4 bolts necessary to anchor the bracket to the sidewall and an additional 4 bolts to anchor the brackets to the ceiling, the incremental estimated cost per vehicle is $1.44 (= 18 x 8 x $0.01). This cost may be used for additional welding or other measures in favor of bolts. Therefore, the incremental cost per vehicle is $6.48 (= $1.44 + $3.60 + $1.44). The total incremental cost per vehicle for improving overhead luggage rack suspension is estimated to be approximately $10 including the RPE multiplier (= $6.48 x 1.51).

buses which require strengthening the side walls and roof. The average weight increase is estimated to range from 399 (=14 lb x 660/2,200 + 564 lb x 1,540/2,200) to 784 (=14 lb x 660/2,200 + 1,114 lb x 1,540/2,200) pounds per vehicle. Total material costs thus are comprised of these countermeasures and the unit costs per countermeasure have been applied to the total population to which they will apply in Table 25a. Material costs here have been assumed to be the same across large bus type.

The total cost of the countermeasures necessary for varying large buses to meet the requirements are in Table 25b. The agency estimates that approximately 30 percent of currently manufactured large buses have the necessary side wall and pillar strength. The industry wide material costs vary from $0.715 million to $1.301 million, yielding an average cost of $325 ($0.715 M/2,200) to $591 ($1.301 M/2,200) per bus.

Table 25a
Material Cost Estimates
(2020 Dollars)

Countermeasure	Cost per Large bus	Number of Large buses	Fleet Cost per Countermeasure
Window reinforcement (a)	$8.31	660	$0.0055 M
Shock-resistant latches (a)	$40	660	$0.0264 M
Overhead storage reinforcement (a)	$10	660	$0.0066 M
Side wall/pillar reinforcement (b)	$381 - $761	1,540	$0.586 M - $1.173 M

Table 25b
Estimated Material Costs – Fleet Totals
(2020 Dollars)

	Cost per Large bus	Number of Large buses	Total Cost Increase
Reinforcement of existing structure (a)	$58	660	$0.038 M
Increased structure (a + b)	$439 - $820	1,540	$0.676 M - $1.262 M
Total Cost Range	$58 - $820	2,200	$0.715 M - $1.301 M

6. Testing Cost

The required test in the FMVSS No. 227 final rule is based on the complete vehicle test from ECE R.66. The test is estimated to cost $38,000, not including the cost of the large bus itself, and assuming the bus is equipped with 57 seats. Testing cost is not explicitly included in this analysis but is considered research and development or overhead for the manufacturers, which is already included in the 1.51 markup factor from variable costs to retail price equivalent.

However, there are various options available to manufacturers to use as a basis for certification to the requirements of the FMVSS No. 227 final rule. These options may reduce the cost of complying with the standard: (1) rollover test of body sections representative of the vehicle, (2) quasi-static loading tests of body sections, (3) quasi-static calculations based on testing of components, and (4) computer simulation (finite element analysis) of complete vehicle.[95]

Lower cost alternatives would include compliance by using modeling and engineering analyses (such as a plastic hinge analysis of portal frames of a large bus). Testing body sections of the vehicle, as contemplated by ECE R.66, Alternatives 1 and 2, would allow manufacturers to "section" the vehicle or otherwise obtain a body section representative of the vehicle and of the weakest section of the vehicle. It could base its certification on these tests, without testing a full vehicle.

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[95] Further information regarding the alternative certification methods of ECE R.66 is available at: Motorcoach Roof Crush/Rollover Testing Discussion Paper, March 2009, Docket No. NHTSA-2007-28793-0019

If manufacturers elect to conduct a test of a full vehicle, there are various methods available to reduce the costs of the test. One such method is by testing a vehicle which is not completely new. As the requirements in the final rule pertain to the large bus structural integrity, we believe that a manufacturer could test the relevant body design on an old large bus chassis or other underlying structure, and could sufficiently assess and certify the compliance of the vehicle's structural integrity to the standard. Similarly, the agency believes that more costly portions of the large bus (such as the engine and other portions of the powertrain) could be replaced in a complete vehicle test of a large bus with ballast equal to the weight of the absent components.

7. Leadtime

NHTSA sets forth a compliance date of the first September 1, three years after publication of the FMVSS No. 227 final rule. We believe that this lead time is appropriate as some design, testing, and development will be necessary to certify compliance to the new requirements.

Based on our research, we believe that manufacturers may need to make structural design changes to their new large bus models either by changing the strength of the material or the physical dimensions of the material. In addition, the manufacturers may need to strengthen the seat and luggage rack anchorages, improve the type of latches used on emergency exits, and improve the mounting of side windows. As such, the agency concludes that three years of lead time would be needed to enable manufacturers to make the necessary changes.

B. Fuel Economy Impact

Manufacturers which have designed their large buses to meet ECE R.66 requirements indicated the weight increase to meet ECE R.66 was 550 to 1,100 pounds, and do not expect to have to increase weight to meet the additional requirements of this rule. The additional weight due to increased steel to retain windows is estimated at 12 pounds per large bus, and 2 pounds for overhead storage reinforcement, for a total of 14 pounds. Shock-resistant latches are estimated to weigh the same as the current latches.

The total weight increase due to the requirements of the regulation ranges from: (a) 14 pounds for improvements in window and overhead storage reinforcement, and shock-resistant latches; (b) 564 (550 + 14) pounds to 1,114 (1,100 + 14) pounds if window retention improvements, shock-resistant latches, overhead storage reinforcement, and structural improvements are necessary. The lower bound weight increase, 14 pounds will apply to the 660 large buses (= 2,200 – 1,540) not requiring reinforcement to the superstructure of the large bus. The other 1,540 large buses will require a variable increase in weight, between 564 to 1,114 pounds.

The curb weight of a large bus varies but the trend is toward longer, heavier, and large buses. The three large buses that NHTSA tested have the following specifications (Table 26). The vehicles were selected for the research program such that they would represent the range of roof characteristics (such as design, material, pillars, shape, etc.) of large bus roofs in the U.S. fleet.[96]

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[96] *Motorcoach Roof Crush/Rollover Testing*. National Highway Traffic Safety Administration. March 2009. NHTSA-2007-28793. Available from: http://www.regulations.gov/#!documentDetail;D=NHTSA-2007-28793-0019.

Table 26
Manufacturer's Large Bus Specifications

	1991 Prevost LeMirage	1992 MCI MC-12	2000 MCI 102-EL3
Curb weight (with full fluids)	29,500 lb	28,000 lb	40,003 lb
GVWR	40,000 lb	37,800 lb	49,900 lb
Length (feet)	40	40	45
Passenger occupancy	47	47	57

We used the following formula for estimating the impact of marginal weight increases on fuel economy:

*(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. Using this formula, we can estimate the impact that a weight increase would have on large bus fuel economy. First, we assume that the average in-use weight of a large bus is 45,000 pounds. The basis for the weight estimate of the average in-use large bus is the curb weight with full fluids of the most recent model large bus tested (40,003 pounds) with the addition of about 30 occupants (assumed average weight of 164 pounds, the weight of a Hybrid III 50th percentile dummy). Second, the average baseline mpg of a large bus is estimated to be 6.4 mpg (miles per gallon).[97] Third, the projected price of diesel was taken from a reference case of the Annual Energy Outlook 2021 (in 2020 dollars) starting in 2020. The analysis uses a 3 percent and a 7 percent

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[97] Motorcoach Census 2017, A Study of the Size and Activity of the Motorcoach Industry in the United States and Canada in 2017, John Dunham & Associates. June 5, 2019. Available at: https://www.buses.org/assets/images/uploads/pdf/FINAL_2017_Census_1.pdf

discount rate. The discounting procedures for future benefits and costs in regulatory impact analyses are based on the guidelines published in Appendix V of the "Regulatory Program of the United States Government", April 1, 1990 - March 31, 1991.

The typical large bus drives 40,000 miles per year.[98] Adding 564 pounds changes the average fuel economy of that large bus from 6.4 mpg to 6.3365 mpg. Over an average year, the large bus would use 6,250 gallons at 6.4 mpg and would use 6,313 gallons at 6.3365 mpg, so adding 564 pounds results in 63 more gallons of diesel used per large bus annually. The estimated impact on a year to year basis was computed and then discounted back to present value at a 3 percent and 7 percent discount rate. The same method was applied to each estimated potential weight increase value – 14 pounds, 564 pounds, and 1,114 pounds – and discounted back to present value. Additional lifetime fuel consumption per large bus for the estimated 14 pound increase in weight is 36 gallons and for 564-1,114 pounds weight increase is 1,430 - 2,822 gallons. Table 27 shows the range of the estimated incremental weight increases and the impact on fuel costs at the 3 percent and 7 percent discount rates.

[98] Ibid.

Table 27
Present Discounted Value of
Increased Lifetime Fuel Costs per Large Bus

Countermeasures	Weight Increase (lb)	New Fuel Economy (mpg)	Incremental Increase in Lifetime Fuel Costs @3%	Incremental Increase in Lifetime Fuel Costs @7%
Window Retention Improvements Overhead Luggage Support No Side Wall/Roof Improvements	14	6.3984	$86	$65
Window Retention Improvements Overhead Luggage Support Low Estimate of Side Wall/Roof Improvements	564	6.3365	$3,450	$2,632
Window Retention Improvements Overhead Luggage Support High Estimate of Side Wall/Roof Improvements	1,114	6.2760	$6,806	$5,192

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 27 and multiplying by the number of applicable vehicles (e.g. $3,450 for 564 lb at a 3% discount rate * 1,540 = $5.313 million). Tables 28 and 29 show the total incremental fuel economy costs for 3 percent and 7 percent discount rate.

Table 28
Total Fuel Economy Impacts (2020 Dollars)
Discount rate @ 3%

	Costs per Large bus	Number of Large buses	Total
No sidewall/roof reinforcement (14 lb)	$86	660	$0.057 M
Sidewall/roof reinforcement (564 -1,114 lb)	$3,450 - $6,806	1,540	$5.313 M - $10.481 M
Range of Total Fuel Costs	$86 - $6,806	2,200	$5.369 M - $10.537 M

Note: M = millions

Table 29
Total Fuel Economy Impacts (2020 Dollars)
Discount rate @ 7%

	Costs per Large bus	Number of Large buses	Total
No sidewall/pillar reinforcement (14 lb)	$65	660	$0.043 M
Sidewall/pillar reinforcement (564 -1,114 lb)	$2,632 - $5,192	1,540	$4.053 M - $7.996 M
Range of Total Fuel Costs	$65 - $5,192	2,200	$4.096 M - $8.039 M

Note: M = millions

The average fuel cost per large bus is obtained by dividing the total cost in Tables 28 and 29 by the number of large buses produced annually. The average fuel cost is $2,441 (= $5.369 M/2,200) to $4,790= ($10.537 M/2,200) per large bus at a 3 percent discount rate, and $1,862 (= $4.096 M/2,200) to $3,654 (= $8.039 M/2,200) per large bus at a 7 percent discount rate. As seen in Tables 28 and 29 the average cost per large bus is different from the estimated range of cost increases which varies by incremental weight increases.

C. Cost Summary

Large buses have low fuel economy and high annual mileage. Thus, weight increases impose a comparatively large cost in terms of total fuel consumption costs per vehicle. In the case assumed here, where steel is applied to enhance the structure, the fuel costs over the lifetime of the large bus will exceed the cost of materials. However, the agency notes that alternative materials and designs, such as the use of high strength steel sections, rigid polyurethane foam filling to reinforce and stabilize thin walled hollow sections, and optimized designs that redistribute the impact loads and enhance the energy absorption capability may be utilized to improve the structure without necessarily adding as much weight.[99,100]

The following summarizes the estimated cost and fuel economy impacts of the rule:

Material cost

- Range of incremental cost increases per large bus: $58 for minor improvements; $439 - $820 when side walls/pillars require increased support (in addition to the minor improvements to the window mounting, emergency exit latches, and luggage compartment);
- Number of vehicles: 660 will need minor improvements (30% of fleet), 1,540 will need minor improvements and side walls/pillars improvements (70% of fleet);
- Total cost: $0.715 million to $1.301 million, $325 to $591 average incremental cost increase per large bus

Fuel economy impact

- Added weight per vehicle: 14 lb per large bus for minor improvements; 564 – 1,114 lb per large bus when side wall/roof require increased support
- Additional life-time fuel consumption per large bus: 36 gallons for minor improvements; 1,430 – 2,822 gallons when side wall/pillar require increased support

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[99] Lilley, K. and Mani, A., "Roof-Crush Strength Improvement Using Rigid Polyurethane Foam," SAE Technical Paper 960435, 1996. Available at: http://subscriptions.sae.org/content/960435/

[95] See also Liang, C. and Le, G. Optimization of bus rollover strength by consideration of the energy absorption ability. International Journal of Automotive Technology. Vol. 11.(2) 173 – 185. Available at: http://www.springerlink.com/content/tk824863k66w0228/export-citation/

- Fuel cost: $5.369 million to $10.537 million at a 3 percent discount rate; $4.096 million to $8.039 million at 7 percent discount rate.
- Average fuel cost per large bus: $2,441 to $4,790 at a 3 percent discount rate; $1,862 to $3,654 at a 7 percent discount rate.

The total annual cost is:

- $6.084 million to $11.838 million at a 3 percent discount rate; and
- $4.811 million to $9.340 million at a 7 percent discount rate.

The average total cost per large bus is (dividing the total annual cost by 2,200 large buses):

- $2,765 to $5,381 at a 3 percent discount rate; and
- $2,187 to $4,245 at 7 percent discount rate.

V. COST-BENEFIT AND COST-EFFECTIVENESS ANALYSES

This chapter provides cost-benefit and cost-effectiveness analyses for the rule. The Office of Management and Budget (OMB) requires all agencies to perform both analyses in support of rules, effective January 1, 2004.[101] For the cost-benefit analysis we are comparing vehicle costs and fuel costs to injury and fatality benefits. In order to conduct a cost-benefit analysis the agency must translate injury and fatality reductions into a monetary value. Two concepts are used for this purpose: the "economic cost of crashes" and the "value of a statistical life". Together, these components represent the comprehensive cost of crashes.

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 30 shows NHTSA's current estimates of the economic costs as well as comprehensive costs for each injury level. These represent unit savings that will result at each injury level from both crash avoidance and crashworthiness countermeasures. The comprehensive value of societal impacts from fatalities and injuries includes a variety of cost components and includes cost components that comprise economic costs. Table 30 summarizes the cost components and corresponding unit costs in 2020 economics. As shown in

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[101] See OMB Circular A-4. Available at: http://www.whitehouse.gov/omb/circulars_a004_a-4/

the table, the cost components included medical, EMS, 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). The unit costs were revised from those published in the agency's 2015 report (Blincoe, 2015 et al).[102] Table 30 shows comprehensive and economic costs in 2020 dollars.

[102] Blincoe, L., Miller, T., Zalloshnja, E., Lawrence, B., The economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised), DOT HS 812 013 National Center for Statistics and Analysis, Washington, D.C., May 2015.

Table 30
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
EMS	$129	$264	$496	$999	$1,020	$1,076
Market Prod	$3,424	$24,318	$80,820	$176,891	$424,096	$1,172,349
Household Prod	$1,083	$8,926	$28,500	$47,158	$119,849	$364,180
Ins. Adm.	$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.

Benefits are realized throughout a buses' life. According to OMB Circular A-4, the analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value in equivalent units of consumption and to discount them at the rate consumers would normally use in discounting future consumption benefits.

There is general agreement within the economic community that the appropriate basis for determining discount rates is the marginal opportunity costs of lost or displaced funds. When these funds involve capital investment, the marginal, real rate of return on capital must be considered, estimated here at 7 percent based on analysis of the average before-tax rate of return to private capital in the U.S. economy conducted by OMB.

However, when these funds represent lost consumption, the appropriate measure is the rate at which society is willing to trade-off future for current consumption. This is referred to as the "social rate of time preference," and it is generally assumed that the consumption rate of interest, i.e., the real, after-tax rate of return on widely available savings instruments or investment opportunities, is the appropriate measure of its value. If we take the rate that the average saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3 percent in real terms on a pre-tax basis.

Thus, fatal equivalents are required to be discounted to present value at 3 and 7 percent per OMB Circular A-4 where 3 percent represents the “social rate of time preference,” and 7 percent represents the average rate of return to capital.

Safety benefits occur when there is a crash severe enough to potentially result in occupant death and injury, which could be at any time during the vehicle’s lifetime.

The 3% discount rate results in a multiplier of 0.7849 and the 7% discount rate results in a multiplier of 0.5988. These discount factors can be derived by using values in Tables 34a and 34b - taking the exposure proportion and multiplying it by the mid-year discount factor, year by year and summing that result over the lifetime of large buses. In Table 31, the injuries reduced are multiplied by these factors to account for the injuries at the time that crashes occur.

Combining the above information with the expected number of injuries and fatalities that would be reduced by the FMVSS No. 227 final rule the agency is able to project the potential monetizable benefits of the rule. Depending on the belt usage rate (15% or 90%) and the discount rate (3% or 7%), the rule is expected to save between $17.59 million and $29.40 million per year in lost quality of life and economic costs associated with motor vehicle injuries and fatalities. See Tables31a and 31b, below.

Table 31a
Value of Benefits
From Reduced Comprehensive Costs at 15% Belt Usage (2020$)

Injury Severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury Reduced	0.0000	0.0000	2.9877	0.5086	0.2625	2.5200	
Economic Value	$44,752	$541,175	$1,286,349	$3,194,328	$7,307,122	$11,930,276	
Monetized Benefits Undiscounted	$0	$0	$3,843,257	$1,624,740	$1,917,870	$30,064,779	$37,450,647
Monetized Benefits at 3%	$0	$0	$3,016,573	$1,275,259	$1,505,336	$23,597,845	$29,395,012
Monetized Benefits at 7%	$0	$0	$2,301,342	$972,894	$1,148,421	$18,002,790	$22,425,447

Table 31b
Value of Benefits
From Reduced Comprehensive Costs at 90% Belt Usage (2020 $)

Injury Severity	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury Reduced	0.0000	0.0000	3.2376	0.5518	0.2837	1.7912	
Economic Value	$44,752	$541,175	$1,286,349	$3,194,328	$7,307,122	$11,930,276	
Monetized Benefits Undiscounted	$0	$0	$4,164,651	$1,762,565	$2,073,213	$21,369,099	$29,369,529
Monetized Benefits at 3%	$0	$0	$3,268,835	$1,383,437	$1,627,265	$16,772,606	$23,052,143
Monetized Benefits at 7%	$0	$0	$2,493,793	$1,055,424	$1,241,440	$12,795,817	$17,586,474

B. Equivalent Fatalities

In order to monetize benefits and apply a value of a statistical life, we need to convert nonfatal injuries into portions of a fatality in order to calculate the number of equivalent fatalities prevented by the rule. This involves dividing the value of each injury severity category by the value of a fatality to determine how many injuries equal a fatality. These relative injury factors are listed in Tables 32a and 32b, below, in 2020 dollars. Tables 32a and 32b also show the calculations for determining the undiscounted equivalent lives saved for the rule.

Table 32a
Undiscounted Equivalent Lives Saved at 15% Belt Usage

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury Reduced	0.0000	0.0000	2.9877	0.5086	0.2625	2.5200	
Relative Injury Factor[103]	0.0030	0.0470	0.1050	0.2660	0.5930	1.0000	
Equivalent Lives Saved	0.0000	0.0000	0.3137	0.1353	0.1556	2.5200	3.1247

Table 32b
Undiscounted Equivalent Lives Saved at 90% Usage Rate

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
Injury Reduced	0.0000	0.0000	3.2376	0.5518	0.2837	1.7912	
Relative Injury Factor	0.0030	0.0470	0.1050	0.2660	0.5930	1.0000	
Equivalent Lives Saved	0.0000	0.0000	0.3399	0.1468	0.1682	1.7912	2.4461

However, fatal equivalents benefits are benefits realized throughout the vehicle life and thus also need to be discounted in order to reflect present values of these benefits (in 2020 dollars). The agency uses the 3% and 7% discount rates to determine the present value for future benefits and costs. These discount rates are based on the guidelines published in Appendix V of the "Regulatory Program of the United States Government", April 1, 1990 - March 31, 1991.

Those discount multipliers are multiplied by the undiscounted equivalent lives saved (ELS) in Tables 32a and 32b to determine their present value in ELS. The final discounted ELS values are shown in Table 33. The discounted equivalent lives saved range from 1.46 to 2.45

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[103] See Table 30 Comprehensive and Economic Costs for relative injury factor.

lives, where the lower bound represents a 7 percent discount rate and the upper bound represents a 3 percent discount rate.

Table 33
Equivalent Lives Saved Discounted

	15% Belt Use	90% Belt Use
3% Discount	2.4526	1.9200
7% Discount	1.8711	1.4647

1. Value of a Statistical Life

The comprehensive value of societal impacts from fatalities and injuries includes a variety of cost components. As shown in Table 30, the cost components included medical, EMS, 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). 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 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).[104]

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.

[104] 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

Table 34a
3% Discount rate and Discount factor 0.7849

	Adjusted VSL (millions)	Survival Probability	Exposure (VMT)	Aggregate Exposure	Exposure Proportion	Mid-Year Discount Factor (3%)	Aggregate Discount Factor
1	$11.60	0.9995	64,901	64,869	0.0710	0.9853	0.0699
2	$11.60	0.9985	63,628	63,533	0.0695	0.9566	0.0665
3	$11.60	0.9953	62,381	62,088	0.0679	0.9288	0.0631
4	$11.60	0.9874	61,157	60,386	0.0661	0.9017	0.0596
5	$11.60	0.9747	59,958	58,441	0.0639	0.8755	0.0560
6	$11.60	0.9574	58,783	56,279	0.0616	0.8500	0.0523
7	$11.60	0.9354	57,630	53,907	0.0590	0.8252	0.0487
8	$11.60	0.9092	56,500	51,370	0.0562	0.8012	0.0450
9	$11.60	0.8790	55,370	48,670	0.0532	0.7778	0.0414
10	$11.60	0.8453	54,263	45,869	0.0502	0.7552	0.0379
11	$11.60	0.8083	53,177	42,983	0.0470	0.7332	0.0345
12	$11.60	0.7687	52,114	40,060	0.0438	0.7118	0.0312
13	$11.60	0.7270	51,072	37,129	0.0406	0.6911	0.0281
14	$11.60	0.6836	50,050	34,214	0.0374	0.6710	0.0251
15	$11.60	0.6392	49,049	31,352	0.0343	0.6514	0.0223
16	$11.60	0.5942	48,068	28,562	0.0312	0.6324	0.0198
17	$11.60	0.5491	47,107	25,866	0.0283	0.6140	0.0174
18	$11.60	0.5045	46,165	23,290	0.0255	0.5961	0.0152
19	$11.60	0.4608	45,241	20,847	0.0228	0.5788	0.0132
20	$11.60	0.4183	44,336	18,546	0.0203	0.5619	0.0114
21	$11.60	0.3774	43,450	16,398	0.0179	0.5456	0.0098
22	$11.60	0.3385	42,581	14,414	0.0158	0.5297	0.0084
23	$11.60	0.3017	41,729	12,590	0.0138	0.5142	0.0071
							0.7849

Table 34b
7% Discount rate and Discount factor 0.5988

	Adjusted VSL (millions)	Survival Probability	Exposure (VMT)	Aggregate Exposure	Exposure Proportion	Mid-Year Discount Factor (7%)	Aggregate Discount Factor
1	$11.60	0.9995	64,901	64,869	0.0710	0.9667	0.0686
2	$11.60	0.9985	63,628	63,533	0.0695	0.9035	0.0628
3	$11.60	0.9953	62,381	62,088	0.0679	0.8444	0.0574
4	$11.60	0.9874	61,157	60,386	0.0661	0.7891	0.0521
5	$11.60	0.9747	59,958	58,441	0.0639	0.7375	0.0472
6	$11.60	0.9574	58,783	56,279	0.0616	0.6893	0.0424
7	$11.60	0.9354	57,630	53,907	0.0590	0.6442	0.0380
8	$11.60	0.9092	56,500	51,370	0.0562	0.6020	0.0338
9	$11.60	0.8790	55,370	48,670	0.0532	0.5626	0.0300
10	$11.60	0.8453	54,263	45,869	0.0502	0.5258	0.0264
11	$11.60	0.8083	53,177	42,983	0.0470	0.4914	0.0231
12	$11.60	0.7687	52,114	40,060	0.0438	0.4593	0.0201
13	$11.60	0.7270	51,072	37,129	0.0406	0.4292	0.0174
14	$11.60	0.6836	50,050	34,214	0.0374	0.4012	0.0150
15	$11.60	0.6392	49,049	31,352	0.0343	0.3749	0.0129
16	$11.60	0.5942	48,068	28,562	0.0312	0.3504	0.0109
17	$11.60	0.5491	47,107	25,866	0.0283	0.3275	0.0093
18	$11.60	0.5045	46,165	23,290	0.0255	0.3060	0.0078
19	$11.60	0.4608	45,241	20,847	0.0228	0.2860	0.0065
20	$11.60	0.4183	44,336	18,546	0.0203	0.2673	0.0054
21	$11.60	0.3774	43,450	16,398	0.0179	0.2498	0.0045
22	$11.60	0.3385	42,581	14,414	0.0158	0.2335	0.0037
23	$11.60	0.3017	41,729	12,590	0.0138	0.2182	0.0030
							0.5988

C. Benefit-Cost Analysis

The benefit-cost analysis measures the net benefit which is the difference between benefits and costs in monetary values. After determining the number of equivalent fatalities prevented and the total amount of the monetizable benefits that can potentially result from this rule, the agency is able to project the expected net economic impact on society. The benefit-cost analysis contained in this section compares the costs discussed (in Chapter IV, above) to the total benefits as calculated in the preceding paragraphs. In other words, the costs to equip large buses each year with the relevant countermeasures and the increased costs associated with the added weight to large buses are compared to the benefits that can be realized through the value of the fatalities/injuries prevented and the associated economic costs avoided. The result is the net economic impact on society. The monetized benefits are expected to outweigh the costs irrespective of the discount rate and belt use. The rule is expected to produce a net benefit ranging from $8.25 million to $23.31 million. See Tables 35a and 35b, below.

Table 35a
Comprehensive Benefits and Net Benefits
15% Belt Use Rate
(In Millions of 2020 Dollars)

	3% Discount Rate	7% Discount Rate
Benefits from Improved Bus Safety	$29.40	$22.43
Costs	$6.08 to $11.84	$4.81 to $9.34
Net Benefits	$17.56 to $23.31	$13.09 to $17.61

Table 35b
Comprehensive Benefits and Net Benefits
90% Belt Use Rate
(in Millions of 2020 Dollars)

	3% Discount Rate	7% Discount Rate
Benefits from Improved Bus Safety	$23.05	$17.59
Costs	$6.08 to $11.84	$4.81 to $9.34
Net Benefits	$11.21 to $16.97	$8.25 to $12.78

D. Cost-Effectiveness Analysis - Net Benefit to Society per Equivalent Life Saved

Cost -effectiveness analysis determines the cost society expends to save a life, or its equivalent in nonfatal injuries. In order to calculate the cost per equivalent life saved for this rule, the agency divides the projected total cost (cost to equip the vehicles + fuel/weight impacts) by the number of equivalent lives saved. The agency projects that the rule would cost between $2.48 to $6.38 million per equivalent life—well under the Departmental value of a statistical life. Table 36 shows these calculations.

Table 36
Net Cost to Society per Equivalent Life Saved
(In Millions of 2020 Dollars)

	15% belt use 3% discount	15% belt use 7% discount	90% belt use 3% discount	90% belt use 7% discount
Cost (New Vehicle + Fuel)	$6.08 to $11.84	$4.81 to $9.34	$6.08 to $11.84	$4.81 to $9.34
Equivalent Lives Saved	2.45	1.87	1.92	1.46
Cost per Equivalent Life Saved	$2.48 to $4.83	$2.57 to $4.99	$3.17 to $6.17	$3.28 to $6.38

VI. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT

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 the FMVSS No. 227 final rule on small entities. The head of the agency has certified that this final 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 a final regulatory flexibility analysis, we discuss below many of the issues that a final regulatory flexibility analysis would address.

Overview of the objectives of and legal basis for the FMVSS No. 227 final rule

NHTSA is publishing the FMVSS No. 227 final rule under the National Traffic and Motor Vehicle Safety Act ("Motor Vehicle Safety Act") and the Moving Ahead for Progress in the 21st Century Act ("MAP-21").[105] MAP-21 directs the Secretary of Transportation (NHTSA, by delegation) to, among other items, "establish improved roof and roof support standards for motorcoaches" if such standards would meet the requirements and considerations set forth in subsections (a) and (b) of § 30111 of the Motor Vehicle Safety Act. Further, the Motor Vehicle Safety Act states that the Secretary of Transportation (NHTSA) is responsible for prescribing motor vehicle safety standards that are practicable, meet the need for motor vehicle safety,

[105] See Pub. L. No. 112-141.

and are stated in objective terms.[106] This rule is needed to improve the safety of occupants in large buses and meets §§ 30111(a) and (b). The FMVSS No. 227 final rule requires increased strength of the large bus superstructure as well as window and overhead luggage rack retention in large buses. The data suggest that few large buses, if any, meet these requirements.

Description and estimate of the number of small entities to which the rule will apply; compliance impacts

The FMVSS No. 227 final rule affects large bus manufacturers and large bus roof hatch emergency exit manufacturers. Generally, large bus operators that are small businesses do not buy new large buses, but purchase used large buses. Thus, large bus operators that are small business would not be directly affected by a rule on new large buses, but are affected in an indirect way by large buses in the second market.

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. For those involved in the manufacturing of emergency exit roof hatches (metal stamping, NAICS code 332116), the firm must have less than 500 employees to be classified as a small business.

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[106] See 49 U.S.C. § 30111.

This final rule directly affects large bus manufacturers. There are sixteen (16) manufacturers and second-stage manufacturers that are large businesses (more than 1,000 employees for manufacturers). There is also an estimated ten (10) small large bus and second-stage manufacturers, which are 38 percent of the businesses (Table 37). The average cost increase for a large bus is estimated to range from $325 to $591. The average large bus made on a cutaway chassis by a second-stage manufacturer costs nearly $200,000. Given the average cost of large buses ranges from $200,000 to $400,000, the FMVSS No. 227 final rule would increase the average price of a large bus by 0.1 to 0.3 percent.[107]

In addition, the agency believes that certifying compliance with the FMVSS No. 227 final rule would not have a significant impact on the manufacturers. Small manufacturers have various options available that they may use in certifying compliance with the final rule. The economic impact of certifying compliance with the FMVSS No. 227 final rule would not be significant. One option available to small entities is to certify compliance by using modeling and engineering analyses (such as a plastic hinge analysis of portal frames of a large bus). ECE R.66 itself accounts for and accommodates this compliance option, and this approach has been used for years by European manufacturers in meeting ECE R.66. Thus, there are established practices and protocols that small manufacturers may use to avail themselves of this basis for certifying compliance with the final rule.

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[107] Federal Transit Administration. (2007), An Evaluation of the Market for Small-to-Medium-Sized Cutaway Buses. Available at: http://www.fta.dot.gov/documents/AnEvaluationofMarketforSmalltoMediumSizedCutawayBuses.pdf. See page 21. The estimated cost of <35' foot cutaway bus with a GVWR of 28,000 and seats 40 is $175,000. The average cost for over-the-road type buses is from *Motorcoach Census 2008*. Available at: http://www.buses.org/files/ReportDec08.pdf See page 14. The average purchase price was $450,000.

We explained in Chapter II, Analysis of Alternatives, that the aforementioned engineering analysis model would not be appropriate as the agency's method of assessing the compliance of vehicles with a Federal motor vehicle safety standard. However, those methods are available and feasible to manufacturers in certifying the compliance of their own vehicles as they have knowledge of the specific elements of the large bus structure. We believe that a small manufacturer would be closely familiar with its vehicle design and would be able to utilize modeling and relevant analyses on a vehicle-by-vehicle basis to reasonably predict whether its large bus design will meet the requirements of the FMVSS No. 227 final rule.

Second, the small manufacturer could test body sections of the vehicle, as contemplated by ECE R.66, Alternatives 1 and 2. The manufacturer would be able to "section" the vehicle or otherwise obtain a body section representative of the vehicle and of the weakest section of the vehicle. It could base its certification on these tests, without testing a full vehicle.

Third, we note that in the event small manufacturers elect to conduct a test of a full vehicle, there are various methods available to reduce the costs of the test. One such method is by testing a vehicle which is not completely new. As the requirements in the FMVSS No. 227 final rule pertain to the large bus structural integrity, we believe that a manufacturer could test the relevant body design on an old large bus chassis or other underlying structure, and could sufficiently assess and certify the compliance of the vehicle's structural integrity to the final rule. Similarly, the agency believes that more costly portions of the large bus (such as the engine and other portions of the powertrain) could be replaced in a complete vehicle test of a large bus with ballast equal to the weight of the absent components. The small manufacturer could base its certification on such testing, which do not involve a destructive test of an actual large bus.

Fourth, we also note that the product cycle of large buses is significantly longer than other vehicle types. With a longer product cycle, we believe that the costs of certification for manufacturers would be further reduced as the costs of conducting compliance testing and the relevant analyses could be spread over a significantly longer period of time.

Finally, we note that the requirements in the FMVSS No. 227 final rule may indirectly affect the operators of large bus—some of which may be small businesses. As mentioned above, we anticipate that the impact on these businesses will not be significant because the expected price increase of the large buses used by these businesses is small ($325 to $591 for each large bus valued between $200,000 and $400,000). Further, we anticipate that fuel costs for these businesses will increase between $1,862 and $4,790 over the lifetime of a large bus (in 2020 dollars). The expected increase in costs is small in comparison to the cost of each large bus. Additionally, we anticipate that these costs will equally affect all large bus operators and therefore we expect that small operators will be able to pass these costs onto their consumers. This final rule may also affect emergency roof exit manufacturers to a degree. There is at least one emergency roof exit manufacturer, for which employment numbers could not be located. It is estimated that this manufacturer may be a small business (Table 37).

Table 37
Employment of Large Bus and Second Stage Manufacturers

Manufacturer	# of Employees
Ameritrans	>1,000
BCI Bus & Coach International	>1,000
Bonluck Bus	>1,000
Creative Mobile Interiors, Inc.	<1,000
Daimler Buses, and Daimler Trucks North America LLC (including Setra, Thomas Built Buses Inc., Freightliner, Custom Chassis Corporation)	>1,000
Forest River (including Glaval and Starcraft)	>1,000
Gillig	>1,000
Motor Coach Industries	>1,000
New Flyer Industries Inc.	>1,000
North American Bus Industries, Inc.	>1,000
Supreme Corporation	>1,000
Temsa Global	>1,000
Thor Industries Inc. (including Goshen Coach, General Coach America, Champion Bus, ElDorado, Federal Coach, Krystal Koach)	>1,000
Turtle Top	<1,000
Van Hool	>1,000
Volvo Group (including Prevost)	>1,000

With regard to new large buses, this final rule would not have a significant economic impact on a substantial number of small entities that are manufacturers.

Some of the emergency roof exit manufacturers may be small businesses. The requirements would increase the sales of roof hatches with shock-resistant latches but is not expected to have a significant impact on these businesses.

A description of the projected reporting, recording keeping and other compliance requirements of a final rule 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.

There are no reporting requirements associated with this rule.

An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the final rule

We know of no Federal rules which duplicate, overlap, or conflict with the FMVSS No. 227 final rule.

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

There are no significant alternatives to the FMVSS No. 227 final rule which accomplish all the objectives of the rulemaking while minimizing the impact on small entities.

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 the year 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. The FMVSS No. 227 final rule is not likely to result in expenditures by State, local or tribal governments of more than $158 million annually. The costs of this FMVSS No. 227 final rule are estimated to be less than $12 million.

APPENDIX A. Comprehensive Unit Costs

The comprehensive value of societal impacts from fatalities and injuries includes a variety of cost components. Table A-1 summarizes the cost components and corresponding unit costs in 2020 dollars. As shown, the cost components included medical, EMS, 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). The unit costs were revised from those published in the agency's 2015 report (Blincoe, 2015 et al.).[108] Blincoe et al reported unit costs in 2010 dollars as shown in Table A-2, and the unit costs were adjusted in 2020 dollars as shown in Table A-1.

Table A - 1
Comprehensive Unit Costs (2020 dollars)

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
EMS	$129	$264	$496	$999	$1,020	$1,076
Market Prod	$3,424	$24,318	$80,820	$176,891	$424,096	$1,172,349
Household Prod	$1,083	$8,926	$28,500	$47,158	$119,849	$364,180
Ins. Adm.	$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.

[108] Blincoe, L., Miller, T., Zalloshnja, E., Lawrence, B., The economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised), DOT HS 812 013 National Center for Statistics and Analysis, Washington, D.C., May 2015.

Table A - 2
Comprehensive Unit Costs (2010 dollars)

Cost Components	PDO	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	FATAL
Medical	$0	$0	$2,799	$11,453	$48,620	$136,317	$384,273	$11,317
EMS	$59	$38	$109	$221	$416	$838	$855	$902
Market Prod	$0	$0	$2,726	$19,359	$64,338	$140,816	$337,607	$933,262
Household Prod	$60	$45	$862	$7,106	$22,688	$37,541	$95,407	$289,910
Ins. Adm.	$191	$143	$3,298	$4,659	$15,371	$28,228	$72,525	$28,322
Workplace	$62	$46	$341	$2,644	$5,776	$6,361	$11,091	$11,783
Legal	$0	$0	$1,182	$3,351	$12,402	$26,668	$82,710	$106,488
Congestion	$2,104	$1,416	$1,426	$1,450	$1,490	$1,511	$1,529	$5,720
Property Damage	$3,599	$2,692	$7,959	$8,510	$16,027	$16,328	$15,092	$11,212
QALYs	$0	$0	$23,241	$364,113	$813,444	$2,060,724	$4,594,020	$7,747,082
Total	$6,075	$4,380	$43,943	$422,866	$1,000,572	$2,455,332	$5,595,109	$9,145,998
Relative QALYs	0.0000	0.0000	0.0030	0.0470	0.1050	0.2660	0.5930	1.0000